Philippine Metals

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Department of Science and Technology

METALS INDUSTRY RESEARCH AND DEVELOPMENT CENTER


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Advanced Manufacturing Center
Beyond the Conventional.
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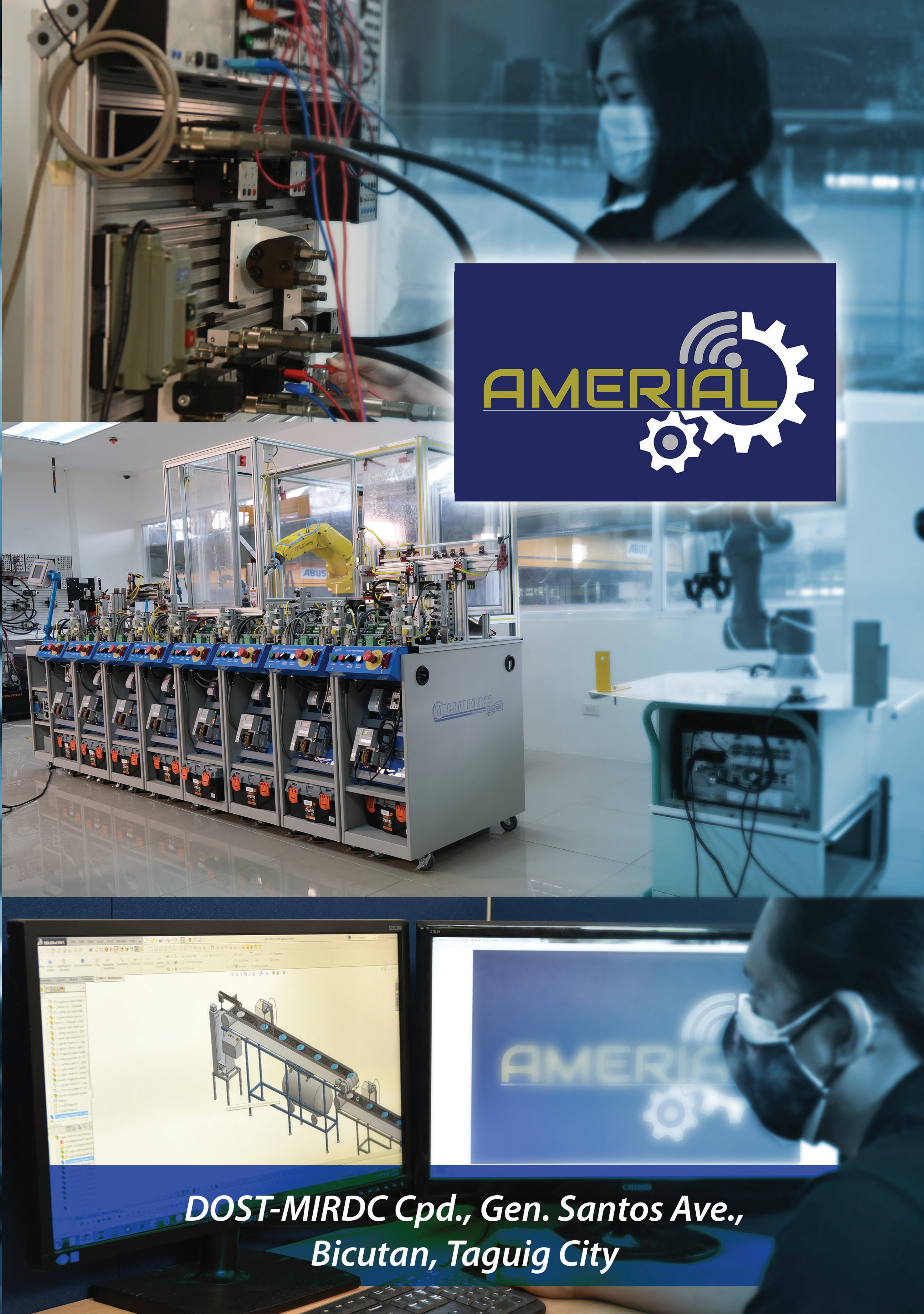
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MECHATRONICS
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Philippine Metals

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Department of Science and Technology -
Metals Industry Research and Development Center
Bicutan, Taguig City 1631
Republic of the Philippines
Telefax: (632) 8837-0479
Email: mirdctips@mirdc.dost.gov.ph
Website: http://www.mirdc.dost.gov.ph

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

It is our mandate to assist the micro, small, and medium enterprises in the metals, engineering, and allied industries so that businesses become more productive and competitive. That is why, despite the pandemic, we persist to serve the industry, which is a very crucial part of elaborate supply chains that allow both the business sector and the general public to gain mutual benefits.

Research and development fuel our aspiration to serve the industry. From our R&D initiatives, we are able to develop new products and processes – technologies that we share with the industry. Through information exchange activities, we proactively mold the industry's science, technology, and innovation culture.

The Philippine Metals publication is our way of presenting to our readers the R&D initiatives implemented by our researchers and engineers, with the invaluable support of our technicians. The R&D activities typically cover materials and process research, as well as product and equipment development. This year, we are including a paper on scientific and technical services and another paper about the recent industry study we conducted.

We have seen and felt the effects of the pandemic. We still face challenges brought by the continuing pandemic, but, amid all the abrupt changes and hardship, we are learning how to be resilient. We offer the Center's R&D outputs as tools for the industry to adopt and utilize. As we raise the industry's awareness, appreciation, and adoption of locally-developed technologies, we equip our MSMEs with the ability to recover quickly from any difficult situation.

On behalf of the Department of Science and Technology – Metals Industry Research and Development Center, I proudly present to you the Philippine Metals Volume 8.

Robert O. Dizon
Executive Director

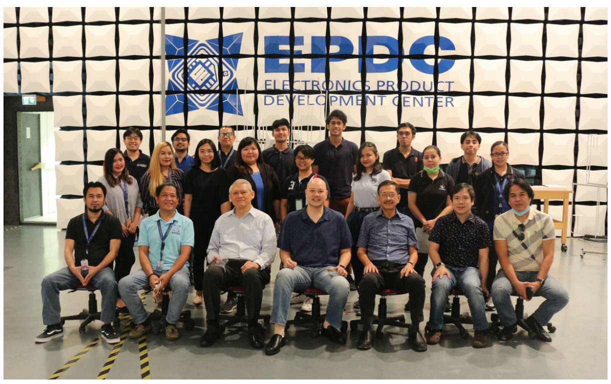
EPDC ELECTRONICS PRODUCT DEVELOPMENT CENTER

WHAT IS EPDC?

ENABLING ELECTRONICS PRODUCT DEVELOPMENT IN THE PHILIPPINES

The Electronics Product Development Center (EPDC) is a project under DOST-Advanced Science Technology Institute and co-implemented by Electronics Industries Association of the Philippines (EIAPI).

Inaugurated in July 2015, the Electronics Product and Development Center (EPDC) is a world-class electronics testing facility designed to support the electronics industry by providing various technical support services to promote innovation and high value product development. The Center aims to house hardware and software tools that can be used by companies or schools to design, develop, and test hardware and software for electronics products.

