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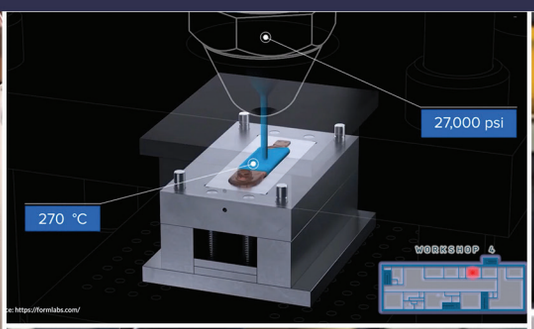

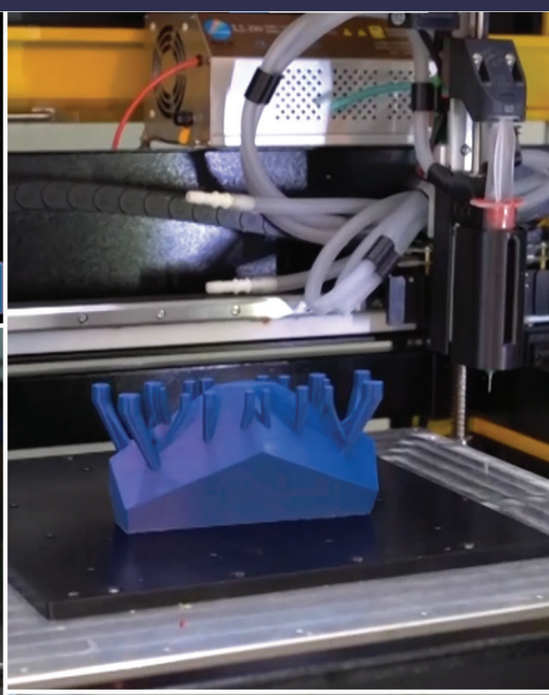

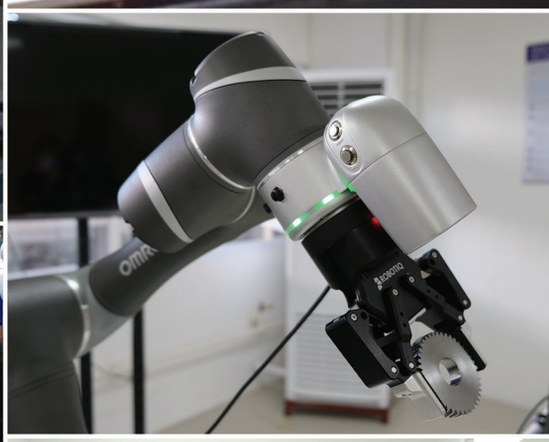

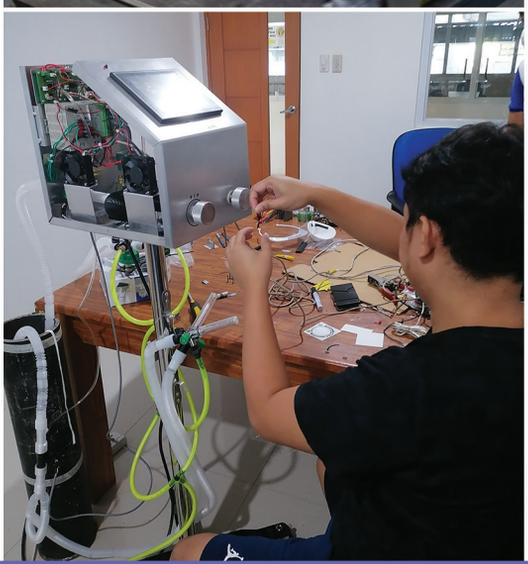

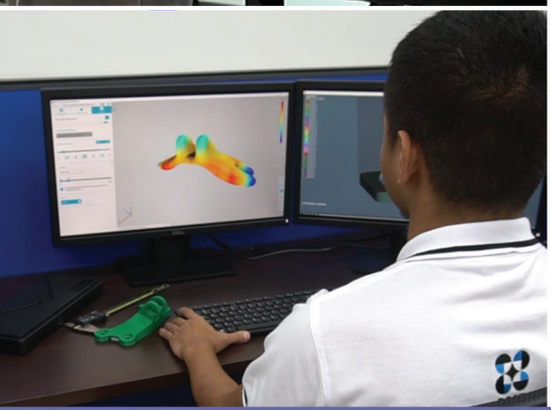

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Philippine Metals

ERRATUM TO “Philippine Metals 2022 Volume 9” by the DOST-MIRDC

Please be informed that the Philippine Metals Volume 9, released this 2022, is assigned a new ISSN 2980-4957.

The Philippine Metals, first published in 1971, was initially assigned ISSN 0115-1177. The Philippine Metals Trends and Events publication applied for a new ISSN in 1991, which indicated its former title as Philippine Metals and was issued ISSN 1908-9988, effectively canceling the former ISSN 0115-1177.

Upon checking DOST-MIRDC’s records, the Center has been publishing Philippine Metals with an erroneous ISSN (i.e. 0115-117).

The Philippine Metals 2022 volume 9 and its subsequent issuances will continue counting the previous eight volumes even with the new ISSN 2980-4957.

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About the cover:

Shown are some of the MIRDC's facilities. The Center remains a strong ally of the metals, engineering, and allied industries amid the pandemic.

Contents

Preface

Research and development (R&D) becomes meaningful only when it is shared. The Department of Science and Technology-Metals Industry Research and Development Center (DOST-MIRDC) has always strived to provide relevant services to the metals, engineering, and allied industries. Similarly, we see to it that the programs and projects we pursue are beneficial not only for our industry partners but for our partners and stakeholders in the academe and the government as well.

We are deeply involved in information exchange activities as our proactive contribution to the DOST's goal of providing science, technology, and innovation-based solutions to the country's most pressing problems. These activities provide a platform to engage with our valuable stakeholders and allow us to share our R&D initiatives.

The Center held the 1st National Metals and Engineering Conference (NMEC) in June 2022, as part of the celebration of the 2022 Metals and Engineering (M&E) Week. The Center's engineers, as well as researchers from the academe and the industry, presented technical papers at the NMEC. The papers presented were grouped into the following categories: 1) Simulations, Engineering, and Design, 2) Metals and Allied Industries Processing, Machining Technologies, and Emerging Material Technologies, and 3) Process Automation, Industry 4.0, and Smart Manufacturing Systems.

The NMEC served as an avenue for the exchange of information gathered from various R&D initiatives. We are proud that the 1st NMEC has strengthened even more the R&D culture in the academic community, and has catalyzed among industry players the desire to embark on continuous R&D as a means to innovate and cope with fast-paced changes in demands of the local and global markets.

On behalf of the DOST-MIRDC, I proudly present to you Volume 9 of the Philippine Metals. This publication is one of the ways that show the DOST-MIRDC's commitment to carrying out relevant R&D that provides significant contributions to help the local metals, engineering, and allied industries increase their levels of productivity and raise their capabilities to become globally competitive.

Robert O. Dizon
Executive Director

Design and Fabrication Of Fixture for C70 Type Probe Needle Card Soldering Process*

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Harveen C. Bongao*[6], Hohn Lois C. Bongao*[7], Ruem G. Arribas*[8], Constancio Andong Jr.*[9]

Abstract

One of the essential requirements in the soldering process of probe needle cards is to have better fixtures for more accurate and simple operation. The fixtures must properly be designed to mitigate dimension variations in the soldering of probe needle cards. Workpiece positioning and constraining are important factors, but existing fixtures used in the soldering process of C70 type probe needle cards are not properly suitable for holding the workpiece, resulting in a rejected part and the need to rework. There have been reported 63 reworks in the year 2020 in a semiconductor company due to excess solder and uneven hypertac pins. This paper presents a solution by designing a fixture with proper locating and balanced clamping methods. The required measurements of the workpiece for the design of the fixture in building a C70 type needle card must be long-lasting, durable, and pass based on the operator acceptance standards in the soldering stations. A total of 37 needle cards were produced using the developed fixture with no reworks reported. The results obtained from a survey of 6 operators show that the developed fixture was found acceptable in terms of its functionality, efficiency, and effectiveness. The design addressed the following requirements: the fixture must securely hold the workpiece; the fixture must be simple to operate, and the fixture must reduce process time while producing a high-quality product.

Keywords: *fixture, hypertac pins, probe needle card, printed circuit board, soldering*

I. Introduction

In a manufacturing system, good quality products are produced by providing jigs and fixtures for high accuracy, ease of operation, and reduced work fatigue, especially in the production of electronic packages [1]. In the fabrication of semiconductor packages, wafer testing is an important process, where each of the contacts must be properly connected and aligned. To test these connections, a probe needle card is needed [2]. There are three common types of needle cards used in wafer testing: vertical, cantilever, and blade type as shown in **Fig. 1(a), (b),** and **(c)** respectively.

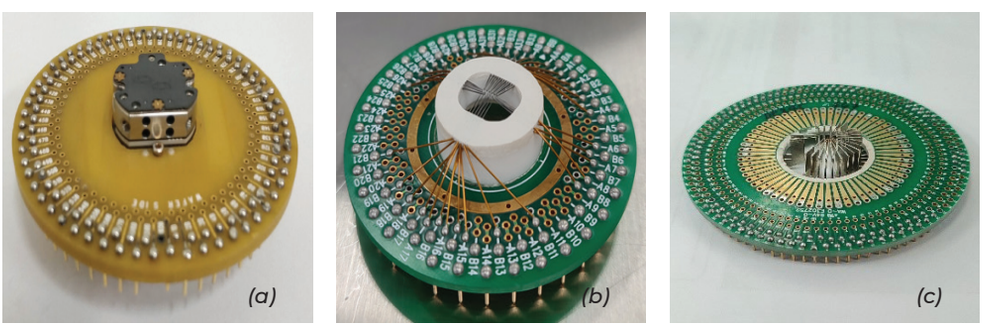

Fig. 1

(a) Vertical type probe needle card
(b) Cantilever type probe needle card
(c) Blade type probe needle card

* Presented during the National Metals and Engineering Conference (NMEC), June 15, 2022.

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Several sub-processes are involved in these tests. Cantilever type needle card are bent to a specific angle. The probe ring needles are formed by defending the die arrays. The soldering process involves the mounting of the probe ring and the soldering of the hypertac pins and needles to the printed circuit board (PCB). The soldering process is divided into three sub-processes: hypertac pin installation, probe ring mounting, and needle soldering to the PCB. Each process makes use of a different fixture. These processes should have better fixtures to attain maximum productivity on working personnel. When the fixtures are unstable, there can be variations in the workpiece dimension that can lead to rejects of products. Therefore, the work holdings are necessary for the manufacturing of electronic packages [4].

However, the cantilever type needle card soldering process often has problems due to the instability of the multiple layer type of fixture for each soldering process [3]. During the first process, which is the installation of the hypertac pins, as shown in **Fig. 2(a)**, the four clamps that hold the PCB were blocking some of the pin holes. To fully install all the pins, the soldering personnel needs to remove the clamps. The quality and reliability of the soldered pins and PCB are affected, as the design was not entirely suitable for holding the workpiece in place. **Fig. 2(b)** shows that the output after hypertac installation has excess leads, resulting in uneven pins. This will cause the rejected part to be reworked.

Due to the lack of a dedicated tool, each soldering process requires the use of a different kind of fixture. The fixture used in the soldering of needles to the PCB is only an alternative jig from a used board, which is not an appropriate tool to hold the needle card in a fixed position due to its non-planar design as shown in **Fig. 3(a)** and **(b)**. Therefore, a single-layer fixture is necessary.

The number of soldering reworks for the year 2020 has been gathered as illustrated in **Fig. 4**; all data is based on the probe department's system repair history, and a total of 68 cards have been reported for rework due to excess solder lead and uneven hypertac pin height.

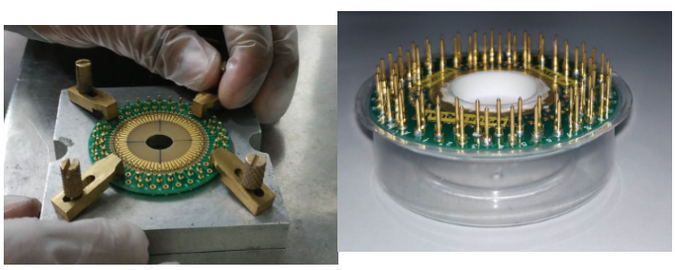

Fig. 2. (a) Hypertac pin installation (b) Result after hypertac installation

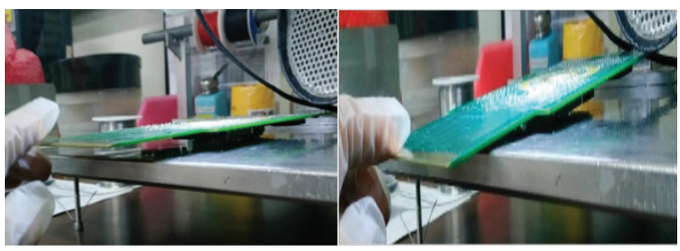

Fig. 3. (a) Fixture used in the soldering of needles to PCB (b) inspection of soldered PCB

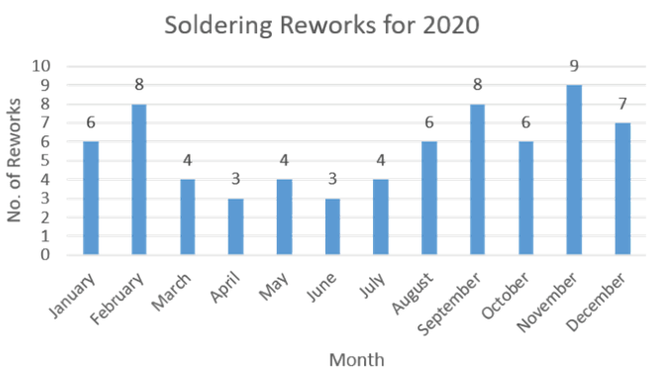

Fig. 4

Soldering Reworks in 2020

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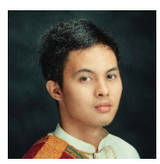

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In this study, a method of design and fabrication of a single fixture for the entire soldering process for probe needle card was conducted to mitigate issues in holding and clamping workpieces. This paper specifically aims a) to combine three fixtures (hypertac installation fixture, ceramic mounting fixture, and soldering of needles fixture) into one, to reduce worker's effort and process time, b) to design a fixture that firmly holds a workpiece in the proper position to produce a high-quality probe needle card and avoid reworks, and c) to test and evaluate the fixture in terms of functionality and efficiency through actual testing of all soldering personnel, as well as to conduct a survey.

Every jig and fixture must support, locate, and clamp workpieces that are highly accurate, safe, and convenient. In the fabrication and assembly of probe needle cards, these qualities must be considered [5]–[7]. In some context, the jigs and fixture might be less necessary but is helpful in production where precise measurements are less likely desired over cost and time of production [8].

II. Materials and Methods

A. Materials

The materials used for this study serve the function of the device. Aluminum is chosen as the best material for this study because of its good properties like corrosion resistance. It is readily available in the market, cost-effective, and can be used to produce durable and long-lasting fixtures for several applications. Companies throughout the country use aluminum fixtures to manufacture strong products that are distributed both nationally and internationally. Using aluminum in fixtures guarantees a quality product that will remain efficient for years to come.

B. Fabrication And Assembly

The assembly is made up of two major components: the baseplate and the workpiece holder. On the entire assembly, the base plate clamps workpieces for stability in a defined and repeatable manner with grid points arranged in uniform coordinates [9]. While the cover keeps the workpiece in place during the build process. **Fig. 5(a)** and **(b)** show the conceptual design and exploded view of the fixture.

The purpose of a workpiece holder is to clamp the workpiece against the surface of contact. The workpiece that will be inserted into the fixture is made up of PCB and hypertac pins. A screw is used to securely fasten the cover, workpiece, and baseplate together. The guide pin/locating pin ensures that the cover is properly positioned concerning the base plate. A base plate is a flat supporting plate or frame with holes drilled in it for the insertion of hypertac pins.

The hypertac pin is the basis for the baseplate pin holes. The part of the hypertac pin that will be inserted into the base plate has a measurement of 0.70mm, whereas the hole in the baseplate is 0.75mm to have a clearance of 0.05mm to ensure that the pins are not difficult to install or remove. The pinhole layout is based on the PCB where the length and width of the baseplate are determined by the worker's comfort and ease of handling. The dimension of the designed baseplate is presented in **Fig. 6**.

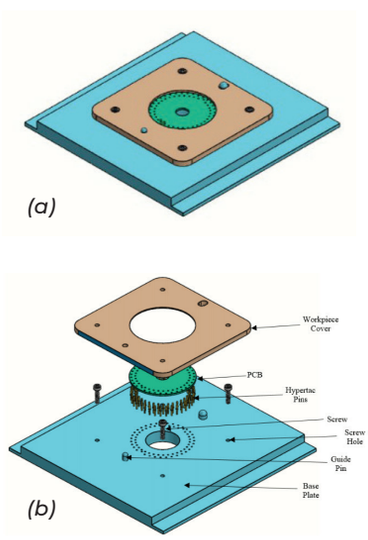

Fig. 5

(a) Conceptual Fixture Design
(b) Exploded view

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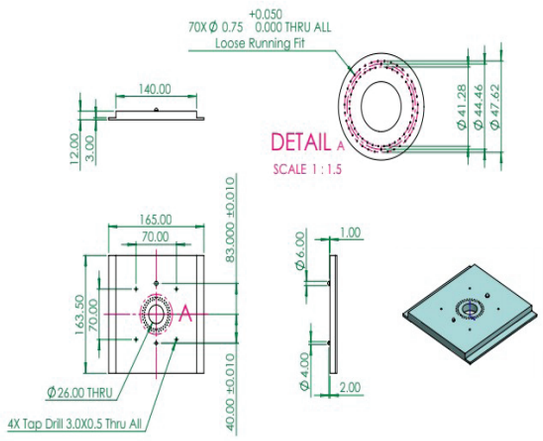

Fig. 6. Base Plate Dimension

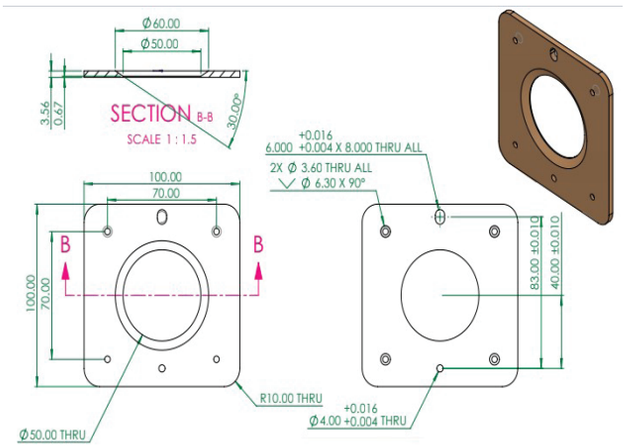

Fig. 7. Cover Dimension

The C70 PCB serves as the cover's basis. The radius of the PCB is 51.30mm, hence the radius of the cover is 50mm to have a proper hold on the workpiece while not reaching the PCB pin hole. The thickness of the holder shown in **Fig. 7** is determined by the height of the needle ring to avoid hitting the needles and to allow for easy and hassle-free soldering.

The fabrication process includes cutting, milling, chamfering, and threading. In milling workpieces, it is necessary to consider removing the burrs of the workpiece to prevent laceration. A chamfer of a 45-degree angle is made to remove sharp edges. The base plate screw holes were threaded so that they can be tightly fastened together.

III. Results and Discussion

Testing and evaluation take place after the assembly is completed. All of the personnel at the soldering station tested the prototype's functionality, effectiveness, and efficiency. The fabricated fixture is presented in **Fig. 8.** The fixture has become a single component since the two parts were fastened tightly and properly together.

All of the soldering processes completed with the proposed fixture are depicted in **Fig. 9.** The hypertac pins are installed and soldered using the developed fixture as shown in **Fig. 9(a)**, while the probe ring mounting and the soldering needles are fitted in the developed fixture for the assembly and soldering as shown in **Fig. 9(b)** and **(c).**

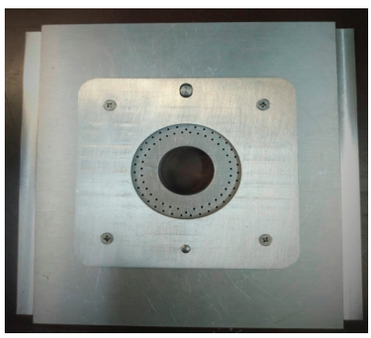

Fig. 8

Fabricated fixture

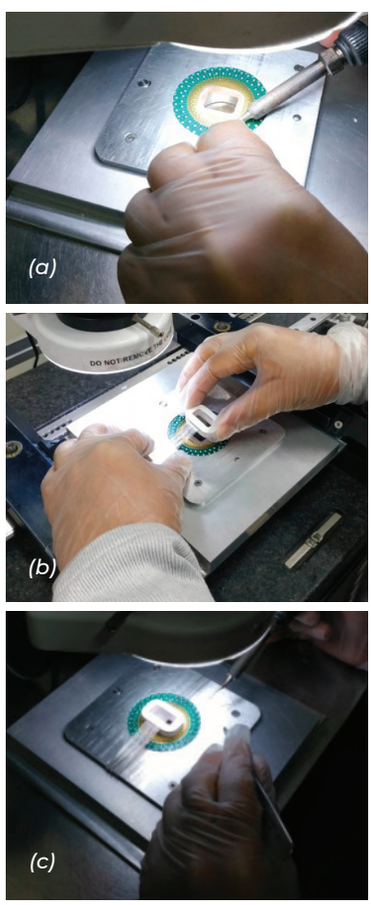

Fig. 9

(a) Hypertac installation
(b) Probe Ring Mounting
(c) Soldering of needles to PCB

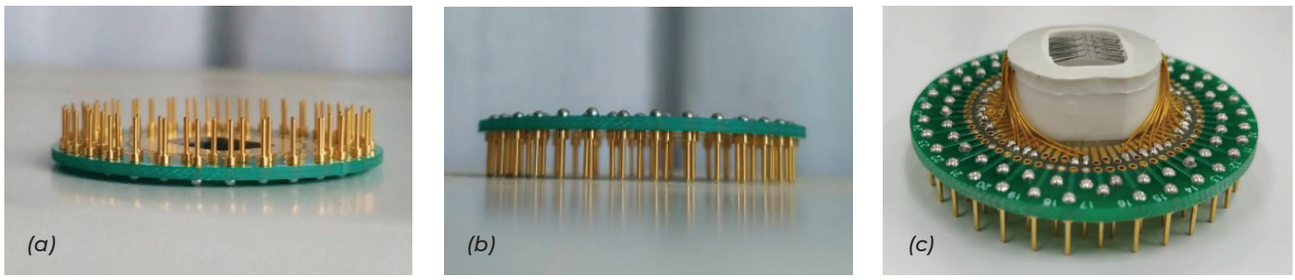

Fig. 10 (a) Result after hypertac installation, (b) Final result using the proposed fixture, and (c) Final product

The properly installed hypertac pins are presented in **Fig. 10(a)** and **(b).** Using the fixture, the hypertac pins are properly aligned and the reworks are significantly mitigated. The final product after the soldering process is presented in **Fig. 10(c)** where this result is considered of good quality. This has been used and tested by 6 operators for electrical testing of wafers with no reports of rework for the soldering station, as checked and monitored in the probe shop monitoring transaction.

Figure 11 shows the number of repairs performed with the old fixture, as well as the difference when the new fixture is used; all data is based on probe department system repair history. From January 1, 2021, to August 19, 2021, when old fixtures were used, there were reports of reworks due to excess solder leads on hypertac pins, resulting in uneven pin height. Since August 21, 2021, when the proposed fixture with the proper clamping method and designed based on the requirements needed to build the C70 needle card was implemented, a total of 37 C70 needle cards have been produced, and there have been no reports of rework, and all products have been completed with high quality; no excess solder leads on hypertac pins, and all pins are even.

The proponent surveyed the soldering personnel and discussed the system's approach as well as the study's aims and purpose. Through this, valuable feedback was recorded and used to conclude the functionality, efficiency, and effectiveness of the proposed fixture. A total of 6 personnel weighed in on the project, yielding the following results.

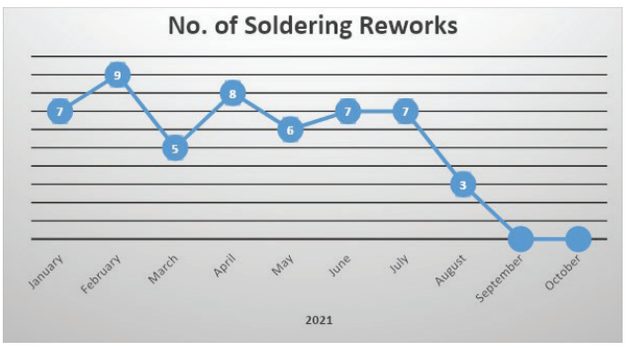

Fig. 11 Collected Soldering Reworks for the Year 2021

To validate the usability and performance of the developed fixture, it has been tested by 6 operators, and their perception using the device is gathered. As a result, the fixture works and functions appropriately according to its feature, makes the process easier, fully operational during the testing and evaluation, and easy to adapt and use by the operators with an average rating of 4 (very satisfying) in a Likert's scale, 1 as the lowest and 5 as the highest. The efficiency and effectiveness also have an average rating of 4 which indicates that the proposed fixture is more convenient to use than the existing set-up, improved the cycle time of the process, lessens the assembly of the process, doesn't require excessive force, and lightweight, and its materials are readily available. In addition, the maximum capacity of the fixtures satisfies the production requirement, and the product doesn't emit pollution that will harm the environment.

IV. Conclusion

Based on the findings, the researcher was able to design and construct a suitable fixture for the construction of a C70 type needle card. Capable of combining the existing three fixtures into one, thereby shortening the manufacturing process time. This study accomplished its objectives which were to design and fabricate an appropriate fixture for the C70 type needle card soldering process. The design addressed the following requirements: the fixture must securely hold the workpiece, the fixture must be simple to operate, and the fixture must reduce process time while producing a high-quality product. According to the results obtained during testing and evaluation, the developed device was useful and efficient in the soldering station process.

V. Acknowledgments

The authors acknowledge the Technological University of the Philippines Taguig Research and Extensions Services for allowing this research to be presented and published.

VI. Statement on Conflict of Interest

The authors declare no conflict of interest.

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Design and Development of Cross-Flow Micro Hydroelectric Turbine*

Nathaniel S. Oliveros*[1], Abelor T. Mendoza*[2]

Abstract

Electricity, among the different forms of energy, has become an essential part of human civilization, and many Filipinos still have no access to electricity. Geographically, our country is endowed with flowing water sources. This can be taken into an advantage in developing small-scale hydro-power that provides a clean, renewable source of electrical energy and is very useful in remote communities that are yet to be reached by a national electrification system. Currently, the NEUST Gabaldon Campus operates a Micro-Hydro Power Plant at the foot of Mount Mingan and can produce up to 10kW/hr from water coming from upstream. But, during the dry season, the water flow becomes inadequate to generate power with the present design. Hence the NEUST-MEIC proposed to develop a Cross-Flow Turbine that can be used in the area. The current cross-flow turbine was designed to reach over 700 rpm, has an outer diameter of 316mm, an inlet pipe of 128 mm, and is suitable for 300 to 350 L/s of water. It has a blade angle inlet of 30o and a 16o angle of attack, and the blade angle inside the runner is 90o. It has a total of 28 blades. The radius of curvature of the blade was set to 48.9mm. The cross-flow turbine developed was already fabricated and ready for various tests to measure its performance. The NEUST-MEIC is currently in the final stage of its Turbine Test-Rig.

Keywords: *Cross-Flow turbine, turbine design, Micro Hydro-Electric turbine, Casting, Metal Innovation*

I. Introduction

The Nueva Ecija University of Science and Technology (NEUST) is implementing the development of the Metal Casting roadmap for Region III with the help of the Metal Industry Research and Development Center (MIRDC) through the Metals and Engineering Innovation Center program.

The main goal is to identify future research and development needs to accelerate the growth of advanced manufacturing of models and small batch production. A focused workshop was conducted to develop and document metal casting capability gaps, solutions, and recommendations for areas of investment that will strengthen and catalyze the University metal casting facility in advanced casting production. NEUST recommends Cross flow turbines to design for this project under the direction of the Department of Science and Technology (DOST).

Cross-flow turbine has lower performance compared to other types of turbines. Cross flow turbines are considered to produce renewable energy. Hydroelectric Power Plant is one of the lowest polluting energy sources that convert water's potential and kinetic energy into electrical energy.

Efficient equipment requires cheap operating and maintenance costs and offers reliable and flexible operation. The cross-flow turbine contributes to a significant portion of the reduction of the overall efficiency of the hydro-power plant. The average efficiency of a micro-hydropower plant is considered in the range of 50 to 60 percent. However, the study by Nasir (2013) shows the highest efficiency to be 88% through simulation. The higher turbine efficiency would mean higher power output and, consequently, higher income for the same amount of investment

* Presented during the National Metals and Engineering Conference (NMEC), June 15, 2022.

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II. Materials and Method

The initial design is based on a maximum head of 10 to 20m, where the University considered the flow and height of the conditions in the Gabaldon Nueva Ecija, where the initial micro-hydroelectric power plant is located. Then after this, we optimized all the parameters of the design like the diameter of the impeller, size of the blade, and hub size for the water stream in NEUST- Gabaldon Campus. The design size comes out for two reasons: first, the water stream is much more available in NEUST – Gabaldon Campus, and second, this size is easy to assemble and fabricate compared to other small size turbines.

The Turbine was designed to reach over 700 rpm to produce much higher efficiency. The outer diameter of the Turbine is taken at 316 mm. The inlet of the Turbine is 128 mm. Design value of flow at the maximum head was calculated to be 300 to 350L/s. The blade angle β_1 at the inlet is 30°.

The angle of attack α_1 given by the surface of the nozzle is 16°, and the blade angle inside the runner (β^1_1 and β^1_2) is 90°. The number of blades of the runner is taken at 28.

Figure 1 shows the detailed design of the cross-flow turbine where:

R is the radius of blade curvature;

β is the angle between relative velocity and peripheral velocity (also can be termed as the angle between the tangent of the blade and runner periphery or blade angle);

α represents the angle between absolute and peripheral velocity; the sub-scripts '1' and '2' in the case of α and β represent the inlet first stage and inlet the second stage, respectively, and super-script 'I' in the case of α and β represents at the inside diameter of the wheel;

r_1 is the inner radius of the turbine runner;

r_2 is the outer radius of the turbine runner;

r_1/r_2 is the diameter ratio

H is the design head; and

Q is the design flow;

The University's primary goal is to design and fabricate the **hub** of the cross-flow turbine employing a centrifugal casting machine and crucible furnace. We melted the metal in the crucible furnace, and the mold was placed in the centrifugal machine where we cast the hub.

The hub holds the blades and the case of the cross-flow turbine. The diameter of the hub is 110 mm base and 65 mm head (**Fig. 2**). Several trials are performed to produce the perfect mold design of the hub using a Centrifugal Casting Machine. After several trials, improvements have been made in the hub's surface and structure, which are closer to the design product of training used in cross-flow Turbine.

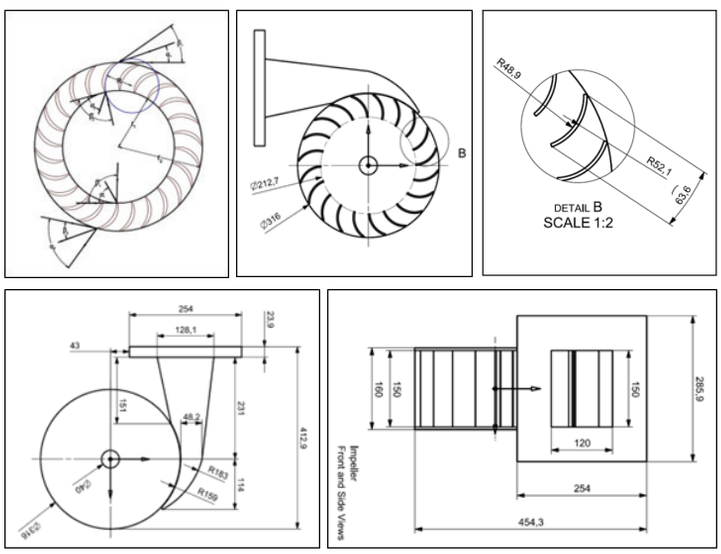

Fig. 1. Impeller Blade Details

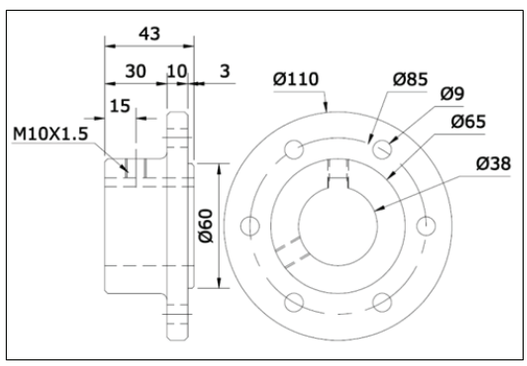

Fig. 2. Hub Detailed Design.

III. Results and Discussions

Our design is already fabricated based on our measurements. It was necessary to carry out preliminary tests for the model to identify the Turbine's performance characteristics. However, due to limited time and resources, only a few tests were carried out, and few parameters were tested in the Mechanical Engineering Department at the College of Engineering. Since we have no source for the volume flow rate of water needed to run the Turbine, the test will not be considered.

To test the actual performance of our design, we need to travel to the Gabaldon Neuva Ecija after this pandemic or when we get back regularly to our University. It is necessary to test the cross-flow turbine in Gabaldon because the design of the cross-flow turbine is based on the geography of the place.

The turbine housing is entirely made of mild steel plates, which is tougher than grey Cast iron, good in impact and frost resistance and rigid enough to withstand high operational stress and enable a smooth operation.

Figure 3 shows the fabrication process carried out at the Metal and Engineering Innovation Center (MEIC). Fabrication can be carried out by a team of two to four trained faculties. The cross-flow turbine has been developed, which suits local manufacturing capacity. Machine tools required were standard, such as Crucible Furnace, Centrifugal Casting Machine, Lathe Machine, Welding Machines, and a number of jigs and fixtures.

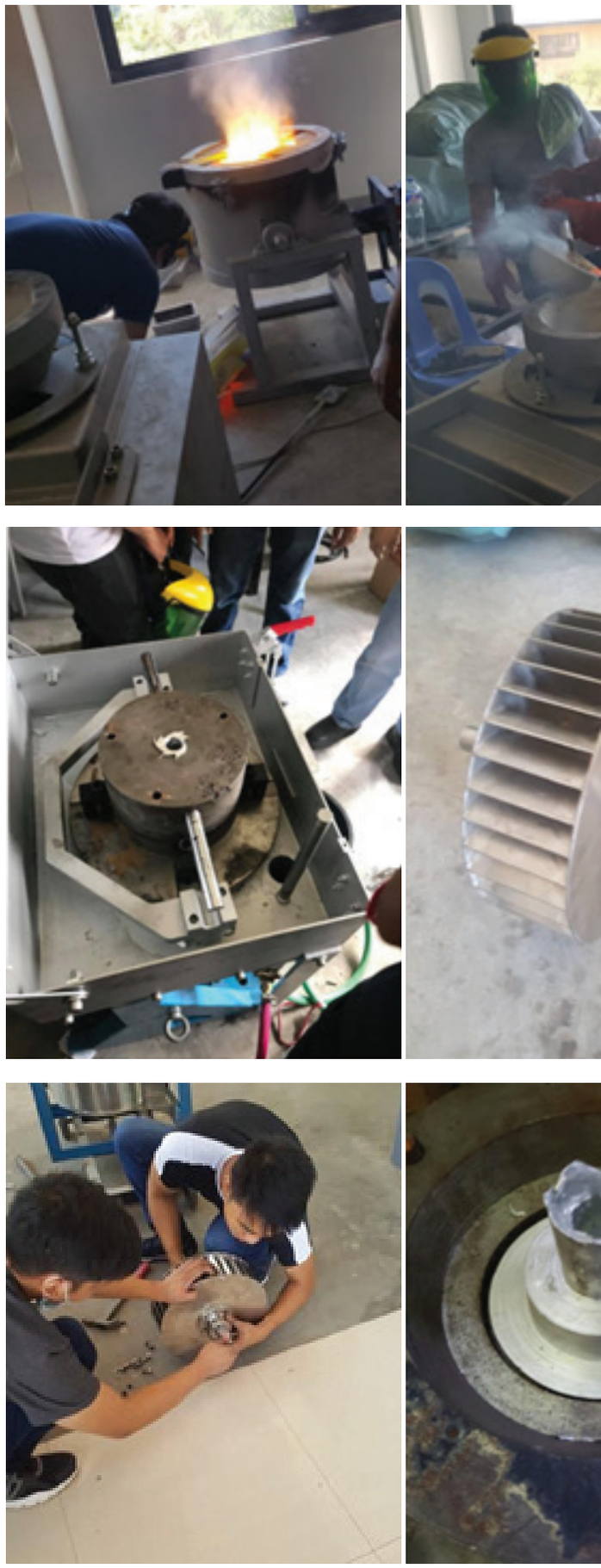

Fig. 3

Melting, Casting, and Fabrication Pictures of the Cross-Flow Turbine






IV. Conclusion

This project aims to design and develop a low-cost cross-flow hydro turbine that can be locally produced. The research gives clear procedures for designing and fabricating a cross-flow hydro turbine after organizing the information from different sources. Therefore these provide simplified procedures for design and manufacturing steps. The cross-flow hydro Turbine is successfully designed, and a physical prototype model has been fabricated at the MEIC and Mechanical Engineering Department.

V. Acknowledgement

The Department of Science and Technology (DOST) and Nueva Ecija University of Science and Technology funded and support this project.

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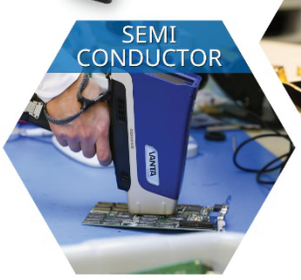

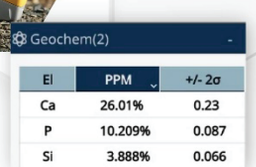

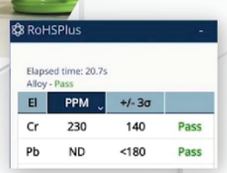

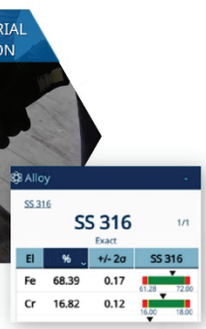

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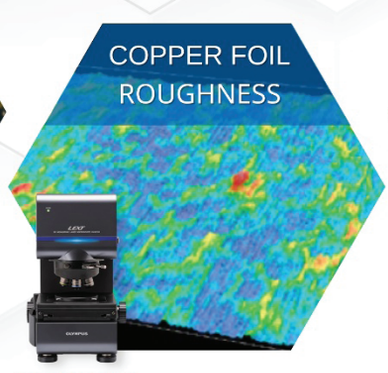

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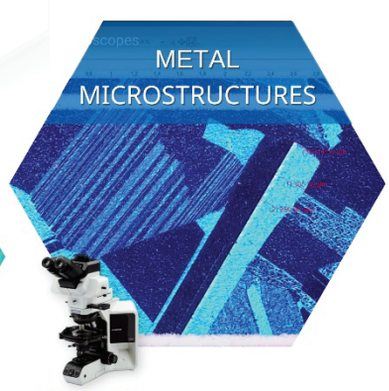

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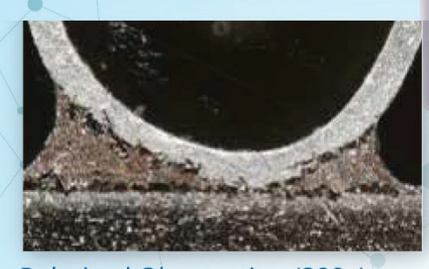
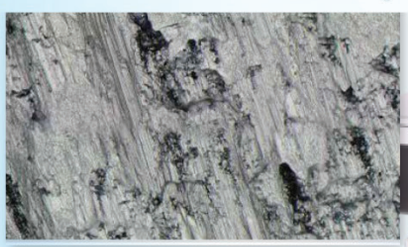
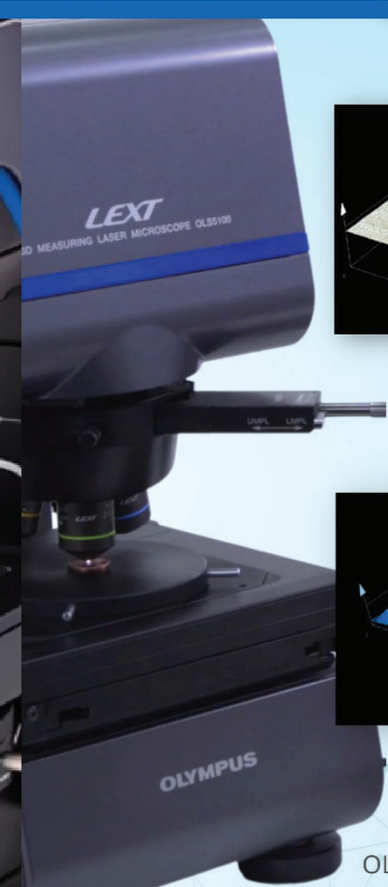


Polarized Observation (300x)
Peeling of weld in a radiator fin

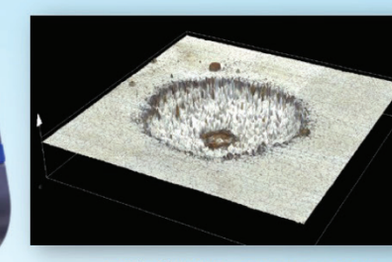


2x2 Stitched Image (1000x)
Fractured metal surface

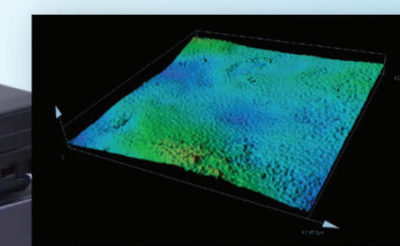
DSX1000 Digital Microscope



OLS5100 3D Laser Microscope



Height Measurement
Corrosion on stainless steel



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Development of Steam Dryer, Mixer and Molder for Paper Clay Making*

Adonis A. Closas*[1], Kenneth James Bryle G. Magsayo*[2], Romeo M. de Asis*[3], Wendell D. Talampas*[4]

Abstract

The process of making paper by hand has been the same as today as what others have been doing hundreds of years ago. Unlike the conventional paper mill, handmade papers are considered to be environmentally-friendly being chemical-free with every aspect of the production process and uses much less energy per ton of paper produced. Since the handmade paper making process was already established by the company, equipment for the whole production process was already existing. The paper clay making on the other hand, would need to design and develop of steam dryer, mixer and molder for paper clay making. Improvements of the equipment design used in the handmade paper making can directly remove the efficiency constraints in the production line. Moreover, the design, fabrication, and testing of the prototyped steam dryer, clay mixer and clay molder were successful. It can provide the company the needed mechanized facility for efficient production and meet market demands on time. These improvements and new fabricated equipment are set to optimize production capacity and product quality, which in turn are projected to bring about increase in product demands, which can consequently lead to more local employment opportunities.