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PCB Prototyping

Electromagnetic Compatibility Testing

SERVICES

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The EPDC, in its continuous effort to uplift the value chain of the electronics industry, is offering Electronics Product Prototyping, Electromagnetic Compatibility Test (EMC) Emission Testing services, Immunity Testing Services, Parametric Testing, RoHS Testing, Product Safety Testing Services, Trainings and Seminars. With these services of EPDC, we hope to further enhance and expand the capabilities and global competitiveness of the local electronics industry.

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ELECTRONICS PRODUCT DEVELOPMENT CENTER

Taguig City, Philippines

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This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 6th day of September 2019.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 5144.01
Valid to May 31, 2021

For the tests to which this accreditation applies, please refer to the laboratory's Mechanical Scope of Accreditation.

The United State's Federal Communications Commission(FCC) expressed its continuous recognition of EPDC's accreditation granted by the American Association for Laboratory Accreditation(A2La).

Now that EPDC is ISO17025 certified, local electronic and manufacturing companies will be able to test their products for compliance locally instead of doing the tests overseas ultimately saving them time and expense. Furthermore, the accreditation situates EPDC globally with other electronics testing centers around the world as it recognized several testing methods of the center for its international compliance.

PROJECTS AND CLIENTS

EPDC has handled multiple projects and clients from the academe, industry, government, and also hobbyists. The EPDC has handled the testing of appliances and newly developed electronic devices for certification. Apart from testing, EPDC has helped in the development of multiple projects through hardware, software development and through the fabrication of embedded PCBs. EPDC is also currently developing a Breath Simulator and Oxygen Concentrator to assist with the testing of ventilators and support with the ongoing pandemic response.


Breath Simulator


Product Prototyping

EPDC ELECTRONICS PRODUCT DEVELOPMENT CENTER
MIRDC Compound, Gen. Santos Ave., Bicutan, Taguig City, 1631 Philippines
Te 837 2071 loc 3235, 2168
Email epdc@asti.dost.gov.ph
www.facebook.com/EPDCDOST

Development of Conical Plastic Container and Packaging Box for the Improvised Explosive Device

Denise Daryl A. FLORANTE*[1], Vladimir M. SARMIENTO*[2], Alvin M. BUISON*[3], Ulysses B. ANTE*[4], Joseph Alfred V. GARCIA*[5], Fred P. LIZA*[6]

Abstract

The fabrication of a 3D printed conical improvised explosive device (IED) disruptor for bomb disposal application was conducted using additive manufacturing or 3D printing. The conical IED disruptor samples were fabricated using Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA) material and 3D printed via fused deposition modeling (FDM). The fabricated samples were subjected to a water leak test and functional test, comparing them with the existing IED disruptors of the Philippine Army. Both the 3D printed IED disruptor and the existing IED disruptor were observed to have no water leaks. 3D printed IED disruptor samples were seen to have an equivalent efficiency to the existing IED disruptors. Innovations on the 3D printed IED disruptor were further developed by standardizing the box casing with a universal detonating cord holder for easy setup and greater stability during the actual use of the IED disruptor.

Keywords: *Additive Manufacturing, Acrylonitrile Butadiene Styrene, Polylactic Acid, Fused Deposition Modeling*

Introduction

An improvised Explosive Device (IED) is a bomb made from improvised materials that could destroy vehicles, buildings, and individuals that are usually placed in crowded areas that require immediate action [1]. It can be almost anything with any type of material, and initiators IEDs are usually composed of an initiation system or fuse, detonator, power supply of the detonator, container, and explosive fillers [2].

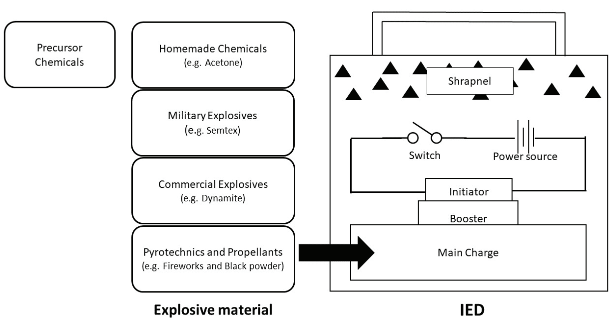

Figure 1. Components and explosive position in an IED

Ongoing research investigations were conducted to counter this IED. The Explosive Ordnance Disposal (EOD) of the Philippine Army is one of the agencies in our country tasked to study different types of explosives, including IEDs, and the process to counter or neutralize these explosives. To safely neutralize the IED, it must be contained or blasted under controlled conditions. To do this, an IED disruptor is used to detonate IEDs at a safe distance under controlled conditions. This device is a simple but effective medium to destroy the bomb's circuitry or itself. Currently, the Philippines has no standard IED disruptor that can be used for such purposes.

In this project, fabrication and standardization of conical IED disruptors employing additive manufacturing technology were conducted to generalize and innovate the design of the Philippine Army (PA). Visual inspection, water leak test, and functionality test were also performed. This project also aims to develop a feature in IED disruptor that can allow

*1 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*2 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*3 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

the PA's EOD units to quickly mobilize and set up the disruptor in the IED disposal operation.

Materials and Methods

The development of IED disruptors involved benchmarking, 3D modeling, 3D model slicing, 3D printing, assembly of the IED disruptors, and design verification via functional testing. During the functional testing, some necessary design considerations (dimensions, thickness, and materials) are incorporated in the final prototype.

1. Benchmarking of the IED Disruptor

The MIRDC project team conducted several meetings with the counterpart RDC, ASCOM, PA project team to discuss the IED disruptor's existing designs. The improvised IED disruptor uses only available household materials that are not military-grade and with low durability. Some of the problems encountered during the deployment of the improvised IED disruptor are as follows:

- The cardboard box is prone to moisture absorbance;
- The base cover of the funnel may have leakage when not sealed properly;
- The smooth surface of the funnel causes difficulty in assembling the detonating cord; and
- The packaging box was made of an illustration board that can deteriorate due to long storage duration and exposure to water/moisture.

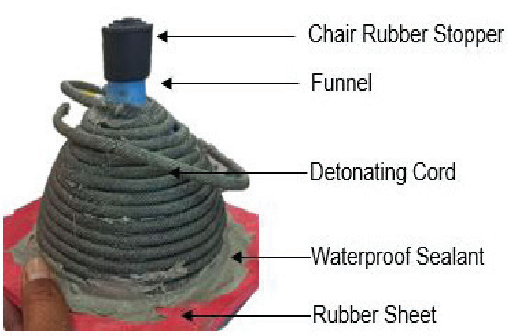

Figure 2. Improvised IED Disruptor

Due to the inconsistency of the materials and fabrication methods, some of the resulting IED disruptors have failed in the actual operation. The target design was to develop a conical plastic container capable of holding up to 500 mL of water and disarming an IED in an actual operation.

2. Designing of the IED Disruptor

Two different 3D models of conical water containers were developed that can store up to 500 mL of water (as shown in **Figure 3**). The first model of the conical water container is a plain cone with two clips placed near the base and vertex of the cone (as shown in **Figure 3a**). These two clips that fasten both ends of the detonating cord coiled at the cone's surface, and this model was labeled as Sample A. The second design is also a cylindrical cone structure designed to have grooves that guide the coiling of the detonating cord (as shown in **Figure 3b**). The number of grooves designed was equal to the minimum recommended number of coils of detonating cord suffice for a successful IED detonation. This model was labeled as Sample B. The 3D model of the entire assembly of the IED disruptor is shown in **Figure 4**. As shown, the design of the packaging box is compact, and is simple to hold for easier mobilization of the IED disruptor during operation. This packaging box includes a pair of tilt-adjustment stands that helps easy deployment of the disruptor even in an uneven area.