Keywords: *Development, dryer, mixer, molder, paper clay*

I. Introduction

The process of making paper by hand has been the same as today as what others have been doing hundreds of years ago. Unlike the conventional paper mill, handmade papers are considered to be environmentally-friendly being chemical-free with every aspect of the production process and uses much less energy per ton of paper produced. The paper clay making on the other hand, would need to design and fabricate new equipment for the clay dough mixing and the molding processes. Both processes are labor intensive as the process equipment are mostly manually operated. Improvements of the equipment design used in the handmade paper making can directly remove the efficiency constraints in the production line. There had been research studies conducted about mixing of solids and molding of pulp products. This studies addressed the mechanical behavior and proposed numerical simulation on the twin-shaft mixers and evaluate the power consumption during the mixing cycle. Results show that increasing the filling level and the volume for a constant tanks geometry and number of arm-blade assemblies reduce energy waste, power consumption, increase productivity and profitability [8]. Other studied, the justification of feed mixer of Forages. Analyzing different constructions of blade shaft mixers such as blade with a circumferences of 250mm and 210mm were investigated. The results obtained that with this design, the degree of uniformity of the feed mixtures was raised, which contributed to a reduction in energy intensity [4]. Moreover, [1] studied about mixers a device use for mixing solids used in pharmaceutical industry. In this study static mixers, as well as Turbula and V-shaped drum mixer were tested. Results obtained that static mixer was good for mixing of powders with less energy requirement.The authors used experimental methods to identify the suitable parameter of producing paper clay. The experiments consisted of

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mixing stoneware slip and paper pulp using different percentage mixture between paper and clay. The testing process has three (3) stages consisting of a lather hard, bone dry and firing, with two (2) different firing temperatures of 900°C and 1,200°C. The experiment also used nine (9) different parameters. The experiment showed satisfactory results and outcome and proved that the paper clay is suitable for ceramic design manufacturing. The test also showed that the material can sustain and can support large-scale sculpture body. The paper clay material is capable of providing light weight body and prevents it to collapse or break. In the design process, paper clay is also easier to control. Paper clay will merge natural textures on the surface, with its rough and spontaneous textures make sculptures of high aesthetic value [7]. The pulp molding technology adopted is one in which the mold is lowered into the pulp slurry vat where the slurry is formed on the mould with the aid of the vacuum pump sucking in both the fiber and water. The mold is then lifted up, fixing into the counter-mold. The suction effect from the vacuum pump is transferred to the counter-mold where the molded product is received, all the while, still sucking water from the product. On completion of the project, it can be concluded that the treatment that the pulp slurry is subjected to prior to molding has a great impact on both the molded product and the molding process. Only pulp slurry that had been properly beaten is usable in the formation of products using the vacuum technology. Also, the lower the consistency of the slurry, the easier the formation of the pulp molding. The size and capacity of the vacuum pump and the electric motor powering the pump should correspond to the size of the pulp molding to be formed [6]. Also, [5] have designed and fabricated a recycled paper egg tray machine aimed at fabricating a 30-cavity wastepaper egg tray machine of size 10 with transfer and counter molds producing 12 egg trays/hour with a vacuum pump rating of 1.64kW using an already mechanically disintegrated pulp. The design capacity is 12 egg trays/hour and works on the principle of vacuuming the pulp slurry when the consistency is about 5%. The suction effect from the vacuum pump is transferred to the counter-mold where the molded product is received, all the while, still sucking water from the product. The product is removed from the counter-mold when the suction is blocked and taken for further drying to the desired moisture content. Findings of the research also showed that long-term stability and final recovery of the material should also be examined [2]. Therefore, improvements and new equipment are set to optimize production capacity and product quality, which in turn is projected to bring about increase in product demands, which can consequently lead to more local employment opportunities. Thus, the objective of the study is to design, develop and testing of a steam dryer, clay mixer and clay molder for paper clay making.

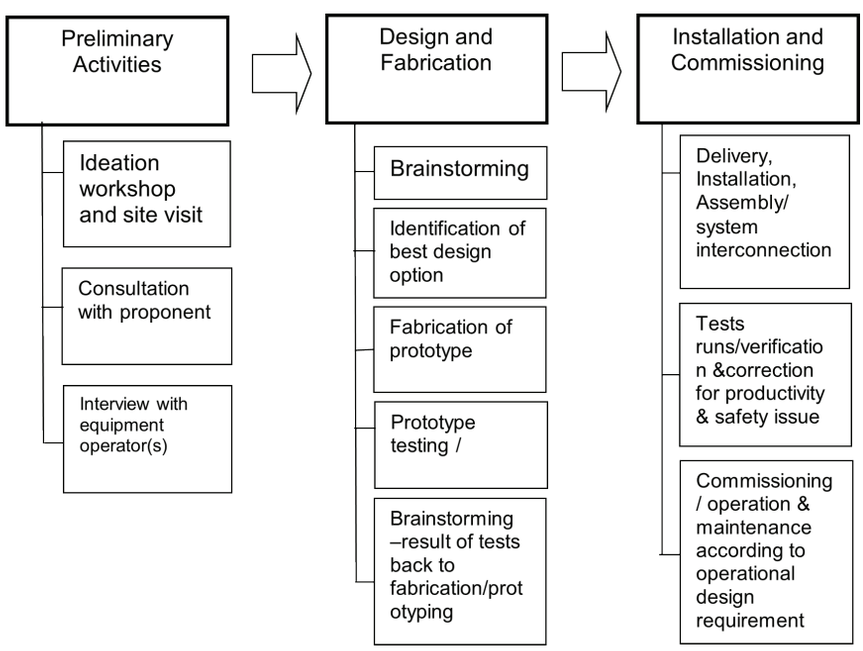

Fig. 1. Process Flow of Activities

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II. Materials and Methods

In **Fig. 1**, the project starts with the preliminary activities, these include ideation, site visit and technical consultation with the proponent. The consultation provides detail on the current issues and concerns of the company, including details of the current plant setup, process flow, equipment and the plant operation as a whole. The preliminary activities will provide the basis for the design and fabrication of the proposed improvements of equipment as well as the new equipment to be installed. This will be followed by the installation and commissioning of the equipment. **Figure 1** represents the entire project implementation.

III. Results and Discussion

1. Design and Fabrication of Stainless-Steel Dryer

The first equipment to be fabricated was the stainless-steel dryer. The stainless-steel dryer uses steam to heat the dryer surface and dry the paper clay materials by direct contact with the dryer surface. While it was the first equipment to be fabricated, testing of the dryer is still to be conducted, once the said equipment will be delivered and deployed at plant site. **Figure 2** shows the completed stainless-steel steam dryer with its stand.

2. Design and Fabrication of the Mixer Machine

Fabrication of the clay dough mixer started with the mixer body being rolled for the desired shape (**Fig. 3a**). The mixer in its completed form showing the manually operated chute (**Fig. 3b**). The manually operated chute uses a lever to open the chute to dislodge the mixed clay dough materials and can be closed by pushing the lever to its closed position for another batch of mixing.

The research team was able to conduct a test run for the dough mixer (**Fig. 4**). It was observed during the test run that the dough mixer will be capable of handling paper clay dough material for mixing.

Fig. 2. Completed Stainless-Steel Steam Dryer

Fig. 3. (A) Rolling of Mixer Body and (B) Completed Clay Dough Mixer

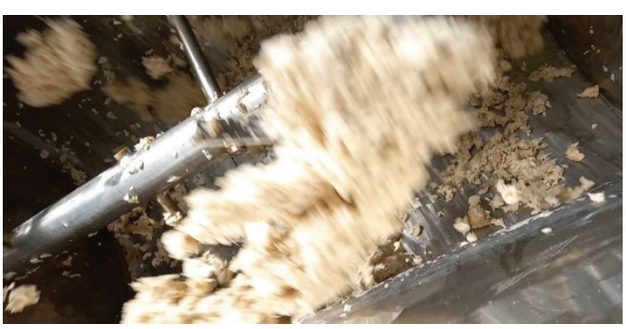

Fig. 4. Dough Mixer During the Test Run

Fig. 5. Paper Clay Molder

Fig. 6. Inspection of the Molding Machine

Fig. 7. (L) Screw Feeder and (R) Molding Plates of Molding Machine Showing the Narrow Feeding Tube

Fig. 8. Final Molder Design

3. Design and Fabrication of the Molding Machine

Figure 5 is a paper clay molder using molding plates.

The first setup of the paper clay molder was its molding plates were placed in a horizontal position, with one molding plate (male plate) moving horizontally to a stationary plate (female mold). The area between the exit point of the screw feeder of the molding machine and the entry point to the female plate was too narrow for the sticky material to pass through and push itself to the molding plate for the molding action. Figure 6 shows the project leader inspecting the molding plates of the paper clay molding machine.

The second trial, raw materials were feed in the screw feeder of the molding machine which works without any problem. However, as the feed materials exits the screw feeder, another problem occurs. It was found out that the sticky wet materials coming from the screw feeder were starting to congest in the small feed tubing, making the incoming wet materials to pile up in the feed tubing entrance. Consequently, a squeezing action made by the screw feeder would take the water content out of the wet materials, causing them to dry out and lumped, blocking the narrow tubing. Figure 7 shows water content of the raw materials squirting out from the screw feed cap, indicating that materials were lumping inside the narrow feed tubing going to the molding plates.

After a long successive trial and error experiment the researcher had came up a final designed and developed a modified molder shown in Fig. 8.

IV. Conclusions and Recommendation

The design, fabrication and testing of the prototyped clay mixer and clay molder was successfully designed, fabricated and tested. It can provide the company the needed mechanized facility for efficient production and meet market demands on time. These improvements and new fabricated equipment are set to optimize production capacity and product quality, which in turn is projected to bring about increase in product demands, which can consequently lead to more local employment opportunities. It is recommended that for paper clay molder unit may add the kneading process in the design to make the machine more flexible.

V. Acknowledgement

The authors would like to thank the Northern Mindanao Consortium for Industry Energy and Emerging Technology Research and Development (NorMinCIEERD) of the Department of Science and Technology (DOST) region 10 for the research and development funding. Special thanks are also given to University of Science and Technology of Southern Philippines (USTP) Cagayan de Oro City Campus for the support to make this research a success and for awarding us the USTP PRAISE Awards for Intellectual Property Rights Award under Industrial Design. Also, would like to thank Cagayan de Oro Handmade Paper Inc. for adopting the technologies developed.

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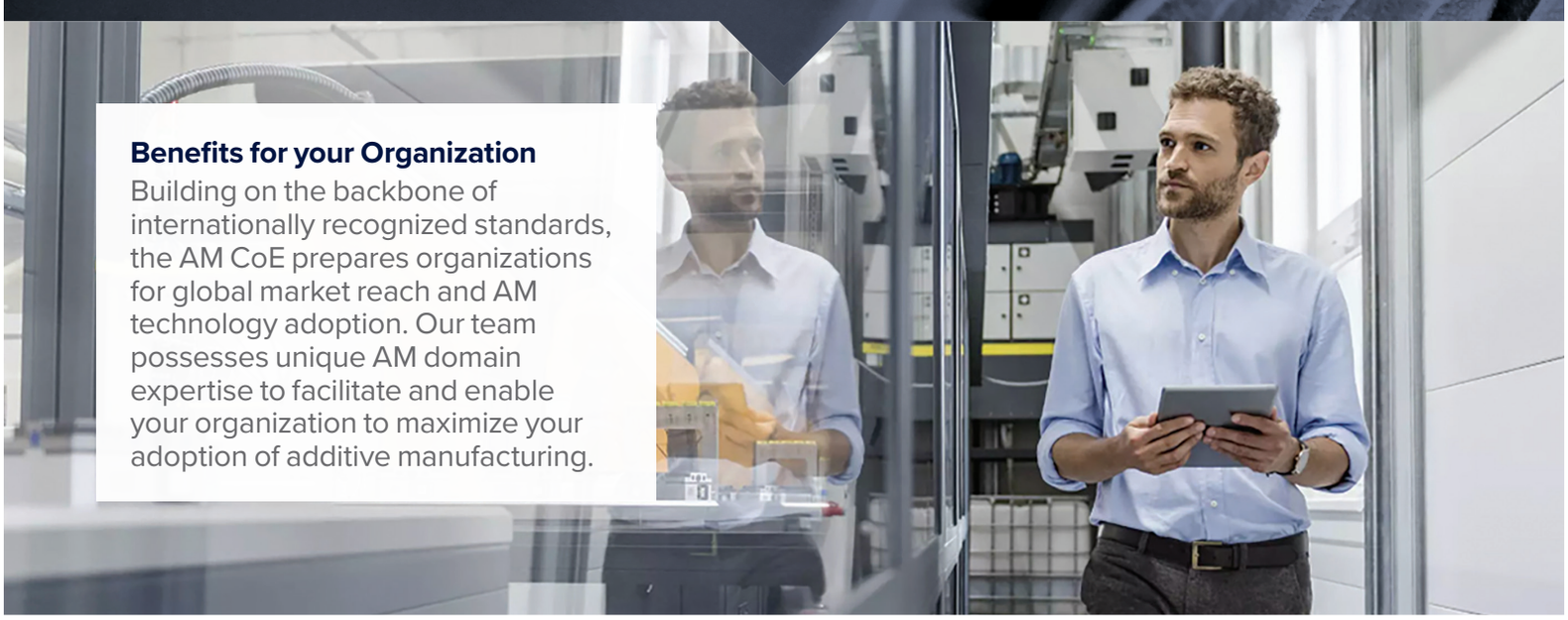

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Portable Coconut Grater with Presser*

Engr. Dahlia Gay A. Bunolna*1, Engr. Chosme Jones D. Aggihao*2, Ms. Karen A. Puguon*3

Abstract

The indigenous people of the north especially the Ifugaos are known not only for the Banaue Rice Terraces but also for their ingenuity. Before the introduction of rice farming, the staple food of the Ifugaos was gabi/taro locally known as 'latud/pihing' commonly enhanced by shells or mud fish. With the empowering of towns through the One Town, One Product (OTOP) program, latud/pihing and binakle have become an Ifugao delicacy, their desirability and palatability enhanced by coconut milk, thus with the aimed of increasing the efficiency of local food enthusiast in the preparation of the delicacy not only of latud/pihing but other local snacks needing coconut milk mixture like binakle, the design and development of a Portable Coconut Grater with Presser. The extraction of coconut milk for the preparation of delicacies is laborious through manual grating or the 'kayod'. Moreover, bringing one coconut to the market for grating purposes incurs additional expenses for the indigent people. This machine is designed to improve the grating speed and pressing quality. Results revealed that the portable coconut grater was able to grate coconut and reduce pressing time by 93% compared to the manual grating and pressing process. Although the portable grater used low cost materials, the performance and durability equated the grating machine available in the market. Through the development of the portable coconut grater, an Ifugao homemaker and entrepreneur would be able to maximize time and resources as well as increase efficiency and income.

Keywords: *grating machine, pressing machine, coconut, food preparation, Ifugao, applied research*

I. Introduction

The pandemic had adversely affected the economic lives of people especially those who are self-employed. The members of the community who lived by peddling their wares and products, small-scale eatery operators and home makers who prepare homemade snacks for additional income before going to the fields were greatly affected by the pandemic.

As a university that embraced sustainable extension and community engagement as one of its mandate, we are being challenged to create projects and to develop technology that would introduce relevant and employable skills to the members of the community to help them eventually rise and recover from the adversity brought about by the pandemic. IFSU is one with national, regional and local authorities in alleviating the lives of Ifugao stakeholders and citizens through the development and transfer of technology.

Bakle (making of rice cakes), one of Ifugao's traditional rice culture is performed during the month of August as a post-harvest thanksgiving festival for a bountiful harvest. The community takes this time to collaboratively thank the gods and the spirits of their ancestors for a bountiful harvest. Inspired by this tradition, homemakers prepare bakle as snack and are consigned in canteens near the provincial office/capitol, in the municipal hall, in the elementary and secondary schools, in the market square and even in IFSU food court. Latud/pihing (taro stalk), a delicacy in Ifugao, that perfectly complements chicken and pork, are prepared and consigned in local eateries around the province.

* Presented during the National Metals and Engineering Conference (NMEC), June 15, 2022.

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These two delicacies remain to be favorites of the Ifugao people as they are served not only during thanksgiving occasions but are served in food establishments in the province. Coconut oil serves as a main component in the preparation.

The coconut tree is one of the most important crops in the Philippines. It is a kind of palm tree with a single straight trunk and has been used for many purposes since prehistoric times. Every part can be utilized - the fruits, wood, and leaves. The uses of coconuts range from cooking and nutrition to skin health, cancer prevention, beauty products, and fuel. The flesh is served as food, milk and flour. However, the fruit to be utilized needs peeling and most importantly grating and pressing. For a home-maker, grating and peeling manually consumes time and energy while decreasing the quantity of production.

As a vibrant university in the capital town of Lagawe and in recognition of the plight of food peddlers, small-scale eatery operators and home makers who prepare homemade snacks for additional income, immediate intervention must be advanced for them to continue bakle and pihing preparation and production. While there may be a slight draw back in their regular monthly income, they will not be totally displaced as they will continue to be productive multi-disciplinary members of the community. Slowly and eventually, these self-employed members of the community whose interest and love is traditional snack and viand preparation would spring back in full swing to their feet, recovered from the scars of the pandemic.

This study aimed to introduce a low-cost machine that is designed to combine the process of peeling and grating in one device. This newly designed machine is suitable to be used domestically since it is small-sized, lightweight and is convenient to carry and store. It works with a composition of a clamping mechanism, grater, peeling blade, movable arm and a pair of end-cutting blade.

II. Materials and Method

The research used applied research design for the gap analysis phase and design phase; the project development design for the fabrication and assembly phase; functionality testing phase; prototype development phase; and technical evaluation phase. The study utilized personal interviews and surveys for the acceptance and economic impact review of the improved coconut grater.

The grater needs electricity for the motor to spin the blade. After manually cutting the coconut fruit into two pieces exposing the flesh, the other half is positioned facing the rotating blade and pressed until all the flesh was grated. A bowl or a wide container is put below the plate like vessel to catch the grated flesh. The process is finished in approximately 3-5 minutes depending on the size of the coconut and the thickness of the flesh. After grating the flesh, the user scoops all tiny pieces dashed on the plate like vessel and puts it away ready to be squeezed.

After grating, the flesh is put in the container above the jack and is lifted upward until it reaches the cover squeezing it until all the juice are extracted. The juice now flows on the small hole leading to the tube and dropping on a container where the juice is collected and set aside ready for cooking.

III. Result and Discussion

Portable Grater Design

As shown in **Fig. 1**, the body is made up of metals. It has a height of 1 meter, width of 0.25 meter and a length of 1 meter. The body is made by the combination of angle bar, flat bar, flat sheet, stainless pan and etc.

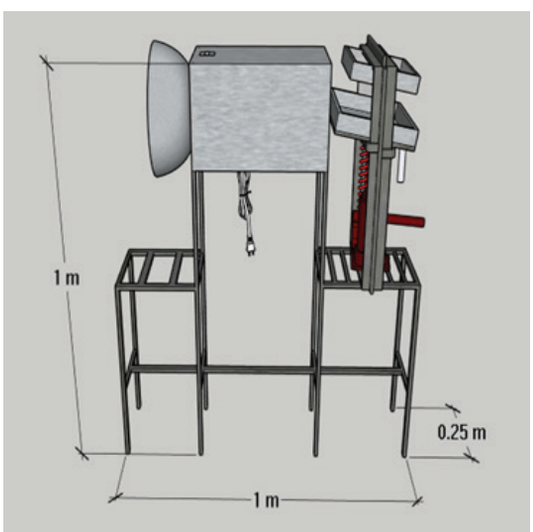

Fig. 1

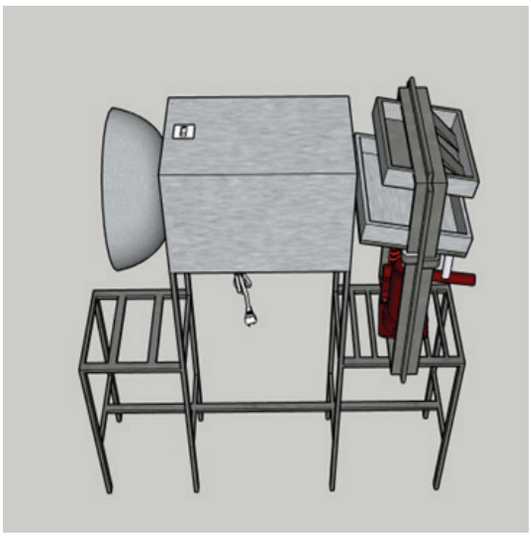

Fig. 2

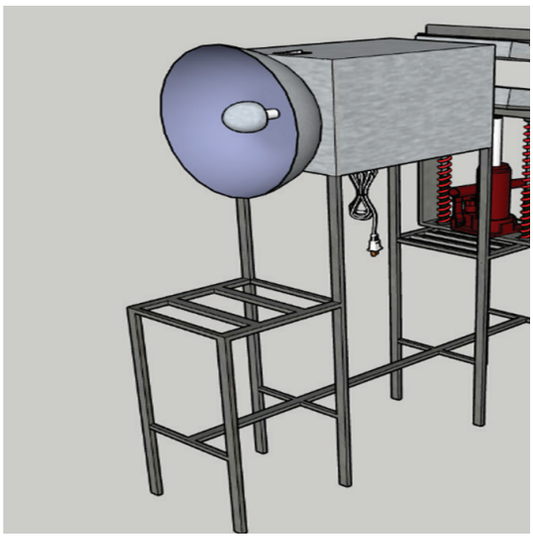

Fig. 3

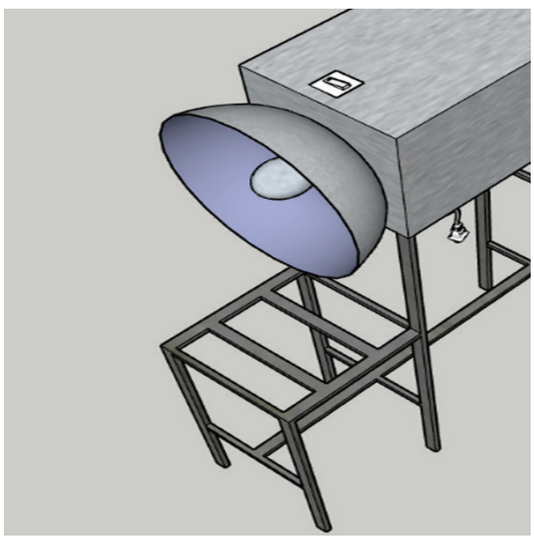

Fig. 4

Fig. 5

It has eight legs enough to hold the whole equipment (**Fig. 2**). The back of the stainless plate contains the motor, capacitor and wires. It is rectangular enclosed with a stainless sheet (**Fig. 3**). The presence of electricity makes the motor automatically rotate the grater blade.

The portable grater has a safety switch and stainless plate with a diameter of 0.34 meter in front designed to catch the splashing flesh to avoid the messy splattering (**Fig. 4**). The center of the plate has a rotating cylinder with numerous spikes designed to break the coconut flesh into tiny pieces (**Fig. 4**). A container is placed below the stainless plate to collect the falling grated flesh.

Another spare blade is designed for the grater. It is used to grate the coconut flesh into larger pieces. It is attached into the center of the stainless plate. It is made up of metals with sharp edges (**Fig. 5**).

For the presser, it has a hydraulic jack with a flat sheet on top where the user can place the stainless container. The flat sheet is welded on a flat bar connected to the hydraulic jack and positioned 10° diagonally. The stainless container is rectangular in shape with a small hole. This container will hold the grated flesh.

After putting the grated flesh on the container, the user will operate the hydraulic jack to lift the container until it reaches the flat sheet above squeezing the grated flesh. A container is placed below the tube to collect the juice.

This machine is designed to be durable. Cleaning after usage is necessary to avoid rust.

In the development of the utility model, the researchers used the following materials: AC motor, commercial coconut grater blade, universal motor speed controller set, electrical wires, capacitor, potentiometer (w/ selector switch), male plug, push-button switches, heavy-duty foot switch, Windows 10 desktop computer, stainless steel sheet (food-grade), angle bars, stainless steel pipes (food-grade), steel flat bars, heavy-duty swivel casters (w/ 2-wheel brake), and bolt and nuts. During the fabrication and assembly phase, the researchers used welding electrodes and stainless-steel filler rods, as well as the argon tank refill. During the functionality test, a tachometer is required for measuring the motor speed. The construction and development of the project has gone through the following procedures: conceptualization of the design, identification of the needed supplies and materials, fabrication of parts, assembly of the mechanical parts of the project based on the conceptualized design, and connect electrical components of the utility model. The researchers conducted functionality test. If there were things found not in conformity to the expected output, the proponents needed to do necessary revisions until the expected output is arrived at. Guests and experienced users of commercial graters were invited to rate the machine during functionality and technical performance testing.

IV. Conclusion

This low cost portable coconut grater and squeezer was designed and developed to perform the grating and squeezing of coconut flesh in one device. The prototype was able to grate and squeeze the coconut flesh reducing the time by 93% compared to manual grating and squeezing. Though the machine is low-cost, it was proven to be gender friendly as it can be used by all sexes in the society. Husbands can take part in the preparation of bakle and latud to be sold online, peddled and consigned in local food establishments around the province. Quantity of production is increased while reducing grating time and squeezing effort.

The researchers recommend that this simple machine/technology be shared to the community via Extension and Community Engagement especially to the self-employed members who are into the preparation of snacks and viand needing coconut milk as a main ingredient. Since the shelf life of the coconut is very short, this machine would be able to maintain the freshness of the coconut milk, thereby, enhancing the palatability of the food products prepared.

Further, improvement of the design is also recommended. The body of the machine is mostly weld. The researchers recommend bolts to be used for attachment instead of welding. Steel in some parts may be replaced with stainless for more lightlessness.

V. Acknowledgement

The authors would like to thank the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) for entrusting and funding this research, as well as the IFSU-MEIC Team for extending their profound knowledge and effort towards the realization of this study.

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Evaluating Roasting Performance Using the Developed Solar Thermal Processing System*

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Jude Andrea Eve P. Maternal*[4], Jonathan H. Perez*[5]

Abstract

With the development of innovative solar technologies, it is possible to utilize solar flux in the medium temperature range for the post-harvest processing of agricultural products. This study will be taken up for the enhancement of current post-harvest processing facilities of Micro, Small, and Medium Enterprises (MSMEs) using renewable energy by developing a system for roasting cashew nuts and other perishable agricultural products. This study aims to evaluate the viability of a developed Solar Thermal Processing (STP) System by testing its thermal efficiency and productivity. The STP system will be fabricated and tested for energy efficiency and compared with existing technology. It was then evaluated based on ASAE S580.1 (Testing and Reporting Solar Cooker Performance) standards. Also, the result shows that the solar concentrator can concentrate solar irradiation up to four times, producing from 165.2°C to 396.6°C, and generating a drum temperature of almost 200°C. Based on the roasting cashew kernels sample suggests the ideal operating drum temperature and time for a 5 kg load is 100°C-120°C for 50-60 minutes and for 10 kg, 110°C-120°C for 60-90 minutes, respectively. Lastly, the machine was able to reduce roasting time by 30 minutes for a given full load of 10 kg with a moisture reduction of 5%-10% per minute which helps the small and medium-sized enterprises farmers to give inclusive and sustainable growth in the countryside. Products would have a longer shelf life, be lightweight, and give competitive prices than raw agricultural products.

Keywords: *Solar-Thermal, Thermal Efficiency, Cashew Nuts, Roasting*

I. Introduction

Mindanao has abundant natural resources. It is considered the Philippines' food basket, producing 40 percent of the country's food needs, and contributing more than 30 percent to the country's food trade. Agriculture accounts for one-third of its land area. Northern Mindanao is an agro-industrial region with one of the highest concentrations of coconut, mango, cashew, coffee and other crops [1]. According to the 2015 Philippine Statistics Authority report [2], 11.29 million people depended on agriculture as a means of subsistence. This represented 29.2% of the country's total employment, with many of these farmers in the micro, small and medium-sized enterprises (MSME) category. MSMEs make up 99.6% of the 900,914 business enterprises in the Philippines, based on 2015 Philippine Statistics Authority figures [2], less than 8,195 or below 1% are in the agriculture, forestry, and fishing industries. There is still a need to emphasize the importance of establishing more MSMEs in the agriculture sector, especially if we will consider that rural poverty is still extremely high in the Philippines. One of the reasons why agricultural MSMEs are outnumbered by other industries is because of the lack of technical support to the farmers, many are discouraged to venture into agriculture while others have shifted to other industries.

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Local food processors especially MSMEs faced with challenges like maintaining market share; a wide variety of imported processed foods readily enter the market due to increased trade liberalization and innovating or introducing new products. High capital investment and acquisition of state-of-the-art equipment deprived our local manufacturers of the opportunity to expand product lines to meet a diverse range of customer requirements and become globally competitive. Consequently, there is the priority need of the food processors for affordable equipment to increase production efficiency and compliance to standard requirements that will enable MSMEs to become more competitive in both local and foreign markets.

However, the conventional methods of roasting are inefficient, uncontrollable, laborious, tedious, energy and time consuming. These practices also provide a very un-hygienic environment to farmers/operators such as direct exposure to heat radiations and smoke. Many technological efforts have been made to facilitate the rural communities by mechanizing the roasting process [3], but all rely on fuels or electric energy. This scenario creates a tremendous need to discover such alternate resources for heat generation which are non-depleting and environment-friendly, i.e., solar thermal energy. The solar concentrators offer an alternative use for fossil fuels. It can produce thermal energy at high temperatures without environmental emission by concentrating solar irradiance. Some of the major drawbacks of fossil fuels are avoided by solar concentrators. The system will help to identify the maximum solar irradiance at a given time to improve its solar tracking and solar cooking.

Data from PAGASA shows that the Philippines, particularly Region X, receives an average of 5,500 W/m2 on an average of 7.8 solar hours every day (**Table 1**). This abundance of solar energy is enough for solar technologies and to process agricultural products.

This study will be taken up for the enhancement of existing post-harvest processing facilities using renewable energy by developing a Concentrated Solar Thermal Processing (STP) for roasting cashew nuts. Existing roasting techniques are not adaptable for the growers of developing countries due to high initial investment and rapidly escalating prices of non-renewable energy resources. The

Table 1. Solar Radiation from the National Solar Radiation Center of DOST PAGASA in El Salvador, Misamis Oriental Station for the Period January 1, 2013, to March 2016 (Latitude: 8o 32' N, Longitude: 124o 33' E).

Months	2013		2014		2015		2016	
	Total (W/m^2)	Average (W/m^2)	Total (W/m^2)	Average (W/m^2)	Total (W/m^2)	Average (W/m^2)	Total (W/m^2)	Average (W/m^2)
January	133,371	3,818	97,828	3,156	139,806	4,660	12,617	
February	149,841	5,351	151,942	5,627	171,423	5,714	23,292	
March	205,412	6,626	181,946	5,869	189,573	6,115		27,240
April	201,450	6,498	183,406	6,114	186,841	6,228		
May	206,425	6,659	209,822	6,768	200,158	6,456		
June	158,763	5,212	149,863	6,180	150,646	5,021		
July	178,645	5,763	154,860	4,995	478,735	4,797		
August	164,773	5,315	199,967	6,451				
September	160,620	5,181	152,751	5,091				
October	142,980	4,612						
November	144,905	4,674	166,456	5,481				
December	112,817	3,639	142,517	4,840	158,142	5,101		
Total	1,940,002	63,348						
Average	161666.833	5,279	162,914.36	5,506.54	168,165.50	5,511.50		

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innovation is expected to lessen energy poverty in far flung agricultural communities that is out of reach of government infrastructure because small scale farmers will have the capacity to process their surplus harvest and sell more valuable products. Farmers will have economic freedom from traders because their products would have a longer shelf life, light weight and commands better prices than raw agricultural products. A Concentrated Solar cashew roaster will be fabricated and will be tested for energy efficiency and economic benefits to the farmers and compare it with existing technology. The outcome is that it would give chance for small and medium-sized enterprises farmers to become entrepreneurs and give inclusive and sustainable growth in the countryside.

This will have a big impact on the quality of life of the farmers, not just increasing income but also creating healthier working conditions, safer foods, less wastage, more inclusive growth and less exploitation from traders. The Development of Concentrated Solar processor offers an alternative for fossil fuels. Through concentrating solar irradiance thermal energy is produced at high temperature without carbon footprints. Some of the major drawbacks of fossil fuels are avoided by solar concentrator. Further, the solar data generated from this study as to the concentrated solar irradiance will help identify the ideal conditions for solar technology and improve solar tracking and solar cooking in the region.

II. Materials and Method

1. Experimental set-up and site location

The solar concentrator plays an important role in the system (**Fig. 1**). It supplies the heat needed for processing the agricultural commodities thus assessment is necessary to identify how much solar flux can be generated from the solar concentrator as shown in **Table 2.**

Site validation is one of the key variables in evaluating the solar concentrator's performance. Selecting the right location boosts the efficiency of solar technologies. The experimentation is conducted at the rooftop of LRC building 23 inside the campus of the University of Science and Technology of Southern Philippines located at CM Recto Avenue Lapasan, Cagayan de Oro City (Latitude: 8.4855°N, Longitude: 124.6564°E). The oven solar cooker is a drum-type rotating at a speed of 10 rpm, recommended speed for the roasting process. The solar flux will be reflected into the oven aperture allowing the drum as the receiver to absorb the heat.

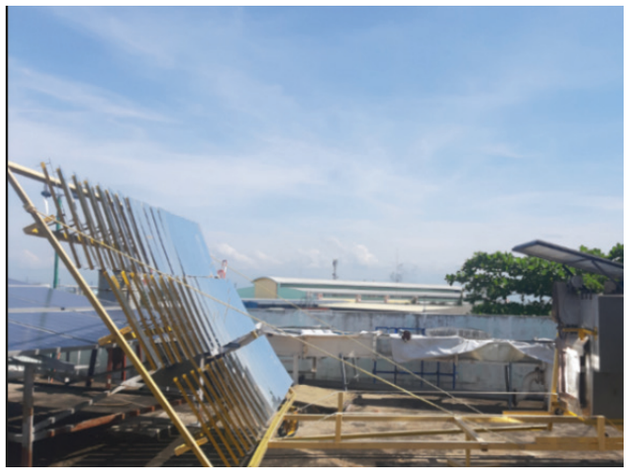

Fig. 1. Linear Fresnel Reflector Set-Up

Table 2. Solar Concentrator Parts

Solar Concentrator Type:	Linear Fresnel Reflector
Reflector Area:	$3m^2$
Number of Mirrors:	68 pcs
Size of Mirrors:	5 in. width × 24 in. length

2. Experimental materials

Cashew kernels from a local supplier were used as a test sample. Before conducting the experiment, cashew kernels were evaluated first in terms of the moisture content, color, and size. This is to classify the quality of the cashew before it undergoes the process of roasting. After the test, cashew kernels were packed and sealed for analysis.

3. Experimental parameters

The following are the parameters considered for the evaluation of the STP's performance.

Available Solar Irradiance: The available solar irradiance is an essential element to produce solar thermal energy using the Linear Fresnel Concentrator. A pyranometer is used to measure the available solar irradiance.

Concentrated Solar Irradiance: Using the linear Fresnel concentrator will convert the available solar

irradiance into concentrated solar irradiance, which produces a higher amount of solar flux pyranometer used to measure the concentrated solar irradiance.

Temperature: This refers to how much is the temperature produced by the solar concentrator which is available for heating. A thermal gun and thermometer are used to measure the temperature.

Humidity: It is the amount of water vapor in the air. If there is a lot of water vapor in the air, it will take more heat making roasting or drying time to be slower.

Cloudiness: Cloud cover (also known as cloudiness, cloudage, or cloud amount) refers to the fraction of the sky obscured by clouds when observed from a particular location. The cloud cover is correlated to the sunshine duration as the least cloudy locales are the sunniest ones while the cloudiest areas are the least sunny places. It is categorized as the following shown in **Table 3.**

Table 3. Cloud Cover Categorization

Sky Condition	Description
Clear (C)	no clouds to 1/10 cover
Scattered (S)	1/10 to 5/10 cover
Broken (B)	5/10 to 9/10 cover
Overcast (O)	100% cloud cover (gloomy day)

4. Experimental procedure

To determine the thermal efficiency and cooking power of the solar concentrator, the performance testing procedure will adopt the method of water boiling test and time requirement to attain maximum temperature. Data of solar irradiance will be gathered from 8:00 am-5:00 pm using a manual data collection table.

The roasting of cashew kernels was conducted based on ASAE S580.1 (suggested time for testing and reporting solar cooker performance) [4], [5]. Testing is done in no-load condition and with a full load of 10 kg. Time, temperature, and moisture content are the key parameters in this performance analysis.

5. Data analysis

The amount of solar flux varies depending on the weather condition. This will affect the duration of the roasting process. The data gathered for analysis includes the amount of Solar Flux, Thermal Efficiency Cooking power and moisture reduction.

III. Results

1. No-load experiment

The results no-load experiment show that the STP's solar concentrator was able to produce a solar flux up to four to six times the available solar irradiance amounting to 165.2°C to 396.6°C. At no-load conditions the maximum drum temperature reaches 296°C. Shown in **Fig. 2** is the solar flux recorded on February 2, 2021. Its equivalent temperature was shown in **Fig. 3.** The effect of cloud cover certainly affects the amount of concentrated solar irradiance, limiting the amount of temperature available for heating, which has correlated to the same observation as [6].

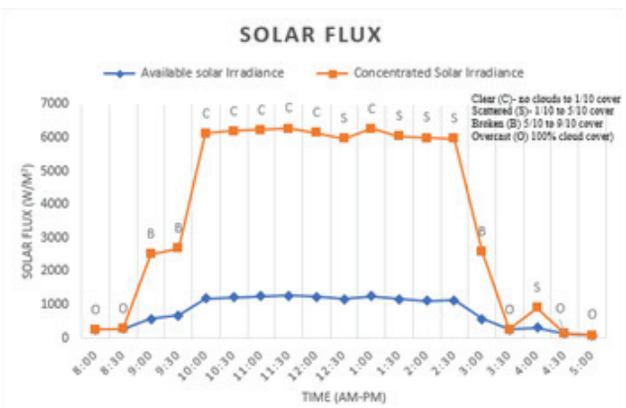

Fig. 2. Solar flux recorded

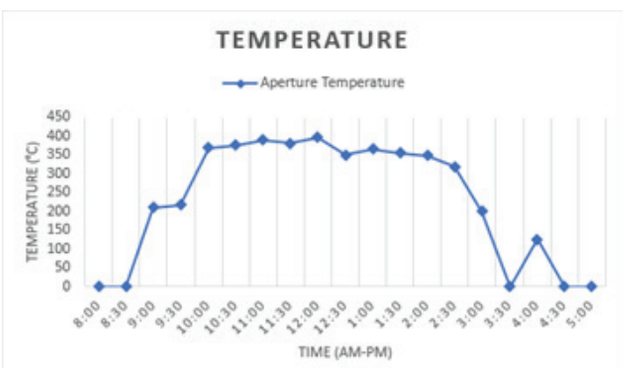

Fig. 3. Equivalent Temperature for the concentrated solar irradiance

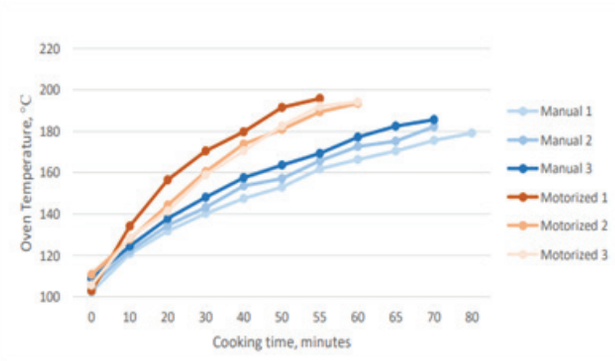

Fig. 4. Cooking Time vs Temperature for Manual Operated and the STP

2. Full load experiment

Under a full load condition of 10 kilograms, the researcher conducted three trials each for the manually operated solar cashew nut roaster and the motorized cashew nut roaster. The cooking time recorded for each of these trials is shown in **Fig. 4.**

It is observed that the manually operated cashew nut roaster had a slow temperature rise than the motorized solar cashew nut roaster, which then constitutes its slower cooking time. The average cooking time of the manually operated cashew nut roaster is 93 minutes (1 hour and 33 minutes), while the average cooking time of the motorized solar cashew nut roaster is 63 minutes (1 hour and 3 minutes). A 30-minute difference in cooking time is a significant improvement in the aspect of improving the performance of the existing cashew roaster and equates to an additional two to three batches of cashew kernels to be roasted in a day, which shows same trend as the results of [7].

3. Moisture content Analysis

The initial moisture content of pre-dried cashew kernels ranges from 5-8%. The experimental investigation results in an average moisture reduction of 3.9% per hour by the STP's roaster.

IV. Conclusion

The assessment of the STP system thermal and productivity test results produce a solar flux of up to four times the available solar irradiance equal to 396.6°C intended for heating. Using the STP solar concentrator unit, oven chamber can hold a maximum temperature of 296°C. Roasting time was reduced by 30 minutes for a full load of 10 kg with an average moisture reduction of 0.06% per minute. Increased roasted cashew kernels production helps to increases profit for the farmers. Lastly, proper data collection on the concentrated solar irradiance is needed in order to identify the ideal conditions for solar technology and also to improve the solar cooking in the region.

V. Acknowledgement

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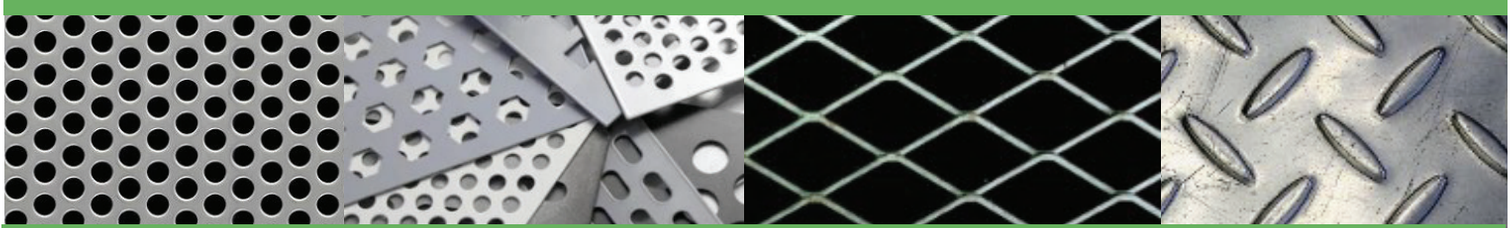

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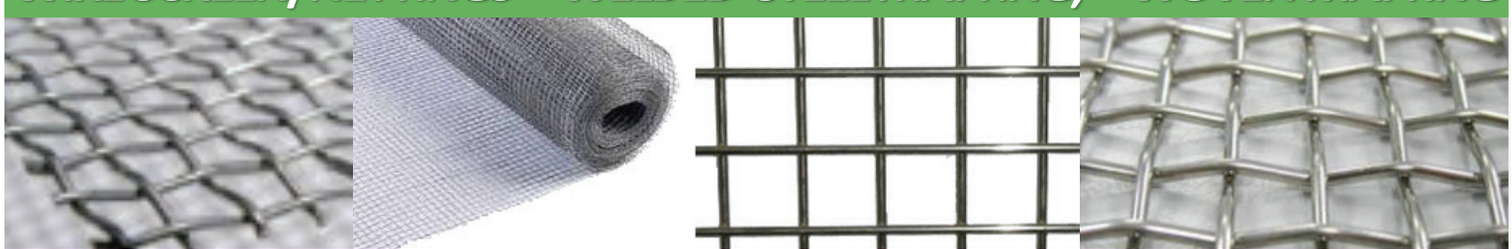

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Cloud-Based Multi Alarm Warning System for Real-Time Disaster Detection*

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Abstract

The Philippines has a National Disaster Risk Reduction and Management Council that provides a mobile alert in the presence of natural disasters. This study aims to deepen the real-time accuracy of disaster awareness by designing a device that can detect earthquakes and floods to inform users through mobile applications in live data. The low-cost microcontroller and sensors, ESP32 Wi-Fi Dev Module, HC-SR04 Ultrasonic Sensor, and ADXL335 Accelerometer are integrated to provide a multi disaster detection in Cavite City as one of the priority subject areas. Solar Panels are installed to provide continuous power to the device to enable environment detection in case of a natural disaster. Any mobile application users will be notified in real-time of a flood if the road is passable to all types of vehicles, not passable to light vehicles, and not passable to all types of vehicles, including the flood level in inches. The device was able to detect ground shaking rated at intensity one (1) and gathered 98.59% of accuracy for flood detection. With the following output, it can be deduced that the users may be alarmed and notified at times of flood increase and ground shaking in real-time to strengthen disaster awareness for survivability.

Keywords: *Earthquake, flood, disaster, multi alarm, cloud based*

I. Introduction

The National Disaster Risk Reduction and Management Council (NDRRMC) with telecommunication companies comply with Republic Act No. 10639, Free Mobile Disaster Alerts Act [1], [7]. The mobile alerts or Emergency Alert and Warning Message (EAWM) remind the protocols in case of disasters. The alerts are being sent to the citizens after the Philippine Atmospheric, Geographical, and Astronomical Service Administration (PAGASA) issues an advisory and could inform the citizens before and after a disaster. The message reminder is sent usually before and after a disaster occurs. Researchers aim to provide a real-time monitoring system for earthquakes and floods so that users can be alarmed by the proper protocols through the mobile application.

The project's development requires C++ programming knowledge and Google Firebase to integrate the real-time awareness of the residents when it comes to floods that could give them disease and earthquake presence that could occur at any time on top of the citizen's awareness and consciousness. The researchers will also optimize the prototype with solar cell installation to allow the functioning of the prototype in the absence of electrical power.

II. Materials and Methods

The mobile application that the users will use must be connected to a cloud database that continuously collects data from the prototype. The prototype is a pole-like material, as shown in **Fig. 1**, that will be installed in the chosen locations within the city to observe ground shakiness for possible earthquakes and flood alerts. The project uses HC-SR04 ultrasonic sensor that uses sound waves to calculate

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the distance when the echo bounced back to the sensor [5]. Detection of the possible earthquake through ground shaking, ADXL 335 was used to determine any changes within the X, Y, and Z-axis that will be integrated through programming [3]. For the system to be connected to the cloud, the ESP32 Wi-Fi module will be the microcontroller [4]. ESP32 Wi-Fi will send the serial data through a Wi-Fi connection to Google Firebase. All numerical and alphabetical data will be displayed on the Firebase that will serve as another data in Kodular for the development of the android application.