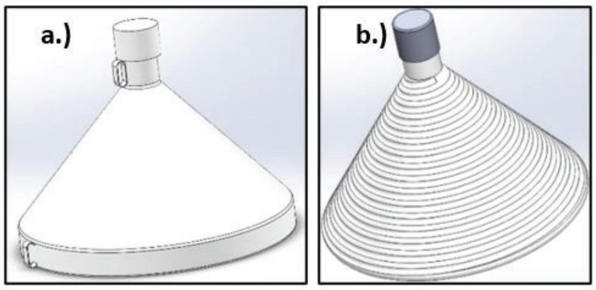

Figure 3. 3D model of the conical IED disruptor

*4 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*5 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*6 *Chief Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

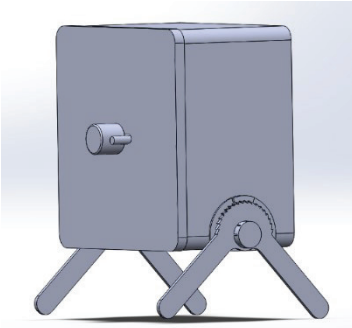

Figure 4. 3D model of the IED disruptor assembly

3. Slicing of the 3D model of the IED Disruptor

Ultimaker Cura software was used in slicing the 3D model of the IED disruptor components (as shown in **Figure 5**). This software was used to convert the 3D model files into commands that convert the 3D model object into gcode for the 3D printer [3]. This slicing software was used to apply values in the print settings and control how the IED disruptor components should be built inside the 3D printer. **Table 1** summarizes some important print settings used in 3D printing of the IED disruptor components. The listed parameters significantly affected the cost and quality of the IED disruptor.

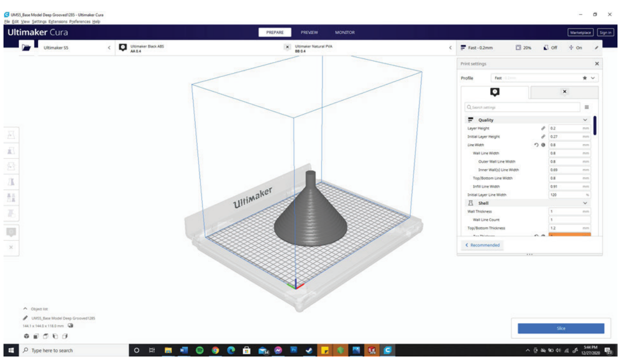

Figure 5. Screenshot of the slicing software used in printing the IED disruptor.

Table 1. Print settings used in slicing the 3D model of IED disruptor components

Printing parameter	Value
Layer Height	0.2 mm
Line Width	0.8 mm
Wall thickness	2.4 mm
Print Speed	70 mm/s
Print Temperature	200 °C
Print supports	None
Build plate adhesion type	Brim

4. 3D printing of the IED Disruptor

Ultimaker S5 Fused Deposition Modeling (FDM) 3D printer was used to fabricate IED disruptor components (as shown in **Figure 6**). Sample A was printed using the setting listed in **Table 1** with an additional wall as shown in **Figure 6b**. Sample B was also printed using the same setting, but the spiralized outer contour was enabled (as shown in **Figure 6c**). The material used in the printing was PLA and TPU for the cap of the conical water container. A regular glue stick was used to ensure a better bedplate adhesion.

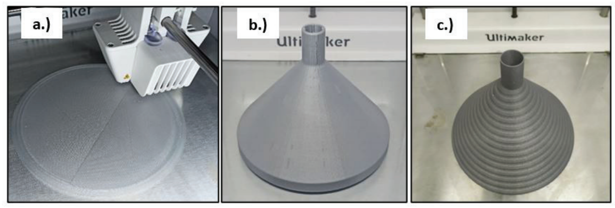

Figure 6. Image of the conical water container a.) During printing and images after printing the b.) Sample A and c.) Sample B models

Results and Discussion

1. Printing preparations and considerations

Printing time is generally highly dependent on the size, complexity, and print setting used [4]. The conical water container and packaging box were printed using the spiral outer contour mode. This setting was used to print the model more quickly and to print the cone's cross-section continuously, which resulted in watertight prints [5]. This setting also sets the number of wall lines to one. The number of wall lines indicates the thickness of the container's shell. This was sufficient to hold the water for the conical container and contained the water-filled conical container. Additionally, this reduces material consumption and eliminates the loss of intensity associated with water bursting during the operation. Both the layer height and line width were set to 0.2 mm and 0.8 mm, respectively.

In printing all of the components that resulted in thicker layers that somehow compensate the thin walls of the conical water container and packaging box due to the minimum number of walls used in the fabrication.

2. Water leak test

Additionally, a water leak test was conducted to determine the presence of water leaks in the 3D printed

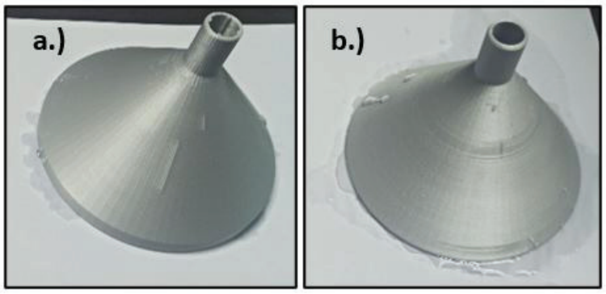

Figure 7. Images of the Sample A of the conical water container taken during water leak test in a.) Trial 1 and b.) Trial 2

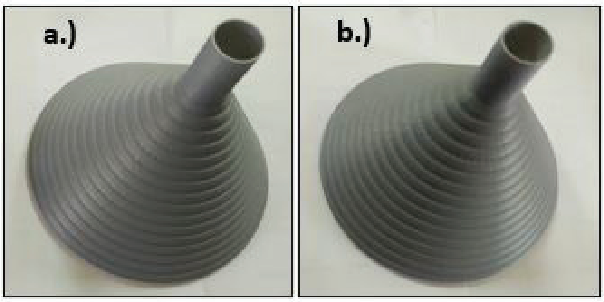

Figure 8. Images of the Sample B of the conical water container taken during water leak test in a.) Trial 1 and b.) Trial 2

conical water container. Water leaks can be seen in some areas of Sample A, including the cone's body and base edges (as illustrated in **Figure 7**). Water leaks formed in the cone's base edges and body can be attributed to the material's non-continuous extrusion on the top of each layer, which resulted in spaces or gaps between layers forming between the model's two walls [6].

To test the capabilities of the 3D printer, the spiral outer contour printing parameter was used to print Sample B. As illustrated in **Figure 8**, there are no visible water leaks. Sample B was printed in a single wall with a continuous material extrusion, resulting in a smooth surface devoid of holes or gaps [7]. This setting enables the 3D models to be printed in less time and with less material.

3. Functional Testing

The 3D-printed IED disruptor components were assembled and functionally tested by the RDC, ASCOM, PA, and EOD Battalion and representatives from the AMCen project team. The prototype was evaluated and compared with the improvised IED disruptor in terms of disarming an IED. Other factors to consider include weight, durability, volume, and the number of coils of detonating cord , to prevent inconsistent results. Based on the field testing, the developed IED disruptor has successfully disarmed an IED. The EOD Battalion supervised the test and prepared several IEDs to evaluate and compare the 3D printed and existing disruptors.

Conclusion

The IED disruptor components were successfully fabricated using the available AM technology housed in AMCen. All the components were 3D printed using PLA and TPU for the conical water container caps.

This study presented two different design models of conical water containers, which is one of the major components of IED disruptors. Sample A model, was designed to be more rigid and durable by printing it on a double wall. It was found that printing in two (2) or more walls produced spaces and gaps in between

Figure 9. Image from the field testing in Unknown Distance Range (UDR), Brgy. Lawi, Capas, Tarlac

layers that resulted in water leaks. The sample B model was designed to have a single wall that enabled the spiral outer contour setting. This setting helps the design to be watertight and more cost-effective in fabrication.

This project gave the Philippine Army a standard design and specifications for an IED disruptor that can be included in the Philippine Army inventory to be used by the EOD Battalion to contain any IED or blast it in place under controlled conditions from a safe distance, ensuring the safety of soldiers.

Suppose the demand increases to quantities that will require mass production of the prototype, the design of the developed IED disruptor is compatible with plastic injection molding. MIRDC, through the Die and Mold Solutions Center, may also assist with the development of a plastic injection mold for the developed IED disruptor.

Acknowledgment

This work is a part of the project, Development of Conical Plastic Container and Packaging Box for the Improvised Explosive Device, in collaboration with the Research and Development Center (RDC), Army Support Command (ASCOM), Philippine Army (PA). We would like to acknowledge the DOST-MIRDC staff in the fabrication of a 3D printed IED disruptor and its field testing in Unknown Distance Range (UDR), Brgy. Lawi, Capas Tarlac.

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Rapid Prototyping of Column for Radiation-Grafted Adsorbents for Wastewater Filtration

Jose Bernardo L. PADACA III[*1], Maria Angela B. FAUSTINO-LOPEZ[*2], Johann Rafael D.B. BISCOCHO[*3], Alvin M. BUISON[*4], Fred P. LIZA[*5]

Abstract

Rapid prototyping of column for radiation-grafted adsorbents for wastewater filtration was done through a research project in collaboration with the DOST - Philippine Nuclear Research Institute. This was done via fused deposition modelling using polycarbonate for most parts (side wall, top and bottom caps, and core), and thermoplastic polyurethane for the O-rings. The design used for the column was based on household filter systems, and its slit openings and total area was optimized based from a flow simulation. Prior to 3D printing of the whole assembly, separate parts were printed to test fittings, and offset clearance was adjusted from the initial 0.1 mm to 0.3 mm which provided the perfect fitting. The final prototype was subjected to functional test, and a flow rate of 178 ml/min, which is at service requirement acceptable value. Furthermore, no leaks were detected, demonstrating the viability of additive manufacturing for enclosures requiring leak-tightness.

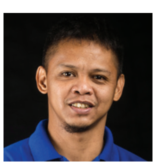
Keywords: *Additive Manufacturing, Plastic Enclosure, Fused Deposition Modeling*

Introduction

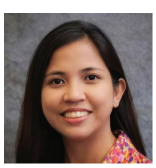
Additive manufacturing (AM) or 3D printing is the process of building an object layer-by-layer from a digital design [1]. The process of AM is in contrast with traditional methods of subtractive manufacturing which cuts, drills, and grinds away excess material from a bulk piece. This makes AM an eco-friendly way of producing parts. Also, since the part model is from a digital design, it can be easily modified when optimizing, speeding up the prototyping stage. AM can greatly benefit organizations in their production process.

In the Philippines, an additive manufacturing facility has recently been established, the Advanced Manufacturing Center (AMCen), housed at the Department of Science and Technology - Metals Industry Research and Development Center (DOST-MIRDC) [2]. One of its thrusts is to support research and development institutes in developing their prototypes. One of the projects implemented by AMCen in the past year is in collaboration with the DOST - Philippine Nuclear Research Institute (DOST-PNRI), on the development of a radiation-grafted adsorbents filter column. In the early stages of the project, PNRI-CRS project team utilized rudimentary set-ups using simple beakers, syringes, and PET bottles.

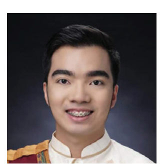
This work presents the rapid prototyping of a column enclosure for PNRI's filtration system, which provides the controlled flow characteristics required to ensure efficient performance. Additive manufacturing by fused deposition modeling was employed, using polycarbonate (PC), to fabricate the column enclosure. The model used for the enclosure was optimized using a Solidworks Flow Simulation; the specifics of the simulation studies will be reported elsewhere.



*1 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines



*2 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines



*3 *Science Research Specialist I*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

Materials and Methods

Design Optimization and Column Filter Model

The design for the project was initially created from available water filters used in households. However, the team needed to achieve a set of parameters for the project, specifically a required flow rate of at least 150 bed volumes per hour, and cores which are better optimized for easier placement and maintenance. Through simulation, the following optimized dimensions to achieve specified parameters for the column filter model were obtained:

Table 1. Dimensions for the optimized core configuration

Core slit configuration	Inlet opening diameter	Slit height	Slit width	Number of slits	Inlet opening area	Total slit opening area
50mm-50mm Offset 0.3mm slit width	13 mm	81.5 mm	0.3 mm	4 mm	132.73 mm	97.8 mm

As verified by simulation, this design will achieve the target flow rate of not less than 150 L/hr, as well as modularity and easier maintenance in replacement of fully saturated filter material. Also, from initial discussions of the design, it was agreed to use polycarbonate (PC) as the material of choice for 3D printing, due to the possibly harsh chemical nature of wastewater. The design of the column filter is shown in **Figure 1**.

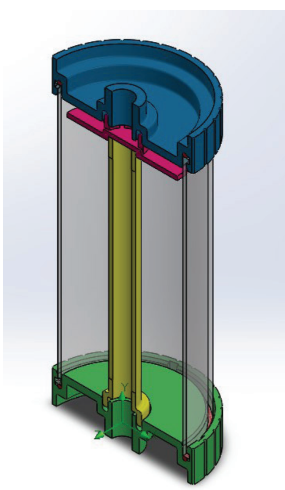


Figure 1. Column Filter Design; Components: blue - top cap, green - bottom cap, clear - side wall, yellow – core, pink - core barrier, red - O-rings/ gasket

The main chamber of the column consists of the top cap, bottom cap, and the side wall. The top and bottom caps are identical to minimize future tooling requirements. They are mated together by a twist-locking mechanism. O-rings are placed in between mating surfaces so they are compressed during the twist-lock action, ensuring leak-tightness.

The core's functions are as follows: a.) evenly distribute flow along its length and; b.) act as support around which filter fabric is wound. The core barrier ensures that wastewater coming out from the top slits of the core do not go directly to the outlet. It directs the water to flow outward first, passing through the filter fabric layers, before exiting through the outlet.