III. Results

The multi alarm feature must be measured and evaluated individually for the earthquake alarm in real-time and flood data accuracy. Earthquake simulation was conducted by screwing the bottom of the device on a moving platform where at least the intensity of one earthquake is simulated. The alarm delay of the device is rated at 1.77s for the mobile phone installed with the application. A 10-trial test for flood detection accuracy compared to a measuring tool for flood depth is shown in **Table 1.** The average accuracy of the device's flood detection is rated at 98.59%. The device performance was observed in one week, where data from firebase and mobile applications is compared, as shown in **Fig. 2.**

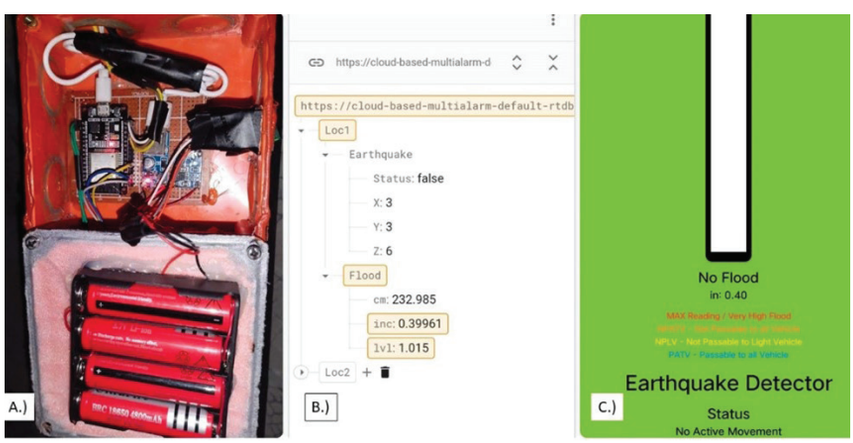
Fig. 1. Design of the Device

$$ccuracy = \left(1 - \frac{/Actual\ Flood\ Depth_{in} - \ Flood\ Depth\ in\ Application_{in}/}{Actual\ Flood\ Depth_{in}}\ x\ 100\right)$$

Table 1. Accuracy of Flood Level Using HC-SR04 Ultrasonic Sensor

Trial	Actual Flood Depth (In)	Flood Depth in Application (In)	Accuracy (%)	Percent Error (%)
1	0	-0.04	95.79	4.21
2	5.5	5.68	96.60	3.27
3	7.8	7.72	99.08	1.03
4	10	10.01	99.89	0.10
5	12	12.07	99.34	0.58
6	14	13.96	99.75	0.29
7	18	18.09	99.47	0.50
8	20	19.85	99.28	0.75
9	22.5	22.13	98.40	1.64
10	24.7	24.27	98.30	1.74

The negative reading of flood level is due to the HC-SR04 continuous reading that leads to uncertainty.



Day 5-6:24 PM

Inactive Earthquake / Ground Shaking

Fig. 2. Day Five Testing of the Device

IV. Discussion

Cloud ability was one of the main focuses of the researchers to integrate sensors with environmental condition detection. A similar project where flood levels are sent via text messages using Global System for Mobile Communication module [6]. The researchers improved the communication set-up between devices and users through real-time capability through a mobile application as provided an article about the Republic Act No. 10639, the Free Mobile Disasters Alerts Act is already existing, and text messages alone cannot be a complete channel of information at times of continuous disasters [7]. The used accelerometer by the researchers to detect earthquake or ground shaking was also used by Computer Engineering Students of John Paul College, where it must be placed near the ground and will provide a sound signal with its vicinity during an earthquake. The researchers broaden the scope of users by integrating the data of sensors into a single mobile application [2].

V. Conclusion

Disaster Awareness must be included in the continuous development of a city. PAGASA informs the NDRRMC of the forecasted earthquake and will send a text message to the citizens before and after a disaster. During the earthquake, the researchers filled the gap by installing the developed mobile application with a premade voice instruction for a better survivability method. Using the mobile application will also allow users to monitor the flood condition to promote their readiness for the environmental condition they are residing in. The device was made possible due to the low-cost sensors integrated into a single device. HC-SR04 Ultrasonic Sensor is effective in terms of calculating the flood depth with a rating of 98.59%. ADXL335 accelerometer sensor can detect earthquakes at intensity one and above. The sensors' readings were connected to the google firebase through the ESP32 microcontroller, which enables its cloud sending ability

VI. Acknowledgments

The researchers would like to acknowledge Engr. Tommy A. Ditucalan from San Sebastian College-Recoletos de Cavite for having served as the gateway for the researchers to publish the work to Metals and Engineering Week 2022. The researcher's adviser, Engr. Paolo Lozada, placed the researchers on the success of the project. The parents of the researchers, the Cavite City Local Disaster Risk Reduction Management Office, Engr. Eden Caerlang, Mrs Erlinda Dacayan Caerlang, and Mr Hizon Pastor Pili, are those people who gave assurance to the researchers that the project has a place in the community.

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Professional site	[6] Natividad, J. G., & Mendez, J. M. (2018, March). *Flood monitoring and early warning system using ultrasonic sensor*. In IOP Conference Series: Materials Science and Engineering (Vol. 325, No. 1, p. 012020). IOP Publishing. doi:10.1088/1757-899x/325/1/012020
Data Sheet	[7] Republic Act No. 10639 *An Act Mandating the Telecommunications Service Providers to Send Free Mobile Alerts in the Events of Natural and man-made Disasters*

IoT Based Intelligent Classroom*

Grosby A. Dela Cruz*[1], Marvin O. Mallari*[2], Arzel P. Pinpin*[3]

Abstract

Nowadays, automation became the part of today's development of technology. Security in laboratory equipment as well as the improper usage of classrooms has been the problems found in any institution. Developing an intelligent classroom with the implementation of automation has a lot of benefit. Using a microcontroller such as Raspberry Pi will be the main controller of the system, and IoT will manage the classroom schedules. Door, lighting, and air conditioning was automated with the used of 12v relay and a motion sensor. Scheduling software is also installed on a computer system for the administrator to easily manage the classroom or laboratory schedules by adding, editing, and deleting schedules and also registering users. Once the Passive Infrared senses motion, the solenoid lock of the door will unlock, and the lighting and air condition will turn on. The system will only be activated when there is a schedule in the intelligent classroom. Even there is a plotted schedule when the room is already unoccupied, lighting and air conditioning will turn off. This can be installed in any classroom or school laboratories to avoid any unauthorized access of the equipment. Now visualize the advancement that can be attained once automation is applied.

Keywords: *IoT, Automation, Intelligent Classroom, Raspberry Pi, Scheduling System*

I. Introduction

Putting technology to work to improve the security of the laboratory equipment in any institution is very vital nowadays. With the implementation of modern technology such as IoT and electronic hardware and devices installed [1] can automate classroom or laboratory utilities.

Unauthorized access, misuse or removal of laboratory and its equipment is the primary concern of any institution. Laboratory personnel is the one responsible to safeguard the laboratory equipment against theft and misuse, but the more automation is applied, the effective the security measures becomes.

Holy Cross College, the school with a heart, is an academic institution located in Sta. Ana, Pampanga. Holy Cross College laboratories are being monitored by a laboratory technician. However, unauthorized access, schedules that are not being followed, and lights are turned on even the premise is unoccupied are observed [1].

Intelligent classroom can be done during planning stage [1] and with the application of hardware and software, **"IoT Based Intelligent Classroom"** will secure the laboratory equipment, automate the lighting and air conditioning, and lessen the unauthorized access or use of the classroom or laboratory.

Automation is the main concept in the project, where automation is the technology used in controlling the production and delivery of products and services [3].

In line with the foregoing discussion, the study will specifically seek to answer the following questions:

1. How to secure laboratory equipment?
2. How to automate the classroom or laboratory utilities such as lighting and air conditioning?

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3. How to lessen the unauthorized access of the laboratory?

The researchers aim to develop **"IoT Based Intelligent Classroom"** for Holy Cross College, a project that will secure the laboratory equipment, and automate lighting and air conditioning unit with the following specific objectives:

1. To improve security measures in laboratory with the use of automation.
2. To automate the laboratory's lighting and air conditioning.
3. To develop a system that will manage classroom or laboratory schedules.

II. Research Methods

Waterfall method is a systems development life cycle that each phase has to be completed first before going to the next phase [2]. Waterfall method has five phases, the system design, implementation, integration and testing, deployment of the system, and maintenance [1].

System Design

To develop the whole system, Python will be used to develop a scheduling system to manage the entrees in the classroom or laboratory. Laboratory technician or any authorized personnel can manage users and schedules.

The system will only be activated when there is a schedule in the classroom or laboratory. A passive infrared is installed to detect motion. Once the sensor senses motion, and when there is a schedule, the door will unlock, lighting and air conditioning will turn on. However, when there is no schedule plotted in the system, door, lighting, and air conditioning automation will not activate even the sensor senses motion. A touch sensor is also installed so even when the door locked of the occupied laboratory at the end of every schedule, occupants can still leave the premise. The researchers used Raspberry Pi as the main controller of the whole system.

Implementation

All the components in the system are tested, faculties from the School of Engineering, Computer, and Library Studies evaluated the system before the implementation to check if the system meet the requirements.

The proponent used survey questionnaire to gather the data needed for the study, and evaluation tool to get the comment or point of view of the evaluators regarding the developed system.

Integration and Testing

After each and every component is tested, the system was tested in a whole by the respondents.

Block Diagram

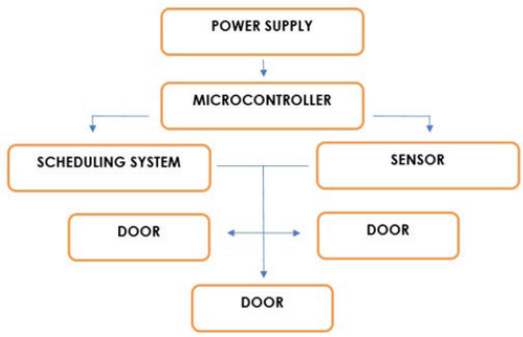

Fig. 1. System Block Diagram

When the system is plugged to the 220v outlet, it will supply voltage to the microcontroller that will run the whole system, once there is a plotted schedule, the system will be activated and when the sensor senses motion, door controller will unlock, and lighting and air conditioning will turn on (**Fig. 1**). The system will be deactivated every end of the plotted schedule.

Deployment of the System

Holy Cross College spent thousands of pesos in purchasing equipment to provide quality education for students. Currently, the Computer Engineering laboratory of Holy Cross College, the school with a heart, has door knobs that uses keys to unlock, manually switching on and off lighting and air conditioning, and unsecured cabinets where equipment such as microprocessors, logic circuits digital trainer, oscillators, and etc. are placed.

Using the **"IoT Based Intelligent Classroom"**, unauthorized access in the premise and misuse or possible theft of the laboratory equipment will be prevented.

Maintenance

As the system can be installed in any classroom or laboratory of Holy Cross College, any authorized personnel or laboratory technician can manage the scheduling software.

III. Results and Discussions

Development

The system **"IoT Based Intelligent Classroom"** was developed to provide security for the laboratory equipment and to make sure that the class schedules are being followed to avoid unauthorized access of the premise. The development of this study is also to equip our school and students about the latest trends in technology.

Testing

To make sure that the whole system is working without errors, testing was done by the faculty of School of Engineering, Computer, and Library Studies who are knowledgeable in the said system.

Implementation

To fully implement the system, an authorized personnel or laboratory technician can add, edit, and delete schedules and users to a computer system or laptop that is networked in the system. If for example plotted schedule are, first subject 8:00AM-9:00AM, and second subject is 10:00AM-11:00AM, the system will be activated at exactly 8:00AM and will be deactivated at exactly 9:00AM, so even when the sensor senses motion at 9:00AM-10:00AM, it will not unlock the door. The system will again be activated at exactly 10:00AM to 11:00AM.

IV. Conclusion

The **"IoT Based Intelligent Classroom"** is a system developed by the researchers for Holy Cross College, the school with a heart, using the current trends in technology such as Internet of Things and automation, the researchers were able to automate door, lighting, and air conditioning to secure the laboratory equipment and avoid or lessen the unauthorized use of utilities and access of the premise. The system developed provides ease to the institution and laboratory technician as the system will definitely secure the laboratory equipment.

V. Acknowledgement

To God, thank you for your grace and blessings which made this study possible, to our family who are our rock and source of strength, to our colleagues in SECLS who are very supportive and respectful. To Holy Cross College, we thank you for all the opportunities.

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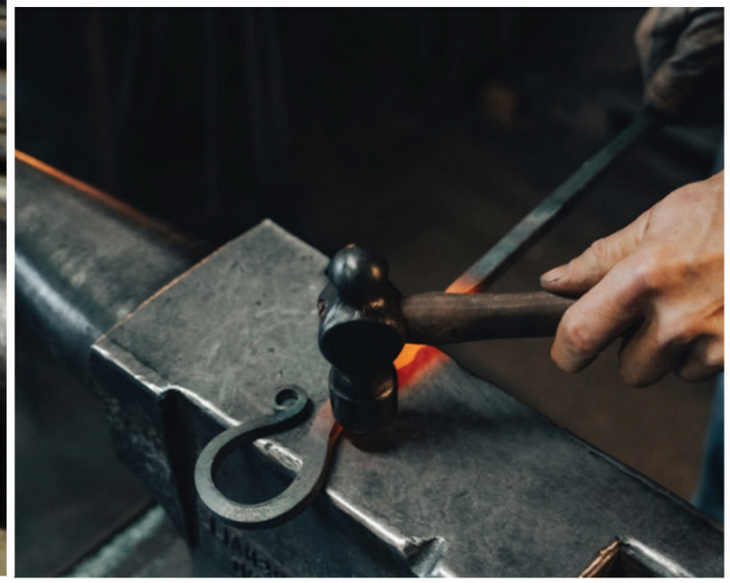

Design and Development of a Locally Developed Hemodialysis Machine*

Robin M. Costales*[1], Kim Paulo S. Orquia*[2], Nicole Ann Portia U. de Luna*[3], Rodrigo S. Jamisola, Jr.*[4]

Abstract

This study describes the development of a local hemodialysis machine prototype for patients with advanced kidney failures. The prototype was developed based on the existing dialysis machine used here in the Philippines. Pressure sensors, bubble sensors, and stepper motors are integrated into the design to satisfy adult patients' requirements. Other components such as PLC, HMI, LED bulbs, and buzzers were used. 3D printed parts were also developed for the particular components that are not available in the local market. Moreover, alarms were also incorporated into the system design. The dialysis machine was tested using water as the sample liquid in different settings and parameters. The results show that the minimum requirement for a dialysis machine was satisfied. The pressure sensor values for the pump at 5 rpm read 228.33 mmHg, 14 mmHg, and 6 mmHg for the venous, arterial, and transmembrane, respectively.

Keywords: *Localized hemodialysis machine*

I. Introduction

The number of Filipino suffering from kidney disease increases continuously with no signs of being under control. A recent study by Tang et al. showed the Philippines as the third highest case in Southeast Asia of incidence and prevalence of chronic kidney disease and kidney replacement therapy in relation to population size and income [1]. This is alarming considering that the health care in the country is barely affordable by the majority in case of serious illnesses like kidney disease.

Hemodialysis is needed for patients with 10 to 15 percent kidney function, either for long-term treatment or awaiting a kidney transplant. Prasad and Jha pointed out that at least 2.9 million people need dialysis in Asia (**Table 1**). Compared to the availability of dialysis machines in Asia, this constitutes a gap of around minus 66 percent. The annual costs of hemodialysis in developing countries is much less compared to developed countries, e.g., compared to the US the cost is around 30 times lower in India. But still, patients in developing countries often cannot afford the costs.

Many, if not all, of the high technology medical equipment used in the country originated from foreign countries using foreign talent and foreign labor. This foreign product, which is designed to be affordable in its own foreign market, is barely affordable to the local consumer. This is especially true for equipment used for treatments of more serious diseases, which drives the local cost of treatment for these diseases to be very high. Mushi et al. mentioned that the global average annual cost per hemodialysis patient ranged from Int$ 3,424 to Int$ 42,785 [2]. (The units are in 2012 International Dollars (Int$) converted to Purchasing Power Parity (PPP) using World Bank conversion tables in [2].) In 2019, the Philippines gross national income per capita is Int$ 10,230 [2]. Thus, hemodialysis treatment costs are admittedly too costly for the average Filipino family income. In the work of Shinkman, R., it discussed the big business in dialysis care and the author recommended patient empowerment to address this [3].

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Table 1. Incidence and Prevalence of CKD and KRT in Relation to Population size and National Income. This Table was Adopted from Tang et. Al, 2020. (CKD – Chronic Kidney Disease, KRT – Kidney Replacement Therapy).

Region	Population (million)	GDP (billion)	Estimated CDK Prevalence	KRT		Leading cause of kidney failure
				Incidence (pmp)	Prevalence (pmp)	
East Asia						
China (Mainland)	1,395	$13,608	10.8%	NA	NA	GN
China (Hong Kong)	7.4	$341	NA	164	1,388	DM
Taiwan	23	$579	11.9%	493	3,392	DM
Japan	127	$4,872	13.0%	310	2,599	DM
South Korea	51	$1,415	10.0%	310	1,816	DM
Southeast Asia						
Singapore	5.6	$310	NA	332	1,596	DM
Malaysia	32	$297	9.1%	251	1,345	DM
Philippines	105	$314	NA	164	607	DM
Thailand	68	$455	17.6%	338	1,307	DM
Brunei	0.4	$12	NA	387	1,814	DM
Cambodia	15	$23	NA	NA	40	Uncertain
Indonesia	265	$1,015	12.5%	161	452	HTN
South Asia						
India	1,340	$1,939	7%-9%	226	134	DM
Nepal	26	$25	10.6%	NA	1,500	DM
Bangladesh	167	$249	16%-18%	210-250	NA	GN
Western Asia (Middle East)						
Jordan	9.7	$40	5.5%	30	530	DM

Note. Values are according to the latest available data. Currency values expressed in US dollars.
Abbreviation: CKD, chronic kidney disease; DM, diabetes mellitus; GDP, gross domestic product; GN, glomerulonephiritis; HTN, hypertension; KRT, kidney replacement therapy; NA, not available; pmp, per million population.

Moreover, there are various reasons for both kidneys to fail, usually diabetes, inflammation of the kidney, and high blood pressure. There are only two options to stay alive: either kidney transplant or continuous dialysis treatment. The transplant cost can cost around 500 thousand to a million pesos, while dialysis treatment costs 3,500 pesos on an average per session.

Dialysis works by processing blood from an artery, purifying it, adding vital substances, and returning it to a vein. Patients who have two or three treatments a week could cost about P28,000 to P42,000 per month. Those are very costly and unaffordable by most Filipinos. Contributing to this costly treatment for dialysis is the machine itself. Dialysis machines are imported, which usually are expensive [4,5]. Thus, this study focuses on the development of a local dialysis machine that uses commercially available components, stepper motors, and 3D printed parts.

Furthermore, 3D printed components are utilized as a substitute to components that are not commercially available and critical components for the dialysis machine.

*4 *Balik Scientist/Associate Professor in Robotics and Machine Learning at Botswana International University of Science and Technology*

With these advantages, the cost of the development of a local dialysis machine could be lowered, but still the performance is comparable to that of foreign available equipment.

The Advanced Mechatronics, Robotics and Industrial Automation Laboratory (AMERIAL) in MIRDC developed a prototype of Dialysis Machine for the patients with kidney failures. The dialysis machine is a mechatronics platform with three major components: sensors, intelligence, and actuators. The dialysis sensors will provide the necessary information on the status of the blood as it flows through the machine. The intelligent decision algorithm that will be based on the machine learning will process the data and provide a real-time decision. The actuators are motors that will execute the required task.

The prototype is created using only commercially available components and stepper motors. The use of these components is significant in lowering the cost of production for the prototype. Moreover, parts that are not available commercially and critical for the machine are produced using 3D printing technology.

II. Material and Methods

The locally developed dialysis machine is made of commercially available components, 3D printed parts, stepper motor, and pressure sensors that monitor and clean unwanted waste products in the blood of the patient. The sensor inputs are processed into the PLC and then transferred the command to arduino to control the peristaltic and heparin pumps using signal pulses. Other data, such as mmHg level, are gathered into the PLC and then displayed to the HMI (Human Machine Interface).

a) Block Diagram

The PLC controls the pumps speed and processes data from the sensors to be displayed in the HMI. An analog module converts the data from the pressure sensors to the PLC. Moreover, an Arduino microcontroller is responsible for the servo motors, as shown in **Fig. 1**.

Figure 1 shows the overview of the system for the localized dialysis machine. The PLC controls the pumps speed and process data from the sensors to be displayed in the HMI. An analog module converts the data from the pressure sensors to the PLC. Moreover, an Arduino microcontroller is responsible for the servo motors.

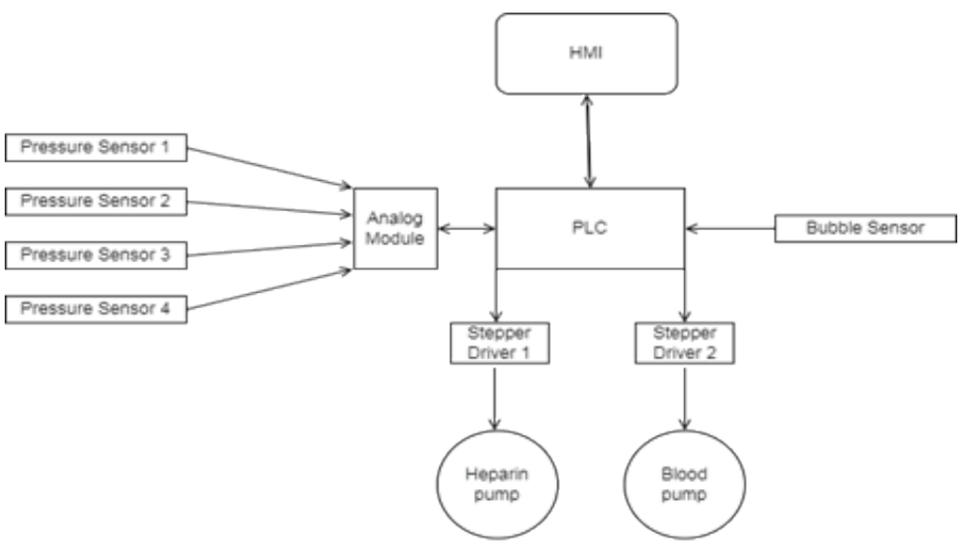

Fig. 1. Block Diagram for the Controls of the Hemodialysis Machine

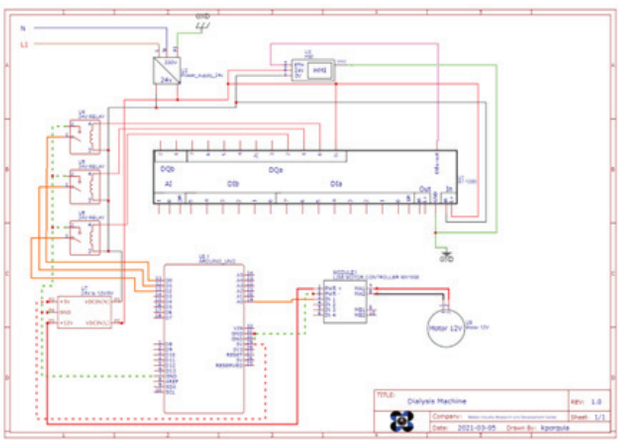

Fig. 2. Electrical Diagram

b) Electrical Diagram

The relative layout of the components and the wire connections between each components are shown in **Fig. 2**. The PLC and the HMI are connected to the 24V power supply. Moreover, the PLC is connected to the relay modules that serves as an input for the arduino microcontroller. Furthermore, the servo motors are connected to the arduino that is connected to the 5V power supply.

c) Mechanical Components

The system is composed of commercially-available standard parts such as bubble sensor, ultrathin filters, blood tubes, 3D printed heparin and peristaltic pump and metal casing as the cabinet of the Dialysis Machine.

Below shows the important components of the developed localized dialysis machine.

Bubble Sensor

Enclosure

Blood Pump

d) Design of Control System

The control system hardware is composed of pressure sensor, stepper motor, stepper motor driver, arduino, HMI, and PLC.

The PLC is the central control system of Dialysis Machine due to its excellent reliability and simple operation. Its primary function is to receive input signals from the sensors and HMI. The PLC process it all and outputs into the arduino to control the stepper motor's speed and run time.

The selection of PLC has considered several factors such as its I/O port number, Input Voltage, communication port and its cost.

III. Results and Discussion

Water was prepared as an input to test the functionality of the developed prototype, **Fig. 3**. The sensors used were subjected to functional testing to determine if it responded correctly and according to the program uploaded in the PLC and HMI.

Here is the table of the results of actual testing of localized hemodialysis machine using water. The trials was done to determine the sensors reading at different rpms.

Fig. 3. Locally Developed Hemodialysis Machine

Tables 1-3 show the readings recorded at 10 rpm, 7 rpm, and 5 rpm, respectively. The arterial pressure remains constant throughout the testing because it is the input of the dialysis machine. While, the venous pressure increases due to the increase in the flow rate caused by the increase in the motor speed. However, the transmembrane pressures remain constantly low due to the membrane filter that restricts the pressure.

Table 1. Motor Speed at 10 rpm

Speed at 10 rpm			
	Venous Pressure	**Arterial Pressure**	**Transmembrane Pressure**
Trial 1	312 mmHg	14 mmHg	5 mmHg
Trial 2	311 mmHg	14 mmHg	5 mmHg
Trial 3	312 mmHg	14 mmHg	5 mmHg

Table 2. Motor Speed at 7 rpm

Speed at 7 rpm			
	Venous Pressure	**Arterial Pressure**	**Transmembrane Pressure**
Trial 1	268 mmHg	14 mmHg	6 mmHg
Trial 2	268 mmHg	14 mmHg	6 mmHg
Trial 3	269 mmHg	14 mmHg	6 mmHg

Table 3. Motor Speed at 5 rpm

Speed at 5 rpm			
	Venous Pressure	**Arterial Pressure**	**Transmembrane Pressure**
Trial 1	228 mmHg	14 mmHg	6 mmHg
Trial 2	229 mmHg	14 mmHg	6 mmHg
Trial 3	228 mmHg	14 mmHg	6 mmHg

IV. Conclusion

The local hemodialysis machine prototype can emulate the basic function of a commercially available machine. The pressure range, blood pump speed, and bubble sensing requirements were satisfied. The pressure readings of the equipment ranges from 0mmHg to 500mmHg, while the pump speed ranges from 1 to 10 rpm. Moreover, the bubble sensor was able to detect the presence of a bubble inside the tube.

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Philippine Paper Currency Recognition System for Visually Impaired*

Jamillah Mae Dela Cruz *1, Engr. Favis Joseph Balinado*2

Abstract

Money is already a part of human lives. Every human being needs it in order to buy their necessities, but not all have the capability to use it efficiently. According to International Monetary Fund, money has three functions: store of value, medium of exchange, and unit of account.

The number of visually impaired people in the Philippines is almost 1.11 million, according to a study conducted by the Philippine Eye Research Institute of the National Institute for Health in 2018, and it just keeps rising. They have physical limitations in identifying each currency. With this increasing number, the need for new inventions to assist them in their daily lives is growing as well.

In line with those challenges, this paper proposes to design a Philippine paper currency recognition system to help them gain an essential tool to lessen their burden in everyday lives. The system is composed of numerous components that aid in the analysis of the characteristics of the bill. The microcontroller, as the primary component, is responsible for the overall operation and performance of the system. Additionally, the RGB color sensor was also used since each Philippine bill has unique colors. Moreover, there is a speaker that will produce the sound depending on the denomination of the bill. The system was tested using the 6 kinds of Philippine Banknotes. The accuracy of the system prototype is 96.67%.

Keywords: *Paper Currency, recognition, system, visually impaired*

I. Introduction

Nowadays, due to the pandemic, there is a noticeable increase in mobile wallet usage globally. Its popularity skyrocketed because it provides contactless payment. However, it is still cannot be ignored that there are still many people who prefer physical money to buy the things that they need, and no country has totally gone cash-free. Up to 71% of Filipino adults, equivalent to 51.2 million people, are still unbanked in 2019 (Adrian, 2020).

Every country has its own banknotes that its citizens legally use as payment within their territory. Philippine banknotes are issued by the Bangko Sentral ng Pilipinas (Central Bank of the Philippines). It is made uniquely and contains characteristics used to distinguish the banknotes, such as the design and color. Each of the Philippine bills has its own color for people to quickly recognized the denomination. The feature can be simply seen in plain view. Nevertheless, with all that is said above, it is difficult for those who are visually impaired to differentiate the banknotes from each other. They have physical limitations to determine the denomination of the money.

This research aims to help the visually impaired in the country. The denomination of the bill will be recognized by using the characteristic of the paper bill, which is its color. It helps visually impaired people to know the value of money they have on

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hand. The system uses Arduino as the main component that manages the operation of the system. It receives the data from the color sensor, processes it, and then sends an output to the speaker. The speaker will produce a sound in accordance with the nominal value of the Peso Bill.

II. Methodology

The proposed system is to design and develop a system that can recognize the Philippine paper currency using the Arduino Uno. The first stage is collecting the data regarding the feature of the currency, which is its color, by using the RGB color sensor (TCS3200). The Arduino Uno is the main component in the entire system. It is a microcontroller that receives the data from the color sensor and then processes it according to the program code. The program codes are written in software called Arduino IDE. After that, the microcontroller will release output to the speaker. Finally, the speaker will play a sound in accordance with the denomination of the money.

Hardware/Software

This research project comprises five main components: power supply, Arduino, RGB color sensor, MP3 module, and speaker (**Fig. 1-3**).

Power Supply
A power supply is an electrical component used to supply electrical power to the loads. In this project, a 9V battery is used to run the whole system.

Arduino Uno
In this project, Arduino Uno is used as the main component that manages the operation of the system. It is a microcontroller board that is formed based on the single-chip produced by Atmel, ATmega328P.

RGB Color Sensor
The color sensor used in this project is TSC3200. It includes a Taos TCS3200 RGB sensor chip and four white LEDs. It has an array of photodetectors with four filters, red, green, blue, and no filter.

MP3 Module
In this project, DFPlayer Mini MP3 Player is used. It sends the output directly to the speaker. It has an adjustable volume with 30 levels.

Speaker
A Digital speaker module is used in this project to play the sound in accordance with the nominal value of the money detected. The volume is regulated using a potentiometer.

Arduino IDE
It is an open-source software that is used to write the necessary codes to program the system of this project.

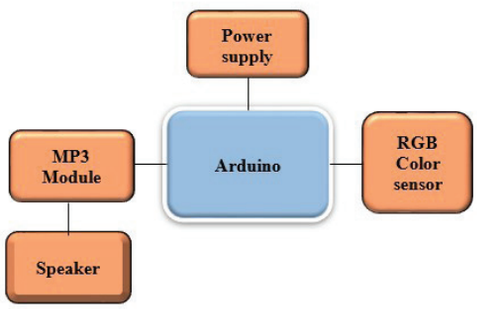

Fig. 1. Block Diagram of the Currency Recognition System

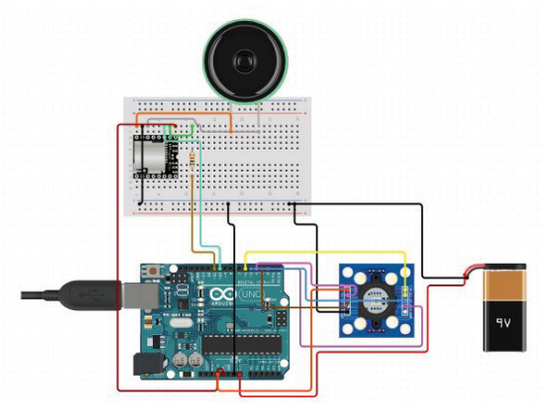

Fig. 2. Schematic diagram of the system

Fig. 3. Prototype of the system

III. Results and Discussion

This part is testing each of the components to ensure they are working properly according to their specifications.

Table 1 shows the summary of the testing done on each of the components. This data means that the system functions as what is intended because the expected outcome is equal to the actual output.

Table 2 summarizes the system detection to the Philippine banknotes, 20, 50, 100, 200, 500, and 1000. Each denomination is tested for 10 trials. The 20, 50, 100, and 500 paper currencies have an accuracy of 100%, while the 200 and 1000 banknotes have 90% accuracy.

The data gathered by the researcher are based on the functionality testing of the prototype and of each component. According to the study's objectives, the researcher intends to design and develop a currency identification system for the visually impaired in the Philippines. The summary of the testing done on each component shows that the system functions as intended because the expected outcome is equal to the actual output. These tests demonstrate that the system works and thus meets the objectives by conducting a functionality test.

There are various approaches that can be done to develop and design a system that identifies paper currencies. [8] suggested a fully automatic currency recognition using Radial Basis Function Network. The model of this study focuses only on the Saudi Arabian paper currency. The image of the note is acquired using a high-resolution scanner or a digital camera. Yousry et al. (2018) proposed a currency recognition system that uses an Oriented FAST and rotated BRIEF (ORB) algorithm. This system is applicable to Egyptian currencies incorporating the six kinds of banknotes. Image processing is used to remove the noise in the digital image. Semary et al. (2015) proposed in their paper a system of currency recognition of Egyptian banknotes. It uses image processing techniques such as noise removal (Gaussian blurring), segmentation, and hole filling to extract the region of interest and perform template matching. The system has an accuracy of 89%.

Table 1. Summary of Results of Component Testing

Test Item	Item Name	Test Result
1	Battery	Successful
2	Color Sensor	Successful
3	Microcontroller	Successful
4	DFPlayer Mini MP3 Module	Successful
5	Speaker	Successful

Table 2. Paper Currency Detection

Currency	Results
20	100%
50	100%
100	100%
200	90%
500	100%
1000	90%

All the case studies use image processing in order to recognize and analyze the features of the paper currency. The first step is always acquiring the image of the banknote and converting it to extract the features using different methods. The result is attained by matching the acquired features to the database.

In this paper, because of each of the Philippine paper currencies' unique characteristics, another method is used that does not require image processing. The Philippine banknote has an equivalent color to its denomination. This paper proposes a system that does not require the usage of a high-resolution scanner or camera. The necessary component that is used to collect data for the system is the color sensor. It makes the system simple and makes the processing time short.

IV. Conclusion

Based on the research results, the following conclusions were drawn in line with the objectives of the study.

- The RGB color sensor accurately detects the color parameter of the paper currencies.
- The physical condition of the money greatly affects the color reading of the sensor.
- The speaker was able to produce sounds that correspond to the denomination of the money.
- The developed device is tested functional because the expected output matches the actual output. The system prototype has an accuracy of 96.67%.

V. Recommendation

Based on the summary findings, the researcher recommends calibrating the program code to improve the prototype and increase the recognition accuracy. It is also advised to add more system features. Future researchers may incorporate a counterfeit detector for the system to be more beneficial for visually impaired people. They may also consider integrating multiple currencies from different countries in one system.

VI. Acknowledgment

I, the researcher, humbly extend my deepest gratitude to the following who made this study a success:

First and foremost, thanks to Almighty God for the inspiration and motivation to make this research possible and complete it successfully despite all the struggles that were faced.

To Engr. Favis Joseph C. Balinado, I would like to express my deep gratitude for the help and guidance throughout the research work. Their valuable suggestions help the study to move forward.

To my parents, their patience and encouragement are a big help for the researcher not to lose their focus.

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Design and Development of Pneumatic Rail Code Stamper for To247 and To268*

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Jane E. Morgado*[6], Harveen C. Bongao*[7], Hohn Lois C. Bongao*[8], Ruem G. Arribas*[9], Constancio Andong Jr.*[10]

Abstract

Rail coding is used for marking lead frames before the die-bonding process. It seeks to differentiate the units created batch-by-batch. The current rail coding procedure for TO packages in the case of a semiconductor company needs to be automated to eliminate the manual marking using tweezers. Since the engraving process is highly dependent on the operator, it affects production cycle time and quality. This work presents the design and development of a pneumatic rail code stamper for TO-247 and TO-268 transistor packages. Enhancing the process and shortening the rail coding procedures increases the production output. A pneumatic rail code stamper uses a pneumatic system to eliminate unreadable marks that can cause mixed devices, no rail code, and wrong rail code by identifying the required pressure for TO-247 and TO-268 lead frames, processing one good lot at rail coding operation, and visually inspecting traceability readability. Compared to the manual method, the pneumatic rail code stamping decreased the average cycle time per lead frame (in seconds) by 10.52% and 8.78% for TO-247 and TO-268 devices, respectively. Moreover, the minimum pressure applied to the lead frame was determined to be at 0.5 – 0.6 MPa to achieve a readable marking. The results show that the pneumatic rail code stamper can improve production output rate and produce good quality products avoiding visual defects on lead frames and misprocesses such as no rail code, wrong rail code, and a mixed lot, making it more efficient and valuable in the rail coding process.

Keywords: *Die-bonding, lead frames, pneumatic rail code, pneumatic stamper, transistor packages*

I. Introduction

The assembly of different semiconductor products is divided into standard design packages and custom design packages [1]. Some leading semiconductor company today assemble complex products such as high-power discrete devices in SOT227 and EXP TO247. In line with the industry's changing requirements, many semiconductor companies venture into the customization of different semiconductor packages. Examples of modifications of standard TO247 are EXP TO-247 and TO-264 standards. Rail coding is part of the assembly procedures to designate the lead frame before the die-bonding. This aims to distinguish units produced by batch and for close monitoring across the manufacturing line. Moreover, this process ensures that devices will not mix with other batches [2].

The current rail coding procedure is manually done using a pair of sharp metal tweezers in the lower corner of the lead frame as shown in **Fig. 1**.

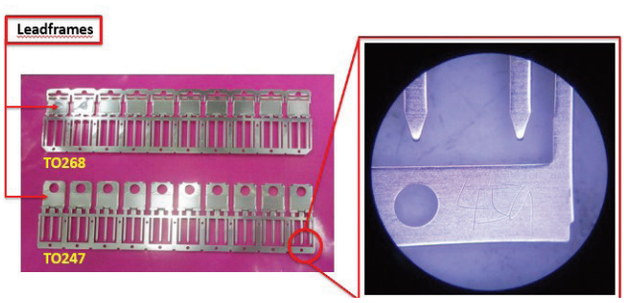

Fig. 1. Carved 3-Digit No. Under a Low Power Scope. *Courtesy of Team Pacific Corporation.*

* Presented during the National Metals and Engineering Conference (NMEC), June 15, 2022.

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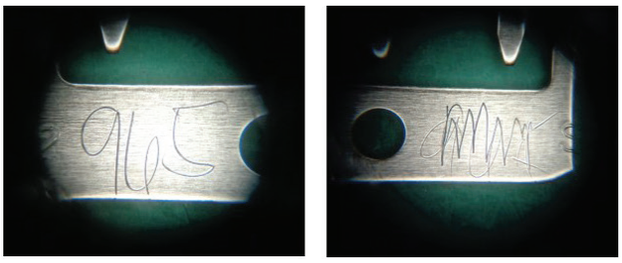

Fig. 2. Sample of Wrong Rail Code. *Courtesy of Team Pacific Corporation.*

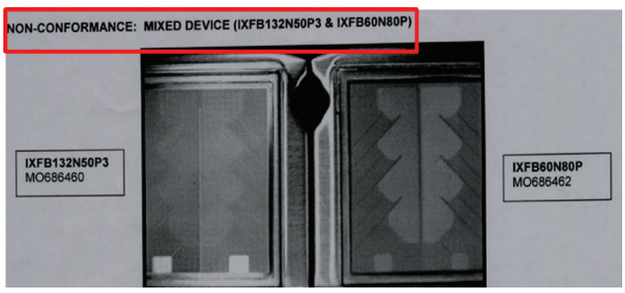

Fig. 3. Sample of Non-Conforming Product Report (NCPR) on Mixed Device. *Courtesy of Team Pacific Corporation.*

Since the engraving is done manually by the operator, the quality and the time of production are affected as illustrated in Fig. 2. Moreover, Fig. 3 shows evidence that unreadable codes are causing the product to be mixed with another batch because of the wrong rail code.

Pressure marking is more reliable than manual marking since it has greater accuracy and consistency [3]. There are other methods of marking lead frames such as ink-jet, laser etching, ink ablating, and laser bonding but in some cases, it needs to be plated first during the processing [4], [5]. Laser-etched marking is done before the plating process wherein the marks will be covered and will result in unreadable code. While another process of marking is done by printers which creates a mark by thermal transfer due to high temperature. The printer solution varies from 300 to 600 dots per inch (DPI). These printers are costing approximately $ 1,500.00. But some automated applicators are available from $30,000.00 to $80,000.00 depending on the features [2]. Moreover, the pneumatic system is greatly used in the system of manufacturing and production. The importance of using this process is due to its accuracy and cost [6].

This work aims to develop a pneumatic rail code stamper to eliminate human-related errors that lead to an increase in product lead time and possible customer complaints and achieve the following: determine which pressure yields good readability when applied to the lead frame and analyze its effect on the output capacity by investigating the manufacturing cycle time.

II. Materials and Methods

A. Materials

This work involves the use of the following parts in the assembly of the Pneumatic rail code stamper: pneumatic solenoid valve, pneumatic cylinder, 24V power supply, air pressure regulator, foot pedal, toggle switch, indicator lamp, safety cover, and lead frame rail guide.

B. Design

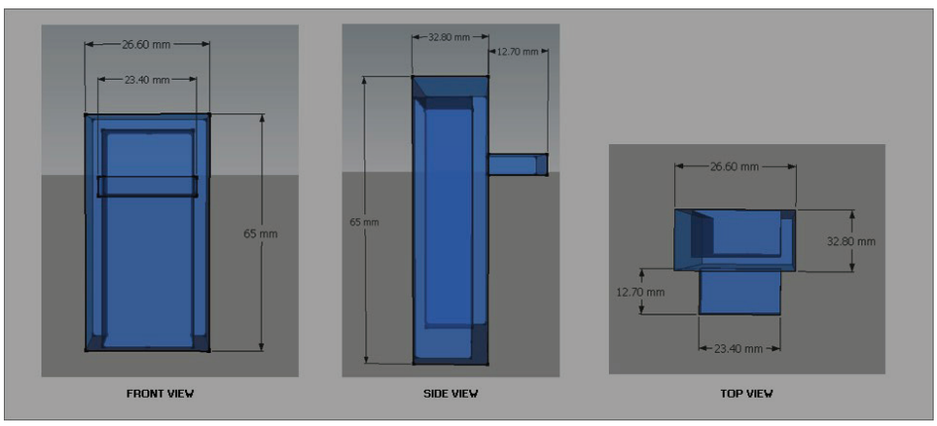

Fig. 4. Design of Safety Cover of Tool Stamper.

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Figure 4 shows the design of the cover of the tool stamper that is attached to the pneumatic cylinder. This design provides safety to the operator while marking the lead frame.

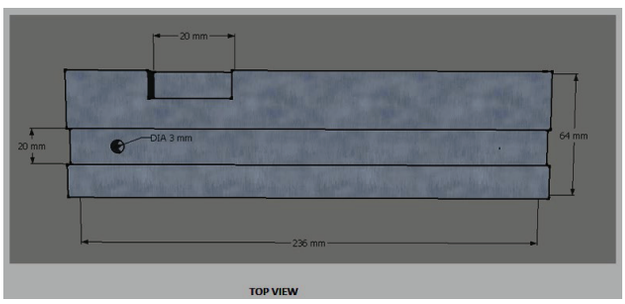


Fig. 5. Design of Rail Guide for Pneumatic Stamper

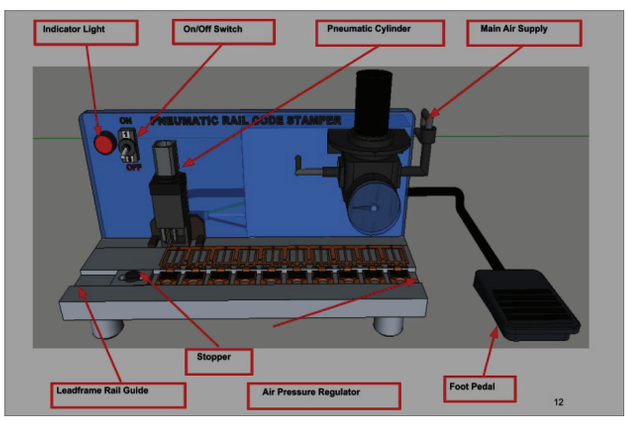


Fig. 6. Pneumatic Rail Coder Design

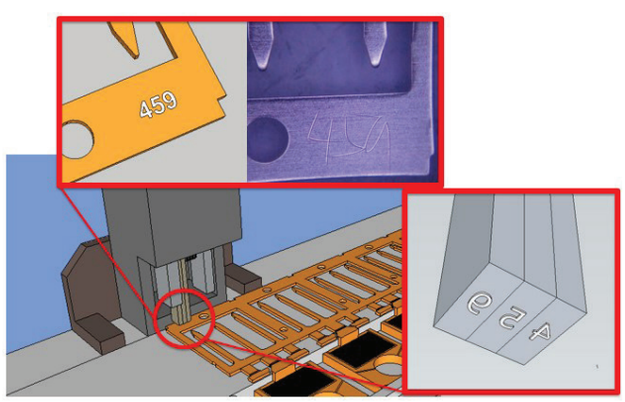


Fig. 7. Stamper Tool and Sample Stamp on the Lead Frame

Figure 5 shows the rail guide for the pneumatic stamper where the stopper and transistors outline will be clamped. The two different transistor devices such as TO-247 and TO-268 are to be inserted one batch at a time.