Rapid Prototyping of Column Filter Model

To be able to create a prototype while consuming as little time as possible, 3D printing was employed, specifically fused deposition modeling (FDM). The FDM process involves the use of a filament (usually polymers such as PLA, ABS, PC, PP, etc.), and is fed into a heated nozzle. As the plastic is melted, it flows through the nozzle and is deposited onto a stationary build platform, whose path is determined through the sliced CAD model. This process is repeated layer by layer, until the part is complete. **Figure 2** shows a schematic diagram of the FDM process. [3]

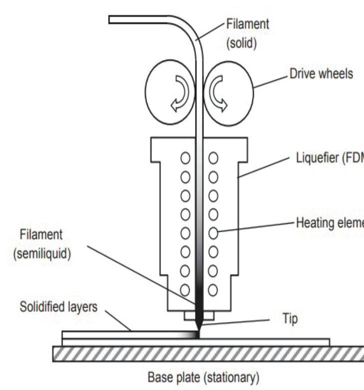


Figure 2. Schematic diagram for the FDM process

**4 Sr. Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

**5 Chief Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

Printer Parameters and Part Preparation [4-5]

Before the CAD model is placed into the machine, a process called slicing is performed. The slicing process involves adjustment of parameters that will affect the quality of the print. While there are a multitude of parameters that can be adjusted, the following parameters will dictate the quality of print the most:

1. *Print Orientation* - the mechanical properties will differ along different directions, as 3D printing is a directional process. As the bonds of the material tend to be weaker along layer lines, it is important to consider the functionality of the part and the stresses it will experience, to determine the optimal print orientation.

2. *Layer Height* - this describes how high one layer of the part will be. This parameter affects mechanical and dimensional properties, as well as the aesthetics of the part. Smaller layer heights lead to finer details and more precise dimensions; however, it also leads to more layer lines, which are the weakest bonds. The layer height used in the prints is 0.1 mm.

3. *Print Density* - affects the mechanical strength of the part. Higher density means a stronger part; however, it will take longer printing time and more material. The infill density used in the prints is 100%.

4. *Print Speed and Temperature* - the bonds of each layer of the material are dictated by these parameters. The bonding may be compromised if the previous layer is allowed to cool for too long before the next layer is placed, and similar issues may arise with bonding integrity if the next layer of material is placed too quickly. The print speed used is 30 mm/s, and the temperature used is 270ºC, which is the recommended temperature when using Ultimaker PC.

These parameters are what the designer deemed to be the best balance to achieve the best quality and the needed parameters for the project. A record of all parameters used is kept for later comparison, should further samples be analyzed.

Functional Testing

The assembled final prototypes were tested at the PNRI Chemistry Research Section for to evaluate whether the target flow rate of 150 ml/min as well as leak tightness of the design was achieved.

The filter fabric was wound around the core to be able to measure the flow rate. Water is introduced by a pump through the inlet, passing through the core, across the layers of filter fabric and then upwards to the outlet. The water then drains through a hose and into a graduated cylinder where the volume can be measured. The whole process is timed with a stopwatch to determine the flow rate. **Figure 4** shows the functional testing set-up.

Results and Discussion

Prior to 3D printing of the whole assembly, parts were printed to check fitting. This is to eliminate guesswork and unnecessary material waste; an initial set of test prints were printed. This is to ensure that material shrinkage is accounted for, and to ensure perfect mating during assembly.

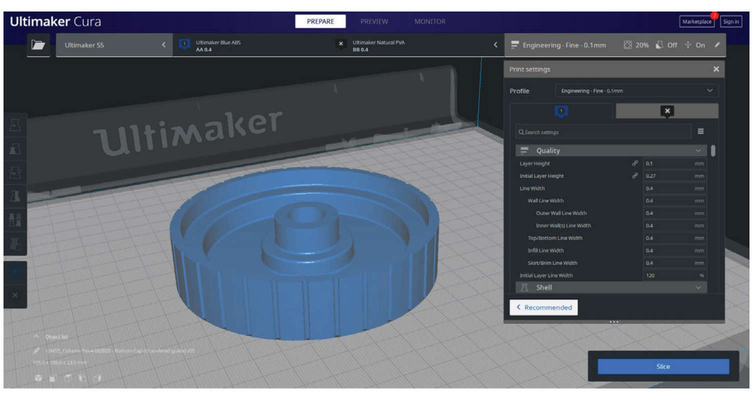


Figure 3. Screenshot of the slicing software interface

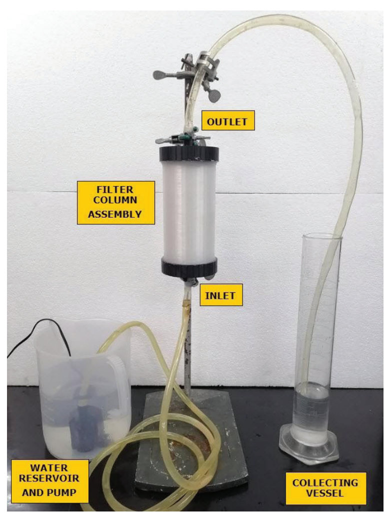


Figure 4. Testing set-up for flow rate measurement of water passing through the column

Figure 5. (left) Fit check portion for the top/bottom cap and (right) fit check of O-ring and top/bottom cap

Figure 6. (left) Fit check for top/bottom cap and core interface; (right) fit check for top/bottom cap and core interface – mated

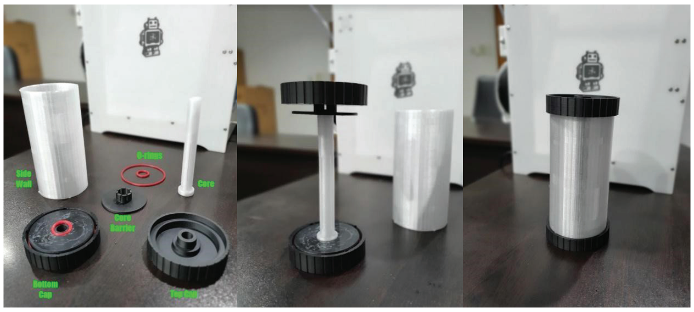


Figure 7. (left) Individual printed components, (middle) internal assembly, and (right) the full assembly

Figure 8. Hose Barbs and Spanner

Figure 9. (a) full assemblies of the final prototype (b) internal assembly components of the final prototype showing the core and core barrier

The mating portions of the individual components were fit-checked together, as seen in **Figures 5** and **6**. Necessary adjustments were made until perfect fitting was achieved. The parts were then printed in their entirety once the adjustments were finalized.

The final printed parts are shown in **Figure 7**. The final printed dimensions were recorded, and subsequently compared to the 3D models to determine any other shrinkage. In the full print of the final parts, two PC filament colors were chosen, Black PC (for bottom/top cap, core barrier, hose barbs, spanner) and Clear PC (for side wall, core). O-rings were printed using thermoplastic polyurethane (TPU) material due to unavailability.

A pair of hose barbs and a spanner were also printed, to aid in the assembly set-up for functional testing, and are shown in **Figure 8**.

With the results of the fit check and functional testing, a final design prototype was created. As per the fit check, an offset clearance of 0.1mm between mating surfaces is insufficient. The offset clearance was adjusted to 0.3mm which provided perfect fitting of the parts. The final prototype filter column is shown in **Figure 9**.

The results of the functional test of the optimized configuration are presented in **Table 2**. The flow rates for without and with the wound filter are at service requirement acceptable values of 123 ml/min and 178 ml/min, respectively. Furthermore, no leaks were detected, signifying the viability of 3D printing in producing enclosures, which will be subjected to water flow and requiring leak tightness, although a layer-by-layer additive process.