C. Device Integration

Figure 6 shows the design of the pneumatic rail code stamper for TO-247 and TO-268. The rail coder is powered by compressed air for the stamping process. The stamping is controlled by a foot pedal.

Figure 7 shows the design of the stamper with a three-digit number used to mark the lead frame. The stamper can be changed manually on the pneumatic cylinder. This is done to create other batches of TO-247 and TO-268.

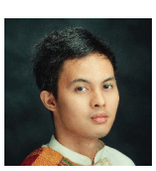
III. Results and Discussion

Variation of Pressure Applied into TO247 and TO268

Figures 8 and 9 show the marking engraved into the lead frame at varying pressures ranging from 0.1 – 0.6 MPa. Through visual inspection, the clearest rail code stamp was achieved on pressures 0.5 MPa and 0.6 MPa. For both packages, the material used for the lead frame is copper-iron (Cu-Fe) alloy [7]. Significant amounts of iron in the composition increase the hardness of the alloy and therefore, require higher pressure applied to achieve a readable marking [8]. This improvement in rail code marking was evaluated in the operations and was found to be effective in identification and tracking.

Manufacturing Cycle Time Analysis

Table 1 shows the time difference between manual and pneumatic rail code stamping. In terms of the time difference (%), the result may seem insignificant. However, when translated into cost, elucidates its impact on the economics of production. The cycle time improvement of 10.52 s and 8.78 on a 24-hour scale, is approximately equivalent to an increase of $7,632 and $5,064 profit per day, respec-



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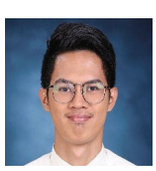

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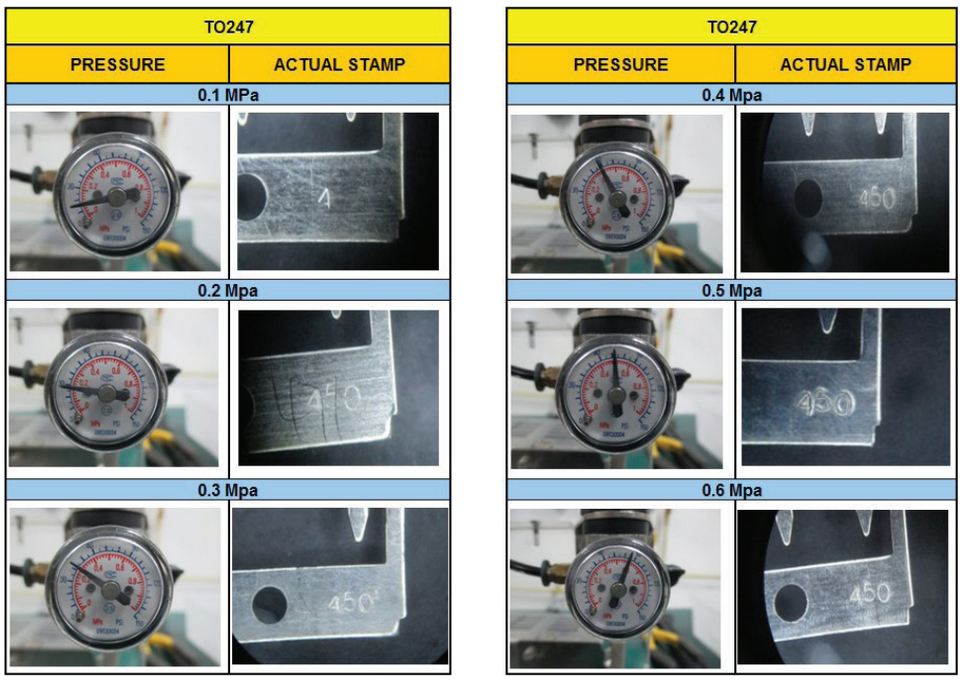

Fig. 8

Pressure Applied to the TO247 Lead-Frame

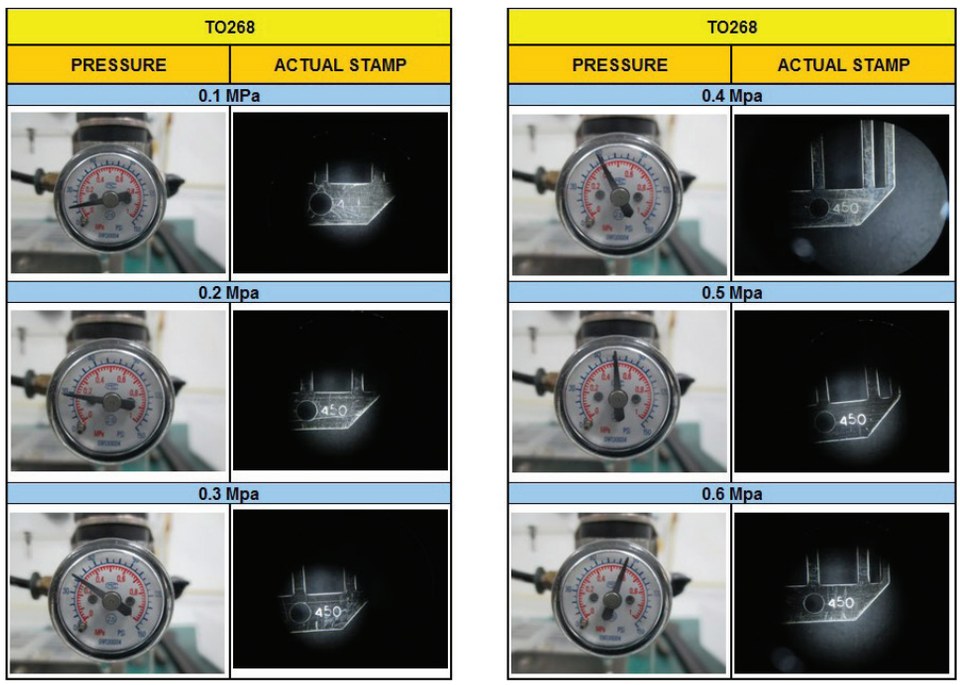

Fig. 9

Pressure Applied to the TO268 Lead-Frame

Table 1. Time Study for Pneumatic Rail Code Stamper for TO247 and TO268 Devices

Device Name	Average Cycle Time per Lead Frame (s)		(%) Difference
	Manual	Pneumatic	
TO247	3.60	3.24	10.52
TO268	3.92	3.59	8.78

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tively. To determine the profitability of this innovation, the return on investment was calculated.

$$ROI = \frac{Final\ Value\ of\ Investment - Initial\ Value\ of\ Investment}{Cost\ of\ Investment}\ x\ 100 \quad (1)$$

Equation 1 was used to calculate the ROI. The present value of the TO247 and TO268 devices is $318 and $336, respectively. With an initial value and cost of investment of $200, the ROI for TO247 is at 59% and 68% for TO268 devices. The positive value of ROI implies a net gain using this equipment in the production line [9].

IV. Conclusion

In this work, a pneumatic rail code stamping machine was designed and developed for TO-247 and TO-268 devices. This work aims to replace manual rail coding of devices and eliminate operator-related errors which affect the manufacturing process performance and eventually the company's profit. The minimum stamping pressure was first determined by testing the pneumatic stamp from varying pressure. At 0.5 – 0.6 MPa, the rail code showed readable results for both devices. The manufacturing cycle time was also analyzed. An improvement of 10.52% and 8.78% was calculated for TO247 and TO268, respectively. This entails a positive ROI for both devices, with a projected profit of $7,632 for TO247 and $5,064 for TO268 based on a 24-hour basis of production time.

V. Acknowledgments

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PYESA: Web-Based Sales Monitoring and Inventory Management System for LMM AUTO SUPPLY with Android Mobile Application*

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Abstract

The LMM Auto Supply Sales monitoring and inventory management system was designed to determine a system to deal with the difficulties and problems that are experienced within LMM Auto Supply located in San Bartolome Sta. Ana. The lack of management system leads to sales tracking and inventory management issues resulting in reporting delays and inaccurate inventory and sales data. Along with this, monitoring the inbound and outbound flow of products is another issue to consider. To address the issues, the researchers presented the android ordering web-based with web-based sales monitoring and inventory management system for LMM Auto Supply. The user needs are analyzed to find the information needed by the end user, the business environment, as well as existing inventory and sales tracking systems. The establishment wants mobile ordering for customers with item details, computerized sales monitoring and inventory which are manually done at the present. The requirements have been analyzed and chunked into specific system of ordering, monitoring and inventory for easy use and access. Towards this approach, the use of online sales and inventory management system with mobile app has been adopted as a systematic way to solve business problems. In addition to the data obtained from the interview with the store manager, the researchers looked for other companies that use Inventory system within the locality. The study aims to automate the sales and inventory processes of LMM Auto Supply to efficiently monitor the product sales and simplify the procedures in preparing timely and accurate inventory reports. Such objectives are of great help in ensuring an efficient flow of operations while creating fast and accurate reports needed for monitoring and compilation. After the system innovation and analysis, it has been established that a web-based inventory management application would be an appropriate solution for the business. The web-based solutions enable different clients to access the system and perform business transactions from varied locations. This application enables the business operators to retrieve up-to-date and accurate store information, perform maintenance functions on the system as well as implement business rules and update data through the application. The inventory system would be of great help to the store managers with inbound and outbound items transactions. Hence much less time and effort would be spent on the inventory management tasks and more time spent on monitoring daily business activities of the store. In addition, store managers can check out available and out-of-stock items that help in preventing long customers queue. Thus customer service and satisfaction would increase therefore an increase in business revenue.

Keywords: *PYESA, Web-Based Solutions, Inventory Management, Sales Monitoring*

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I. The Problem and Its Settings

1. Background of the Study

The Philippines is one of the leading automotive industries in the Asia Pacific with roughly 273.4 thousand automobiles sold in 2019. Japanese Manufacturers are dominating the manufacturing of automotive in the Philippines among the other neighbors in Asia. The Philippine Motor Vehicle Development Program covers automobile production and is implemented by the Board of Investments. The automobile industry consists of two sectors: vehicle parts & components manufacturing and motor vehicle assembly. Automotive is complex with large number of components and parts (plastics, glass, textiles, electronics, steel, rubber, and other metals). The Philippine Domestic Auto Parts Industry is currently composed of 256 companies that produce 330 different components and parts [1]. Technology in this era is developing fast both domestic and international. Doing and finishing stuff or kind of stuff in a small amount of time with less effort with the help of technology. It is a great help to the people who don't have a lot of time doing things and it will save their energy and time. Modern technology has a huge influence on our society nowadays. It influences us on how to communicate with others, traveling, to learn new things, to think better. Most of us depend on technology almost every day and it cannot be ignored in this era. The automotive & auto parts industry, it requires monitoring on their sales and inventory management to help them track all the supplies and sales throughout the day. In urban areas especially in Metro Manila, a lot of businesses insert technology in their business. Both small and big time businesses spend money to provide a system to their store for them to do the task easily and provide good quality service to the customer. While in rural areas especially in the provinces, most of them are not into modernization. The way they transact with their customers and manage their businesses is still in the traditional way. The LMM Auto Supply operates for more than 10 years but still uses the old method of pen and paper in managing their inventory and sales that's why the researchers came up to this project in order for the store to have an automated system that will help them to be more organized in managing their sales and inventory [2].

2. Objectives of the Study

General Objective

The main objective of this study is to develop a Web-Based Sales Monitoring and Inventory Management System for LMM Auto Supply with Android Mobile Application.

Specific Objectives:

A. determine the perspectives on the development of Web-Based Sales Monitoring and Inventory Management System with Android Mobile Application for LMM Auto Supply of Selected Respondents: 1.1. Business Owner; 1.2. Manager; 1.3. Employees; and 1.4. Customers.

B. determine the evaluation of selected IT experts on the development of Web Based Sales Monitoring and Inventory Management System with Android Mobile Application for LMM Auto Supply.

C. identify the level of satisfaction on the development of Web-Based Sales Monitoring and Inventory Management System with Android Mobile Application for LMM Auto Supply of Selected Respondents: 3.1. Business Owner; 3.2. Manager; 3.3. Employees; and 3.4. Customers.

Scope of the Project

The coverage of the system is only for the whole store focusing the inventory management and sales monitoring. When it comes to the level of access in the system, the admin can add, edit, delete, search and view product details and manage the registration of customers in the mobile application while the employees can only search and view the product details. The previous transactions can also be viewed thru the use of logs. The

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mobile application has an add to cart feature and return product. It also has an automatic calculation of sales monthly, annually and it will generate app sales, walk-in sales, lost, and return/refund reports [3]. The system and mobile application will run online because it is a cloud-based system and it is not available in LAN. The mobile application also provides an e-receipt to be presented when they're going to pick up their order and the mode of payment is thru Gcash Application, COD, and COP.

II. Methodology

This chapter presents the methods and techniques of the study, the population and sample of the study, the research instruments, the data collection procedure, the data processing, and the statistical treatment used for the conduct of the study.

1. Research Design

This study utilized a descriptive method of research. Developmental research was appropriate to the study in collecting necessary information about the existing method of pen and paper in managing the sales and inventory of LMM AUTO SUPPLY. It is helpful in describing the actual condition and position of the situation as it occurs at the time of the study to discover the causes of a certain occurrence.

2. Population and Sample of the Study

The researchers used accidental and purposive sampling techniques in determining the number of respondents. This was to obtain the validity of the acceptability measures of the study. In order to apply and guarantee the performance of the system, the researchers selected one business owner, one manager, two employees, 20 customers, and five IT experts to evaluate the proposed system.

3. Research Instruments

The researchers used a questionnaire to assess the efficiency of the Online Sales and Inventory Mobile application. The instruments used for gathering data were validated and assessed by capstone adviser, subject adviser, and IT experts.

Criteria for Evaluation

Usability	Level of access and the user-friendliness of the mobile application.
Speed	The mobile application can be easily edited by the administrator.
Efficiency	The effectiveness of the web system and mobile application resources depends on the business owner, manager, employees, and I.T experts.
Portability	The mobile application can be used anytime the user intends to.
Reliability	The quality of system being dependable.

The researchers adapted the criteria in evaluation from a document from a website that will serve as the evaluation tool for the evaluation of the web-based system and Android mobile application and it was validated by the thesis adviser based on its compatibility when it is used in evaluating the system [5].

4. Data Collection Procedure

The researchers provide informed consent together with the survey questionnaires and evaluation tool to the business owner, manager, employees, customers, and IT experts to get their approval to participate in the study. After getting their permission to participate in the study, the researchers gave them the survey questionnaire to answer before the development of the system and again in the testing and evaluation period. A maximum of one (1) day was allotted to the participants to complete the survey questionnaires and evaluation tool.

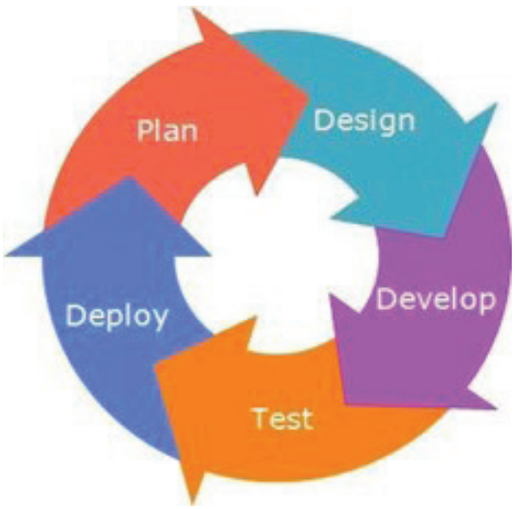
5. Statistical Treatment

This study used some statistical treatment to evaluate and analyze the results of the study. Frequency, count, and percentage were used to get the number of responses coming from the respondents and their percentages. The mean and standard deviation were used to get the general weighted average of the evaluation and satisfactory level of the IT experts, customers, business owner, employees, and manager on the application of the developed system.

Excellent	4.51-5.00
Very Good	3.51-4.50
Satisfactory	2.51-3.50
Fair	1.51-2.50
Poor	1.00-1.50

6. System Development Methodology

The proponents use Agile Method because they are giving a high priority to their locale. Their objective is to keep their locale involved at every step, so they will be satisfied with the proposed product. If there are defects or challenges, then changes can be made during production cycles to fix the issue.



AGILE METHOD Project Development Approach of the Proposed Project

7. Design of Software, Systems, Products, and/or Process

a. Planning - The researchers planned and analyzed the possible features of the web-based system and Android mobile application. The researchers gathered each other's ideas and information from the store in order to build the proposed system.

b. Software Tools - The researchers used XAMPP as a database for securing the files and organizing the records, and as for the interface of the system, the researchers used Visual Studio Code and Sketchware for the mobile Android application. The researchers uploaded the system to a web hosting service to allow real-time data updates.

c. Development - The researchers started to develop the system by writing codes and making an outline of the design of the user interface that will suit the functions and features of the proposed system.

d. Testing and Debugging - After the development of the system, the developers tested the functionality and efficiency of the system. The system underwent testing of its features and capabilities, and it was evaluated by the capstone adviser, business owner, manager, employees, customers, and IT experts. Testing is the allocating of the major or minimal problems of a system while debugging is the process of fixing the problems. The I.T experts mentioned all the bugs, errors, and missing features of the system to the researchers. After the testing, the researchers fixed bugs and errors and fulfill all the missing features before deploying them to the store.

e. Deploy - After complete debugging of the system, it was deployed to the store. The Android mobile application will be used by the customers, while the web-based system that includes sales monitoring and inventory management is intended for the manager and employees of LMM Auto Supply.

III. Results and Discussion

This portion of the study shows the analysis and interpretation of the gathered data from the group of respondents.

A. Pre-Survey Result on the Perspectives of Business Owner

Table 1 shows the pre-survey result on the perspectives of one business owner on the development of auto parts Android ordering web-based content with a web-based sales monitoring and inventory management system for LMM auto supply. Based

Table 1. Pre-Survey Result on the Perspective of One Business Owner

Item No.	Statement	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1	Do you want this store to have an automated sales and inventory management system with an ordering application?	1	100	0	0
2	Do you see yourself having an automated sales & inventory management system with ordering application in the store in the future?	1	100	0	0
3	Do you think that an automated system will help to provide quality service to customers?	1	100	0	0
4	Do you believe that this will help you to reduce or avoid long queues of customers that are waiting to be assisted or entertained by you?	1	100	0	0
5	Do you agree you're your customers will like your store having this kind of system, especially the Ordering Application?	1	100	0	0

Legend: Questionnaire

on the gathered data, the business owner provided an agreement on the implementation of the said web-based inventory. They agreed to have an automated sales & inventory management system with an ordering application in the store. The owner thought that having an automated sales and inventory management system with an ordering application would help them provide quality service to the customers. He believed that this would also help him to reduce or avoid long queues of customers that are waiting to be assisted or entertained. They also agreed that customers would like their store to have this kind of system, especially the ordering application.

Table 2 displays the pre-survey result on the manager's perspectives on the development of auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the gathered data, the manager provided an agreement on the implementation of the said web-based inventory. They agreed to have an automated sales and inventory management system with an ordering application in the store. The manager thought that an automated system would help him to provide quality service to the customers. He believed that this would also help him to reduce or avoid long queues of customers that are waiting to be assisted or entertained, and agreed that customers would like their store to have this kind of system, especially the ordering application.

Table 3 shows the pre-survey results on the perspectives of employees on the development of auto parts ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the gathered data, all the employees provided an agreement on the implementation of the said web-based inventory. They agreed to have an automated sales and inventory management system with an ordering application in the store. They think that an automated system will help them to provide quality service to the customers. They believe that this will help them to reduce or avoid long queues of customers that are waiting to be assisted or entertained by them. They also agree that customers will like their store having this kind of system, especially the ordering application.

Table 4 shows the pre-survey results on the perspectives of selected customers on the develop-

Table 2. Pre-Survey Result on the Perspective of Manager

Item No.	Statement	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1	Do you want this store to have an automated sales and inventory management system with an ordering application?	1	100	0	0
2	Do you see yourself having an automated sales and inventory management system with an ordering application in the future?	1	100	0	0
3	Do you think that an automated system will help to provide quality service to customers?	1	100	0	0
4	Do you believe that this will help you to reduce or avoid long queues of customers that are waiting to be assisted or entertained by you?	1	100	0	0
5	Do you agree that your customers will like your store having this kind of system, especially the Ordering Application?	1	100	0	0

Legend: Questionnaire

Table 3. Pre-Survey Result on the Perspective of Employees

Item No.	Statement	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1	Do you want this store to have an automated sales and inventory management system with an ordering application?	2	100	0	0
2	Do you see yourself having an automated sales and inventory management system with an ordering application in the future?	2	100	0	0
3	Do you think that an automated system will help to provide quality service to customers?	2	100	0	0
4	Do you believe that this will help you to reduce or avoid long queues of customers that are waiting to be assisted or entertained by you?	2	100	0	0
5	Do you agree that your customers will like your store having this kind of system, especially the Ordering Application?	2	100	0	0

Legend: Questionnaire

Table 4. Pre-Survey Result on the Perspective of Selected Customers

Item No.	Statement	Yes		No	
		Frequency	Percentage	Frequency	Percentage
1	Are you in favor of having a mobile ordering application for LMM Auto Supply?	18	90	2	10
2	Do you think that it will benefit you as a customer?	16	80	4	20
3	Once the ordering application is implemented, will you always use it?	18	90	2	10
4	Have you ever tried using or purchasing any items using other ordering applications?	16	80	4	20
5	Do you think that paying through Gcash is the best payment method compared to the other payment methods?	16	90	2	10

Legend: Questionnaire

ment of auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the gathered data of the 20 selected customers, most of them, were in favor of having a mobile ordering application for the LMM Auto Supply. They think that it will benefit them as a customer, they agree that once the ordering application is implemented, they will always use it, they agree that they have tried using or purchasing any items using other ordering applications, and they agree that paying through Gcash is the best payment method compared to the other payment methods.

Synthesis

All the business owners, managers, and employees agreed to the development of auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply because, for them, this would benefit them in inventory and in the monitoring of sales and products. Also, customers agree with the use of this application except for a few who were not familiar with the technology and online applications.

B. Evaluation Result of IT Experts

Table 5 shows the evaluation result of IT experts on the development of auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the evaluation of the five IT experts, the speed, accuracy, usability, efficiency, and portability of the systems was very good with the grand mean of 3.600 and standard deviation of 0.398.

C. Level of Satisfactory of the Business Owner

Table 6 shows the level of satisfaction the business owner had after using the auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the evaluation of the business owner, the speed, accuracy, usability, efficiency, and portability of the systems were very good with a grand mean of 4.00 and a standard deviation of 0.707.

Table 7 shows the level of satisfaction of the manager after using the auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the evaluation of the manager, the speed, accuracy, usability, efficiency, and portability of the systems were very good with a grand mean of 3.800 and a standard deviation of 0.447.

Table 5. Evaluation Result of IT Experts

Criteria	Mean	SD
Speed – refers to the amount of time consumed to complete a task.	4.200	0.447
Accuracy – refers to the correctness, truth, and error-free of the system	3.600	0.548
Usability– the system can be operated easily and can be understood if the user has little knowledge about the system	3.800	0.447
Efficiency – refers to the capability and adequacy in performance or operation.	3.000	0.000
Portability – the quality of being dependable.	3.400	0.548
Grand Mean	3.600	0.398

Legend:	
Excellent	4.51 - 5.00
Very Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Fair	1.51 – 2.50
Poor	1.00 – 1.50

Table 6. Level of Satisfactory of the Business Owner

Criteria	Mean	SD
Speed – refers to the amount of time consumed to complete a task.	5.00	--
Accuracy – refers to the correctness, truth, and error-free of the system	4.00	--
Usability– the system can be operated easily and can be understood if the user has little knowledge about the system	4.00	--
Efficiency – refers to the capability and adequacy in performance or operation.	3.00	--
Portability – the quality of being dependable.	4.00	--
Grand Mean	4.00	0.707

Legend:	
Excellent	4.51-5.00
Very Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Fair	1.51 – 2.50
Poor	1.00 – 1.50

Table 7. Level of Satisfactory of the Manager

Criteria	Mean	SD
Speed – refers to the amount of time consumed to complete a task.	4	--
Accuracy – refers to the correctness, truth, and error-free of the system	4	--
Usability– the system can be operated easily and can be understood if the user has little knowledge about the system	4	--
Efficiency – refers to the capability and adequacy in performance or operation.	4	--
Portability – the quality of being dependable.	3	--
Grand Mean	3.800	0.447

Legend:	
Excellent	4.51-5.00
Very Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Fair	1.51 – 2.50
Poor	1.00 – 1.50

Table 8. Level of Satisfactory of the Employees

Criteria	Mean	SD
Speed – refers to the amount of time consumed to complete a task.	4.000	--
Accuracy – refers to the correctness, truth, and error-free of the system	4.000	--
Usability– the system can be operated easily and can be understood if the user has little knowledge about the system	4.000	--
Efficiency – refers to the capability and adequacy in performance or operation.	4.000	--
Portability – the quality of being dependable.	3.500	--
Grand Mean	3.900	0.224

Legend:	
Excellent	4.51-5.00
Very Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Fair	1.51 – 2.50
Poor	1.00 – 1.50

Table 9. Level of Satisfactory of the Selected Customers

Criteria	Mean	SD
Speed – refers to the amount of time consumed to complete a task.	4.200	0.410
Accuracy – refers to the correctness, truth, and error-free of the system	3.800	0.410
Usability– the system can be operated easily and can be understood if the user has little knowledge about the system	3.800	0.410
Efficiency – refers to the capability and adequacy in performance or operation.	3.200	0.410
Portability – the quality of being dependable.	3.350	0.489
Grand Mean	3.670	0.426

Legend:	
Excellent	4.51-5.00
Very Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Fair	1.51 – 2.50
Poor	1.00 – 1.50

Table 8 shows the level of satisfaction of the employees after using the auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the evaluation of the two employees, the speed, accuracy, usability, efficiency, and portability of the systems were very good with a grand mean of 3.900 and a standard deviation of 0.224.

Table 9 shows the level of satisfaction of the selected customers after using the auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply. Based on the evaluation of the 20 customers, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 3.670 and a standard deviation of 0.426.

IV. Summary of Findings

A. Pre-Survey Results on the Perspective of the Business Owner, Manager, Employees, and Customers

All the business owner, manager, and employees agree to the development of auto parts android ordering web-based content with web-based sales monitoring and inventory management system for LMM auto supply because for them, this would benefit them in inventory and monitoring of sales and products. Also, costumers agree with the use of this application except for a few who are not familiar with the technology and online applications.

B. Evaluation of I.T Experts

Based on the evaluation of the five IT experts, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 3.600 and a standard deviation of 0.398.

C. Evaluation of Business Owner, Manager, Employees, and Customers

Based on the evaluation of the business owner, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 4.00 and a standard deviation of 0.707.

Based on the evaluation of the manager, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 3.800 and a standard deviation of 0.447.

Based on the evaluation of the 2 employees, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 3.900 and a standard deviation of 0.224.

Based on the evaluation of the 20 costumers, the speed, accuracy, usability, efficiency, and portability of the systems were very good, with a grand mean of 3.670 and a standard deviation of 0.426.

V. Conclusions

A. This study concludes that the implementation of the Android Ordering Web-Based Content with Web-Based Sales Monitoring and Inventory Management System for LMM Auto Supply will be beneficial to the locale.

B. The results of the statistical method that takes place in the locale show that the system PYESA would be a great solution for the problems of staff when inventory and sales management takes place in the store.

C. The results also show the effectiveness of the android ordering application for customers when purchasing products from the store by providing a hassle-free transaction between the LMM Auto Supply staff and the customers.

VI. Recommendations

The recommendations on the study:

1. This study needs to develop barcodes and QR codes for payment and security purposes.

2. It also needs to have the feature of Location Mapping to make delivery easier and more accurate to the location of the customer.

3. It must be implemented in the IOS Platform as well because it is currently only running on android and some customers use IOS.

4. This study also needs to add more payment methods through other e-wallets and mobile banking.

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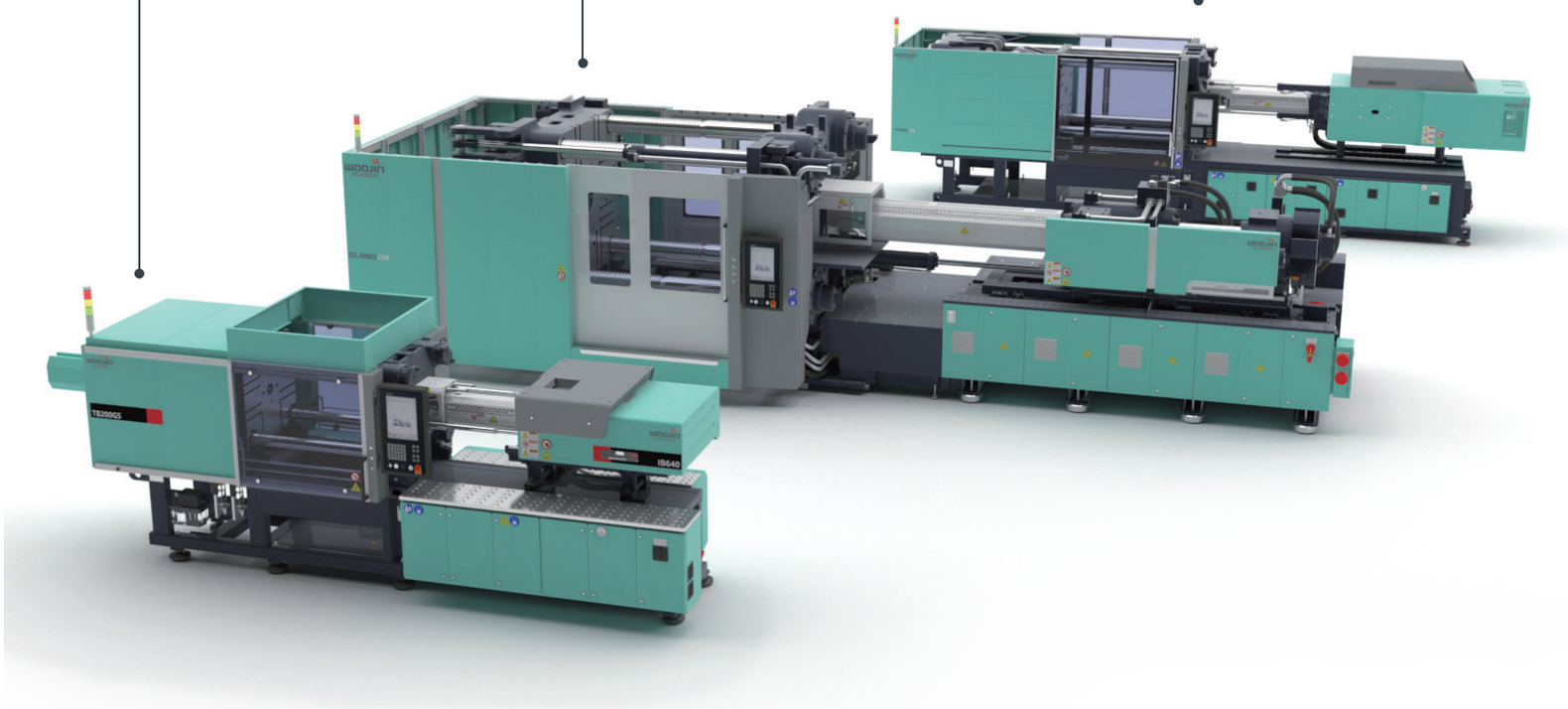

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Auto Indoor Hydroponic Plant Grow Chamber*

Thea Andrea Garcia*[1]

Abstract

Today's technological advancements have made combining science very common, especially in Computer Science and Agriculture, where both sciences are interdependent. This study focuses on innovating and automation of a hydroponic system. It aims to help local farmers innovate their way of planting and help them with an easier process. The Microcontroller Based: Auto Indoor Hydroponic Plant Grow Chamber is an automotive prototype designed to lessen the manpower when it comes to the process of farming. Using an Arduino microcontroller, this paper aims to create an automatic control tool for the flow of nutrients to hydroponic plants. We use an Arduino Uno microcontroller to automatically control the flow of temperature and humidity. The microcontroller can also send data of fluid level (solution) of the hydroponic plants. The Ultrasonic sensor HC-SR04 detects the height of the nutrient solution (water), and the temperature sensor LM35 detects the temperature. The sensor's data will be fed into an Arduino Uno and displayed on a liquid crystal display (LCD).

Keywords: *Hydroponics, Arduino uno, microcontroller, automation, innovation*

I. Introduction

Plant care is a necessary and routine task for keeping plants healthy and also well. Watering, rejuvenation, manure, and other aspects of plant care are just a few. There are so many different kinds of plants, each with its own treatment, and most treatments are performed manually [3]. Despite the diversity of plant species, water remains the primary source of life for all plants to aid in the process of photosynthesis, particularly in hydroponic plants that depends on nutrients from the water [2]. There are different types of hydroponic plants and each one of them has specific plant media. In hydroponics, it is important to know what is the best amount of water to be added and nutrient replacement [4]. Lettuce is one of the best plants to grow in hydroponics system for it has low maintenance process in growing in a hydroponic [1]. With the advancement of computer science, particularly in the field of microcontrollers, an automatic watering system for plant hydroponics is becoming increasingly feasible. As a data sheet, a project of automated tools based on the Arduino Uno Microcontroller and the ATmega328 board will be constructed in relation to this description. The Arduino Uno will serve as the tool's brain, monitoring the hydroponics plants with the help of a proximity sensor (Ultrasonic HC -SR04) to detect the water level. Sensors can detect the temperature and humidity around the plants (LM-35). The height of water and the temperature room will be displayed on the LCD microcontroller.

II. Statement of the Problem

Cultivating crops in soil might need a lot of manpower which will add expenses to the owner of farms. It is also time consuming which needs a lot of effort and procedure depending on the crop to be planted. Soil- based planting have more chances of having pests and can also get diseases from air.

Some farms don't have enough funds to cope with the expenses needed in planting and doesn't have

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systems that can help them track the level of water and nutrients the plants need especially when weather keeps on changing and does not have data software to gather information. These data can be used as reference for future works and to improve the way of cultivating crops. This study would primarily focus on Hydroponics system and problem of the study comprises the following:

1. Creating a system that will automatically check the humidity and temperature of the system;
2. Monitoring the entire process and;
3. Testing how accurate and reliable the system is.

1. Objectives of the Study

1.1 General objective

To design an automated indoor hydroponic grow chamber that will lessen the manpower and needed time for planting while saving expenses on water, labor, and non-use of toxic chemicals.

1.2 Specific Objectives

a. To design a system that will help plants grow on water using Arduino Microcontroller;
b. To develop a system that can monitor the growing system applying humidity sensors, ultrasonic transducer and artificial light system; and
c. To test the functionality of the system.

1.3 Significance of the study

The study is significant to time efficiency, especially on agricultural system, being practiced in farms or in any area. Specifically, it is deemed beneficial to the following:
Farm Owners. This study is significant and helpful for agricultural owners to provide efficient way of cultivating crops. This project is also monitored daily and stored in a database which may help in the improvement of their livelihood.
Future Researchers. The outcome of the study is advantageous to present and future researchers. This study can be a basis for further feeding system innovation.

1.4 Scope and Limitation of the study

This study focuses on automation of indoor hydroponic growing chamber. The proponents used an algorithm that could be implemented in the growing system which would detect the amount of humidity and the temperature of the chamber. To narrow the field of research, the proponents used one type of plant to be grown in the chamber which is lettuce [5]. The proponents also used an algorithm that can store the gathered data that can be used in future references. To gather data, the proponents need to know the variety of the plants, put the amount of humidity that the plant is best with, water and nutrients. Then the information will be displayed to the LCD, this information will include the temperature and humidity. This proto works by the help of Arduino Microcontroller and sensor devices.

Multiple Constraints

Economics - The problem encountered by the proponents economically is the components used to create the system in terms of its costs. This system develops a simple, reliable, and robust.

Environmental - Taking considerations, the dangers that can be encountered in farm, the proponents have decided to create a system that will be placed inside an area in order to prevent the falling of the system by putting in the ground.

Manufacturability - Considering the manufacturability, the proponents have based this system on other existing studies.

Ethical - The proponents made sure that the references of the development of this study were properly cited. The studies were not only cited but also paraphrased in order to avoid plagiarism.

Health and Safety - The study does guarantee the full safety of the farm owners in the area because the system is made from wood and acrylic glass.

III. Methodology

This chapter discusses the conceptual framework, theoretical framework and the proposed design of the system. This area shows how the system is made and the relationship of each system.

1. Research Design

The descriptive and developmental type of research were applied to attain the objectives of the study. It is descriptive because the researcher conducted personal interviews in the gathering

of data. Acceptability testing of the designed system was done using the functionality, accuracy, and reliability tests. Interviews were conducted in gathering of more information as support in the development and design of the system. The study is also prototyping development since a prototype that interconnects subsystems was developed as outcome.

2. Conceptual Framework

As exhibited in **Fig. 1**, the proponents used a software and hardware to determine the system for the hydroponic system. The LCD has three processing options. First is when the humidity sensor gathered the data, the number of degrees will be seen in the LCD. Second is the temperature which will also be gathered by the sensor. The number of data will also be present in the LCD. Third is when the Ultrasonic Transducer measure the water level and will detect if the level is high, mid or low.

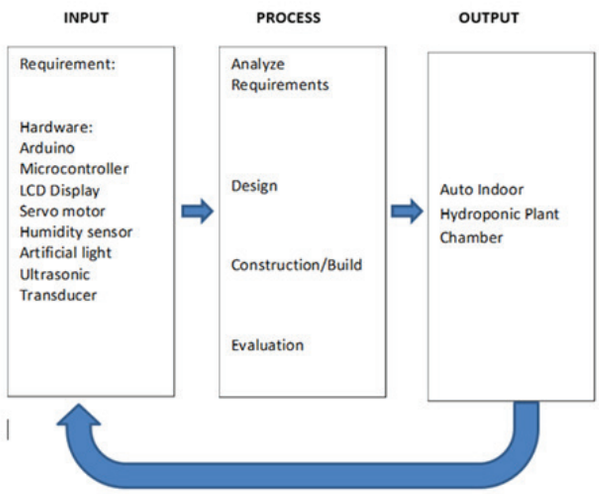

Fig. 1. IPO Chart

3. Block Diagram

The proponents used a block diagram to show how the Auto Indoor Hydroponic Plant Grow Chamber works.

Using Arduino Microcontroller, with automatic air vent powered by servo motor. automatic ON/OFF LED Lights, on during night time, OFF During day time with two compartments: lower compartment sealed for water storage, and the upper compartment transparent. with chassis protection for the entire circuit. vent automatically open/close depends on the humidity. with LCD that displays the humidity value. with power adaptor. with floating platform for plat positioning.

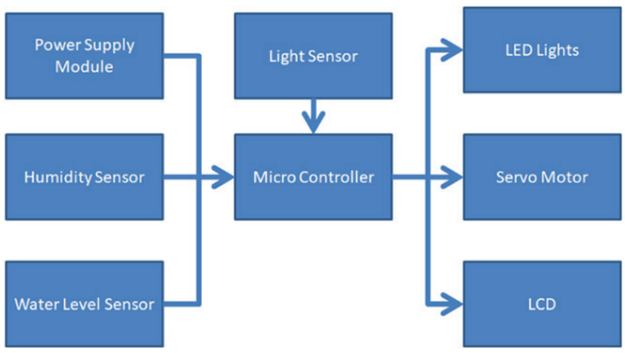

Fig. 2. Block Diagram

4. System Flow Chart

The researchers used a flowchart to summarize the flow of the system.

The flowchart of the system shows that the system starts when it is plugged in using ac. Then the sensors will gather data and send it to the microcontroller. After the gathered data the system will now process as how it was programmed. The light sensor will turn on during night time with the help of microcontroller. Then as the microcontroller gets all the data it will then give commands to the lights, servo motor and LCD to do the tasks in the program.

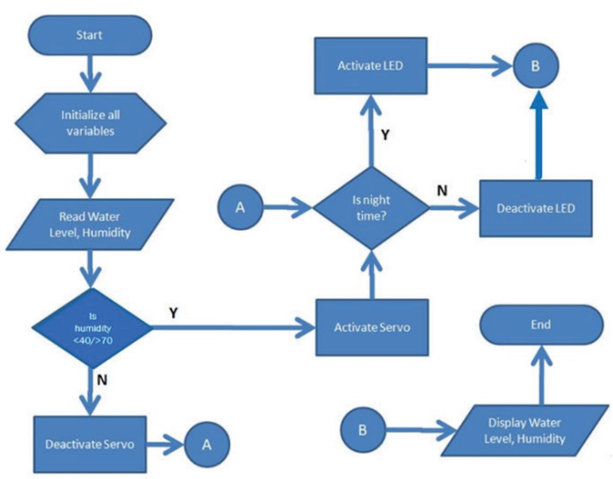

Fig. 3. Application Flow Chart

5. Proposed Design

This illustrates the proposed design by the researchers. The proponents used LCD display, ultrasonic transducer and a humidity temperature sensor to display the given measures of the sensors when the system is working. The servo motor will open and close the valve if the reading in the humidity sensor is not the same in the program. The whole system is programmed by C++ for it is easier to program Arduino and sensors with.

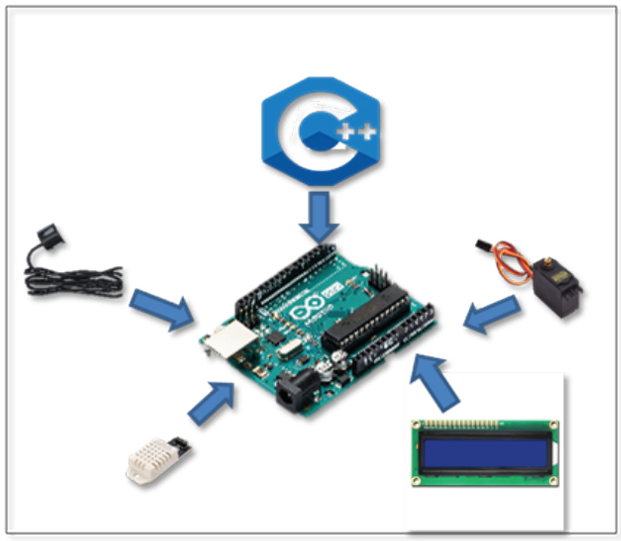

Fig. 4. Proposed Design

6. Data and Process Modeling

The development of the system needs to work together using a tool or model that serves as a guide to meet the objectives of the study. The tools and models provide step-by-step techniques to solve requirements in each phase of the model. By careful evaluation and analyzation from gathering of data up to the development of solution, Prototyping Development Model was chosen as the tool to provide the required outcome. It provides step-by-step phases to come out with the desired product.

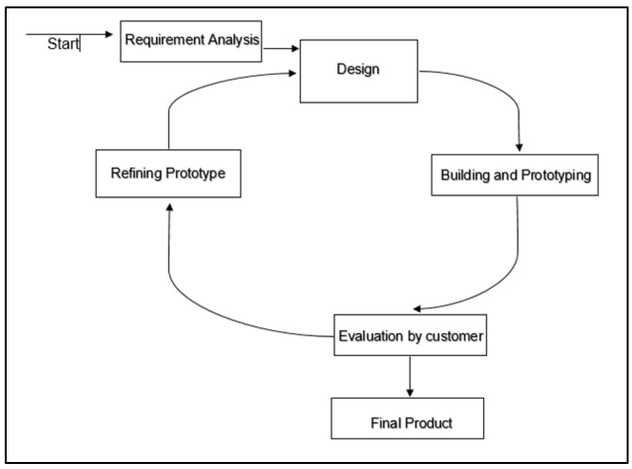

Fig. 5. Prototyping Development Cycle

Prototyping development model is the model of software development life cycle where it starts with a simple implementation of the software requirements and then iteratively enhances until the full system is developed. The model lets the developer and client interact so that the requirements for the software can be established. In prototyping development model, the system can be designed quickly and thus can undergo immediate evaluation. The final product of the design is the prototype which after developed, the clients or stakeholders evaluates the prototype and provides feedback or recommendations and suggestion to the developer. Until all the requirements are met, the development continues in an iterative manner. All phases of the Systems Development Life Cycle (SDLC) with respect to the development of software for the prototype was examined including the Requirement Analysis, Design, Building and Prototyping, Evaluation, Refining Prototype until the Final Product.

IV. Accuracy Testing

In order to test if the system is reliable and accurate, the proponent took seven samples in which the tests were taken on a specific day and time. The succeeding table shows the results.

Results on the conducted tests as well as the expected output and actual output is exhibited in **Table 3**. During the test, 80% was successful and 20% was unsuccessful because there were times that the servo is not functioning well on opening the valve due to unstable changes while the sensor is reading measures.

Tables 3 and **4** shows the test and the expected output that was conducted. During the test, 80% was successful and 20% was unsuccessful due to humidity measurements were unstable.

Table 5 shows the test from inside the chamber and the time that data's where collected. It shows different degrees due to weather or temperature outside the box that can affect the system's humidity also. **Figure 17** shows the relationship of the humidity with time recorded continuously by the humidity sensor.

Table 6 shows the tests conducted with the ultrasonic transducer with water level detection. It shows that 80% was successful and 20% was not successful because of water input not measured with the level for the container.

Tables 6 and **7** shows the test and the expected output conducted. The shows 80% were successful and 20% not successful due to measurement was not well balance.

Table 3. Open and Closing of Valves

Test	Humidity	Expected Output	Actual Output	Result
1	@ 40°	Valve will open	Valve remains close	unsuccessful
2	@ 60°	Valve remains close	Valve remains close	successful
3	@65°	Valves remains close	Valve opens	unsuccessful
4	@ 70°	Valve remains close	Valve remains close	successful
5	@ 75°	Valve will open	Valve opens	successful

Table 4. Result of Valves Opening and Closing

Actual Output	Percentage	Result
Valve remains close	80%	Successful
Valve opens	20%	Unsuccessful

Table 5. Humidity Detection

Test	Time (PTZ)	Humid	Information
1	06:00	65°	The sensor can detect that the humid is up to 65 due to the time and weather.
2	12:00	75°	During noon time where the temperature outside the chamber is increasing, it affects the humidity inside making it increase too.
3	18:00	70°	At the second 6 hours the humid turns down since night time is approaching.
4	00:00	40°	For the third 6 hours the temperature cools down
5	06:00	60°	As the sun is rising, the humid inside is cool

V. Summary

Plants are important to everyone's life. Plants give us the foods that we eat for our everyday life. Soil planting, which is the ordinary way of farming have many risks when it comes to taking care of the plants. One of the factors that can affect the growth of plant is weather changes, pests and other chemicals. This problem leads the proponent to conduct a study about atomization of Hydroponic system. Hydroponic system is a way of planting through the method of water. The proponent uses Arduino Microcontroller as the platform of the produced system. In addition, C++ programming language is used to create the program that makes the system work accordingly. Humidity sensor is used to measure the right amount of moisture the plants need inside the plant box. The servo motor which is connected to the microcontroller will give the command to open and close the valve after gathering the data from the humidity sensor. The proponent made sure that the microcontroller will give proper commands to the components. In order to know that the system is functioning well, several tests is conducted.

VI. Future Works

The proponents make the following recommendations for future researchers:

- Future researchers may use larger system for the hydroponics by using pipes as the pot for the plants.
- Future researchers can replace or add a piezoelectric transducer to keep the plant moist if they don't want the plants roots to be directly placed into the water.
- Future researchers can use other variety of plants in using the hydroponic system.
- Future researchers can make the system as an IoT to improve the program of the system.
- Future researchers can change the power supply into solar energy in case of blackout.

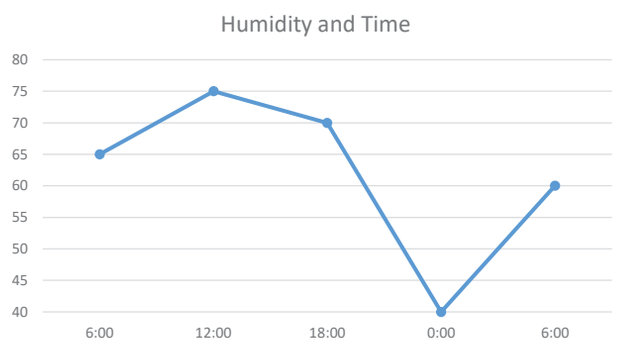

Fig. 7. Humidity Detected by the Humidity Sensor

Table 6. Water Level Detection

Test	Measure (Liters)	Expected Output	Actual Output	Results
1	10	High	High	Successful
2	9	High	High	successful
3	5	Low	High	Unsuccessful
4	4	Low	Low	successful
5	3	Low	Low	successful

Table 7. Results of Water Level Detection

Actual Output	Percentage	Result
High	50%	Successful
Low	40% 10%	Successful Unsuccessful

VII. Acknowledgment

The researchers would like to extend their deepest appreciation to the following people who have been part of the success of this study:

First and foremost, to our Creator, for his guidance, knowledge, and strength He gave to the proponents as they complete this study;

They would also like to express their gratitude to their family for their endless support, especially in terms of finances;

Gratitude is also expressed to Dr. Neil P. Balba, Engr. Favis Balinado, and Engr. Jomer Catipon who played a big role in the development of this research's system. This study would not be possible without their comments, recommendations, and advice;

To their classmates for always being there in times of difficulties, making this research journey more bearable; and

Lastly, they would like to thank each other for motivating themselves in times of problems, stress, and sleepless nights while doing this research.

VIII. Conclusion

After several tests, the system can respond to the program using microcontroller, the Arduino Uno. The proponent achieved the following objectives:

- The proponent was able to build an automated hydroponic system using Arduino Microcontroller.
- The proponent was able to program all the components to its designated purpose for the system.
- The servo motor was able to open and close the valve but still found some errors due to servo motor was stuck open.
- The proponent was not able to put piezoelectric transducer instead of ranging transducer due to error functionalities.
- The proponent was able to identify the right room temperature for the lettuce when put indoors.

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Fused Deposition Modeling of a Plastic Transponder Enclosure*

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Abstract

The U.S. Agency for International Development Oceans and Fisheries Partnership (USAID Oceans) and the Futuristic Aviation and Maritime Enterprise (FAME) Inc. developed and installed small scale vessel transponders in Mindanao, Southern Philippines to establish a full-chain seafood traceability. However, commercial readily made enclosures used for these devices are loose-fitting, which may lead to misalignment of the electrical components inside, hence affecting the device lifetime and functionality. In this present work, design and additive manufacturing via fused deposition modeling of polycarbonate was employed to produce an aptly fitting, waterproof, and robust transponder plastic enclosure. Prior to 3D printing of the enclosure, static and hydrostatic load simulations were performed to ensure that the design can withstand possible stresses during actual conditions, yielding to a minimum safety factor of 15, with a maximum displacement of 0.5127mm. The 3D printed enclosure passed laboratory-scale ingress protection testing, demonstrating the viability of using 3D printing for a customized and functional electronics system enclosure.

Keywords: *Additive manufacturing, 3D printing, Rapid production, Electronics housing, Transponder*

I. Introduction

A transponder system was employed by USAID Oceans and FAME Inc. in Mindanao, Southern Philippines to document tuna catch and traceability data at-sea. However, the casing used for the transponders, purchased off the shelf, are oversized, and screw holes must be drilled manually, leading to inconsistencies in the alignment of the electrical components. This can augment vibration on the sensors inside which can significantly affect the device lifetime. Currently, there are only a few units utilized in the said region, and production of the plastic enclosures by injection molding will be impractical [1-3].

Additive manufacturing (AM) or 3D-printing is a more appropriate and cost-effective technique for small lot size production, eliminating the need for tooling [3-4]. It also has environmental advantages since it requires less energy consumption and produces less material waste, unlike subtractive methods such as laser cutting and/or machining [4-5]. Due to its tremendous growth in the past decades, a wide array of materials for AM are commercially available, making it suitable for almost any application demand [6-10]. However, the adoption of 3D printing in the industry is not yet fully appreciated since establishment of industry standards for AM are still in progress [11-12]. In the Standardization Roadmap for Additive Manufacturing 2.0 [13], it was pointed out that further research and development activities must be conducted to fill in "gaps," that is, AM issues where published standards or specifications are yet to exist.

In this work, we present the viability of using 3D printing for a functional electronics system (i.e.,

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transponder) enclosure, which was tested for laboratory scale ingress protection based on the Ingress Protection Code (IPC) of IEC standard 60529. The production of the enclosure was done via fused deposition modeling of polycarbonate. Provisions for gaskets with room for sealants and casing mounting were considered in the design.

II. Materials and Methods

1. Material Selection

Plastic is a more appropriate choice than metal for the enclosure since it can easily be penetrated by radio frequency (RF) waves, which is utilized by the transponder. Furthermore, the transponders are deployed at-sea, a corrosive environment for metals. **Table 1** shows the relevant properties of the most common types of plastics, polycarbonate (PC), polypropylene (PP), chlorinated polyethylene (CPE), and acrylonitrile butadiene styrene (ABS). PC was selected due to its compatibility to prolonged UV exposure, such as the case in this work. It also has high flexural strength and impact strength, making it suitable for sudden impact from forces such as hauling nets and other fishing items. Furthermore, it has a relatively high melting point compared to PP, satisfying the working condition for prolonged sun exposure.

2. Design for Assembly

In the design for assembly the mounting requirements of the sensors inside the component, as well as outside peripherals that include the solar panel mount, antenna, and boat mast connection, were considered. Provisions for gaskets/seals was also included for waterproofing. The final design for the enclosure, as well as a rendered image, are shown in **Fig. 1**. The 3D-modelling was done using Solidworks 2020. The actual transponder electronics assembly will be reported elsewhere.

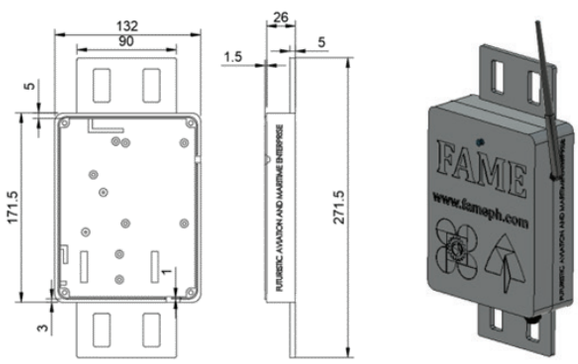

Fig. 1. Enclosure Design and Rendering

Table 1. . Decision-Matrix for the Casing Material, Showing the Relevant Properties of PC, PP, CPE+, and ABS.

Material	Compatibility to UV Exposure	Flexural Strength (MPa)	Izod Impact Strength (kJ/m2)	Printing Temp (°C)
PC (Polycarbonate) [14]	Suitable	95.5	14.8	260-280
PP (Polypropylene) [15]	Not suitable	13	27.1	205-220
CPE+ (Chlorinated polyethylene) [16]	N/A	64	0.86	250-275
ABS (Acrylonitrile Butadiene styrene) [18]	Not suitable	70.5	10.5	225-260

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3. Simulation

In order to predict the mechanical properties of the 3D-printed product, the 3D model was subjected to simulations to evaluate its point load-bearing and pressure-bearing capabilities. This was done via finite element analysis (FEA) using Autodesk Fusion 360 Software. NASTRAN is the solver for Fusion 360, wherein its static calculation is governed by [19-20]:

$$[\ ]K\{\ \}u = \{\ \}P \qquad 1$$

where {u} is unknown displacement components vector at grid points, {P} is applied loads vector to grid points, and [K] is the stiffness matrix, related to the properties of structural elements connected between grid points.

3.1. Static Load Simulation

In order to determine the maximum loads that the enclosure is able to withstand, static load analysis was performed. Several loads such as the weight of the full assembly with its components as well as possible stresses to the front and sides of the casing from accidental hits during fishing operations, were utilized. A load value of 50 N (approx. 5 kg) was applied in the simulation.

3.2. Hydrostatic Simulation

One of the required features of the enclosure is that it has to achieve IEC 60529 ingress protection level of IPX7, which should withstand submersion in water at 1 meter depth for 30 minutes. This means that the enclosure will undergo pressure from the water. It is important that with applied constant pressure, gaps along the mating surfaces of the enclosure assembly be non-existent or kept small enough such that water will not be able to enter. A hydrostatic load simulation was done to predict whether there will be displacements along the said mating surfaces to detect any possible gaps that might form for water to enter.

4. Fused Deposition Modelling

Fused deposition modeling (FDM) is the most common AM method for printing of plastic objects. In this present work, we used an Ultimaker S5 FDM 3D printer. The CAD design of the plastic enclosure to be printed was converted into a Standard Triangle/Tessellation Language (STL) file, and was then uploaded to Ultimaker Cura, the slicing software for Ultimaker. The printer then builds the casing layer-by-layer by melting extrusion of a PC filament from the heated nozzle. The nozzle moves and extrudes the plastic filament in the XY direction, depending on the pattern from the digital model. Then when the current layer is done, the nozzle moves upwardly then prints the next layer until the whole object is printed. The extruded plastic solidifies at a rate of 0.1 s [17]. The printing parameters used are presented in **Table 2.**

Table 2. . Printing Parameters Used for the Transponder Enclosure.

Printing Parameter	Value
Line Width	0.15 mm
Wall Line Count	5
Print Time	26 hours
Layer Height	0.1 mm
Infill Percentage	30%

5. Functional Testing

The whole electronics system will be tested for solid and liquid ingress based on IEC 60950, and the aspect for electrical requirements will be reported elsewhere. In here, a laboratory scale ingress protection testing was performed to characterize the 3D printed transponder enclosure.

5.1. Water (Liquid) Ingress

The IEC 60529 does not describe a standard test on water ingress. The IP Code describes

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Fig. 2. (L) Casings Taped Together for a (R) One-Meter Liquid Ingress Test Done in a Water Drum.

Fig. 3. Test Probes for the Dust Ingress Protection Test: (L to R) 50 mm Test Probe (IP 1X), 12.5 mm Test Probe (IP 2X), 2.5mm Test Probe (Ip 3x), and 1 mm Test Probe (IP 4X).

only the acceptance condition for ingress of water, where it was stated, "It is the responsibility of the relevant technical committee to specify the amount of water which may be allowed to enter the enclosure and the details of a dielectric strength test, if any." As such, the following experimental set-up, shown in **Fig. 2**, was utilized. A one-meter-height water drum was filled with water, where the casing was submerged. The holes of the enclosures, such as the provisions for cable and antenna glands, were fastened with 3D-printed models. To determine the water tightness of the casings, a layer of tissue paper was placed inside the enclosures, and these were then sealed with a plastic-compatible epoxy. **Figure 2** shows the set-up described in this section.

5.2. Dust (Solid) Ingress

For the dust ingress protection, probes of sizes 50 mm (IP 1X) to 1 mm (IP 4X) were used, to check if they can penetrate any enclosure opening. The test probes were also 3D printed from ABS filaments; the stiffer plastic choice compared to PLA. **Figure 3** shows the test probes for the dust ingress protection test.

III. Results and Discussion

1. Simulations

In the simulation set-up, the back face of the enclosure is fixed, and a rigid contact was set between the cover and the base to simulate the epoxy sealant in the actual set-up. This determines the stiffness matrix, [K] in equation 1. Furthermore, the loading vector matrix, {P} is user defined, and was set to 5 kg (50 N) in all the simulation sets. The unknown displacement, {u} is what is seen graphically as output from the simulation software. The following figures show the results for the static and hydrostatic simulations, respectively.

1.1. Static Load Simulation

A 5-kg loading was set at the front face of the casing, based on the impact loads that the casing is expected to encounter, which may lead to fracture of the casing and damage of the electronic components inside. Static loading for this parameter setting yielded a minimum safety factor of 14.87 with reference to the yield strength of polycarbonate, with a maximum displacement of 0.5127 mm at the center of the casing which was shown in **Fig. 4.** Under the same rationale as the first simulations, the same load of 5 kg, was also set at the sides of the casing, as shown in **Fig. 5.** Simulation results yield to a minimum safety factor of 15 and a displacement of 0.0021 mm at the casing center. Moreover, a displacement of around 0.0005 mm was observed to occur at the top and bottom casing contact area.

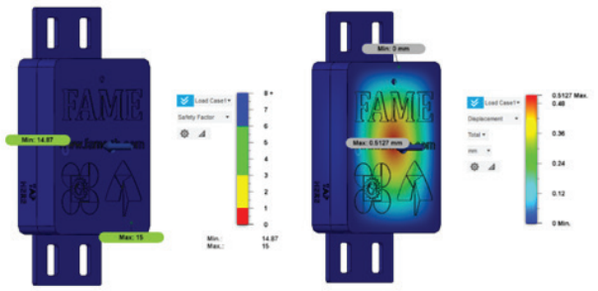

Fig. 4. Static load simulation of 50 N at front of casing. Resulting safety factor of casing (L) and displacement (R).

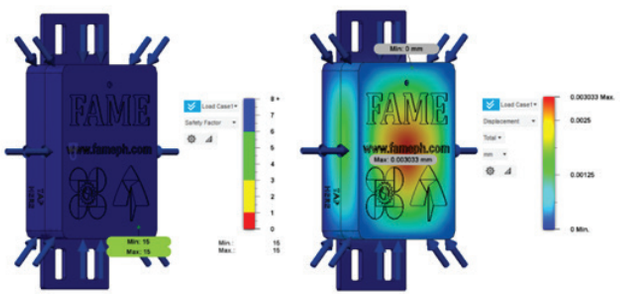

Fig. 5. Static load simulation of 50 N at sides of casing. Resulting safety factor of casing (L) and its displacement (R).

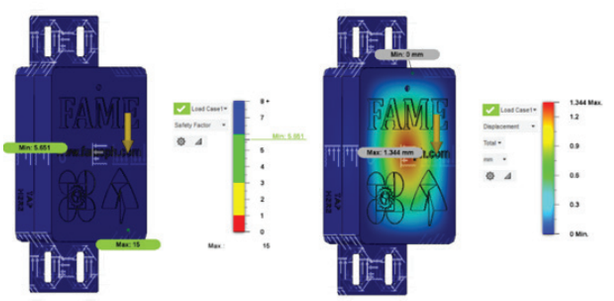

Fig. 6. Hydrostatic load simulation of casing at 1 meter depth of water. Resulting safety factor of casing (L) and its displacement (R).

Fig. 7. Actual photos of the 3D-printed transponder enclosure assembled and disassembled.

1.2. Hydrostatic Simulation

As shown in **Fig. 6**, a maximum displacement of 1.344 mm will occur near the center of the front face of the casing. At the mating sites such as the joint line of the rear and front halves, minimal to no displacement is observed. This indicates that, when assembled using a properly sealing liquid gasket, the enclosure assembly will be able to achieve the desired ingress protection rating (IPX7). These results will be further supported by actual submersion of the 3D printed assembly in water at a depth of 1 meter. All the simulations yielded a high safety factor, and the expected maximum displacement is 1.344 mm, at the front face of the casing for hydrostatic loading. As such, in the actual 3D printing, the thickness of the front part of the casing was increased by 1 mm to account for this displacement, as well as the bottom part for uniformity. The deformations at the sides are expected to be negligible due to its minimal value, compared to the deformations described above.

2. 3D printed enclosure

The 3D printed enclosure (**Fig. 7**) was designed in such a way that it can withstand accidental hitting during service as well as a certain level of waterproofing such that the electronics housed inside are protected from rains and water splashes. Actual measurement of the electrical components to be housed inside the enclosure such as circuit boards, display panels, and cabling in order to achieve the correct fitting were done. To ensure a waterproof design, liquid gaskets were used to seal off any gap that may exist in the mating portions of the assembly. Cable glands were also employed in the entry points of the power and communication cables. Mounting of the enclosure in different parts of the fishing boat was also given importance. The mounting design was conceptualized such that the enclosure can be mounted in several different orientations as well as different types and sizes of mounting locations.

Fig. 8. Photos of the enclosure after the liquid ingress test.

3. Water (Liquid) and Dust (Solid) Ingress

The indicators (tissue papers) placed inside the enclosure were examined after the submersion test, as shown in **Fig.** 8. The tissue inside the enclosure remained dry. This agrees well with the simulation results, which proves the printed enclosure to be water-tight. Prodding of test probes was also done, and it was ensured that the casing was able to protect against prodding of the test probes of size down to up to 1 mm. Both the laboratory-scale liquid and solid ingress tests, based from Ingress Protection Code (IPC) of IEC standard 60529, yield acceptable qualitative results, demonstrating the feasibility of utilizing additive manufacturing for enclosures for functional electronics systems. Further confirmatory tests from third-party testing and certification bodies are recommended, to ensure adherence to ingress protection standards.

IV. Conclusions

Fused deposition modeling of a transponder enclosure was demonstrated. Static load simulation was performed via Autodesk Fusion 360 to ensure that the enclosure design can withstand possible stresses during actual operations. A 50-N loading on the front and sides of the casing yielded to a maximum displacement of 0.5127 mm. A hydrostatic load simulation was also performed to ensure ingress protection level of IPX7, which yielded a maximum displacement of 1.344 mm. From this result, the actual thickness of the enclosure was adjusted by 1 mm upon printing to ensure very small warping during actual conditions. Laboratory scale ingress protection tests resulted in acceptable qualitative results. This demonstrates the feasibility of using additive manufacturing, especially for small volume production, for functional electronics enclosures.

V. Acknowledgement

This work was done under the Department of Science and Technology - Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) - funded project entitled, “Research on Advanced Prototyping and Development Using Additive Manufacturing Technologies (RAPPID-ADMATEC).”

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Mejora Manufacturing Inc. for RubberFlex: Synthetic Plywood Made from Scrapped Dextrose Rubber Caps Combined with Wood Fragments*

Sarah Khate C. Montederamos*[1], Christian S. Marcial*[2], Pamela Kate F. Fontelara*[3], Agnes M . Idio*[4]

Abstract

Mejora Manufacturing is a company dedicated to delivering quality products to its consumers. The main product of the study is the Rubberflex, a synthetic plywood with the composition of 10% pulverized rubber caps, 85% pulverized wood scraps and 5% binding agent. Study was conducted with the cities of Bacoor, Imus and Dasmariñas as the target locations. Target market are construction supply shops with market aims of establishing market share at 10% increasing at 4% annually. Average annual demand of plywood is 1,364,928 pcs and climbing at 4.5%, 9.47% and 5.11% for Bacoor, Dasmariñas and Imus respectively. Supply in the 3 cities is only at 1,225,408 pieces annually climbing at the same rate of the demand. Unfilled demand for the market is determined at 434,795 pcs in the year 2019 and 10% share targeted by the company would be at 43,480 pieces. The production process is compost of pulverizing the rubber caps and scrap wood simultaneously, then transported to the ribbon mixer along with the binding agent, extruded to it designated thickness and cut, cooled, cured and packaged for delivery. Prototype, was made manually to determine its properties against the natural plywood. Prototype made had the dimensions of 3 inches by 3 inches by 0.5inch. Results show that color is brown, flammability is less than the natural plywood. Pain applied need to be at least 2 coating and varnish only need 1 coating, ability to be sawed and nailed are at par with the natural plywood. Compressive strength yield of the prototype is at 5.2 MPa for parallel and 6.8 MPa for perpendicular and which is at par with the natural plywood at a minimum requirement of 5MPa and 6.2MPa respectively. Financially, the company would experience no liabilities, high profit ratios at 0.09 in the 1st year and a 1.5 years payback period. The product is therefore recommended to be used for walling and furniture, given that the minimum thickness for furniture is 12.5mm and for walling is 6mm.

Keywords: *Manufacturing, Plywood, Rubber Caps, Feasibility, Marketing, Production, Financial*

I. Introduction

Plywood has a lot of benefits and it includes increased stability, high impact resistance, and surface dimensional stability, high strength to weight ratio, panel shear, and chemical resistance [5]. In relation to this, the supply of locally produced wood for the downstream wood processing industry is getting depleted and is likely to run out soon. Once the supply of locally produced wood, including hardwood, runs out, wood processors will have to rely on imports. According to the Philippine Wood Processors Association, there is a shortage of hardwood in the global market, jacking up the cost of imported hardwood [4].

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On the other hand, rubber, a highly elastic solid substance, light cream or dark amber in color, polymerized by the drying and coagulation of the latex or milky juice of rubber trees and plants is one the most used material in the industry today. [1][2]. One of them is the rubber dextrose caps and according to the statistics from Department of Health, there are 1, 436 hospitals in the country as of October 2017. 33.15% comprises of government hospitals and 66.85% comprises of private hospitals. An average of 94,199 patients in the hospitals per day. [3][6] Thus, if each patient uses dextrose there is an average of 2,825,970 pieces synthetic rubber caps wasted per month per hospital.

With this, the researchers tend to find a way to eliminate these wastes and reduce logging of trees. This study aims to utilize the waste materials like the rubber dextrose caps that is being thrown away in places like landfills and oceans that contributes to the health problems of people and wildlife. That instead of throwing it why not use it as one of the properties in creating a product that would benefit us financially and environmentally.

II. Scope and Limitation

This study covers only the evaluation and determination of the market feasibility of the said product. Data collected would only be from the randomly selected respondents of hardware and wood crafting stores from the month of August 2018. Research locale only covers the cities of Bacoor, Dasmariñas and Imus in the Philippines. The study would be limited to producing the small scale prototype of the product through manual procedures. Study would only be conducted during the months of July 2018 to December 2018.

III. Statement of the Problem

An average of 2,825,970 pieces synthetic rubber caps wasted per month per hospital. 1 rubber cap weighs approximately 4g each thus every month 11,303.88kg of rubber is transported and dumped in landfills and garbage areas.

A. Objectives

Generally, the study aims to construct and determine the market feasibility of plywood that is made from scrap wood and discarded dextrose rubber caps. Specifically, the synthetic plywood would contain the following features; (a) passed the commercial standards in terms of breaking load and compressive strength. (b) Has a surface that could be painted, varnished and is smooth (c) High resistance to water.

IV. Conceptual Framework

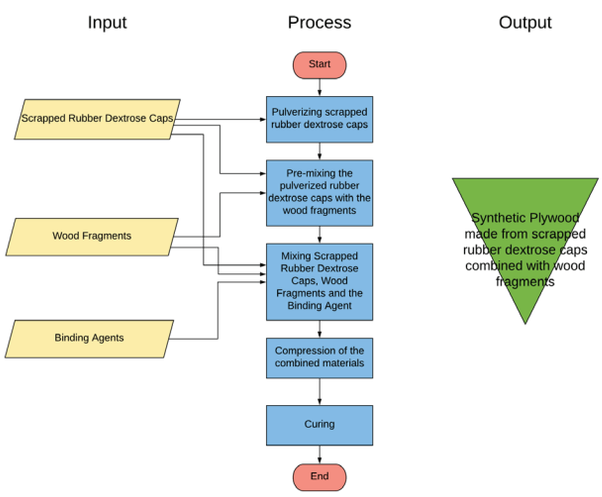

Fig. 1. Conceptual Framework of the Product Rubberflex

V. Marketing Aspect

A. Marketing Objectives

Generally, the study aims to determine the marketability of the synthetic plywood made from scrapped rubber dextrose caps combined with wood scraps through identifying potential demand. Specifically, the study aims to achieve the following: (1) To identify the potential customers and to determine the plant's capacity to meet the unfilled demand. (2) To establish Mejora Manufacturing Inc. as supplier of quality synthetic plywood. (3) To establish a market share of 10% and increasing at 4% annually.

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B. Market Location

According to the Philippines Statistics Authority: Construction Statistics from Approved Building Permits for Second Quarter of Year 2017 that was released on September 2017, CALABARZON led other regions where a total of 9,448(26.3%) construction which is topped by Cavite with 4,089 (11.4%) constructions [7]. Since Cavite has the highest percentage in number of constructions, the proponents' ideal target would be the municipalities of Bacoor, Imus and Dasmariñas since there are a lot of hardware in the said area.

VI. Demand Supply Analysis

Hardware owners do not want to run out of stocks thus they order their supplies in advance depending on the demand of the customer. However, there are times that they do not have enough stocks of the product their customers are looking for. These are the unfilled demand, which presents a market opportunity for the company. The projected unfilled demand is obtained through the formula below:

Unfilled Demand = Projected Demand – Projected Supply(9)

The unfilled demand for 2018 in Bacoor is 14.67%, for Dasmariñas is 4.72% while in Imus 11.05% of the total demand. Since the proponent's aims to cover 10% of this unfilled demand, the company must supply of 21,601 pieces in Bacoor, 6,922 pieces in Dasmariñas, and 14,957 pieces in Imus. This totals to a target supply of 43,480 pieces in 2019.

Table 2 shows the projected market share for the year 2019 – 2023. The market share is expected to increase by 4% annually. This increase will base on the production capacity of the plant and promotions by the company.

VII. Proposed Market Programs

A. Product Description

Synthetic plywood is produced by mixing pulverized rubber caps and pulverized wood fragments. The product has the property that would reduce water absorption, which is the primary cause of rotting and growth of microorganisms. It has also the ability to endure changing and unpredictable weather condition. Product dimensions are available at various length and width depending on customer request. However standard thickness of the product would be available at 19mm, 12.5 mm and 6.0 mm with a standard cu similar to plywood size of 8ft x 4ft. The product is compost of 60% Rubber caps (pulverized) and 40% Scrap wood (pulverized). 10% of the 2 major raw materials combined weight would be the amount of adhesive or bonding agent to be used.

B. Price

The proponents will sell the product at an affordable price to get customers' attention and to create a healthy competition among others. The price will be based on the costs of materials, processes and other related charges in manufacturing and delivering of these products.

Table 1. Unfilled Demand for Plywood (2018-2023)

Year	Unfilled Demand in Bacoor	Unfilled Demand in Dasmariñas	Unfilled Demand in Imus
2018	205,728	63,264	149,568
2019	216,006	69,221	157,226
2020	226,795	75,741	165,276
2021	238,125	82,873	173,738
2022	250,021	90,677	182,634
2023	262,510	99,215	191,984

Table 2. Market Share for Plywood (2018-2023)

Year	Unfilled Demand (in pieces)	Market Share (in percent)	Market Share (in pieces)
2019	434,795	10%	43,480
2020	459,762	14%	64,367
2021	486,274	18%	87,529
2022	514,436	22%	113,176
2023	544,359	26%	141,533

Table 3. Price Comparison

Price Comparison		
Thickness	RubberFlex	Regular Plywood
6mm	360.00	380.00
12.5mm	680.00	720.00
19mm	1,120.00	1,200.00

VIII. Production Aspect

A. The Processes

As shown in **Fig. 2** the process begins with the pulverizing of rubber caps and wood scraps simultaneously. Wood scraps is pre evaluated to ensure that no metal or other foreign material is mixed in with it, this is done during the procurement of raw materials by the inspection of the Quality Assurance Department. After pulverizing the materials along with the binding agent, it would proceed to the pre mixing stage where a dough like consistency would be produced inside the ribbon mixer. The dough would then proceed to the sheeter where it would be extruded to the designated thickness in production. The sheeted dough would then be cut, cooled, cured and packaged ready for shipping.

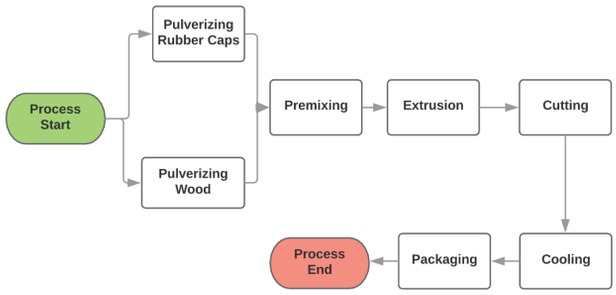

Fig. 2. Process diagram of RubberFlex

Fig. 3. Project prototype

B. List of Raw Materials

Table 4. List of Raw Materials and Cost per unit

Material	Quantity	Cost per Unit
Scrapped Rubber Caps	9,360 kg/week	Php 15.50 per kilogram
Pulverized Wood Fragments	3,370.04kg per week	Php 38.70 per kilogram
Hardening/ Binding Additives	1,273 liters per week	Php 1,720.00 per liter

Table 5. Property Comparison

Properties	Description	
	RubberFlex	Regular Plywood
Color	Grayish	Brown
Texture	Smooth	
Wood Fiber	85%	100%
Rubber Content	10%	None
Binding Adhesive Contents	5%	None
Composition	Made from pulverized synthetic rubber caps and wood fibers	Made from virgin wood fiber
Resistance	High resistance to water	Low water resistance
Compressive Yield Strength (Parallel)	5.2Mpa	Min. 5.0 MPa
(Perpendicular)	6.8MPa	Min 6.20 MPa
Flammability	Flammable	Flammable
Ability to absorb Paint	1 coating	2 coating
Ability to absorb varnish	1 coating	1 coating
Ability to be Nailed and sawed	Good	Good

C. Prototype

Prototype, as shown in **Fig. 3** was made manually in order to evaluate and optimize the production process. The product is composed of 10% Rubber caps (pulverized) and 85% scrap wood (pulverized). 5% of the two major raw materials combined weight would be the amount of adhesive or bonding agent to be used.

Table 5 indicates the comparison between the synthetic plywood and the regular plywood.

D. Product Limitations

The product is therefore limited to applications of Walling and Furniture applications. Optimal thickness for Furniture application should be at least 12.5 mm thick and for walling it should be 6mm thick. Since prototype is only made manually the proponents were unable to produce the thinnest size of 6mm. Since the proponents was unable to test the prototype in terms of bearing load and stress, ceiling application is still for further study.

IX. Financial Aspect

A. Return of Investment and Payback Period

Return of Investment (ROI) would be able to indicate good or poor management performances, capitalization and the organization's approach to business. Of the ROI per period is 10%-15% or higher, the company is doing well in business [8].

$$ROI = \frac{net\_income}{investment} \quad (11)$$

Payback period is the length of time that it takes for the cumulative gains from an investment to equal the cumulative cost as stated by newleaf-llc.com. it is also considered that investments having shorter payback periods has the lower risk compared to long payback periods [8].

$$Payback\_Period = A + \frac{B}{C} \quad (12)$$

Where:

A = *the last period with a negative cumulative cash flow*

B = *the absolute value of cumulative cash flow at the end of period* A

C = *total cash flow during the period after* A

Table 6. Cash Flow Schedule

Year	Cash Flow	Cumulative Cash Flow
0	(4,500,000.00)	(4,500,000.00)
1	(676,261.37)	(5,176,261.37)
2	9,975,230.96	4,798,969.59
3	35,229,657.17	40,028,626.76
4	71,429,056.79	111,457,683.55
5	124,376,265.38	235,833,948.93

From **Table 6**, payback period could be computed as follows:

$$Payback\_Period = A + \frac{B}{C}$$

$$Payback\_Period = 1 + \frac{|(5{,}176{,}261.37)|}{9{,}975{,}230.96}$$

$$Payback\_Period = 1 + 0.5189$$

$$Payback\_Period = 1.52 years$$

X. Conclusion

In the course of this study, it has been proven that the RubberFlex can enter the market and compete with the natural plywood. Several tests such as compressive strength, flammability, water testing and ability to absorb paint and varnish were conducted to know if the RubberFlex would be at par with the natural plywood. Since the minimum requirement for the compressive strength is 5 MPa and the result of the product prototype for parallel is 5.2 MPa while for the perpendicular is 6.8 MPa, the hardness of the RubberFlex is within the standard. Moreover, the average annual demand of the product is 1, 364, 928 pieces and increasing at 4.5%, 9.47%, and 5.11% for Bacoor, Dasmariñas and Imus respectively. Supply within the 3 cities aforementioned is at 1, 225, 408 pieces annually and increasing with the same rate as the demand. With this, it can be said that the company can supply the demand of the target market. Financially, the company would experience no liabilities with high profit ratios at 0.09 due in the first year a 1.5 years payback period.

XI. Recommendations

The proponents highly recommend the following: (1) Further study of the product for improvement. (2) The wood fragments should not be damp nor wet for the mixing. (3) Bearing stress test for the suspension of the product for ceiling application (4) Test regarding the product's ability to be adhered with other products such as wallpapers (5) Further study regarding the flammability of the product. (6) Further experimentation with the curing time of the synthetic plywood

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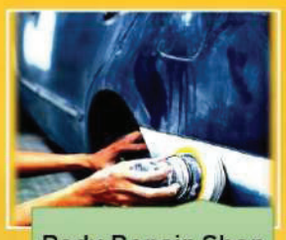

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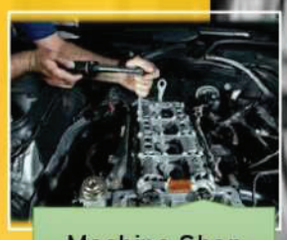

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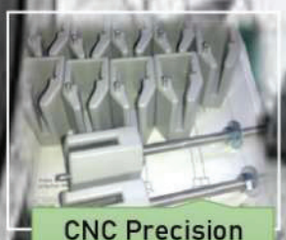

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Elemental Analysis of Available Intramedullary Nails in the Philippines: Comparison of EDXRF, Arc-OES and SEM-EDS techniques*

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Abstract

Intramedullary nail continues to evolve with introduction of new technologies as it is considered a gold standard in treating bone defects caused by disease, trauma and accidents which are evidently higher in developing countries like the Philippines. Recently, Philippine Orthopedic Center invented the Antibiotic Intramedullary Nails (ABIMN), a threaded stainless rod coated with antibiotic cement to treat infections that commonly occurs in bone defects. This product has been widely used, however, few studies in chemical characterization that may be useful in screening either for safety or product development were found. The elements present in ABIMN were investigated and compared with other standard nails, Kuntscher Nail (KIMN) and Intramedullary Nail with Interlocking Screw (IMNIS) using X-ray Fluorescence (XRF), Arc-Optical Emission Spectroscopy (Arc-OES) and Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS) techniques. The concentrations of each element obtained from these 3 methods were also compared. A total of 5 nails (with 5 focal points each) were subjected to nondestructive EDXRF and SEM-EDS first, and then analyzed using the destructive Arc-OES after. Results from ABIMN and KIMN showed comparable concentrations of Iron (x̄ABIMN = 70.71%, x̄KIMN = 68.64%), Chromium (x̄ABIMN = 18.58%, x̄KIMN = 16.76%), Nickel (x̄ABIMN = 7.67%, x̄KIMN = 10.09%) and Manganese (x̄ABIMN = 1.35%, x̄KIMN = 1.11%) using 2 methods. Titanium (x̄IMNIS = 90.90%) and Aluminum (x̄IMNIS= 5.29%) using SEM-EDS and EDXRF were also found to be comparable in testing IMNIS sample. Concentrations obtained were analyzed statistically by Pearson's correlation coefficient (PCC) and regressed to observe the presence of linearity.

Keywords: Intramedullary nail, EDXRF, Arc-OES, SEM-EDS, Pearson's correlation coefficient

I. Introduction

The World Health Organization (WHO) reported in 2018 that road accident is the 8th leading cause of death globally wherein, countries from Southeast Asia contributed a higher rate than other areas at 20.7 deaths per 100,000 population [1]. As the trend projects that this will continue in the foreseeable future, the Philippines, one of the developing countries in South East Asia, already considered road accident a major concern when an approximate 7,000 deaths reported last 2017 and also a large number were figured as orthopedic trauma patients [2]. The challenge is that inadequate care from these patients could also lead to higher mortality rate as various orthopedic infections occurs frequently from these defects.

The Philippine Orthopedic Center addressed this concern when they developed the Antibiotic Intramedullary Nail (ABIMN), a threaded stainless rod coated with antibiotic cement to treat infections that commonly occurs in bone defects. Following the principle behind antibiotic cement-

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coated interlocking intramedullary nails that often used vancomycin, tobramycin, and gentamicin as antibiotics, the ABIMN shorten the usual two-step process in orthopedic surgery involving initial debridement and antibiotic delivery first and followed by external fixation, by eliminating the latter. This also benefits the patients who are not eligible for external fixation or doesn't prefer an external fixator applied [3-10].

This study aims to investigate the elements present in the Antibiotic Intramedullary Nail (ABIMN) and compare it with other available intramedullary nails in the Philippines, Küntscher Intramedullary Nail (KIMN) and Intramedullary Nail with Interlocking Screws (IMNIS), using three analytical techniques namely Energy Dispersive X-ray Fluorescence (EDXRF) Spectroscopy, Arc Spark Optical Emission Spectroscopy (Arc-OES) and Scanning Electron Microscopy combined with Energy Dispersive Spectroscopy (SEM-EDS).

II. Materials and Methods

Intramedullary Nails

A total of five intramedullary nails with five focal points each were used for this study.

A. Antibiotic Intramedullary Nails - Three nails with 330 mm length and diameters 10, 12 and 13 mm were achieved by setting a 400mm x 4mm threaded rod into the ABIMN mold, with one nut distally and one nut proximally along with a stopper outside the mold to make a 330mm ABIMN (longest length possible). Four (4) grams of vancomycin into a mixing bowl and packed in placed by hand into both sides of the mold. After setting, the mold is opened and lifted out, excess bone cement is removed using a osteotome, sanded off using a bone file and excess of the threaded rod is cut using a rod cutter or a Berbecker.

B. Küntscher Intramedullary Nail (KIMN) - One KIMN with 10 mm x 440 mm dimension was purchased from Olten Instruments, Pakistan.

C. Intramedullary Nail with Interlocking Screws (IMNIS) - One IMNIS with 10 mm x 400 mm dimension was purchased from Smith & Nephew, England.

Chemical Testing

A. Energy Dispersive X-ray Fluorescence (EDXRF) - Test was conducted using Portable X-ray Fluorescence Spectrometer, Thermo Niton, XL3t GOLDD+ and was repeated 5 times at different location points [11]. Accuracy of measurements was regularly tested using Certified Reference Materials SS 465/1 and 466/1 (British Chemical Standard, MBH Analytical Ltd.).

B. Scanning Electron Microscopy - Energy Dispersive Spectroscopy (SEM-EDS)- Previously analyzed samples from EDXRF were tested by Materials Research Section- MIRDC (MRS-MIRDC) using Hitachi SU5300 Electron Microscope following methods ASTM E766-14 [12], and ASTM E1508-98 [13].

C. Arc Spark Optical Emission Spectroscopy (Arc-OES) - Previously analyzed samples from SEM-EDS were tested for Arc-OES. Samples for ABIMN and KIMN were flattened using 2000 kN Universal Testing Machine (UTM), Shimadzu, grinded using P60 grit aluminum oxide sanding paper and tested using Optical Emission Spectrometer (Bench Top, Spectro Brand, Model MAXx lmf07) following the ASTM E353-19 [14]. Five-point readings were conducted on each sample. Each element was calibrated and validated using various Certified Reference Materials (CRMs). IMNIS was not subjected to analysis due to unavailability of Titanium based program in the software.

Concentrations obtained were analyzed statistically by Pearson's correlation coefficient (PCC) denoted by rxy and referred to as the sample correlation coefficient or the sample Pearson correlation coefficient (SPSS) [15]. According to the Cauchy–Schwarz inequality, PCC valued between +1 and − 1. PCC value 1 indicates positive linear correlation, 0 is no linear correlation, and − 1 is total negative linear correlation.

Correlation between metal concentrations were regressed to a linear model with slope, m, and intercept, c, as a function of concentration, thus, y=mx +c. The most common method for fitting a regression line is the method of least-squares which calculates the best-fitting line for the observed data by minimizing the sum of the squares of the vertical deviations (residuals) from each data point

to the line. No between positive and negative values are seen in this method, because the residuals are first squared, then summed, and plotted. For this study, regression was computed and plotted using the Microsoft Excel tool [15].

III. Results and Discussion

Initially, the experimental design is to compare the results gathered from three techniques but due to the limitations of some equipment, the correlation between the following techniques were the ones considered:

a. EDXRF and Arc-OES for chemical testing of ABIMN and KIMN;
b. EDXRF and SEM-EDS for chemical testing of IMNIS.

Chemical Testing of ABIMN

Arc-OES has been used for benchmarking the results from other analytical techniques like EDXRF and SEM-EDS. Based on the program used for testing the 3 ABIMN, 10 elements (Carbon, Silicon, Manganese, Phosphorus, Sulfur, Chromium, Nickel, Copper and Iron) were determined where each element was calibrated using a CRM except for Iron that was only calculated to the residue of the sum of all other elements to 100% (wt./ wt.). Relative standard deviations were also calculated and monitored to not exceed beyond 10% after five trials. The 10, 12 and 13 mm ABIMN has shown notable Chromium and Nickel content at approx. 18% and 7%, respectively which makes it a stainless steel material. But due to low Molybdenum content, the ABIMN was identified as Stainless Steel Grade 304 (SS 304) [16]. Similar results were also obtained using EDXRF and the database of the equipment also identified the ABIMN as SS 304 material.

However, notable difference was observed for the light elements like Carbon, as the XRF doesn't have the capability to identify its content, and Silicon, where EDXRF results are 172- 224% higher than the one gathered from Arc-OES. Moreover, other trace elements or elements present in minute amounts that were analyzed in Arc-OES like Phosphorus and Sulfur was either not identified by EDXRF or sporadic results were obtained. Refer to **Table 1** for the results.

Chemical Testing of KIMN

The procedure is similar to that of ABIMN but only used one size as this is already a commercially available product. The KIMN was also identified as Stainless Steel from Arc OES analysis due to high concentrations of Nickel and Chromium at 10.80% and 16.80%, respectively. The low Carbon content at 0.019% and high Molybdenum content at 2.04% however, was different from that of ABIMN and was assessed as Stainless Steel Grade 316L material [16]. Similar Chromium and Nickel content from Arc OES test were obtained from EDXRF. In addition, the Silicon and Copper content showed comparable results between two techniques with an approx. 0.04% and 0.07% difference, respectively. The trace elements Phosphorus and Sulfur were still not identified using EDXRF and only characterized the material as Stainless Steel 316 due to limitations of equipment to identify Carbon. Refer to **Table 2** for results.