Table 2. Functional Testing Results

Flow Rate Without Filter	Flow Rate with Filter	Leak-tightness
123 ml/min	178 ml/min	No leaks detected

Further functional tests will be performed by the PNRI CRS in order to evaluate filtering efficiency of the system by using inductively-coupled plasma optical emission spectrometry. Visual inspection of the color intensities of the used filters can also be done in order to evaluate the uniformity of the flow of the wastewater.

Conclusion

The viability of using additive manufacturing for the rapid prototyping of a wastewater filtration column was demonstrated. The design was based on household filter systems, and optimized dimensions were based on Solidworks Flow Simulation. The column assembly was composed of the top and bottom caps, the side wall, the core, the core barriers which were all printed in polycarbonate; and the O-rings were printed in thermoplastic polyurethane. The service requirement of having a leak tight column was achieved by considering shrinkage as well as dimensional tolerances between mating parts.

Acknowledgment

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Investigation of Dimensional Accuracy of a Maritime Enclosure Produced Using Additive Manufacturing

Leif Oliver B. CORONADO*1, Earl John T. GERALDO*2, Joseph Alfred V. GARCIA*3, Marc Adrian O. YU*4, Anjenina U. DURANA*5, Alvin M. BUISON*6, Maria Angela B. FAUSTINO-LOPEZ*7, Jose Bernardo L. PADACA III*8, Fred P. LIZA*9

Abstract

The development of additive manufacturing and emergence of new 3D printing technologies provide rapid progression in creating prototypes. The 3D printing process involves depositing material layer by layer which is based on the data of the 3D Computer-Aided Design (CAD) files that simplify the fabrication. This allows the creation of complex geometries of a wide range of materials such as polymers, metals or ceramics. However, the dimensional accuracy of the actual printed parts may vary. In this study, the dimensional accuracy of the 3D-printed enclosures with different materials produced using an extrusion based printer were investigated. The materials used are polycarbonate (PC), chlorinated polyethylene elastomer (CPE) and tough Polylactic Acid (PLA). The dimensional accuracy of the diameters, length, thickness, and width are measured using precision devices such as micrometers and gages. The results indicate that for the 3D-printed inner diameters, PC has the highest dimensional deviation with a maximum of 36.75%, next to CPE with 17.75 %, and PLA with 11.5 %. PC also manifests elevated dimensional change in terms of the outer diameters with 11.86% maximum. For future work, study of the dimensional change behaviour per type of technology and model profile is recommended.

Keywords: *Additive manufacturing, Dimensional analysis, 3D printed enclosure, Dimensional accuracy, Transponder casing*

Introduction

Additive manufacturing, or better known as 3D printing, is being used increasingly in rapid prototyping and end product fabrication in many fields. With 3D printing, parts can be designed to custom-fit or have specialized applications. One of the biggest challenges of these parts is dimensional accuracy, especially critical for engineering products that require high tolerances which provide functions such as waterproofing. Shrinkage and warping of the material is governed by thermal expansion. This, along with many other variables that occur during the process of 3d printing, reduce the dimensional accuracy of the product. Studies have been done on the variables that affect dimensional accuracy such as the effects of different printing parameters on PLA prints [2]; the effects of using different filaments like ABS, HIPS, PVA [1]; and even the effects of modifying the internal structure/ geometry to compensate for shrinkage [3].

This study will look at the accuracy of linear and radial dimensions, particularly in small builds using a custom enclosure for maritime use as basis. The enclosure was printed in PC, CPE, and tough PLA. Print settings directly impact the dimensions of the output part. To limit the variability of the prints, Ultimaker, a 3D printer manufacturing company, provides preset or “intent profiles” for different printing materials. Using the same profile that is already designed by the manufacturer, certain points on the enclosure will be checked and compared to the 3D model.

*1 *Sr. Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

*2 *Science Research Specialist II Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

*3 *Sr. Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

Materials and Methods

In this study, the dimensional accuracy of parts fabricated using additive manufacturing were investigated. Ultimaker S5, an extrusion based 3D-printer, is used to create the parts. The enclosure is printed in three (3) different materials. The parts are measured using precision metrology devices such as micro-meters and gauges.

Printing Parameters

After acquiring a CAD file, a slicing software is used to set and edit the printing parameters. These include the placing of support and setting the profiles to be used while printing. The slicing software used in this paper is Cura which is the official software for Ultimaker S5. Cura has multiple printing parameters that can be customized to provide the optimal prints. Default profiles are provided based on common printing parameters based on different material data. Cura has multiple default profile types, these are Default, Visual, Engineering and Draft. These profile types and different layer heights are available depending on the material type. **Figures 1** and **2** show the available profile type for printing with PC, CPE, and Tough PLA. **Figure 3** shows the difference between the profiles.

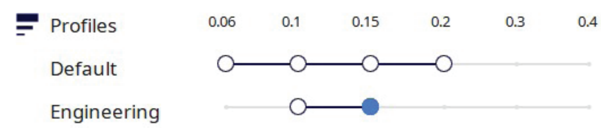


Figure 1. Available profiles for PC and CPE from the software, Cura.

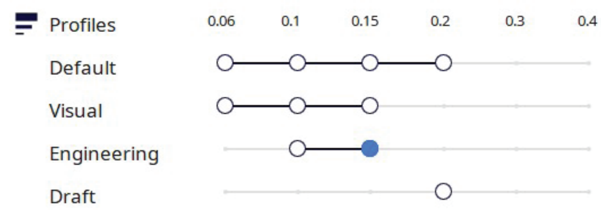


Figure 2. Available profiles for Tough PLA from the software, Cura.

The profiles were designed by Ultimaker and their Ultimaker Material Alliance Program where companies can share developed print profiles for different materials. The engineering profile for 0.15 mm layer height was chosen for the three materials since it has a heavy emphasis on dimensional accuracy [4][5].

Infill

Part infill determines how dense the internal part of the print is. This has a direct impact on part strength, print weight, and print time. An infill density of 30% was used for all three materials. **Figure 4** shows a cut-out of the enclosure where the part infill can be seen.

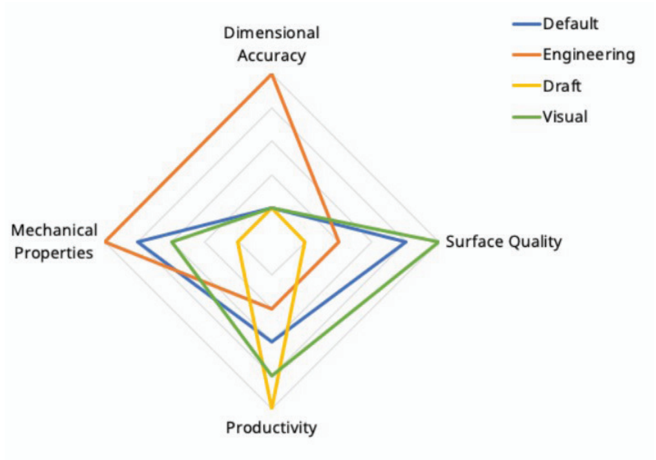


Figure 3. Visualization on the different default profiles.

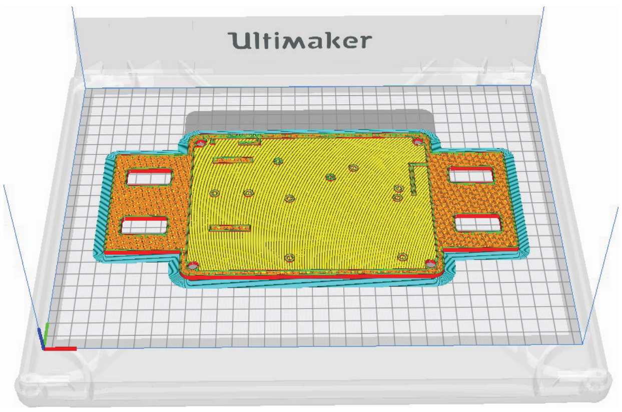


Figure 4. Print preview showing part infill.

*4 Science Research Specialist I
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*5 Science Research Specialist I
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*6 Sr. Science Research Specialist
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

Figure 2. Improvised IED Disruptor

Temperature

The printing temperature is the temperature that the nozzle maintains during printing. This is dependent on the printing materials' thermal properties. The printing temperature directly impacts material flow and print performance. For the Ultimaker S5, the build plate is also heated and is used for better first layer adhesion of materials. **Table 1** contains data provided from Ultimaker's material data sheet (Recommended) as well as the actual printing temperatures from the engineering profile.

Printing Speed

This setting controls the extrusion rate of the printed material. This directly impacts print quality as well as the overall print time. Cura allows the speed control for different parts such as outer walls, inner walls, and infills. This is for fine-tuning the printer in case of over or under extrusion. **Table 2** contains data on the actual print speed used from the different profiles for 0.15 layer height.

Figure 5 shows the 3D printed enclosures that were measured in this study.

Dimensional Metrology

Using precision tools (feeler gauge, micrometer, etc.), the dimensions of the enclosure were measured and compared with the design. **Figure 6** shows the points measured for all enclosures, while the table shows the design measurements.

Table 1. Printing temperatures of different materials.[5][6]

Material	Recommended		Engineering Profile	
	Build Plate Temp. (ºC)	Nozzle Temp. (ºC)	Build Plate Temp. (ºC)	Nozzle Temp. (ºC)
PC	110	260-280	110	280
CPE	70-85	230-60	85	245
Tough PLA	60	210-220	60	215

Table 2. Printing speeds of different materials for different profiles [6].

Material	Print Speed (mm/s)			
	Default	Engineering	Visual	Draft
PC	50	30	N/A	N/A
CPE	60	30	N/A	N/A
Tough PLA	45	30	45	50


Figure 5. 3D printed enclosures made from (a) PC, (b) CPE and (c) Tough PLA.

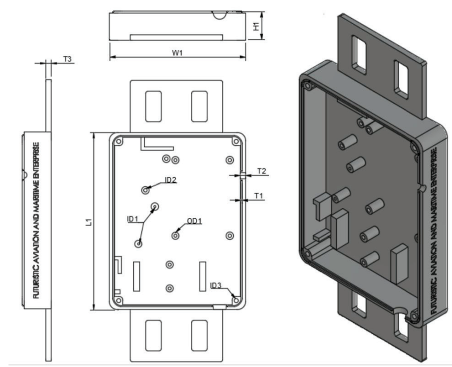
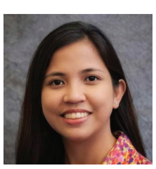
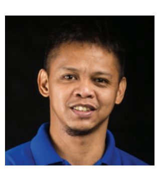


Figure 6. CAD drawing (left) and isometric view (right) of the enclosure.

Table 3. Design (Nominal) measurements.

Designation	Measurement (mm)
OD1	7
ID1	2
ID2	3
ID3	4
T1	1
T2	5
T3	6
H1	27
W1	132
L1	171.5


**7 Sr. Science Research Specialist
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*


**8 Sr. Science Research Specialist
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*


**9 Chief Science Research Specialist
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

Results and Discussion

Table 4 summarizes the data for the linear dimensions (thickness, height, width and length) while the plots summarize the data from the radial dimensions (Outer and inner diameters). From **Table 4**, most of the parameters such as thickness, width, and length for all of the parts measured exhibit shrinkage even at different materials with maximum value of 0.2 mm, 0.57 mm, and 1.05 mm, respectively.

Figure 7 shows the deviation and changes of the diameters from the 3D printed part with different materials. Based on the data, reduction in size is observed for all the inner diameters. For CPE, the three inner diameters decreased by 17.75 %, 11.68 %, and 9.35 %, respectively. For PC, the inner diameters declined about 36.75 %, 18.26 %, and 6.91 %. Lastly, the tough PLA also shows the same trend with shrinkage of 11.5 %, 8.3 %, and 6.75 % for the three different inner diameters.

The trend shows that the outside diameter, which has a nominal size of 7 mm, increased for both CPE and PC by 0.1 mm to 0.3 mm. Meanwhile, the outside diameter of the portion printed using tough PLA shrinks by 0.1 mm maximum. The dimensional deviation in outside diameter is observed for PC material by 11.86 %.

Table 4. Summary of measured values for the different materials.

Dimension	Mean			Standard Deviation		
	PC	CPE	Tough PLA	PC	CPE	Tough PLA
Thickness	-0.17	-0.20	-0.13	0.56	0.52	0.61
Height	0.23	0.51	0.38	0.03	0.04	0.02
Width	-0.57	-0.37	-0.41	0.07	0.36	0.03
Length	-1.05	-0.22	-0.88	0.03	0.10	0.04