Table 1. Mean Average of the Elemental Composition (in % w/w) of 10, 12 and 13 mm ABIMN

Elements / Sample	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Fe
10 mm XRF	-	0.78	1.21	-	-	18.58	0.24	7.56	0.46	70.82
10 mm OES	0.050	0.26	1.21	0.053	0.012	18.62	0.27	7.72	0.45	71.04
12 mm XRF	-	0.96	1.47	-	0.013	18.62	0.18	7.58	0.45	70.34
12 mm OES	0.047	0.35	1.35	0.053	0.0099	18.74	0.21	7.76	0.53	70.60
13 mm XRF	-	0.96	1.60	0.036	-	18.52	0.19	7.53	0.47	70.44
13 mm OES	0.046	0.29	1.26	0.054	0.022	18.42	0.19	7.89	0.51	71.02

Table 2. Mean Average of the Elemental Composition (in % w/w) of 10 mm KIMN

Elements / Sample	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Fe
10 mm XRF	-	0.54	1.32	-	-	16.72	1.95	9.37	0.39	69.17
10 mm OES	0.019	0.58	0.90	0.030	0.0054	16.80	2.04	10.80	0.32	68.10

Chemical Testing of IMNIS

Titanium and Aluminum were the principal elements of IMNIS for both EDXRF and SEM-EDS analysis. The

EDXRF alloy database identified the nail as Ti 6Al-4V or a Grade 5 Titanium Alloy that exhibits high tensile strength and corrosion resistance which is well-suited for surgical implants like intramedullary nails [17]. The accuracy of two techniques however, was validated from the statistical analysis solely due to absence of titanium reference standard. The precision was validated as the relative standard deviation did not exceed 10%. Refer to **Table 3** for results.

Table 3. Mean Average of the Elemental Composition (in % w/w) of 10 mm IMNIS

Elements / Sample	Ti	Al	V	Fe
10 mm XRF	89.92	4.91	4.64	0.322
10 mm SEM-EDS	92.07	5.67	-	-

Table 4. Pearson Correlation Coefficient Where x= EDXRF Data and y=Arc-OES Data (ABIMN and KIMN Samples)

Cr (r_{xy})				Ni (r_{xy})				Mn(r_{xy})			
10mm	12mm	13mm	KIMN	10mm	12mm	13mm	KIMN	10mm	12mm	13mm	KIMN
0.92	0.96	0.98	0.79	0.81	0.84	0.88	0.82	0.93	0.73	0.99	0.99

Mo (r_{xy})				Fe (r_{xy})			
10mm	12mm	13mm	KIMN	10mm	12mm	13mm	KIMN
0.99	0.94	0.96	0.92	0.85	undefined	0.93	undefined

Table 5. Statistical Parameters for Linear Regression Model

Sample	Element	Slope, m	Intercept, y	Linear correlation, R^2
10 mm ABIMN	Cr	0.28	13.50	0.85
	Ni	0.25	5.82	0.66
	Mn	0.076	1.12	0.86
	Mo	0.41	0.17	0.99
	Fe	0.16	60.01	0.71
12 mm ABIMN	Cr	0.29	13.32	0.93
	Ni	0.29	5.52	0.71
	Mn	0.10	1.20	0.98
	Mo	0.33	0.15	0.88
	Fe	-1×10^{11}	70.6	-1×10^{11}
13 mm ABIMN	Cr	0.41	10.79	0.96
	Ni	0.39	4.92	0.77
	Mn	0.20	0.937	0.99
	Mo	0.40	0.12	0.92
	Fe	0.28	51.39	0.86
KIMN	Cr	0.18	13.83	0.62
	Ni	0.29	8.12	0.67
	Mn	0.019	0.88	0.98
	Mo	0.28	1.51	0.85
	Fe	2×10^{-15}	68.1	undefined
IMNIS	Al	0.19	4.72	0.75
	Ti	0.58	39.62	0.65

The relationship between two selected techniques in testing each intramedullary nail were evaluated using the Pearson's correlation coefficient. The elements Iron, Nickel, Chromium, Molybdenum, and Manganese showed consistency through the course of analyses of ABIMN and KIMN and were the only ones considered for statistical evaluation. The authors believed that the selected data already fits to be a good representation in characterizing the intramedullary nails and can be employed for future research. Titanium and Aluminum on the other hand, were the only evident elements in IMNIS testing that was used for PCC computation.

All of the elements except for Iron in 12 mm ABIMN and KIMN exhibited a positive correlation, thus, showed an excellent agreement between EDXRF and Arc-OES. The poor correlation of Iron, that resulted to "undefined", could be attributed to low sensitivity and resolution of Arc-OES in detecting major elements. Moreover, Iron was only calculated to the residue of the sum of all other elements to 100%, thus, dependent on detection and testing of the alloying elements. Refer to **Table 4** for the complete PCC of selected parameters. A positive correlation were also computed for the PCC of Aluminum and Titanium of IMNIS at 0.86 and 0.81, respectively.

Table 5 showed the resulting linear regression based on the variables identified from PCC and was computed using the Microsoft Excel analytical tool.

Based on the resulting linear correlation coefficients of ABIMN and KIMN, the Chromium, Manganese and Molybdenum for ABIMN exhibited a positive strong correlation between EDXRF and Arc-OES. Nickel on the other hand, also had a weak but still positive correlation that could be addressed and verified for future studies. This only shows that the detection and sensitivity and resolution of EDXRF is comparable to a more accurate Arc-OES specifically for these elements. Iron, based on the previously calculated PCC encountered again the same concern in computing the linearity.

Both Titanium and Aluminum had a weak but still positive correlation coefficients for the testing of IMNIS using EDXRF and SEM-EDS at 0.65 and 0.75, respectively.

IV. Conclusion

The intramedullary nails KIMN and IMNIS identified as SS 316L and Ti 6Al-4V, were comparable to the previous studies. The novel ABIMN characterized as SS 304 on the other hand, could be a possible root for further research and improvement of the material that will suit the requirement of a surgical implant.

In addition to chemical characterization, the study also employed the comparison of three widely used analytical techniques in analysis of the intramedullary nails. The Arc-OES and EDXRF showed significant positive correlation for the majority of the elements detected in KIMN and ABIMN, thus, EDXRF could be a reliable analytical technique and could be the first option as it is fast and less expensive. The elemental analysis of IMNIS, however, exhibited also positive correlation but may need another validation and require a more accurate technique to correlate with, to further assess the accuracy of its techniques.

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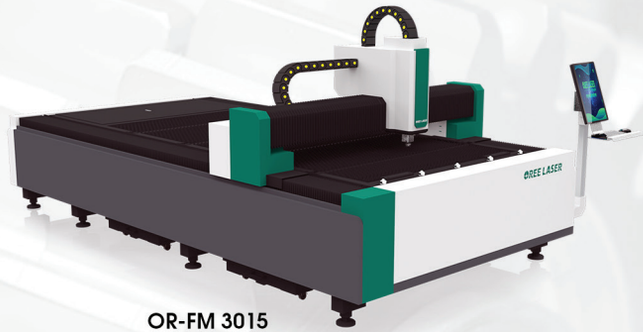

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Experimental Verification of the Effect of Aspect Ratio and Heat Treatment on Magnetic Field of a Finite Permeable Core Solenoid*

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Abstract

Magnetic core confines and concentrates magnetic field inside a solenoid due to its high magnetic permeability, thus, enhancing the magnetic field strength. Ampere's law is applied to approximate the magnetic field inside of an infinite solenoid, and to the magnetic field of finite air-cored solenoids with length (L) to width (w) ratios (aspect ratios) significantly greater than 1. However, according to L. Lerner [8], this becomes significantly less accurate when applied to finite solenoids whose core permeability is much different from that of free space. Lerner developed an exact expression for the magnetic field and inductance of a linear permeable core with finite dimensions, wherein the magnetic field is dependent on the aspect ratio of the material. In this paper, experimental verification of the effect of varying aspect ratio as well as the influence of heat treatment on the magnetic field of the electromagnet's iron core was done. The field magnification test result of a heat-treated VIM/VAR core iron with an aspect ratio of 0.55 is very low with a value of 2.47; an increase was observed but relatively insignificant when compared to the as-machined iron core and 17-4PH stainless steel of the same aspect ratio. When the aspect ratio was increased to 10, the field magnification also increased to 33.17 or roughly 13 times. Clearly, the results show the dependence of the field magnification on the aspect ratio (L/W) for a finite length of solenoid.

Keywords: *finite solenoid, permeable core, aspect ratio, magnetic field, heat treatment*

Introduction

An electromagnet is a type of magnet that uses electricity to produce a magnetic field. When a current is introduced and flows through the wire, a magnetic field is created around the coiled wire or solenoid. The strength of an electromagnet, also known as its magnetomotive force, typically depends on the magnitude of the current and the number of windings. An electromagnet can also be configured with a solenoid surrounding a magnetic core made from ferromagnetic or ferrimagnetic material to concentrate its magnetic flux.

The use of a magnetic core further magnifies the magnetic field strength of an electromagnet. This is the very reason numerous studies lean towards its characterization and optimal design. To describe a few, the study of Hwang et al. [1] considers the design concept of a multipole electromagnet using a parallel iron-core structure and a high-temperature superconducting coil. A U-shaped iron core was explored in the paper of Kalsi et al. [2] as the researchers tried to develop a superconducting magnet for levitating and propelling vehicles. A concept of the porous core electromagnet is

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studied in the works of Pilat & Sikora [3] in which the paper aims to deliver an initial analysis of the proposed powder core and compare the experimental results of the manually manufactured electromagnet.

The magnetic properties of an electromagnet core can also be altered when subjected to a specific heat-treatment process. According to ASTM A848 [4], heat treatment at a very high temperature followed by slow cooling through the transformation maximizes the ferrite grain size, thus improving the magnetic properties. Several studies have even verified this standard. In the studies of Yaghtin et al. [5] and M. Li et al. [6], it was observed that the annealing treatment of iron-OER soft magnetic properties (SMC) and SMC with alumina insulator coating increased the permeability of the composites at low and medium frequency ranges. The same enhancement was noticed in the paper of M. Namkung et al. [7] when polymer-bound iron cores were exposed at a very high temperature.

Little to no researches have been tackled to date about the influence of the physical dimension of the electromagnet core on the magnetic field strength. Generally, the magnetic field of finite solenoids is approximated by an infinitely long solenoid equation. However, it is less well known that this approximation requires much larger aspect ratios to apply to solenoids whose relative core permeability is much greater than that of the surrounding [8]. In the study of Lerner [8], an exact expression was derived for the magnetic field and inductance of a linear permeable core with finite dimensions. Equation 1 and 2 approximates the magnetic field for infinitely-long (B_0) and finite (B) air-cored cylindrical solenoids:

$$B_0 = \mu_0 K \quad (1)$$

$$B = \frac{\mu_0 K L}{\sqrt{L^2+w^2}} \quad (2)$$

where μ_0 is the vacuum permeability, K is the current density, L is the length of the solenoid, and w is the width of the solenoid.

Equation (1) can still be a good approximation for the magnetic field of finite air-cored cylindrical solenoid given that the $L/w > 2$. Otherwise, equation 1 already introduces greater than 10% error to the approximation.

The approximation of magnetic field for permeable-core cylindrical solenoid is much more restrictive than for air-cored solenoids. The infinitely-long permeable-core solenoid can be approximated using

$$B_0 = \frac{\mu_0 K}{(1+\beta\mu_r)} \quad (3)$$

where μ_r is the relative permeability of the core other than the free space and β is the demagnetization factor.

Equation 3 shows that the contribution of β becomes significant as μ_r increases and approaches the approximation

$$B_0 = \frac{1}{\beta}(\mu_0 K) \quad (4)$$

Equation 4 holds for solenoid with a permeable core as long as the L/w is large enough to minimize approximation error. The paper of Lerner, however, derived an exact expression for finite permeable-core cylindrical solenoid as

$$B = \mu 0\, M \frac{\mu_r h(L/w)}{\mu_r + h(L/w)} \quad (5)$$

where M is the constant magnetization and h can be computed as

$$h(\alpha) = \frac{(\alpha^2-1)^{3/2}}{\alpha \cosh^{-1}(\alpha) - (\alpha^2-1)^{1/2}} - 1 \quad (6)$$

where $\alpha = L/w$.

This paper intends to have experimental verification of the effect of varying aspect ratio as well as the influence of heat treatment on the magnetic field of the electromagnet's iron core, with VIM/VAR core iron as the specimen, essentially a high-purity iron.

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Materials and Methods

Chemical Analysis

A 25mm outside diameter x 20mm length VIM/VAR Core Iron sample was analyzed for chemical composition using Spectro LAB LAV m11 Optical Emission Spectrometer (OES).

Sample Preparation

Two (2) sets of VIM/VAR core iron with different outside diameter to length ratio (OD x L) were prepared for heat treatment: a 20 mm x 11 mm core or equivalent to an aspect ratio of 0.55, and a 5 mm x 50 mm core yielding an aspect ratio of 10.

Heat Treatment Runs

The specimens were heat-treated using the treatment cycle shown in **Fig. 1.**

Metallurgical Tests

The samples were ground, polished to 1 micron, and etched with 3% Nital. The samples were analyzed for their microstructure before and after heat treatment using the Olympus GX53 Optical Microscope and Hitachi SU3500 Scanning Electron Microscope (SEM). The average grain size was determined by the comparison method as per American Society for Testing and Materials (ASTM) E112. The samples' microstructure viewed at 100x magnification was compared to a series of graded images using a grain counting eyepiece reticle.

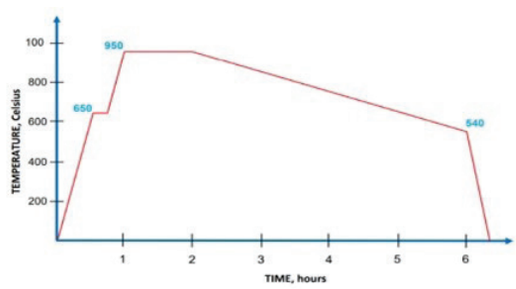

Fig. 1. Time-Temperature Graph of the Heat-Treatment Cycle

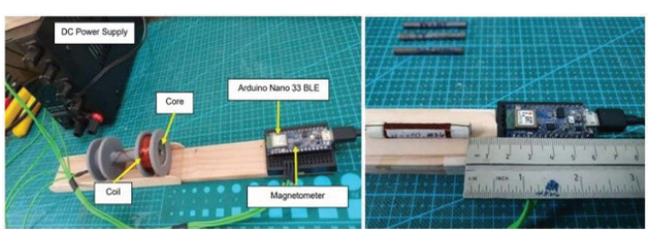

Fig. 2. General Experimental Setup: (a) Consisting of DC Power Supply, Coil, Magnetometer and (b) Distance of Magnetometer from Coil is Recorded

Hardness Test

Hardness tests of the samples were taken before and after heat treatment using Mitutuyo AR-10 Rockwell Hardness Tester (HRC scale).

Magnetic Property Test

The effect of the length-to-width ratio of the magnetic core to the magnetic field strength was determined using the set-up shown in **Fig. 2.** Initially, the set-up was tested without a core. Electric current was supplied to the coil using the DC power supply. The Arduino board, which has the magnetometer attached to a computer, was moved towards the coil until a reading was measured. The reading was recorded and the distance between the board and the coil was recorded. The same procedure above was repeated with VIM/VAR placed inside the coil and using the recorded distance.

Results

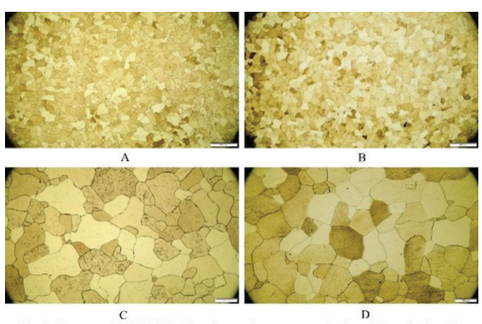

Fig. 3. Images of VIM/VAR Core Iron Microstructure: Before (A) and After (B) Heat Treatment at 50x Magnification and Before (C) and After (D) Heat Treatment at 200x Magnification. Microstructure is Fully Ferritic

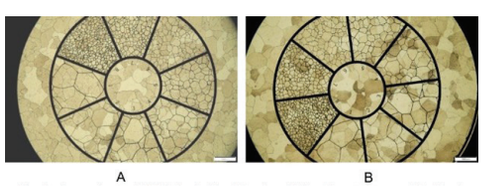

Fig. 4. Approximate ASTM Grain Size Number: Before Heat Treatment (A) G = 4 and After Heat Treatment (B) G-3

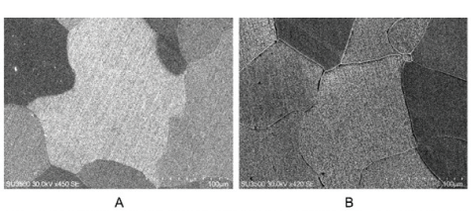

Fig. 5. Imagesof Untreated (A) and Heat Treated (B) VIM/VAR Core Iron Viewed Under Scanning Electron Microscope (SEM). A Reduction on Curvature of Grain Boundaries were Observed. Viewed at 450x and 420x Magnification Respectively

Table 1. Standard Requirement and Actual Chemical Analysis of VIM/VAR Core Iron

	%Fe	%C	%Si	%Mn	%P	%S	%Cr	%Mo	%Ni	%Cu	%Va	%Ti	%Al
ASTM A848	Balance	0.02	0.15 max	0.35 max	0.03 max	0.025 max	0.2 max	-	0.15 max	-	0.1 max	0.1 max	0.1 max
Actual	99.9363	0.012	0.0055	0.0057	0.0046	0.0048	0.008	0.0024	0.018	0.0027	-	-	-

Table 2. Hardness Values Before and After Heat Treatment

	HRB
Untreated	45-53
Heat treated	24-25

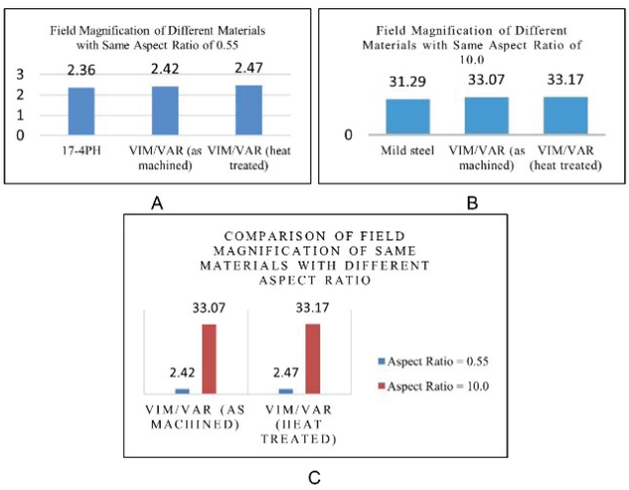

Fig. 6. Effect of Varying the Aspect Ratio and Heat Treatment on Field Magnification. (A) and (B) Same Aspect Ratio But Different Materials. (C) Same Materials With Different Aspect Ratio

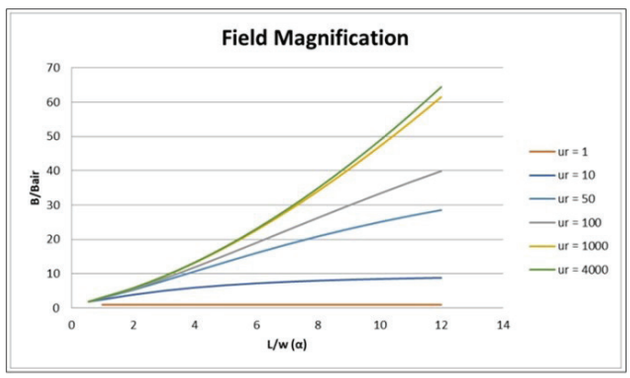

Fig. 7. Plot of the Field Magnifications as a Function of Aspect Ratio (L/w) of Materials With Different Permeability

Discussion

The result of the chemical analysis of VIM/VAR core iron falls within the requirement of the standard. Chemistry is important as impurities have detrimental effect on the magnetic property. Elements such as Carbon, Nitrogen, Oxygen and Sulfur, which all act as interstitial impurities, create large localized stresses on the crystallographic lattices which lowers the magnetic property of the ferrous-based material.

Heat treatment also plays critical role as this will address any stresses and defects caused by cold working during fabrication such as deformed grains which restrict movement of domain walls. The metallographs (**Fig. 3**) show equiaxed, fully ferritic microstructures before and after heat treatment. In **Fig. 5**, a reduction on curvature of grain boundaries was observed after heat treatment. This reduction in curvature minimizes grain boundary energy [9] which is crucial in movement of magnetic domain walls. In **Fig. 4**, the average grain size increased due to heat treatment which is also important in attaining enhanced magnetic property of the material as coarser grain sizes have lower grain boundary surface area, thereby, allowing the easier movement of magnetic domain walls. The decrease in hardness validated the corresponding increase in grain sizes of the heat treated material.

The derived equation of Lerner (Equation 6) is plotted in **Fig. 7**, where the field magnifications of the materials with different permeability are plotted as a function of the aspect ratio. It is generally observed that the magnification increases as the aspect ratio increases for a given relative permeability of material. Clearly, the graph shows the dependence of the field magnification on the aspect ratio (L/W) for a finite length of the solenoid.

Figure 6 summarizes the field magnification (B/Bair) obtained using different materials for varying aspect ratios. Theoretically, an untreated VIM/VAR should already give a higher magnification than 17-4 PH or a mild steel. In the same manner, a heat-treated VIM/VAR should boost the magnification several times higher. The result, however, shows no significant difference in the field magnification among the three materials with the aspect ratio of the specimens held fixed. But when the aspect ratio was increased from 0.55 to 10, the field magnification also increased by roughly 13 times. This agrees with the mathematically derived equation of L. Lerner on the influence of aspect ratio for a finite length of the solenoid.

Conclusion

The following results were obtained and are desirable in achieving enhanced magnetic property:

1. Compositional analysis show that the material is essentially pure iron. The material falls within the requirement of the standard for low-carbon magnetic iron.
2. Microstructure is fully ferritic. An increased in average grain size was also observed which allows easier movement of magnetic domain walls since coarser grains have lower grain boundary surface area.
3. Hardness decreased after heat treatment. This validates the corresponding increase in grain sizes.
4. The reduction of curvature minimizes grain boundary energy which promotes easier movement of magnetic domain walls.

However, as depicted in **Fig.** 6, the following conclusions were drawn:

1. The use of VIM/VAR core iron did not give significant difference in field magnification when compared to mild steel and 17-4ph stainless steel.
2. Using the same heat treatment cycle, the increase in field magnification for VIM/VAR core iron is insignificant.
3. There was a significant increase in the field magnification when the aspect ratio was also increased. Clearly, the magnetic field strength is dependent on the aspect ratio for the specified length of solenoid.
4. The experimental results agree with Lerner's derived expression.

Aknowledgments

The authors would like to thank the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) and Orthopaedic International, Inc. for entrusting this research, as well as to the researchers and technical staff of the Materials and Process Research Division (MPRD) and Heat Treatment Unit of the Technical Solution Services Section for extending their profound knowledge and effort towards the realization of this study.

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Optimization of MPEW Cast Iron and Non-ferrous Melting Process and Equipment for Enhanced Energy and Output Efficiency*

Lemuel Apusaga*[1], Karen Santos*[2], Edrhea Villas*[3]

Abstract

The project entails the improvement of the performance of crucible and cupola furnaces of Metallic Pisces Engineering Works (MPEW), a machine shop and foundry located in General Santos City. After the approved project duration, the newly designed crucible furnace improved by 36% in melting speed and fuel consumption. The improved cupola furnace achieved a melt rate of 1600 kg per hour at a fuel rate of 1:8 coke-to-metal ratio. Except for the cupola furnace fuel rate target, all other targets were exceeded.

Keywords: *cupola furnace, crucible furnace, iron melting, non-ferrous melting*

Introduction

Metal casting technology has been acknowledged in industries and arts for over a century. It's the process of manufacturing a shaped metal component by pouring molten metal into a mold [1]. The industry benefits from and integrates significant advances in manufacturing technologies such as simulation software, rapid prototyping, robotics and automation, and many advances in metallurgy and materials science. Casting products in advanced alloys produced using advanced processes serve the needs of the present society and technologies in terms of performance, costs, and many vital attributes required. Hence, modern metal casting operations collaborate with professionals and specialists to improve casting performances [2].

In the Philippines, the Metals Industry Research and Development Center (DOST – MIRDC) is working on upgrading the capabilities of our metal casting industries to improve its processes and upgrade the performance and costs of the castings. One of the local foundries, the Metallic Pisces Engineering Works (MPEW) based in General Santos City, sought assistance with their casting operations. MPEW is an engineering company that produces products that include marine and fishing tools and machinery. The company has a machine shop and foundry capable of non-ferrous and cast iron castings. For years the company encountered problems concerning its furnaces– the cupola furnace consumed too much fuel with a 4:1 ratio and only produced 120 kgs/hr melt. The crucible furnace also has issues with its melting rate and fuel consumption. Hence, the DOST – MIRDC conducted joint contract research with Metallic Pisces Engineering Works (MPEW) to improve their foundry's melting processes, save on cost, develop more products, and be more competitive.

Theoretical Framework

Upgrading the melting rate and efficiency of MPEW's crucible and cupola furnaces will result in lower fuel costs while increasing the amount of molten metal produced in a shift. Lower melting costs and faster melting rates mean higher produc-

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tivity and improved foundry competitiveness [3]. Enhancing the performance and efficiency of these melting equipment requires improving both the machines' design and features and the operators' operational practices. This project focused more on improving the machine's design and features than the operator's training. Since MPEW is not yet configured for high-volume green sand molding, there are simply not enough practical opportunities for high-volume green sand molding. And, to cover the additional learning specifications of the cupola furnace, namely, the decision to build a batch type or continuous type cupola and the well capacity can be derived. The decision to go with a continuous-type or batch-type furnace is related to the variety of castings the foundry expects to cast. Continuous-type cupola furnaces are ideal for the mass production of small castings [4, 5]. Batch-type furnaces are suitable for large casting. For a batch-type furnace, the capacity dictates the maximum weight of casting that can be poured. It also dictates the tapping temperature of the molten metal [4, 5]. A higher temperature is preferred for thin-walled castings. Generally, lower well capacity means higher tapping temperature. A range of good capacities can be designed to a cupola furnace size.

The specifications of the cupola for MPEW were based on several factors, and several features have been decided based on the need and existing capabilities of the company. These are

a. Cupola diameter. The existing furnace diameter of 18 inches will be retained. The 18" furnace can produce 1600 kg of molten metal per hour. MPEW is not yet equipped for high-volume green sand molding, so the 1600 melt rate is well within the company's present and future capacity needs.
b. Batch-type. Due to its capacity, the furnace was retained as a batch-type furnace.
c. Cold blast. The furnace was decided not to be equipped with a recuperator for preheating the blast air. Recuperators are a considerable investment that is not yet within the priority of MPEW. The hot blast will further increase the melt rate of the furnace – a capability that is not yet needed.
d. No oxygen enrichment. The furnace was assessed to utilize non-oxygen-enriched blast air. Oxygen-enriched blast air also increased the melt rate of the cupola furnace.
e. Divided-blast cupola. The MPEW cupola furnace was converted to a divided blast cupola (DBC) furnace. For a cold-blast, non-oxygen enriched blast air furnace, the DBC offers the highest fuel efficiency. In the Philippines, three foundries operate DBC with a fuel ratio of 1:11.

Materials and Methods

The team prepared drawings for the new crucible and cupola furnace for MPEW following the assessment and discussion with the company officials. For the crucible furnace, a new furnace was built following the design shown in **Fig. 1**, prepared by the researcher and submitted to MPEW. Only the critical dimensions are indicated. After completing the new crucible furnace, a test melt was conducted at a total capacity of 210 kg. The melting rate was reduced for the same fuel rate from 110 minutes to 70 minutes for a 36% improvement.

The existing cupola furnace was modified following the configuration shown in **Fig. 2.** Three rounds of testing and additional modifications on the

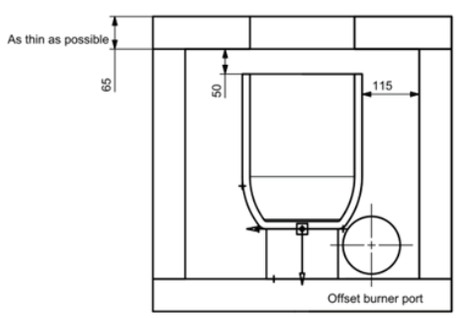

Fig. 1

Proposed design of the new crucible furnace for MPEW

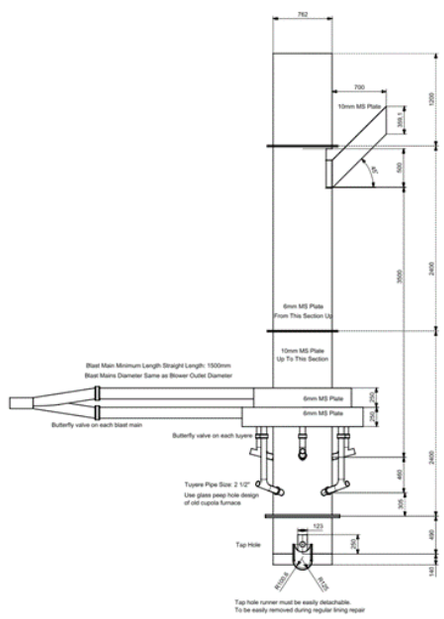

Fig. 2

Divided-Blast Cupola Furnace Plan for MPEW

blower were conducted to reach the target blast air pressure for the cupola furnace. Two rounds of melt testing were conducted after that. In the first round of testing last April 2021, a fuel ratio of 1:6 was used and achieved a melt rate of 1000 kg per hour. In the second round of testing last November 2021, a fuel ratio of 1:8 was used and achieved a melt rate of 1600 kg per hour. The furnace blower was busted during this campaign and needed to be repaired. Additional structural modifications were also requested to improve the operational practices of the cupola. The project was declared complete after the last test as most of the project objectives were achieved. The project team is also confident that the remaining objective of achieving the 1:10 fuel ratio will be surpassed, just as in the other project objectives.

Results and Discussion

The completed crucible and cupola furnaces are presented in **Fig.3a** and **3b.** The final performance of the improved crucible and cupola furnaces is discussed in **Tables 1** and **2** and shown in **Fig. 4.** Three of the four performance targets were exceeded, with the 4th target of 80% achieved during the project duration. The 1:10 fuel ratio did not attain due to the limited project duration time. The cupola furnace was designed to have a fuel ratio of at least 1:11. Hence the project team is confident that the 1:10 fuel ratio target will likewise be exceeded. This project is proof of MIRDC's capability to work on metal casting process improvement activities with constrained performance and cost targets. At the same time, the project is another opportunity to learn in actual industry-funded contract research. Unlike GIA-funded contract research, industry-funded contract research projects have to be sensitive to the needs and capabilities of the client. The possibility that not all proposed solutions will be adopted due to budgetary constraints. In addition, there are real consequences of failure, so solutions must comprehensively consider the client's full circumstances.

Table 1. Project's Goals and Accomplishments

Project Objectives	Accomplishments	Remarks
Assess the existing melting process of cast iron and aluminum and copper alloys at MPEW	Completed. The assessment covered the entire MPEW foundry operations, not just the melting process. This is because the performance improvements in the melting processes directly impact the rest of the foundry processes.	The assessment was used by MPEW to apply for DOST SETUP funding. The acquired equipment arrived in December 2021.
Upgrade the performance of the MPEW cupola furnace used in the cast iron melting process	90% Completed	Upon the completion of furnace repair and modification, all objectives will be completed.
• Increase melting rate from the current 120 kg per hour to at least 1500 kg per hour	Achieved 1600 kg per hour	Exceeded the target by 6%
• Improve fuel efficiency from the current 1:4 metal to coke ratio to at least 1:10 coke to metal ratio	Achieved 1:6 fuel ratio on first testing Achieved 1:8 fuel ratio on second testing	The project team is confident that with the minor modifications on the furnace completed, a fuel ratio of 1:10 will be easily achieved
Improve the performance of MPEW crucible furnace used in non-ferrous metal melting process	100% completed	Exceeded the targets by 26%
• Improve melting speed by at least 10%	Achieved 36% improvement in melting speed	
• Reduce fuel consumption by at least 10%	Achieved 36% improvement in fuel consumption	

Table 1. Summary of Project Accomplishments

Target	Achievements	Remarks
Crucible furnace		
• 10% melting speed reduction	36% melting speed reduction	Exceeded
• 10% fuel consumption reduction	36% fuel consumption reduction	Exceeded
Induction furnace		
• At least 1500 kg/hr melting rate	1600 kg/hr melting rate	Exceeded
• At least 1:10 fuel ratio	1:8 fuel ratio	80% Achieved

Fig. 3. A. New Crucible Furnace; B. Modified Cupola Furnace

Fig. 4. Final Testing of the Cupola on November 2021

Conclusion and Recommendation

At the end of the project duration, the team successfully achieved the following objectives:

- Exceeded the melting speed improvement target for the crucible furnace.
- Exceeded the fuel consumption improvement target for the crucible furnace.
- Exceeded the melt rate target for the cupola furnace.
- Achieved 80% of the fuel ratio target for the cupola furnace.

Considering the project was implemented during the COVID-19 pandemic, with all the challenges faced by the client and the MIRDC project team, most of the project objectives were still accomplished within the approved project duration.

The success of this project was based on the project leader's previous project on cupola furnaces. That project enabled the researcher to acquire practical knowledge of this essential foundry technology.
It is recommended to continue pursuing projects related to foundry and metal casting on mainstream and advanced foundry technologies and processes. The knowledge and practical experiences on such projects will enable the success of similar industry-directed endeavors.

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Design and Development of the BUHAWI Prototype

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Abstract

The DOST-MIRDC designed and developed the Building a Universal Mount for Heavy Barrel Automated Weapon Integration (BUHAWI), a remote-controlled weapon system, in collaboration with the Department of National Defense, Philippine Navy, and Mechatronics and Robotics Society of the Philippines. It is equipped with Browning 0.50 Caliber Machine Gun, M2 Heavy Barrel, and a mechanical system, which are automated using electronic devices controlled by a programmable logic controller and other microcontrollers like the Arduino. Target tracking and locking capabilities of the BUHAWI were developed using Python programming. The BUHAWI testing resulted in several desirable outputs in line with the project's goals, including a mechanical system using worm gears for traverse and elevation movement, hardware and software used for the control system, and functional and field testing on land.

Keywords: *BUHAWI, RCWS, machine gun*

I. Introduction

One area of collaboration with the Philippine Navy is creating a Remote-Controlled Weapon System (RCWS). In support to the DND's Self-Reliant Defense Posture (SRDP) program by improving the firepower capability of its naval floating assets, the goal of this project is to design and develop a locally made RCWS, which can be mounted on ground combat vehicles as well as sea and air-based combat platforms. It can be installed on contemporary military vehicles because it enables the gunner to stay within the vehicle's relative protection.

Other countries have developed their RCWS. Israel's Rafael Advanced Defense System LTD. had developed RCWS, such as Mini-Typhoon, which are currently installed on fast patrol crafts of the Philippine Navy. It can be equipped with a 40 mm grenade launcher, a 7.62 mm machine gun, or a 12.7 mm (.50) machine gun, each having a magazine that holds up to 230 rounds. The system's built-in computer calculates a firing strategy based on information about the target and own ship and the surrounding environment [1].

A target tracking and locking system is an additional feature that can improve the accuracy of an RCWS. These were developed using different object detection systems. Other studies related to RCWS used Scale Invariant Feature Transform (SIFT) and Speeded Up Robust Features (SURF) combined with K-Nearest Neighbors (KNN) and Random Sample Consensus (RANSAC) for verification [2].

To improve the target tracking and locking system, a study was used as a guide for different tracking algorithms such as BOOSTING, Multiple Instance Learning (MIL), Kernel Correlation Filters (KCF), Tracking, Learning, and Detection (TLD), MEDIANFLOW, Minimum Output Sum of Squared Error (MOSSE), and Channel and Spatial Reliability Tracker (CSRT) [3].

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The BUHAWI project involves the integration of the mechanical control for the gun mount, electrical controls for mechanical movements, and software with a Graphical User Interface (GUI). The BUHAWI also includes peripherals, accessories, and sensors to be integrated into the mentioned equipment to operate it with less human intervention.

II. Methodology

1. Hardware Development

Figure 1 shows the 3D model of the BUHAWI. It has a dimension of 840 mm in height, 1230 mm in width, and 1700 mm in length. It has a weight of 316.98 kilograms.

Table 1, shows the materials for the development of the BUHAWI Prototype. An industrial PC was used as the central processing unit of the BUHAWI System. It is connected through a Human-Machine Interface (HMI) for the GUI display. Buttons and sensors are connected and processed through a programmable logic controller (PLC) and Arduino microcontroller for the Joystick Integration. Servo Motors were used for traverse and elevation movements. It is also used for the charging mechanism. Moreover, the firing mechanism used a solenoid valve to click the trigger of the machine gun. BUHAWI also used the Hurricane Camera System, which is composed of a Charge-Coupled Device (CCD), a Forward Looking Infrared (FLIR), and a Laser Range Finder (LRF).

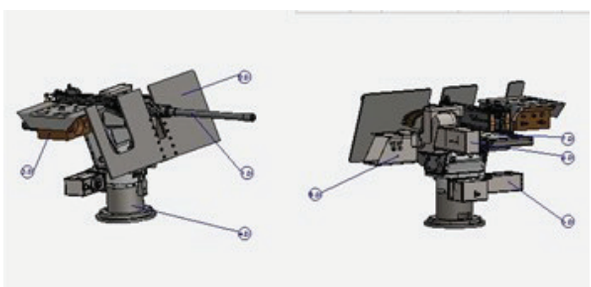

Fig. 1. 3D model of the BUHAWI prototype

Table 1. Materials and Description

Materials	Description
Industrial PC	Advantech ARK-3530 Industrial PC
HMI Display	Advantech FPM-7121T HMI Display
PLC	Omron CP1E PLC
Joystick	Suregrip LU and SU Series Arduino Uno Microcontroller
Servo Motors	1.5 kW Omron AC Servo Motor for Traverse and Elevation Movement 400 W Omron AC Servo Motor for Charging mechanism
Solenoid Valve	48VDC solenoid valve
Hurricane Camera System	CCD, FLIR, LRF Enabled
Gyroscope	TL735G 3 axis attitude gyro
Wind Speed	WXA100-02 series ultrasonic wind speed and direction sensor
GPS Module	Matutec AR-12 GPS Module

BUHAWI is also equipped with sensors, such as a gyroscope, a Global Positioning System (GPS) module, and a wind speed and direction sensor. The connections of these devices are shown in **Fig. 2.**

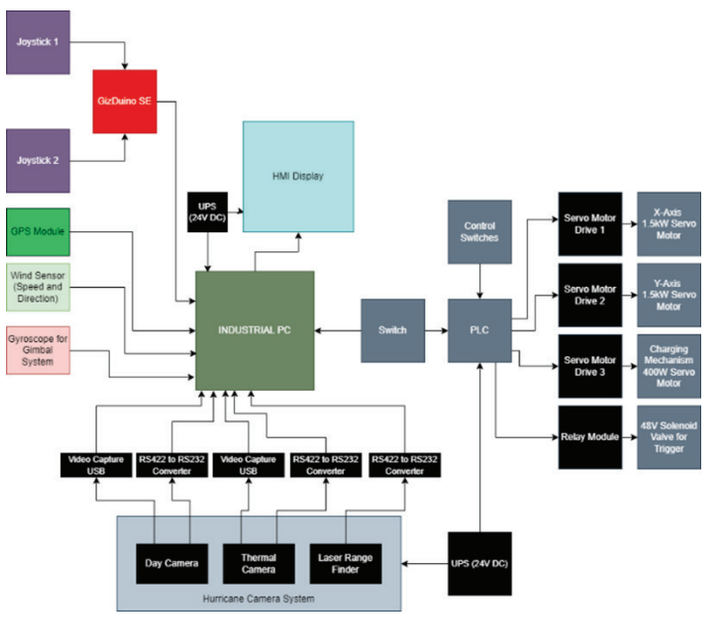

Fig. 2. Block Diagram of BUHAWI Components

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2. Software Development

Python, a programming language for versatile automation and software development, was used in developing the system of Project BUHAWI. Python was used in establishing the GUI, machine communications, data transfer protocols, machine learning algorithms, image processing techniques, and target tracking and locking algorithms.

2.1 Graphical User Interface

TKinter was used to create the dashboard's GUI, on which the operator can utilize the functions and operations of BUHAWI. It has buttons for the needed function for the RCWS, and indicators for sensor values and traverse and elevation movement positioning.

2.2 Target Tracking and Locking

OpenCV was used in handling image processing techniques for target tracking and locking algorithm. NumPy is a partner of OpenCV in handling images and vectors in computing the target tracking and locking system.

Target locking was performed by getting the image's Region of interest (ROI) inside the crosshair box. Then, preprocessing, such as canny edge detection and color segmentation, were performed to get the feature of ROI. After the preprocessing, it was fed to the target locking algorithm. Here, the distance from the center was computed to maintain the target to the center. Then, the resulting distance was fed to PID Computation process. Lastly, it will return the steps of servo motor to take in to maintain the target in the center of the camera feed.

2.3 Sea Vessel Detection Preparations

Training was done through data gathering of images of sea vessels. Data cleaning was performed to remove unnecessary images

Table 2. BUHAWI Software Requirements

Software	Function	Version
Python	Core Language of BUHAWI System	3.7
Tkinter	GUI	3.7
OpenCV	Image Processing	3.4.3
NumPy	Mathematical computations and arrays	1.16.0
Tensorflow	Object Detection	1.15.0
PySerial	Serial Communications Handler	3.5
Arduino	Joystick Data Acquisition	1.18.3
OPCUA	PLC to PC Communication	0.98.10
Sysmac Studio	Omron PLC IDE Platform	1.28.0

Fig. 3. BUHAWI Dashboard Graphical User Interface

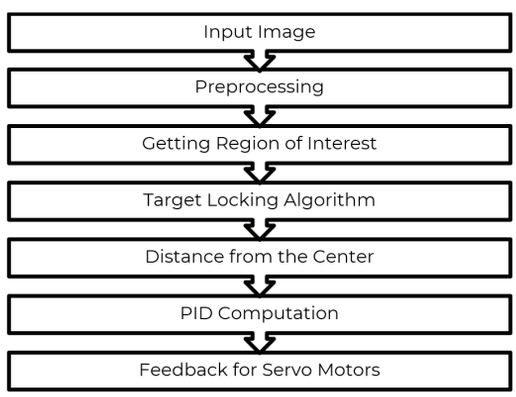

Fig. 4. Target Locking Process

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that might decrease the accuracy of the object detection model. Data Annotation was done by labeling the images on the type of sea vessel used.

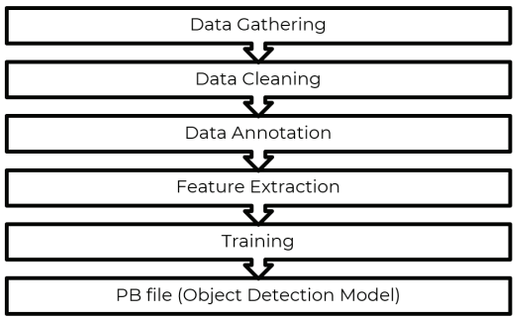

Fig. 5. Object Detection Training

Feature extraction was performed to convert images to numerical and statistical data for machine learning training proper. Training proper was done using the Google Colaboratory, whose larger RAM and processing capability appropriately address the training requirements. When the training was done, having low validation loss, a pb file will be produced, which serves as the brain of the object detection model.

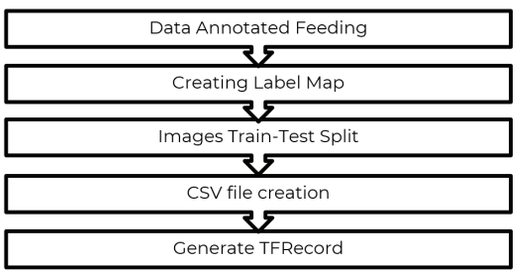

Fig. 6. Feature Extraction Process

Once the training is done and the PB file is produced, the classification process uses the generated file to classify different sea vessels through image object detection. The prediction model will be initialized. The image was fed through the software and it will perform the classification process.

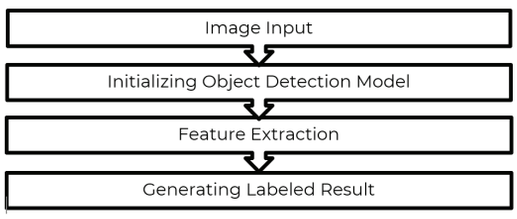

Fig. 7. Classification Process

2.4 Serial Communication

In telecommunication and data transmission, serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or computer bus. BUHAWI used serial communication in transferring data from GizDuino, camera systems, and sensors. It used packet data to transfer the data in a single transfer since serial communication is classified as a half-duplex communication.

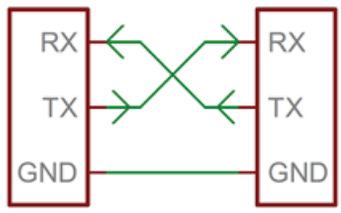

Fig. 8. Serial Data Process

2.5 OPCUA

OPC United Architecture or OPCUA, a program developed by OPC foundation, is the platform used by the system in transferring data and commands from the PLC to the industrial PC. Sysmac studio is the primary PLC IDE for Omron products, the system used for its motors and controls. OPCUA was the gateway of the industrial PC to the PLC program by modifying the data in the PLC, such as the setting of the servo motor displacement and control switches status.

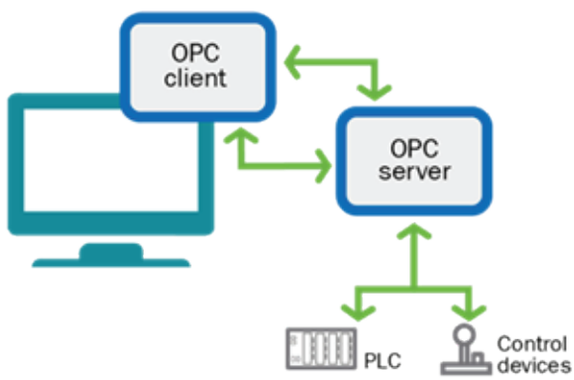

Fig. 9. OPCUA Process

III. Discussion of Results

1. Target Tracking and Locking Algorithms

BUHAWI used three state-of-the-art tracking systems to increase the accuracy and efficiency of BUHAWI's target locking capabilities. Kernelize Correlation Filters was used for fast frames per second (FPS), but had slightly low accuracy in maintaining the target tracked. The Channel and Spatial Reliability (CSRT) has high accuracy, but due to processing time for the accuracy, FPS was compromised and resulted in a slow FPS. Minimum Output Sum of Squared Error (MOSSE) was also used due to its fast FPS, but low accuracy in the making. Originally, CSRT tracker was used due to high accuracy requirements, but during the firing and testing, it did not recover in an instant after firing. Therefore, the final tracker used is MOSSE.

Table 3. Comparison of Target Locking Algorithms

Tracker Name	Pros	Cons
KCF	Fast frames per second	Slightly low accuracy
CSRT	Slow frames per second	High accuracy
MOSSE	Fastest frame per second	Low accuracy

2. BUHAWI Dashboard

To improve the target locking capabilities, the Hurricane Camera System was adjusted to the following settings:

- *Defog Mode* – increasing the contrast of the image to remove the smoke from the machine gun
- *Manual Exposure Mode*- increase in aperture and automatic shutter speed
- *Crosshair box*- increasing the size of the crosshair box for larger area for target acquisition

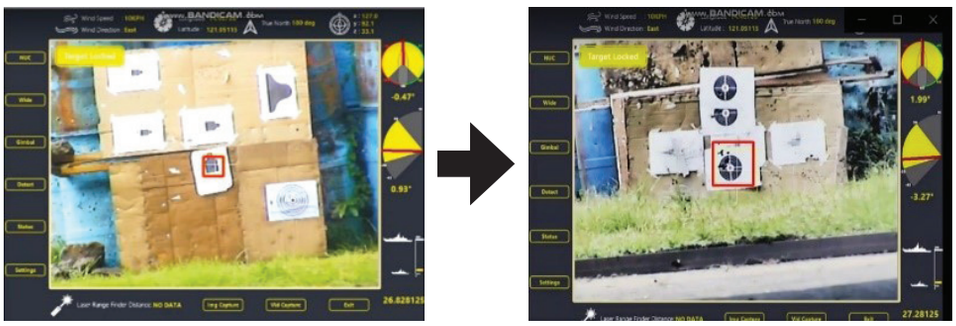

Fig. 10. BUHAWI Dashboard Transformation

3. Sea Vessel Detection

TensorFlow is the platform used in creating the artificial intelligence detection model for object detection and recognition, especially in creating sea vessel detection. BUHAWI can detect objects and classify them based on the dataset and features extracted during the transfer of the learning process.

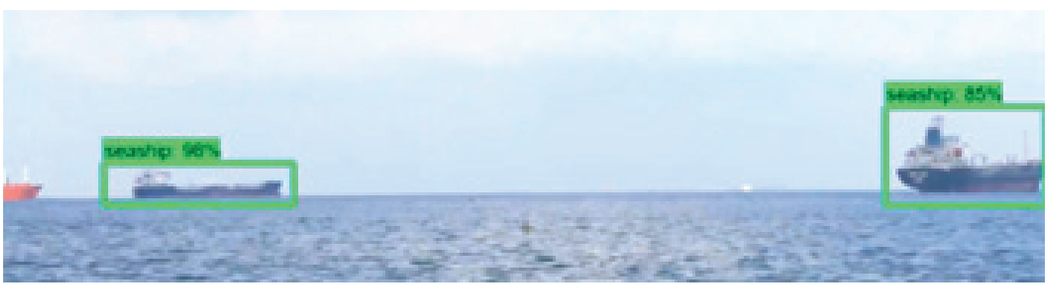

Fig. 11. BUHAWI Dashboard Sea Vessel Detection

4. Firing Mechanism

The firing mechanism of the BUHAWI (**Fig. 12**) was designed with a single electric solenoid valve to press the firing trigger while the 0.50 caliber machine gun was set to automatic mode. The PLC activates the solenoid valve, causing the actuator to push the 0.50 caliber machine gun trigger. The PLC program timer was set based on the required mode of firing, including Single Shot, Burst of 5 shots, and automatic firing. The dwell time for each mode of firing is shown in **Table 4.**

5. Charging Mechanism

Figure 13 shows the final design of the charging mechanism of BUHAWI. A cam actuator is connected to the lead screw, which has a diameter of 15 mm and a thread length of 340 mm. It is powered by and coupled to a 400 w AC servo motor, which pulls the crank of the 0.50 caliber machine gun to load a bullet on its shelf inside the machine gun, ready for firing.

6. Muzzle Brake Compensator

Following a series of land-based live fire tests, a muzzle brake compensator for a 0.50 caliber machine gun was designed. This aided the BUHAWI system's accuracy in hitting its target. Because of the machine gun's mechanical capabilities, the compensator underwent revisions. Different air porting angles were tested, such as 10-degree, 20-degree, and 30-degree air porting angles. These different angles alter the flow of escaping gas from the barrel near the machine gun's muzzle. The final design of the 0.50 caliber machine gun compensator used a 30-degree air porting angle, as shown in **Fig. 14.**

Table 4. Dwell time for each firing mode

Mode of Firing	Dwell Time
Single Shot	50 milliseconds
Burst of 5 shots	250 milliseconds
Automatic	Not applicable

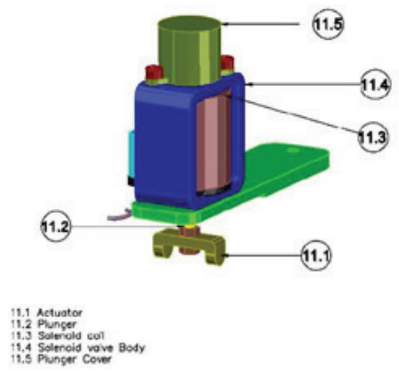

Fig. 12. Firing Mechanism of BUHAWI

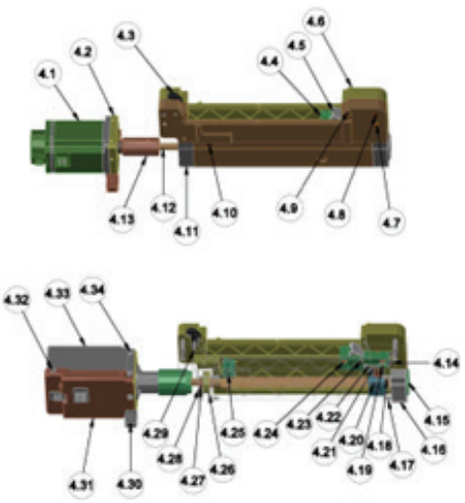

Fig. 13. Charging Mechanism of BUHAWI

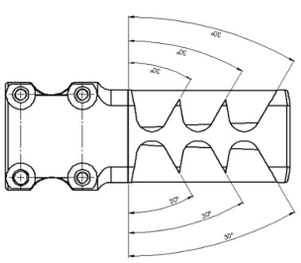

Fig. 14. Compensator with 30-Degree Air Porting Angle

7. Land-Based Firing Test

The objective is to conduct land-based live fire testing of the BUHAWI prior to its mounting on a navy vessel and to determine controllable factors that need improvement. The testing was performed during the day and night.

7.1 Stationary Target Stationary BUHAWI

BUHAWI was placed in three (3) positions at 550 meters distance and fired 10 single shot each. The result was an average of eight (8) out of 10 hits the target.

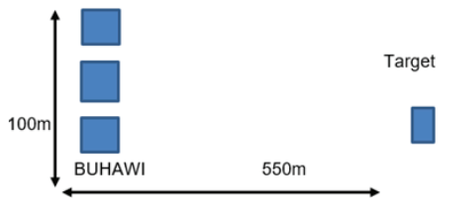

Fig. 15. Stationary Target – Stationary BUHAWI

7.2 Fixed Target Moving BUHAWI

BUHAWI traveled the 100-meter distance at around 5 km/hr and fired a single shot every two seconds and was able to hit the stationary target at 550-meter distance.

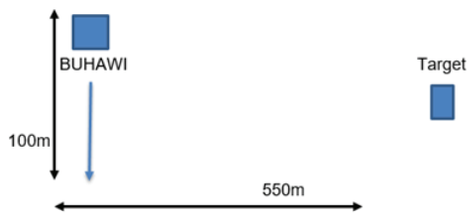

Fig. 16. Fixed Target – Moving BUHAWI

7.3 Moving Target Fixed BUHAWI

The moving target traveled the 100-meter distance at around 5 km/hr and fired 30 single shots in two-second intervals at 550-meter distance by the stationary BUHAWI. The same result was encountered with the second testing protocol. The locking feature of the program was not working, which resulted in aborting the said testing protocol. No shot was made since the locking of the target is not acquired while it is in motion.

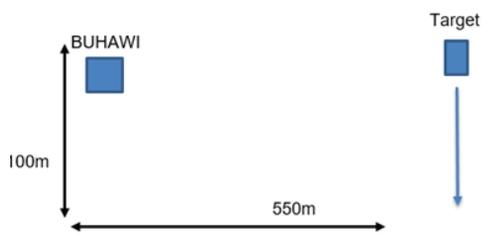

Fig. 17. Moving Target – Fixed BUHAWI

7.4 Moving Target Moving BUHAWI

Both BUHAWI and the target moved parallel and opposite to one another at 5 km/hr. BUHAWI fired a single shot at the moving target every two seconds and used 30 bullets in each test. Similar result with the moving target and fixed BUHAWI was encountered. The locking feature of the program was not working, which resulted in aborting the said testing protocol. No shot was made since the locking of the target is not acquired while it is in motion.

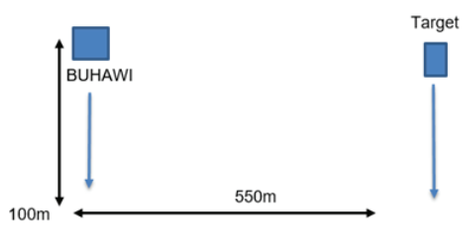

Fig. 18. Moving Target – Moving BUHAWI

IV. Conclusion

The BUHAWI Prototype was successfully developed and tested during the land-based live firing test. Target Tracking and Locking algorithms used were MOSSE and CSRT, depending on what needs to be prioritized between speed and accuracy. BUHAWI dashboard was created with improvements on the camera system parameters and buttons needed for operations. Sea vessel detection model was created and ready for further sea testing. A Charging and firing mechanism were designed and installed on the BUHAWI gun mount. The Muzzle brake compensator successfully helped the BUHAWI system in improving the accuracy in hitting the target with proper groupings

V. Recommendation

For further improvement of target tracking, it is recommended to explore and experiment more algorithms to maintain the tracking and locking mechanism of the BUHAWI. In order to have more knowledge in Artificial Intelligence and have mastery on RCWS, it is recommended that we developed more RCWS for different calibers and applications

VI. Acknowledgement

The authors would like to express their sincerest gratitude and appreciation to the Department of Science and Technology, the Department of National Defense, the DOST – Office of the Undersecretary for Research and Development, DOST – Philippine Council for Industry, Energy, and Emerging Technology Research and Development, the DOST – Metals Industry Research and Development Center, the Philippine Navy (PN), the PN-Naval Sea Systems Command (PN-NSSC), the Naval Research and Technology Development Center (PN-NRTDC), and the Mechatronics and Robotics Society of the Philippines (MRSP).

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[3] H. Darvishi, “Comparison of API trackers in OPENCV using Raspberry Pi hardware,” Specialty Journal of Electronic and Computer Sciences , vol. 6, no. 3, pp. 1-9, 2022.

Key Deliverables

- Make or buy decisions with AM
- Facility build-out for AM
- Part selection and ROI calculations
- Advice on expansion locations
- Mergers and acquisitions
- QMS level 2 document – Process Specification for the following AM processes (ISO/ASTM 52904):
  - PBF-polymers and metals
  - DED
  - Binder Jetting
- Feedstock specifications, PO flow-down and feedstock receiving instructions (ISO/ASTM 52904)
- Benchmarking
- Round robin material testing
- Machine calibration in accordance with ISO/ASTM 52941
- IQ/OQ/PQ settings in accordance with ASTM Guide F3434
- Part qualification to meet critical applications (ISO/ASTM 52941)
- Machine operator training (ISO/ASTM 52942)
- QA training
- Build set-up training
- 3D scanning and inspection
- Support generations and part orientation
- BOM analysis for AM candidate parts
- NDE training for X-ray analysis
- NDE training for CT scans
- Market and technology landscape
- Competitive analysis
- Facilitation and consultation on the following:
  - Melt pool monitoring
  - Feedstock monitoring
- Digital product definition and configuration control implementation
- Machine OEE monitoring and analysis

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Design and Fabrication of Recoil Compensator for Cal 0.50 Caliber Heavy Barrel Machine Gun of Project BUHAWI

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Manuel O. Alberto, Jr.*[4], Romanico F. Salido*[5]

Abstract

The Metals Industry Research and Development Center (MIRDC) developed a recoil compensator intended for a Cal 0.50 Caliber Heavy Barrel Machine Gun which will be mounted to the Project BUHAWI prototype. The compensator reduces the upward deflection of the barrel during live-fire with its three gas openings on both sides positioned at specific angles of opening.

Keywords: *BUHAWI, Cal 0.50 Caliber Heavy Barrel Machine Gun, recoil*

I. Introduction

Shooting with great precision is essential to eliminate the target. One of the factors to control is the movement of the barrel or muzzle to maintain the target at the site should there be a need for a second shot. During firing a natural recoil is observed but should be compensated and optimized to maintain a quick and precise succeeding shot.

The locally designed recoil compensator intended for BUHAWI achieved its objective by addressing the issues of barrel deflection during burst fire. Its design addressed the required angle and opening to direct the propellant gas to escape the barrel and produce the desired movement as its effect.

The main objective of the project is to reduce the barrel deflection of the Cal 0.50 Heavy Barrel Machine Gun mounted on Project BUHAWI prototype. To attain this objective, specifics listed below have been identified as follows:

1. To design and fabricate the recoil compensator; and
2. To evaluate the effects on the deflection of the Cal 0.50 Heavy Barrel Machine Gun mounted on Project BUHAWI.

The Project BUHAWI (Building a Universal-Mount for Heavy Barrel Automated Weapon Integration) is an initiative project of the Metals Industry Research and Development Center (MIRDC) in collaboration with the Mechatronics and Robotics Society of the Philippines (MRSP) and the Philippine Navy (PN).

Fig. 1. Project BUHAWI During a Live Fire Testing at Fort San Felipe, Cavite City

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The project began in 2019 and to date is in the testing and debugging stage. A series of land-based live-fire testing has been conducted to test the integrity of its integrated mechanical and control system assembly. As shown in **Fig. 1**, project BUHAWI at the testing site at Fort San Felipe, Cavite City.

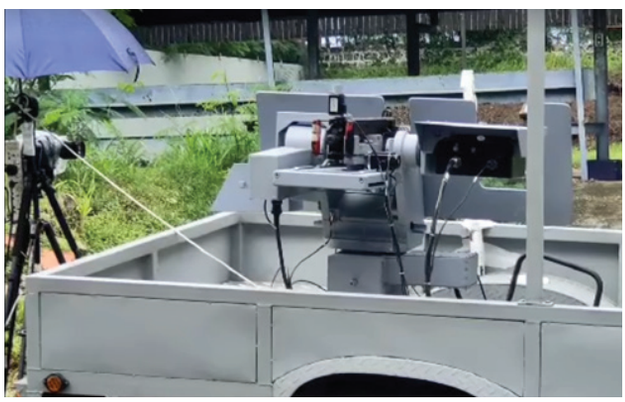

Fig 2. High-Speed Camera Setup During Live-Fire Testing of BUHAWI

During the last live-fire testing, the team used a high-speed camera to determine the deflection of the tip of the Cal 0.50 barrel. Single-shot firing showed a small deflection of the tip of the barrel, but when a burst of two (2) shots was fired, a significant upward deflection was observed resulting in loss of target locking feature on the program of BUHAWI. **Figure 2** shows the speed camera used and focused at the tip of the barrel to observe the deflection.

In addressing the deflection of the barrel of the Cal 0.50 machine gun, especially during a burst fire mode, the application of a recoil compensator/muzzle brake was suggested to address the problem.

A muzzle brake or recoil compensator is a device connected to, or a feature integral to the construction of, the muzzle or barrel of a firearm or cannon that is intended to redirect a portion of propellant gases to counter recoil and unwanted muzzle rise [1]. Barrels with an integral muzzle brake are often said to be ported. The strategy of a muzzle brake is to redirect and control the burst of combustion gases following the departure of a projectile. Most linear compensators redirect the gases forward [2] [3].

Brakes and compensators also add length, diameter, and mass to the muzzle end of a firearm, where it most influences its handling and may interfere with accuracy as muzzle rise will occur when the brake is removed, and shooting without the brake can throw off the strike of the round [4]

A serious tactical disadvantage of muzzle brakes on both small arms and artillery is that, depending on their designs, they may cause escaping gases to throw up dust and debris clouds that impair visibility and reveal one's position, not to mention posing a hazard to individuals without eye protection [5]

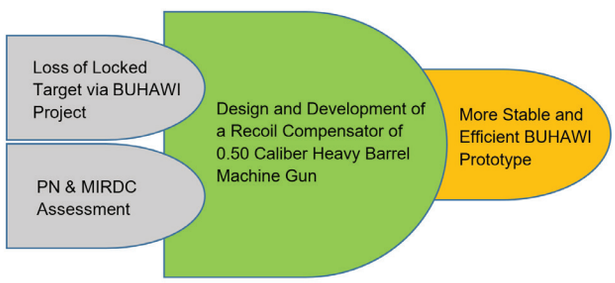

Fig 3. Theoretical Framework of the project

Figure 3 shows the theoretical framework of the project which identifies factors, development and output of the project.

One of the main issues of BUHAWI is losing the target after being locked in the program during a burst fire. This is due to the deflection of the barrel/muzzle as is a natural reaction during firing.

The Philippine Navy together with the MIRDC team conducted an assessment on how the barrel behaves and its increment movement to address and counter it through the introduction of a recoil compensator specially designed for the BUHAWI since the MG 0.50 is mounted in it and has an adverse effect as well in its movement.

The locally designed recoil compensator is aimed to make BUHAWI stable and efficient in hitting its target while in a burst shot.

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Fig. 4

Barrel Deflection Without Recoil Compensator Caught Using a High-Speed Camera at Burst Fire of Two Bullets

II. Methodology

The project involves the assessment of the Cal 0.50 Heavy Barrel Machine Gun mounted on Project BUHAWI and the effects of the locally designed and developed recoil compensator. The following are the steps to be conducted for the methodology of the project:

1. Evaluate the deflection of the Cal 0.50 Heavy Barrel Machine Gun mounted on Project BUHAWI.

   The project team held a brainstorming using the existing design available in the market.

2. Design, review, and fabrication of the recoil compensator.

   The design was generated using Solidworks and was reviewed by the team during its conceptual design stage.

   The project team held brainstorming together with the Philippine Navy and the project team using the existing and available recoil compensator in the market for other types of weapons.

3. Evaluation together with PN using the high-speed camera to compare the difference of without and with a recoil compensator when in operation. Coordination with the Analysis and Testing Division was conducted for the use of a High-Speed Camera to capture the visible movement of the barrel with and without the recoil compensator.

4. Documentation and report generation. The terminal report and final design of the compensator will be submitted after the completion of the project.

III. Discussion

Initially, the barrel/muzzle was tested without a compensator. This is to assess the real movement of the barrel when firing two consecutive bullets or burst fire. Only two bullets were used during the experiment since that was the allowed bullets to be used which is suitable for the small firing range.

Figure 4 shows the deflection of the barrel without recoil compensator at the first and second shot when the gun was set to burst fire. It was observed that the deflection of the barrel is upward as referred to the red line which was initially in line with the barrel.

The high-speed camera was able to measure the deflection of the barrel on the second shot and recorded 58.428 mm. This was done using the software of the high-speed camera Photron FASTCAM Viewer and the scale attached as the background of the barrel (**Fig. 5**).

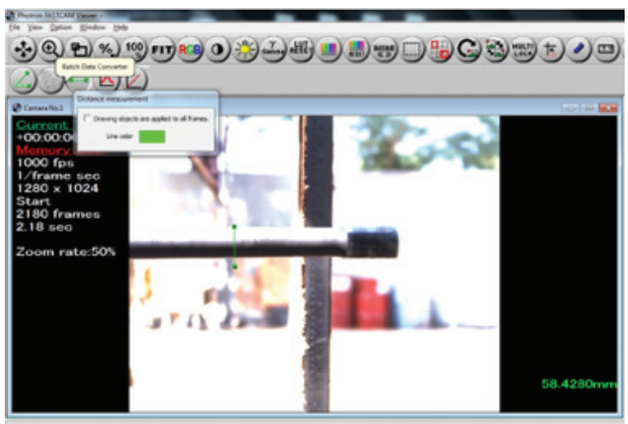

Fig. 5. Barrel Deflection Without Recoil Compensator Measured Using a High-Speed Camera at Burst Fire of Two Bullets which Reached 58.428 Mm.

The project team was able to produce 8 prototypes, but six (6) of those did not meet the initial requirement of extracting the bullet for a single shot firing mode. The cartridge jammed inside the barrel causing an alibi and cannot proceed to fire the second

bullet. The last two (2) prototypes were the ones that passed and extracted the cartridge completely.

Out of the 8 prototypes, these two configurations (**Fig. 6** and **7**), prototype 7 with 30° and 8 with 20° respectively were subjected to six (6) sets of trials containing regular and tracer bullets.

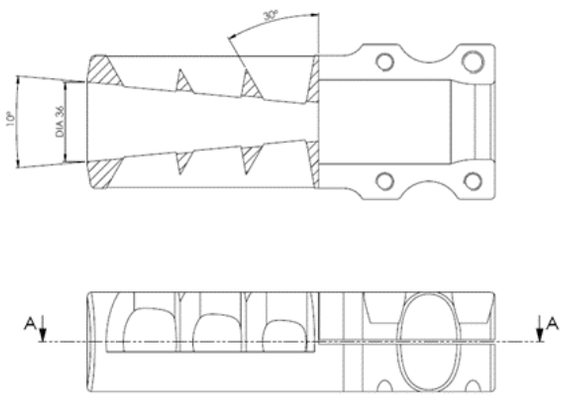

Fig. 6. Drawing of Prototype 7 With 30° Vent Opening on Both Sides of the Barrel

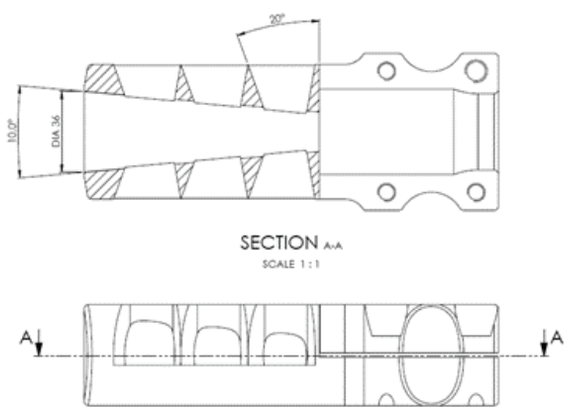

Fig.7. Drawing of Prototype 8 With 20° Vent Opening on Both Sides of the Barrel

In live-fire testing conducted by the team, the barrel was tested for its accuracy of ejecting the cartridge during live fire. It was noted that the barrel and the whole MG 0.50 itself are not new but are in use and service to the Philippine Navy.

The test conducted is 6 trials per condition for a burst live-fire testing using a regular and tracer bullet arrangement. **Table 1** shows the result of the testing in the status column with X as jammed and OK as completed and ejected properly.

Both Prototype 7 and 8 yielded good results as to the extraction of the cartridge from the barrel to fire the next bullet. However, the cartridge which was ejected using Prototype 7 showed scratch marks on the outer surface which was evaluated by the Philippine Navy as an unsmooth recoil process which resulted in the said scratch marks. Both cartridges of Prototype 7 and 8 were compared side by side and observed the noticeable difference in the appearance and while ruled that prototype 8 with 20 degrees opening yielded the best result amount the test conducted (**Fig. 8**). **Figures 9** and **10** show the deflection of the barrel using Prototype 8 and the amount of deflection which was measured using the high-speed camera Photron FASTCAM Viewer.

Table 1. Result of the 6 Trials Per Condition for a Burst Live-Fire Testing Using a Regular and Tracer Bullet Arrangement

Setup	Trial No.	Bullet	Status
Without Recoil compensator	1 2 3 4 5 6	R-T R-T R-T R-T R-T R-T	OK OK OK X/OK OK OK
30 Degrees (Prototype 7)	1 2 3 4 5 6	R-T R-T R-T R-T R-T R-T	OK OK OK OK OK OK
20 Degrees (Prototype 8)	1 2 3 4 5 6	R-T R-T R-T R-T R-T R-T	OK OK OK OK OK OK

Fig. 8. The Cartridge of the Bullets Used During Testing

Fig. 9

Barrel Deflection Without Recoil Compensator Caught Using a High-Speed Camera at Burst Fire of Two Bullets

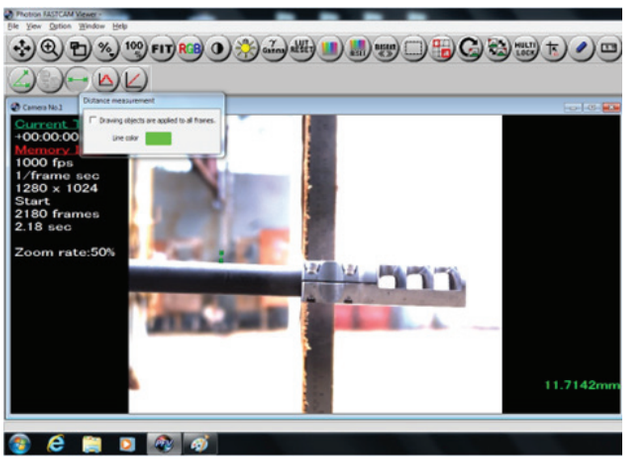

Fig. 10. Deflection of the Barrel Measured Using Prototype 8 With 20 Degrees Opening on Both Sides at 11.7142 Mm.

At the conduct of this study, the objectives of the project were met. A locally designed and fabricated recoil compensator was produced and tested. The evaluation of the deflection of the barrel with and without the recoil compensator resulted in the outcome of creating a functional prototype based on the actual testing.

It was suggested to further test the recommended prototype to assess more other factors as to its design and performance with regards to its reliability, functionality, and durability.

IV. Conclusion

The locally designed recoil compensator has been tested successfully and has met all the objectives set. These were all verified by the Philippine Navy personnel during the live fire testing and assessment of the cartridge as a result of attaching the compensator designed and fabricated by MIRDC.

The deflection of the muzzle was more controlled compared with no compensator as observed using the high speed camera thus increased the accuracy of hitting the target and control of the operator during operation. The results of the designed structure, required angle and opening to direct the propellant gas to escape the barrel and produce the desired movement upon testing have addressed the issues on the BUHAWI thus improved its performance and accuracy.

V. Recommendations

It is recommended to subject both prototypes 7 and 8 to more burst fire testing at the testing site which can accommodate the requirement. The firing range where the testing was conducted for this study was limited to a maximum of 2 bullets per burst fire. This is because the firing range is intended for small firearms only.

Improvement and optimization may be derived when the testing is maximized to the capacity of the MG 0.05 and to evaluate the effects of wear and tear and the extreme temperature.

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Design Improvement of a Riding Type Rice Transplanter Gear Transmission System

Dominic S. Guevarra*[1], Joein L. Luces*[2], Arnold S. Juliano*[3], Virgilio F. Lanzuela*[4]

Abstract

The Philippine Rice Research Institute (PhilRice) developed a prototype of a locally made riding-type rice transplanter however, problems during field tests were encountered that mainly pointed to the power transmission of the machine. This study was therefore conducted to improve the design of the said transmission system. Specifically, this study aimed to 1) simulate and improve the design of a rice transplanter gear transmission using KISSsoft/KISSsys gear software; 2) fabricate the gear system based on the improved design; and 3) test and evaluate the functionality of the improved transmission system of the rice transplanter. Series of gear pairs and other relevant components are modelled and simulated using KISSsoft/KISSsys gear software. The optimum sizes of each gear pair were successfully determined leading to the improvement of the gear transmission system. Various processes were performed during the manufacturing of the gear transmission system. The gear cutting operation was successful hence, improved gears were manufactured. Other machine components were also manufactured successfully using other appropriate machine operations. The improved gear transmission system was attached to the rice transplanter and tested at Nueva Ecija. Feedback from users revealed that the newly developed transmission system generates lesser noise and functionally better than the original transmission system.

Keywords: *transplanter, transmission, bevel gears, gearbox.*

I. Introduction

The Metals and Engineering (M&E) industry, primarily the metalworking sector has been identified as the backbone of all the industries for accelerated development since it directly and indirectly supports and contributes to the growth of the manufacturing industries in particular, and the country's economy in general.

At present, there are few existing companies that are engaged into the design and manufacture of gears and gearboxes in the country that cater the requirements of various local industries. The shortage of the gear manufacturing can be attributed to the complex requirements such as lack of competent technical personnel in gear design and manufacturing. It is therefore imperative that the DOST, through MIRDC, develop its capability on the design and manufacture of gears and provide gear making technologies for the product development as well as shared facilities to manufacturing industries. This will help the metals, engineering and allied industries produce locally developed technology and innovation that will be at par with global standards and address the impending need of the manufacturing industry to improve their performance and productivity.

In 2014, the Philippine Rice Research Institute (PhilRice) developed a prototype of a locally made riding-type rice transplanter thru funding from the

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Department of Science and Technology-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD). All components of the machine were made locally except for the engine and transmission gearbox. The gearbox used in the first prototype was Vietnamese transmission gearbox (**Fig. 1**) and it was located at the rear part of the machine. Series of field tests were conducted and the machine showed promising performance (**Fig. 2**). However, concerning stability the transmission gearbox must be positioned in front of the machine to act as a counterweight in planting assembly. The second prototype of the machine with a localized Vietnamese transmission gearbox (**Fig. 3**) was fabricated and field tested. With the complexity in the design of the gear shifting mechanism (**Fig. 4**) and limitations in fabrication (e.g. cut and weld operation), problems on gear shifting were encountered. In 2016, initial pilot testing of the local riding-type rice was conducted by PhilRice thru funding from DOST-PCAARRD. Using the design of the second prototype, two pilot test units were fabricated by Rollmaster Machinery and Services Corp. In 2018, the two pilot test units were completed and field-tested at PhilRice (**Fig. 5**).

Fig. 1. Vietnamese Transmission Gearbox Used in the Transplanter

Fig. 2. Field Testing of the First Prototype

Fig. 3. Localized Vietnamese Transmission Gearbox Used in the Second Prototyped.

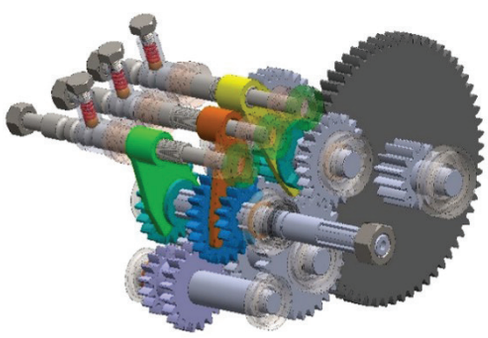

Fig. 4. Cad of Gear Shifting Mechanism Gearbox

Fig. 5. Field Testing and Demonstration of the Second Prototype (Courtesy by Philrice)

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Philippines

Problems encountered during field tests were mainly from the power transmission of the machine e.g. sliding clutch, disengaging shift gears, grinding noise, and breakdown of the shaft and bevel gears (**Fig. 6**).

The project aims to improve the design and fabricate the riding-type rice transplanter transmission system. Specifically, this project aimed to:

1. Simulate and improve the design of a rice transplanter gear transmission using KISSsoft/KISSsys gear software;
2. Fabricate the gear system based on the improved design; and
3. Test and evaluate the functionality of the improved transmission system of the rice transplanter.

Fig. 6. Damage on Spindle Drive

II. Methodologies

The design of the project was based on the existing rice transplanter developed by Rollmaster and PhilRice. The improved design of the rice transplanter gear transmission was based on the simulation and 3D model generated using the KISSsoft/KISSsys gear design software. The optimized gear sizes, new bearing specifications and shafting were considered as an improvement to the transmission system. Likewise, technical drawing was made in preparation for the fabrication of the spiral bevel gears.

Design Improvement of the Rice Transplanter Gear Transmission

With the help of KISSsoft/KISSsys gear software the gear design was easily optimized to improve the design to avoid future failure of the gears. KISSsoft is a modular calculation program for the design, and optimization and verification of machine elements according to international standards and KISSsys is the system add-on to KISSsoft that enables the users to design entire transmission. The analysis was performed simultaneously for all gears, shaft and bearings with some calculation.

Fabrication of the Rice Transplanter Front Transmission

The fabrication of the rice transplanter front transmission was undertaken at MIRDC in conformity with the prepared detailed drawing. All gear components were made of 4140 steels and manufactured using Okuma 5-axis CNC Universal Machining Center. Preparation of gear blanks was done using other appropriate machines.

Transmission Housing. Both front and rear transmission housing of the rice transplanter was made of cast metals and mild steel plates and individual components was fabricated using CNC milling machine. Assembly was done using TIG or SMAW welding process.

Gear components. Gears were manufactured using various processes. The first process was the preparation of gear raw materials. This was done by cutting 4140 round bars into appropriate thickness using a bandsaw. The next process was gear blanking which was done using turning process. The gears underwent the process of internal splining necessary to keep the gears move together with the shafts with the corresponding splines during rotary motion. The final stage of gear manufacturing was gear cutting process which will be done at MIRDC's gear making facility using the versatile 5-axis CNC vertical machining center.

1. ***Spiral bevel gear.*** In making spiral bevel gear instead of using traditional special machine like Gleason or Klingelnerg, which is more expensive, we used other method that based on CAD/CAM using Cimatron v.14 and 5-axis CNC machining to manufacture spiral bevel gear from the result of KISSsoft design. At first, the 3D model of the spiral bevel gear was created. Next, the tool path planning for 3-axis cutting of the tooth profiles of the gear was performed for roughing and semi-finishing. Then, the gear teeth were cut on a 5-axis CNC machining center (Okuma Vertical Milling Center) (**Fig. 7**) using ball nose mills for finishing.

Fig. 7. Cutting the Designed Spiral Bevel Gear on a 5-Axis Machining Center

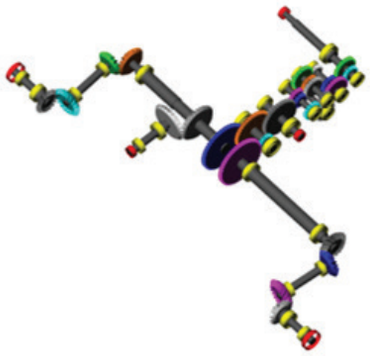

Fig. 8

3d Model of Gear Pairs and Other Components

The machine gear was measured and analyzed by a CMM (Zeiss Duramax RT) measuring method using gear-pro software which allows to compare the actual part to the nominal CAD model.

2. *Bevel gear tooth surfaces.* The tooth surfaces were milled on a 5-axis CNC vertical machining center. In order to guarantee the geometric accuracy and the surface quality of the tooth surfaces, removal of materials was done in 3 sequences: (1) rough cut using a 4 mm ball-end mill, (2) semi-finish cut using 3 mm ball-end mill, and (3) finish cut using a 2 mm ball-end mill.

3. *Gear Shafts.* Gear shafts were fabricated using two process, plain turning and splining. Plain turning which forms the exact cylindrical profile of the shaft using CNC lathe. Splining, which is also similar to gear cutting, was done using milling machine. Shaft splining was done to prevent the gears from slipping off the shaft while rotating.

Functional Testing

Functional testing was done to determine initial performance of the developed transmission. This was performed by PhilRice based on requirement of the client.

III. Results and Discussion

Design Optimization of Gears

Series of gear pairs and other relevant components are modelled and simulated using KISSsoft/KISSsys gear software which was acquired through establishment of gear making assembly facility project of MIRDC. The optimum sizes of each pair were determined using the said gear software. Detailed fabrication drawing was done using NX 3D modelling software (**Fig. 8**).

Tool Path Planning and Machining of Bevel Gear Tooth Surfaces

The teeth surfaces of spiral bevel gears are slanted and complicated surfaces that can be considered as sculpture surfaces. Through CAD/CAM software offers some milling sequences which can be used for cutting this kind of surfaces. It can generate a lot of tool path strategies and the surface finish can be controlled with different cutting adjustments.

Machining Simulation

From the machining simulation results, it can be concluded that the proposed method has been successfully implemented in theory. In order to validate the implementation in practice, an experiment is required. The milling operation for gear cutting was done by 5-axis machining center (Okuma Vertical Milling Center). It took nearly four hours and a half for roughing. The machining time for semi finish and finishing sequences were about 8 and 13 hours, respectively depending on the gear sizes. The machining was completed without trouble.
The original design gear combination was straight bevel gear (**Fig. 9**) while the design at the right side was spiral bevel gear revised due to its advantages of ensuring evenly distributed tooth loads and carry more load without surface fatigue. Thrust loading depends on the direction of rotation. In this gear arrangement, the shaft axes intersect although they are on the same plane. The most extensively used configuration is the right-angle system, where the two engaged gear shafts are at 90° to each other. This right-angle arrangement is best accomplished by conical-shaped bevel gears. The two basic classes of bevel gears are straight and spiral bevel gear.

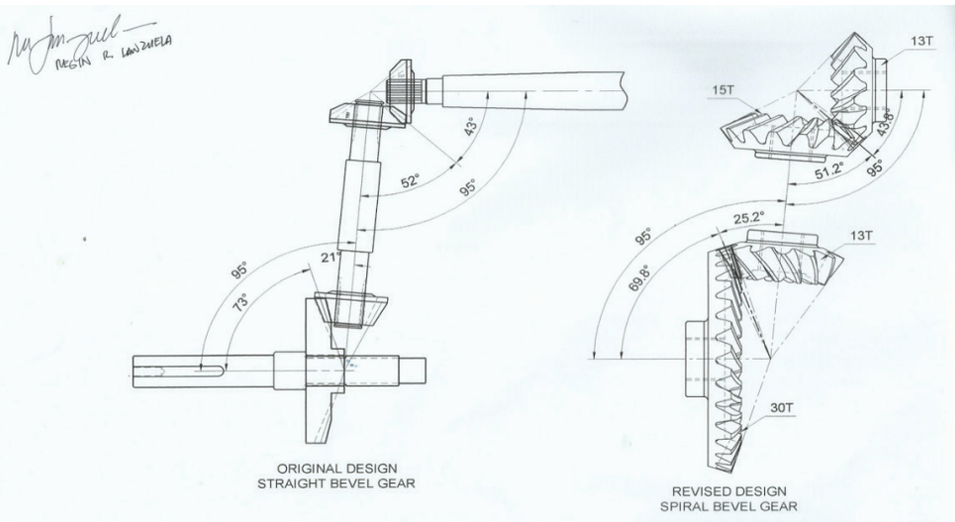

Fig. 9. Front Transmission Sub-Assembly Between Original and Revised Bevel Gear Design

Functional Testing

The improved gear transmission system was attached to the rice transplanter and tested at Nueva Ecija. Feedback from users revealed that the newly developed transmission system generates lesser noise and functionally better than the original transmission system.

IV. Summary

The Metals and Engineering (M&E) industry, primarily the metalworking sector has been identified as the backbone of all the industries for accelerated development since it supports and contributes to the growth of the manufacturing industry of the country as well as the economy. However, at present, there are few companies that are engaged in the design and manufacture of gears and gearboxes in the country to cater the requirements of various local industries. The shortage of gear manufacturing can be attributed to the complex requirements such as lack of competent technical personnel in gear design and manufacturing. It is therefore imperative that DOST-MIRDC developed its capability on the design and manufacture of gears and provide gear making technologies for the product development as well as shared facilities to manufacturing industries. This will help the metals, engineering and allied industries produce locally developed technologies that will be at par with global standards and address the impending need of the manufacturing industry to improve their performance and productivity.

The Philippine Rice Research Institute (PhilRice) developed a prototype of a locally made riding-type rice transplanter however, problems during field tests were encountered that mainly point to the power transmission of the machine. With knowledge on the capabilities of MIRDC, PhilRice thru its fabricator Rollmaster Machineries, Inc. tapped the expertise of the mentioned government agency to assist in the improvement of the rice transplanter transmission system.

V. Conclusion

Conclusion

Series of gear pairs and other relevant components are modelled and simulated using KISSsoft/KISSsys gear software. The optimum sizes of each gear pair were successfully determined using the said gear software leading to the improvement of the gear transmission system.

Various processes were performed during the manufacturing of the gear transmission system. Prior to gear cutting, machining simulation was conducted to prevent possible errors during machining. This was done using Cimatron v.14 and milled using Okuma Vertical Milling Center. The gear cutting operation was successful hence, improved gears was manufactured. Other machine components were also manufactured successfully using other appropriate machine operations.

The improved gear transmission system was attached to the rice transplanter and tested at Nueva Ecija. Feedback from users revealed that the newly developed transmission system generates lesser noise and functionally better than the original transmission system.

V. Recommendations

Based on the results of the study, the researchers recommend the following:

1. The rice tansplanter transmission system should be subjected to prolonged field testing to determine its durability; and

2. Improve other components of the transmission system like the shifting and the clutch mechanisms.

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Effect of Machining Parameters on the Mechanical Properties of AISI 4340 Materials

Florante A. Catalan*[1], Jeffrey C. Obregon*[2]

Abstract

Steel undergoes subsequent processes to achieve its final form and properties. In each of these processes, steel may change its physical properties depending on the conditions it has to undertake. After the primary product of steel making e.g., ingot, billets, blooms, and slabs, it undergoes another process to either make a final product or another raw material for a final product. These processes steel materials undergo may affect its physical properties. Machining is one of the processes that steel may undertakes.

This study focused on the changes in the physical characteristics of steel when subjected to machining process. Limited only to a Low Alloy steel material, AISI 4340, all samples were machined to a specified dimensions for tension testing using the same turning parameters except for the depth of cut. A solid round bar AISI 4340 with a length of 6m is cut into 200mm length to undergo machining using 5 different depths-of-cut including the standard parameters. Hardness measurement was conducted after rough and fine machining to compare with the standard parameters. Changes on physical properties may originate from the edge of the sample since this part is the one exposed in the process of removing excess materials. A slight change in the hardness of the edge occurred after rough machining but no significant changes after finishing. No microstructural changes were reported at the edge of the sample on all parameters. Only the tensile properties showed significant changes between the standard and the other parameters. To further understand the changes in the tensile properties, fractography was performed between the fractured tension test specimen of the worst and standard parameters. Both parameters showed ductile fracture and no significant changes were reported.

Keywords: *Solar-Thermal, Thermal Efficiency, Cashew Nuts, Roasting*

I. Introduction

Machining is one of the most common methods used in manufacturing where material is removed from the part in a controlled condition to achieve the desired shape and dimensions. Machinist opted to use non-standard machining parameters to shorten the machining time. This is true specially during the roughing process where more material is removed from the part to lessen the processing time. Often, the depth of cut is increased so that more materials are remove from the part being machined.

This study focused on the effect of machining a low alloy steel material, AISI 4340, using non-standard machining parameters normally used in the shops to reduce machining time. It aims to educate machinist and shop personnel when standard machining parameters is not applied during machining operation. It also aims to provide a guide on the parameters to be used when conducting lathe machining to AISI 4340 material using dry machining method.

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Natasha A. et al stated that “Machining significantly influences surface integrity, metallurgical structure, grain size and thereby the mechanical, chemical and physical properties of the component.” [1]. It means that due to mechanical stresses the part experienced during the removal of material, lot of things may alter the surface physical property. In this study, grain refinement is achieve using severe plastic deformation (SPD) technique. Surface SPD is achieved during machining-induced grain refinement of the surface and subsurface of a machined material. This study concluded that grain refinement on AISI 4340 material is achieved using cryogenic turning. This is because the heat generated in turning are controlled.

Monica Beltrani et al [2] discussed the effect of surface roughness in tension testing steel material. When sufficient roughness is attained, enough to create a stress concentration that can affect the tensile properties, the measured tensile properties may not be representative of the material. The specimen was machined using the same parameters in turning except for the speed of rotation. There were 5 speed rotation used, 1500rpm, 2000rpm, 2500rpm, 3000rpm and 3500rpm. The average roughness (Ra) was measured in each speed rotations with a range of 1.134µm to 1.967µm where the smallest values were obtained from the 3000rpm rotation. After measuring the roughness, all the specimens underwent tensile test. Monica Beltrani et al [2] concluded that there were no significant changes in the tensile properties using the 5 different speed rotations. This is because the roughness of the specimen is not sufficient to create stress concentration that will affect the specimen tensile properties.

Hard turning has become popular to manufacturers as they continue to seek ways to produce parts with lower cost, lower investment, smaller tooling inventory and quality. Basil K Matthew Paul et al [3] investigated the effect on surface finish and tool wear in a continuous dry turning of AISI 4340 steel using varying parameters. Its objective is to study the effect of varying cutting speed, feed rate and depth of cut on surface roughness, tool wear and cutting force. This experiment found out that the surface roughness is significantly affected by feed rate and cutting speed while depth of cut does not affect the surface roughness substantially.

II. Materials and Methods

A solid round bar AISI 4340 materials with a length of 6 meters was used in this study.

A. **Sample Preparation** - 6 meters solid round bar AISI 4340 was cut into 200mm length which is the same size used to prepare specimen for tension test as shown in **Fig. 1.**

B. **Machining of Specimen** - The samples were machined using the tension test specimen dimensions of a standard round bar specimen in ASTM A370 [6] as shown in **Fig. 2.** The lathe machine used during the preparation of samples was a conventional lathe machine with

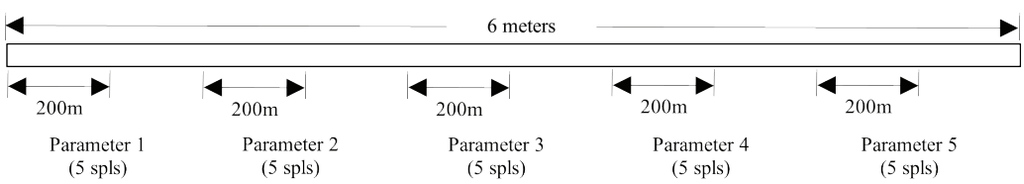


Fig. 1. Test Sample Extraction Plan

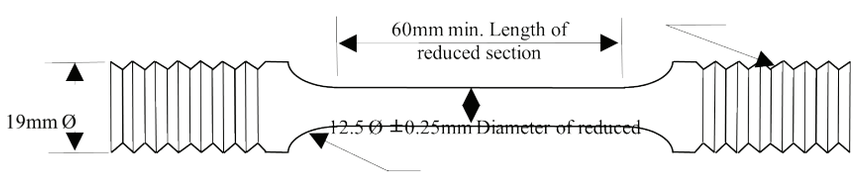


Fig. 2. Standard Tension Test Specimen (ASTM A370)

the following description: Mazak Mate, Quick Turn Smart 150S with property #214.MWS.063 of Metals Industry Research & Development Center (MIRDC). Cutting tool material used for all the machine turning was an uncoated alloyed carbide based on Table 10, page 88 and **Table 3**, page 145 of ASM Handbook Volume 16 (Machining) [4].

The cut samples having 32mm diameter were rough machined until it reaches 19mm diameter. A final machining was done at the center length of the samples to produce the reduced section to further decrease the diameter to 13mm, see **Fig. 3.** Five sets of samples were collected each set consists of 5 pieces 200mm length cut sample. Machining was done using "Dry Machining". The parameters used in machine turning the specimen were the same except for the depth of cut which vary from worst to below the standard, see **Table 1.** The standard parameters used were based on Table 10, page 88 and Table 3, page 145 of ASM Handbook Volume 16 (Machining) [4].

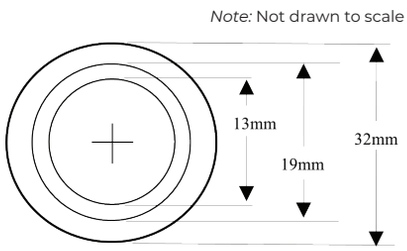


Fig. 3. Cross-Section of Specimen Showing Removal of Materials from the Original Diameter to the Final Diameter of the Reduced Section

Table 1. Designation of Each Set of Samples

Sample Designation		Turning Parameters		
		Speed, rpm	Feed Rate, mm/rev.	Depth of cut, mm
Parameter 1	Roughing	317	0.487	2.5
	Finishing			1.25
Parameter 2	Roughing			2.0
	Finishing			1.0
Parameter 3	Roughing			1.5
	Finishing			0.75
Parameter 4	Roughing			0.75
	Finishing			0.375
Parameter 5 (Standard)	Roughing			1.0
	Finishing			0.5

C. Material Characterization

Chemical composition - To ensure that the acquired material is an AISI 4340, a chemical analysis using an Optical Emission Spectrometer was conducted.

Hardness Test - Hardness measurements were performed from the rough machining as well as in the finishing to determine the effect during the removal of materials using the different depths of cut. To evaluate the difference between the hardness of the cross section of the specimen, the average hardness was determined at the edge and the core of the specimen using Knoop hardness test.

Metallography - Each non-standard parameters such as parameter 1, 2, & 3 was all tested to metallographic analysis after rough machining. Another metallographic analysis was conducted on all parameters after machine finishing to check any microstructures transformation that may occur.

Roughness Test - Roughness of the machined surface may affect the tensile test result. This was checked and measured using the average roughness of the specimen (Ra) for all parameters.

Tension Test - All parameters were tension tested. Three samples in each parameter were machined to the dimensions specified in ASTM A370 [6]. The difference between the results was evaluated and compared with the standard machining parameters.

Fractography - To further understand the effects of each parameter, fractography using a Scanning Electron Microscope was conducted to check the initiation of the fracture. Both worst parameter and standard parameter were tested and compared.

Table 2.

%C	%Si	%Mn	%P	%S	%Cr	%Mo	%Ni	%Cu
0.40	0.24	0.74	0.01	0.0054	0.77	0.23	1.78	0.042

III. Results and Discussion

Chemical composition of the unmachined sample was analyzed and the result of analysis was found to conform to AISI 4340 material, see **Table 2.**

Due to poor handling during roughing, parameter 5 or the standard sample was damaged. Because of this hardness measurement was not conducted for the said parameter. Parameter 4 was treated as the standard since it has the lowest depth of cut than of the other parameter. As expected, parameter 4 as shown in **Fig. 4** shows the minimal hardness at the edge while parameter 2 and 3 has the highest value of hardness.

Figure 5 shows the hardness measurements at the core after roughing where parameter 4 has the highest hardness at the core. This is quite unusual since there is a significant difference between the other three measurements. After a thorough investigation, there was a mistake in the sample preparation. The specimen for hardness was cut at the end where the center mark of the tailstock is located. Heat and strain hardening may have affected the actual hardness at the core. Because of this, hardness measurement at the core for parameter 4 is not considered. The remaining parameters showed almost the same hardness measurements.

After finishing, hardness measurements at the edge and core for all parameters are identical except for parameter 2 which exhibits a little higher than the rest (**Fig. 6** and **7**).

Metallographic test for both roughing and finishing processes for all parameters was conducted. This includes the microstructures on the edge and core of the cross section. All parameters exhibit a bainitic microstructures except for parameters 3 and 4 after roughing which has bainite with martensite (**Fig. 8**). The results of Metallographic Analysis showed that the 6m solid steel bar consists of bainite. The formation of martensite may be due to the rough machining process and therefore no significant changes on the microstructure after the final machining (finishing) that may affect tensile properties.

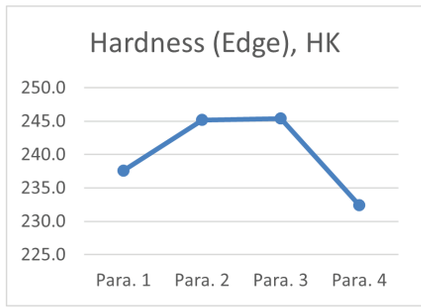


Fig. 4. Average Hardness at the Edge After Roughing

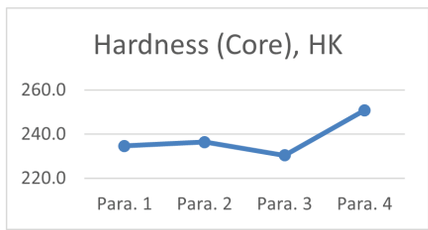


Fig. 5. Average Hardness at the Core After Roughing

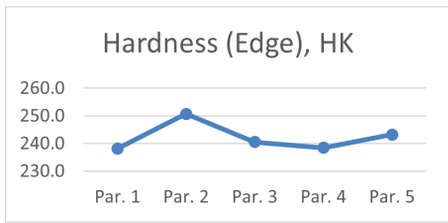


Fig. 6. Average Hardness at the Edge After Finishing

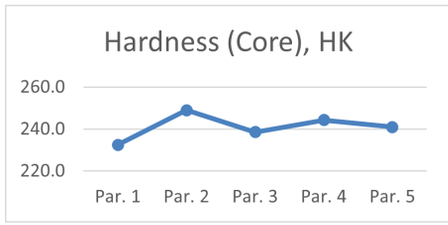
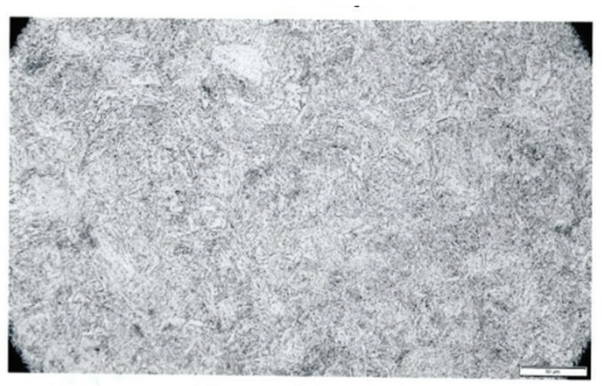
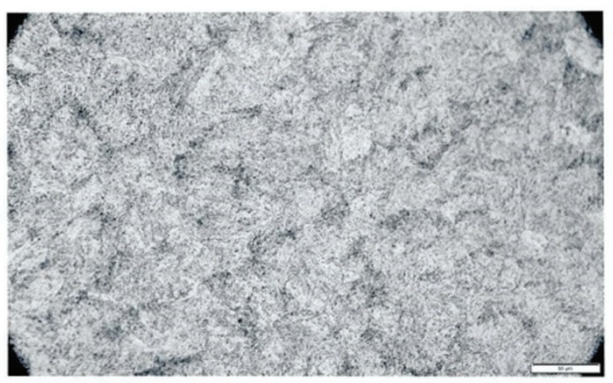


Fig. 7. Average Hardness at the Core After Finishing



Photomicrograph of Parameter 3
Etched with Nital, 500x magnification

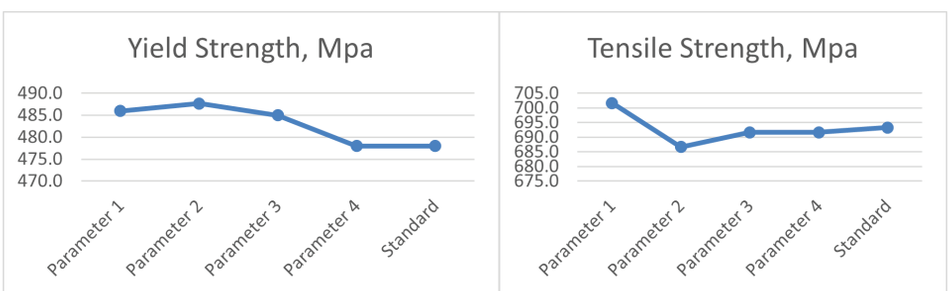


Photomicrograph of Parameter 4
Etched with Nital, 500x magnification

Fig. 8. Photomicrograph of Parameters 3 and 4 After Roughing

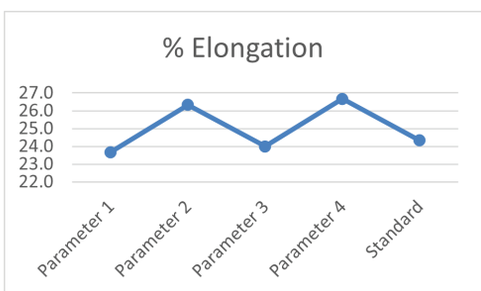
Roughness of the machined specimen for tension test was measured and there is no significant difference found on the average surface roughness (Ra). This means that surface roughness is not a major concern in this study based on the data gathered.

The average results of the tensile properties for parameters 1-4 were collected and compared with the standard parameter as shown in Fig 9 for Yield Strength, Tensile Strength, Percent Elongation and Percent Reduction of Area. The Yield Strength and the Tensile Strength of parameter 4 is consistent with the standard parameter while parameters 2 & 3 show a small deviation with the standard in terms of the Yield Strength. On the other hand, Tensile Strength of parameter 1 has the highest value compared to other parameters (**Fig. 9 a** and **b**). This means that depth of cut during machining have resulted an increase in tensile strength on the AISI 4340 material. It only shows that standard parameters for turning specifically the depth of cut if not observed may alter the mechanical properties of AISI 4340 material in terms of its tensile strength. Other tensile parameters such as the Percent Elongation and Reduction of Area were also collected to check the effect of the depth of cut on the ductility of AISI 4340. Normally, for most steel materials, when the tensile strength increases, the ductility property decreases. As shown in **c** and **d** of **Fig. 9**, percent elongation and percent reduction

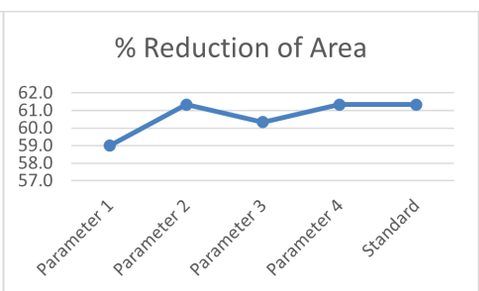


a. Yield Strength, MPa

b. Tensile Strength, MPa



c. Percent Elongation



d. Percent Reduction of Area

Fig. 9. Summary of the Tensile Properties for All the Parameters

of area for parameter 1 decreases compared to the standard parameter.

In an attempt to fully understand the reason why an increase in tensile strength occurred when deeper depth of cut is use during turning, Fractography was conducted on both parameter 5 and parameter 1, the standard and worst parameter respectively. Two fractured tensile test specimen of parameter 5 and one fractured tensile test specimen of parameter 1 were submitted to the laboratory for fractographic evaluation. This test will expose any hardening that may occur after the machining process. Both parameters show Bainitic with some martensitic structures. All samples resembled a cup and cone failure which exhibit in a ductile type of failure. No significant changes were established from this test.

IV. Conclusion

AISI 4340 material is one of the Low Alloy Steel materials commonly available in the market. Machining process for this type of material is the conventional way to shape it to the required dimensions. Standard machining parameters shall be observed to ensure that its physical properties are preserved. Machinist shall be informed and trained enough before processing such material.

Effects on the microstructure caused by heat treatment is not evident based on the microstructure reported by the laboratory. The microstructure of both edge and core are all bainitic with the exemption of parameters 3 and 4. The specimen remains to be ductile when the fractured surface was analyzed for fractography. There are no signs of brittle fracture when observed using the Scanning Electron Microscope. Roughness on the other hand, if sufficient enough may change the tensile property of the material. A higher average roughness (Ra) produces stress concentrations that will lower the value of the tensile strength. However, in this study no effect on roughness was observed.

Not considering the value obtained in parameter 5, hardness results for rough machining increases as the depth of cut is increased. This is expected since we are using dry machining method. Removal of material is a mechanical action that creates shear and tensile loads at the point of contact between the tooling and the specimen. Residual stress may be involved in this process. Although the difference in the values of Fig 9 c & d are quite small, the graphs show a decreasing trend on the ductility property. This is clearly seen on the graph of the Reduction of Area where almost all the parameters tend to decline. This is common for steel materials. Tensile strength is inversely proportional with ductility. Increasing tensile strength will reduce the ductility of the material.

Among the 5 parameters used, the best parameter that maintain the property of the work piece was parameter 4 which has the smallest depth of cut. However, since the standard parameter (parameter 5) is acceptable in the industry, it is more advisable to use it. This is because parameter 4 will need more time for machining compared to the standard parameter.

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Philippine Welding Society started as a vision of various industry professionals whose aim is: to advance the science and professionalize the practice of welding in the country. On September 19, 1991, encouraged by the government, business sector, educators and practitioners, twelve founding members from construction, manufacturing and inspection companies bonded together and established the Philippine Welding Society (PWS). On February 13, 1992, The Securities and Exchange Commission (SEC) registered the Philippine Welding Society as a non-stock, non-profit organization

The Objectives of the Organization are as follows:

(1.) To promote the advancement of the science and practice of welding and to advise and support government entities whenever possible on matters of standardization, public safety and health; (2.) To foster and maintain among members' high ideals of integrity, learning, professional competence, public service and conduct; (3.) To provide proper forum for meeting, exchanging of ideas and opinions, and to be involved in the solution of multifarious problems affecting the country in general and the welding profession; (4.) To conduct workshops and seminars for purpose of keeping its members abreast of progress in the welding field; (5.) To promote orderliness and effectiveness in the maintenance of good fellowship and occupational standards; (6.) To promote and organize research in all matters relating to the science and practice of welding technology; and, (7.) To promote consciousness among members of their serious responsibilities in helping our country move forward in our national development and to consolidate all gains already made.

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3D Printed Nasal Mask Interface for Continuous Positive Airway Pressure Ventilation of Neonatal Patients

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Abstract

A nasal mask interface was developed in order to be used in a bubble continuous positive airway pressure (CPAP) system for newborn infants. The fabrication was performed using additive manufacturing (AM) or 3D printing that achieves faster production lead times and greater design flexibility, whereas changes can be made quickly and produced within 24 to 48 hours. The nasal mask prototypes were fabricated using biocompatible resin through stereolithography. The contact lip was molded with food-grade silicone, and connects to the rigid resin portion through two prongs. The resulting nasal mask prototypes were tested on newborn infants for 24 hours at Philippine General Hospital (PGH). The nasal mask prototypes are suitable for newborns weighing between 1500 g and 1999 g with a maximum nasal bridge length of 20 mm. The nasal mask prototypes were observed to be effective in preventing nasal traumas for the patients and found to be suitable for long-term direct skin contact and held firmly against the face.

Keywords: *CPAP, nasal mask, additive manufacturing, 3D printing, stereolithography*

I. Introduction

The respiratory system of neonates (babies within the first four weeks of life) is underdeveloped, with certain structural, chemical, and regulatory immaturities that render them vulnerable to breathing disorders. [1]

In the event of such disorders, assisted ventilation methods are applied. These can be classified into two groups based on their patient interface. Invasive ventilation methods typically use endotracheal intubation (ETI) inserted into the respiratory tract. Non-invasive ventilation (NIV) interfaces with the patient through the nose and/or mouth. For neonates, prolonged ETI is associated with injuries and trauma to the patient's breath ways. It is advisable to minimize intubation for neonate patients as much as possible, and to instead be supported through non-invasive means. [2],[3]

In the Philippines, the most common NIV interface used is the RAM cannula. This device consists of a medical tube with binasal prongs connecting to the infant's nostrils. Interfacing with the nose is beneficial, as neonates are known to breathe preferentially through the nose instead of the mouth. [1] The prong-type interfaces, however, are known to cause nasal trauma to patients' nasal regions. [4]

An alternative means of directing the supplied air would be a nasal mask—an interface that encloses the newborn's nose, preventing any damage to the nostrils. Instead of prongs, the interface encloses part of the patient's nasal area, creating a sealed volume. This interface can have issues maintaining its seal, and its availability is scarce in the Philippine market.

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Hence, the Advanced Manufacturing Center (AMCen) and the UP National Institute of Health (UP NIH) came together to develop a viable nasal mask.

Additive Manufacturing

Additive manufacturing (AM), involves raw materials that are fused together successively, layer by layer, to create the end product. AM benefits this development process with its rapid design-to-product cycle and cost-effective prototyping. [5]

Of the many different types of AM, two were considered for the project. The first is material extrusion, which is simply the deposition of extruded solids to form a product. [6] Plastics can be extruded in molten form (like in the common fused deposition modeling (FDM) 3D printers). Other substances such as gels and viscous solutions can be extruded in ambient temperature as well.

Another technology is stereolithography (SLA). This AM process makes use of a photosensitive resin which is solidified by an ultraviolet laser. The UV light catalyzes the cross-linking of polymers, ensuring a solid product. These usually require more post-processing than the above material extrusion process. [7] Over time, a variety of resin blends have been introduced by companies such as Formlabs, improving upon the base resin's properties for different uses in prototyping, dentistry, jewelry, medical field, and so on.

In this project, rapid prototyping of nasal masks for ventilation of neonatal patients using AM technologies were utilized, with emphasis on the speed and cost-effectiveness of its prototype fabrication capability, as well as its versatility in manufacturing. Prototype designs were made using the nose measurements of actual patients. Clinical tests were also performed to evaluate the functionality and safety of the nasal masks to the actual patients. This project also aims to develop locally made nasal masks in support for the ventilation of neonatal patients in the country.

II. Materials and Methods

Nasal mask design

The design of the nasal mask was conceptualized with inputs from UP NIH medical professionals. It was comprised of recommendations on appropriate size, material characteristics, orientation and size of connecting prongs, and designs for strap attachment sites.

The weight categories for the neonates in this study ranged from 1,500g to 1,900g. Subsequent data was then used to determine proper sizing of neonate patients. **Figure 1** exhibits the nose diagram showing detailed external parts of the human nose. This diagram was used as a reference for the nurses from Philippine General Hospital (PGH) in determining the nose sizes per patient.

Based on the size and needs of neonatal patients, 3 versions (Design A-C) of nasal masks as shown in **Fig. 2** were designed using Solidworks. Design A and B with the basic features of a normal nasal

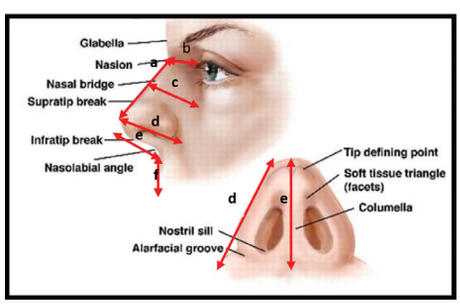

Fig. 1. Nose diagram [8]

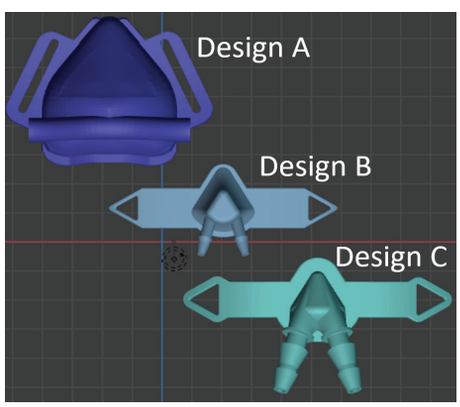

Fig. 2. Design Evolution of the Nasal Mask Design

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mask were initially made and fabricated. This was made to initially assume the size and fit of the mask to the nose and facial contour of neonatal patients. Upon performing the second fit test, medical partners recommended widening the breadth of and increasing the height of the mask. Moreover, there were two proposed sizes for the mask: the first being the size of the second fit-test specimen, and the second being slightly larger. Design C was made with the collected recommendations from the medical experts and test fitting.

The 3D models of the neonatal face with a nasal mask designed to conform to facial topography were shown in **Fig. 3.** Nasal prongs were positioned close and oriented toward the nostrils of the patient. Large diameters were placed to accommodate general medical tubing (ranging from 0.5 to 0.7mm) as recommended by medical partners.

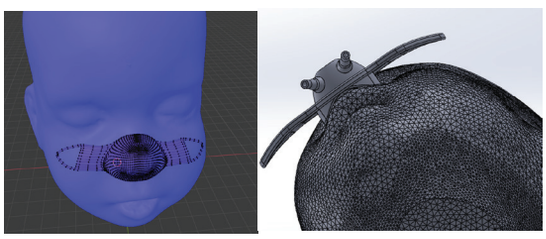

Fig. 3. 3D Model of Neonatal Face With Nasal Mask Designed to Conform to Facial Topography

Material and Process Selection

Based on the recommendations and taking into account the limits of the chosen material and manufacturing process, the design of the nasal mask was initially created. The choice of manufacturing process for this project was closely related to the material selection because a material that works well in one process might not be feasible in the other.

A handful of processes were considered, with the decided method being a combination of SLA and silicone casting. SLA was an attractive fabrication method with its high resolution and the availability of biocompatible resins for production. Silicone casting was used for the deformable contact region between the mask and the face of the patient. Continuous development of the mask was done with the help and speed offered by AM to arrive at a product satisfying the medical partners' criteria. Three short-term fit tests were done for iterative stages to observe the mask's functionality during the real situation. Results from the clinical trial were used for further improvement of the next design. The successful model of the mask was then produced in the size and quantity recommended by UP NIH, and was used in a longer-term clinical trial.

Fabrication Process

The nasal mask prototypes were 3D-printed using Formlabs Form 2 SLA printers using Formlabs BioMed Clear resin as the material for the mask. Preceding prototypes were printed using Formlabs White Resin V4 to save on resin while the design was being developed. The detailed process in using SLA 3D printing was shown in **Fig. 4.**

Cast-in-place molds were also 3D-printed with the same white resin. A 1:1 part mixture of Smooth-On Sorta-Clear Food Grade Silicone was poured into each mold, with the masks set in place for 12 hours to ensure the full curing of the silicone. The masks

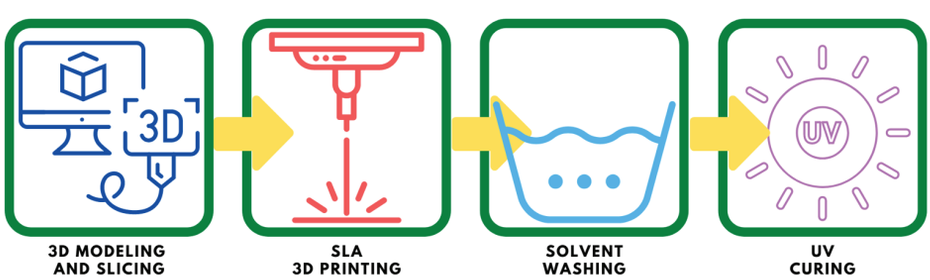

Fig. 4. SLA 3D Printing Process

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were pulled out of the mold upon curing. Strap securement areas were extended away from the nasal interface to avoid constricting the patient's face. Two straps will hold the mask in place, with 3D-printed strap adjusters to accommodate different head circumferences. For the contact region, a perforated wall was extended down from the mask base. This served as anchor sites for the silicone when being cast. The silicone region was modeled with a flat and level surface, which would conform to the patient's face upon use. The overall assembly of the 3D printed nasal was shown in **Fig. 5.**

Fig. 5. 3D Printed Nasal Mask Assembly

Table 1. Measured Nose Parts Per Newborn Patient

Patients	Weight of patients (g)	a	b	c	d	e	f	g
A	1515g	18	7	6	9	7	7	6
B	1600g	18	8	8	9	7	8	5
C	1750g	19	8	7	8	6	7	3
D	1830g	19	7	6	9	5	8	4
E	1700g	20	7	6	9	6	9	4
	Average length	18.8	7.4	6.6	8.8	6.2	7.8	4.4

III. Results and Discussion

Nose measurement of the neonatal patients

Table 1 listed the measurements in millimeters of the nose parts for neonates based on the diagram shown in **Fig. 1**. It can be observed in the nasal measurement study that only the nasal bridge length (a) possessed a positive correlation with increasing size difference. In addition, it is also possible to observe that the height of the nose (d) remains constant within a given weight range. Other dimensions varied considerably with only small correlations.

Clinical Testing

The 3D-printed nasal mask components were assembled and clinically tested by the medical personnel from PGH and representatives from NIH, UPM as shown in **Fig. 6.** The nasal mask prototypes were evaluated in terms of functionality and safety to the newborn infants for 24 hours. Patients were observed to benefit from the nasal mask prototypes by having the natural ventilation support while preventing nasal traumas, due to indirect placing of prongs to the nostrils. The developed 3D printed nasal mask prototypes were also found to be suitable for prolonged direct skin contact due to food grade silicone used for the cushion. This cushion also holds firmly against the face of the patients and helps to significantly reduce skin pressure.

Fig. 6. Actual Clinical Testing of the Nasal Mask to the Newborn Patients

IV. Conclusion

The developed 3D printed nasal masks have been successfully used to deliver CPAP ventilation to newborn patients. The mask has undergone a three-phase design process, which included switching materials and manufacturing methods to cater to the recommendations and fit testing results of our medical partners. The final prototype consisted of a mask directly 3D printed with a biocompatible polymer resin, with a food-grade silicone cushion for comfort and a silicone lip was added for a good seal. Based on the clinical testing, newborns weighing between 1500 g and 1999 g with a maximum nasal bridge length of 20 mm are suitable for use with the nasal mask prototypes. The mask was also made compatible with the existing CPAP setup. The study demonstrated the speed and convenience at which AM can produce design alterations. Whereas, alterations can be quickly made then fabricated within 24-48 hours. This workflow can be useful at producing nasal masks to deliver CPAP ventilation for neonates.

V. Acknowledgements

This project was implemented in collaboration with Dr. Maria Esterlita Uy of UP National Institute of Health and the Philippine General Hospital, and consistent support from DOST-MIRDC, especially the Executive Director, Engr. Robert O. Dizon, the Deputy Executive Director for R&D, Dr. Agustin M. Fudolig, and the Materials and Process Research Division Chief, Engr. Fred P. Liza. Likewise, the project team acknowledges the support provided by the DOST-Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD).

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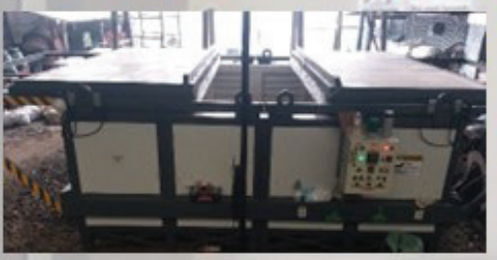



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Construction of a 12.5 ft 3D-Printed Statue of Dr. Jose P. Rizal Using a Hybrid of Additive Manufacturing and Conventional Manufacturing Techniques

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Abstract

For most fabrication processes, current 3D printing machines are limited by the build volume of their hardware. Manufacturing one-of-a-kind, customized statues is one of the categories that demonstrates the great potential on the application of 3D printing in the creative arts industry. However, the material, dimensions, and quality of the statue that is to be made are typically constrained due to the environment in which it is exposed, size and orientation. In this paper, a novel approach of multiple hybrid techniques was explored. The construction of the 12.5-foot monument began by scanning a 1.2-foot clay sculpture using the Solutionix C500, a structured light 3D scanner. This process produces a 3D mesh which was cleaned, resized to 12.5 ft, hollowed to a 12mm shell, and segmented to fit into printers, using the 3D modeling software - Blender. The ready-to-print files included over 150 segmented pieces that were processed with Simplify3D and Cura, resulting in a total print duration of more than 1040 hours on the Ultimaker S5, Cosine AM1, and Gigabot XL, with post-processing and assembly of the parts taking place concurrently with printing and build site preparation. Steel reinforcements were placed inside the assembled shells which served as permanent formwork for the poured concrete. It was demonstrated that 3D printed statues can be constructed by utilizing a combination of conventional and advanced techniques in a short amount of time while also being less reliant on specialized skilled work in conventional large-scale sculpting.

Keywords: *3D printing, Hybrid manufacturing, Additive manufacturing, Philippines*

I. Introduction

3D-printing or additive manufacturing is a method of manufacturing where material is added layer by layer to form an object from a computer-generated 3D model [1]. This allows the implementation of complex shapes and geometries in the design that are very difficult or impossible to do using conventional manufacturing processes. Additive manufacturing is also cost effective for manufacturing small batches with continuous centralized manufacturing [2] and prototyping [1]. Aside from these, additive manufacturing has also found its use in the construction industry, from the initial design process (mock ups of the building), to the construction of the building itself (3D printed concrete and metal) [3].

Monuments and statues are traditionally built using metals, stones, clay, plaster, concrete, polymers, and composites. Construction time differs greatly depending on the method, material, and

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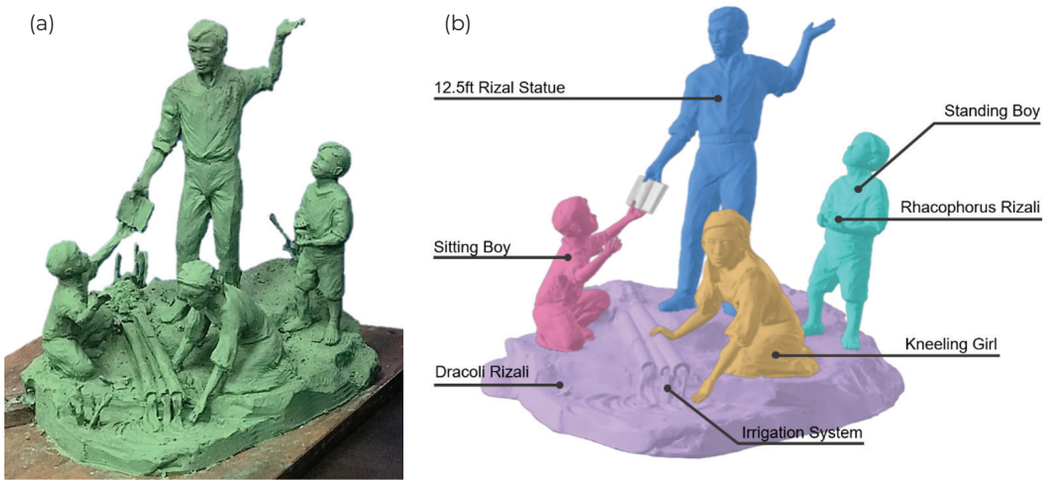

Fig. 1

(a) Clay Model
(b) Segmented Digital Model

complexity of the design. In this project, additive manufacturing methods were integrated with the traditional construction approach to construct a monument with a 12.5 ft statue that can withstand 300 kph winds and a magnitude 7.5 earthquake. This hybrid manufacturing method aims to refine the fabrication process of purely conventional and purely additive manufacturing approaches by being more efficient, less wastage and independent of specifically skilled labor.

Fig. 2. Construction of the Foundation and the Base

II. Materials and Methods

Model

The monument started as a 1.2 ft clay maquette created by Prof. Jose Manuel Sicat. It consists of a base, bamboo trees, two small animals and four individual statues with the tallest pursued to stand 12.5 ft tall as seen in **Fig. 1.** The monument showcases Rizal's contributions to the community during his exile in Dapitan such as mentoring children, discovering species and implementing an irrigation system. The maquette was digitized using the available 3D scanning technologies at the Advanced Manufacturing Center (AMCen) which are the Solutionix C500 and Artec Eva. The generated 3D digital mesh file was then sent to an artist to be edited, polished and scaled.

Construction of Foundation, Base and Internal Steel Structure

The construction of the monument started with a superstructure foundation of size 6.5m x 6.5m x 1m designed to carry 15 tons. This is shown in **Fig. 2** with the construction of a granite- tiled base which is a truncated square pyramid of height 0.763m with a 6.5m bottom base and 5.2m top base.

The main support structure/frame was designed by Engr. Brian U. Rasco from DOST-Central Office (CO). Structural Analysis and Design software applications or STAAD.Pro was used to optimize the design and enhance the features and specifications of the 3D printed statue, which aims to withstand 300 kph wind and 7.5 magnitude earthquake. All the statues

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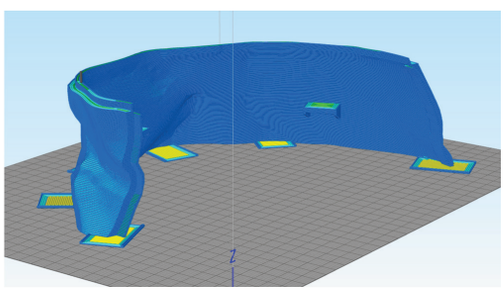
have vertical framing built using 25mm diameter mild steel reinforcement bars that are supported by 16mm lateral ties positioned 200mm apart.

Shells

The scaled 3D mesh of each statue was hollowed out to a shell using the Meshmixer software. The hollow statue was then segmented using the 3D modeling software, Blender, to fit the build volumes of the printers with some adjustments to accommodate the models' shape and its reaction while printing. Additional geometries were integrated using Blender for mounting and ease of assembly. Rectangular pads were added to mitigate warping of prints. This shape provides an increase in surface area between the bed and print and it also allows the use of weights and clamps for additional warping prevention (**Fig. 3**). The team printed a total of 134 individual parts for the 4 statues using the Cosine AM1 pellet printer, Gigabot XLT pellet printer and Ultimaker S5 filament-fed printer. All parts were printed with Acrylonitrile Styrene Acrylate (ASA) copolymer, a thermoplastic elastomer that has an excellent resistance to UV irradiation [4].

Table 1. Printing Parameters Used for Pellet Printers

Layer height	2 mm
Extrusion width	3 mm
Printing Temperature	230 C
Shell Thickness	12 mm



Fi.3. Sliced Part Featuring Rectangular Pads, Mounting and Lip

Assembly

All printed pieces were dry fitted at AMCen before the actual onsite assembly. This is done to ensure that any defects produced during printing such as warping and delamination were repaired with ASA slurry. The ASA slurry is a viscous paste made by dissolving ASA pellets or ASA scraps from printed parts in 99.9% technical grade acetone. This slurry was also used to seam the shells together. After the dry fitting and necessary repairs, the pieces were permanently assembled in sections, a sample shown in **Fig. 4.** The goal is to have the least number of parts possible for the site installation while still having access to the mounting brackets of the pieces and adequate space provision for staggered concrete pouring. This is to reduce the pressure carried by the printed shells.

On-site assembly started by positioning the shells around the internal steel structure of each statue. Once positioned, the shell will serve as the formwork for the concrete.

Fig. 4. Assembled Sections for Kneeling Girl

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III. Results and Discussion

Common Conventional Construction Methods

For conventional construction of monuments, depending on the size and complexity of the sculptures, different methods and materials would be used. Common materials for sculptures are stone, wood, metal, clay, ivory, and plaster, and these are manipulated by sculpting or casting to create figures.

Monuments made of bronze are the most common material for differing sizes. Bronze and fiberglass statues are generally made by casting 1:1 molds of segments of large statues and then assembled. Life-size bronze statues can be typically completed from 6 to 12 months [5]. The Rizal Monument in Calamba City Park, Laguna is a simple 22ft bronze single statue on a 7.87 ft granite pedestal [6] built 6 months starting December 2010 to April 2011 [7]. Similarly, the 26ft statue in Sta. Cruz, Laguna bronze statue unveiled on May 3, 2014 [8].

Statues can also be made entirely of concrete and steel supports, though this would generally take much longer and cost more. The Sacred Heart of Jesus, a 132-foot-tall monument in Roxas, Capiz, is one such example. It was constructed for more than three years, from the fourth quarter of 2011 to January of 2015, with a concrete core and partially hollow interior, steel armature, and concrete exterior [9].

The Heritage of Cebu Monument by Eduardo Castrillo was a more complex monument of several statues made with different materials such as bronze, brass, steel and concrete. It was created in three years, from July 1997 to December 2000 [10].

If the Rizal monument was made with purely conventional methods, it would increase the labor cost, time and construction waste produced significantly as compared to a hybrid structure. Stone or plaster would require one or more highly skilled sculptors to work on the statues for several months. A bronze or fiberglass sculpture would need to be segmented, a temporary armature made, molds created and cast, then finally joined together. The materials used to create the mold and temporary armature would then be thrown away.

Using the additive manufacturing approach exclusively, the 3D printed product will be as weather resistant as bronze, while reducing waste as there would be no need for molds. However, the time required to create the monument cannot be reduced without compromising the strength of the monument. Inherently, the strength of a 3D printed statue would be lower due to the nature of additive manufacturing, which is printing in layers. The Scout, a 30-ft 3D printed statue completed in 2020, took 10220 hours to print all its 365 individual parts [11]. The use of hybrid manufacturing could then be a solution.

Hybrid Construction of Rizal Monument

Table 2 summarizes the details of the Rizal monument using hybrid construction. The total time disregards multiple printers running at the same time, and the simultaneous steel support and base fabrication. In actuality, the creation of the monument from obtaining the clay maquette took 3 months spanning October 2021 to December 2021.

Table 2. Summary of Relevant Cost Related Parameters of the Hybrid Method

Total weight	Weight of 3D shells: 401 kg Weight of concrete: 6,210.98 kg Weight of steel support: 2,371.38 kg Total monument: 8983.36 kg
Total time	3D printing time: 1034 hours Steel Fabrication time: 440 hours

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IV. Conclusion

The hybrid manufacturing technique was used to successfully create the 12.5-foot monument. By combining the strength of traditional manufacturing with the material and time savings of additive manufacturing, hybrid manufacturing reduces construction time and waste and is less reliant on the specialized work required in traditional large-scale sculpting. It also provided reusability of the piece since the design can be digitally modified and reprinted.

V. Acknowledgment

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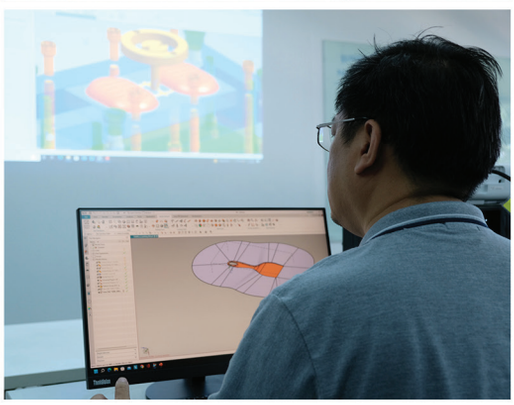

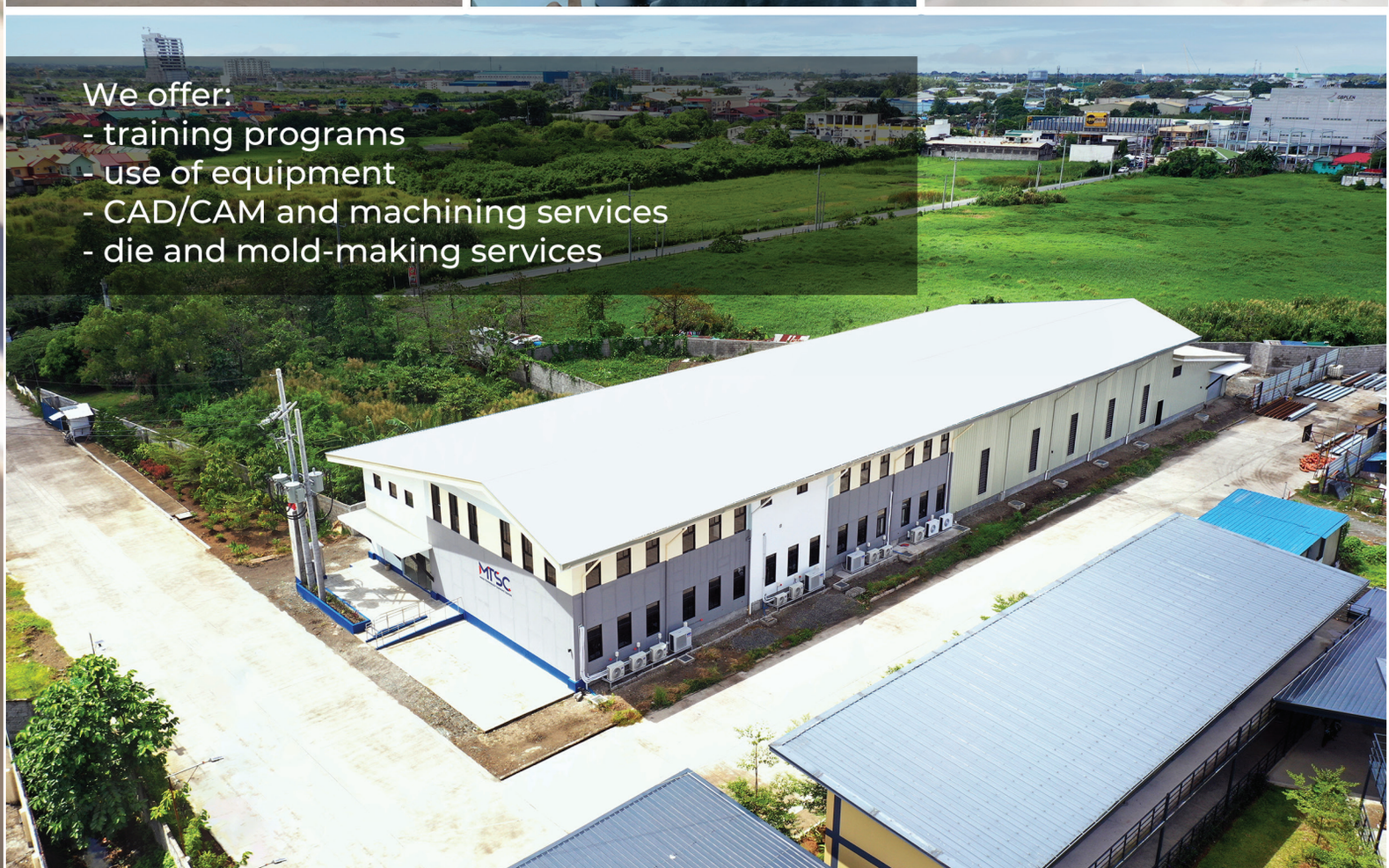

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