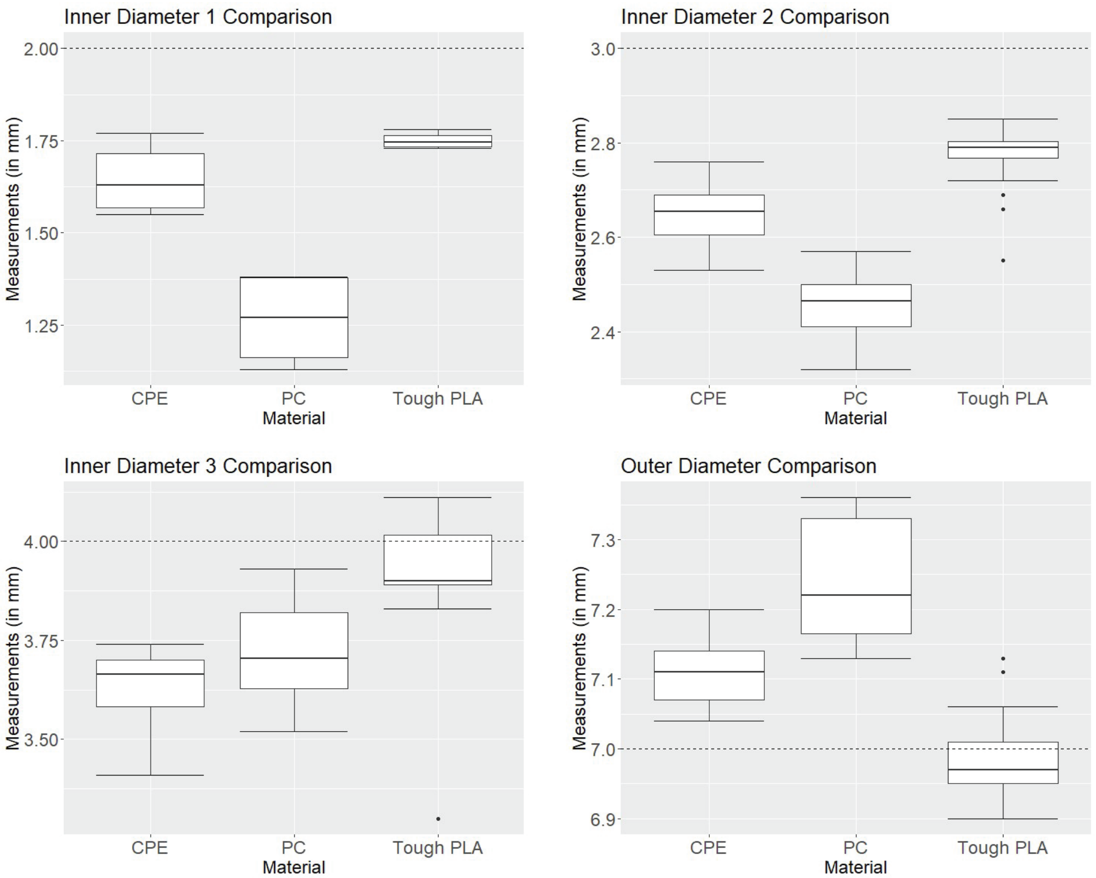


Figure 7. Plots summarizing measured radial values for the different materials.

Conclusions and Future Work

In this study, the dimensional accuracy of a 3D-printed enclosure created using an extrusion based 3D printer is investigated. The parts are varied for three different materials and the findings exhibit shrinkage for all of the printed inner diameter. These vary for as low as 6% up to 36 % dimensional changes for all of the materials. Moreover, a comparable pattern is observed for the outer diameter except for CPE and PC. The deviations in the dimensions are most likely affected by the type of materials and the changes in temperature while the 3D-printing process occurs. The data can be used to adjust the print settings to make the printed part as close as possible to the design.

For future work, study of the dimensional change behaviour per type of technology and model profile is recommended. A more in depth study on shrinkage trend in relation to the material property and printing parameters can be considered.

Acknowledgment

The authors would like to thank the Metals Industry Research and Development Center (MIRDC), Department of Science and Technology - Philippine Council for Industry, Energy,and Emerging Technology Research and Development (DOST-PCIEERD) for funding this research and the Research on Advanced Prototyping and Development Using Additive Manufacturing Technologies (RAPPID-ADMATEC) team for extending their profound knowledge towards the realization of this study.

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Case-depth Uniformity of Pack Carburizing and Vacuum Carburizing: A Comparative Study

Joey G. PANGILINAN*[1], Geoffrey L. ABULENCIA*[2], Ariel R. SERNAL*[3], Serafin G. AGUILAR*[4], Christian D. BRUAL*[5], Randy E. SONGAHID*[6]

Abstract

Carburizing is a heat treatment process that adds carbon on the surface of the steel producing a hardened surface resistant to wear while retaining a soft and ductile core. The added carbon diffuses further to a certain depth and is highly dependent on temperature and carburizing time. Pack carburizing is the current practice of local industries to harden low carbon steels owing to low equipment cost it necessitates. Steels are packed in a stainless steel box filled with charcoal and barium carbonate is added as energizer. This method was compared to a vacuum carburizing, a more advanced carburizing process wherein the steels are carburized under low pressure and acetylene is used as carburizing gas. A simulation software was used to determine the vacuum carburizing parameters. Case-depth uniformity of pack carburized and vacuum carburized rice thresher pegs made of low carbon low alloy steel bolts were compared. Case depth was determined in accordance with SAE-J423 standard. As defined by the standard, effective case depth was determined by taking linear microhardness measurements spaced at least 100 microns apart on a ground, polished and etched cross-section of both pack and vacuum carburized specimens, starting from the surface up to a certain depth with an equivalent hardness of 50 HRC. Total case depth was determined by measuring from the surface up to the line of demarcation between the case and core. To assess the uniformity, three measurements were taken on different locations. The measured total case depth on vacuum carburized specimens is near the 0.4mm case depth set in simulation software. Vacuum carburized has +/- 31.5 microns variation based on three (3) hardness measurements, while pack carburized has a variation of +/- 230 microns. Overall, the vacuum carburizing produced a more consistent carburized layer than pack carburizing

Keywords: *Case hardening, pack carburizing, vacuum carburizing, case depth uniformity*

**This was presented on METCON 2021 on October 22, 2021.*

Introduction

The MIRDC offers technology solutions to industry to improve their products, processes, and services. Among the services that are offered at MIRDC are the research and development and heat treatment process. In this project, the customer, Aton Marketing, requested MIRDC's technical assistance to extend the service life of the rice thresher pegs, a critical component in the rice threshers they manufacture (see **Figure 1**) [1]. According to them these pegs, in the form of threaded bolts, are made from low carbon steels. Impact and abrasions are the two main concerns during threshing. Low-carbon steels are ductile and soft, thus, they wear easily due to abrasion. The current industry practice is to carburize low carbon steels to improve surface wear resistance by increasing the carbon content while maintaining the toughness of the core. Pack carburizing was therefore recommended to address the concern. Aside from the conventional pack carburizing, the MIRDC also recently acquired a Vacuum Carburizing furnace. For the purpose of comparing the case-depth

*1 *Supervising Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*2 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*3 *Metals Technologist IV*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

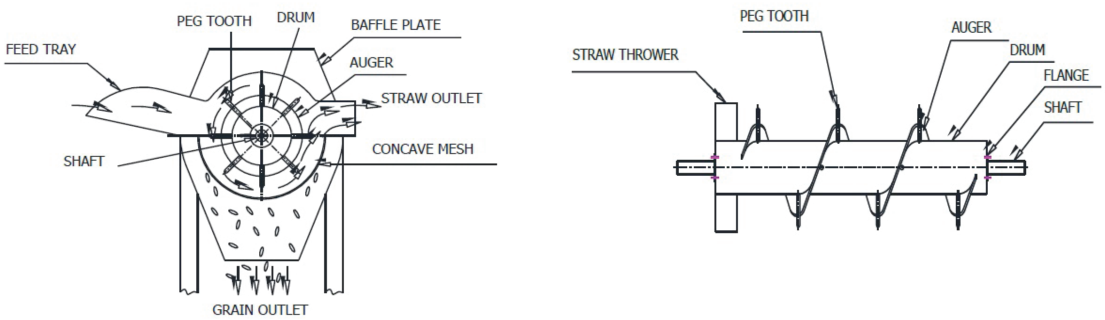

Figure 1. Schematic diagram of rice thresher (left) and peg teeth (right) installed on drum-shaft assembly.

Table 1. Comparison of carburizing processes.

Process	Process temperature		Typical case depth		Case hardness, HRC	Typical base metals	Process characteristics
	°C	°F	µm	mils			
Pack	815-1095	1500-2000	125-1525	5-60	50-63	Low-carbon steels, low-carbon alloy steels	Low equipment costs: difficult to control case depth accurately
Gas	815-980	1500-1800	75-1525	3-60	50-63		Good control of case depth: suitable for continuous operation: good gas controls required: can be dangerous
Liquid	815-980	1500-1800	50-1525	2-60	50-65		Faster than pack and gas processes: can pose salt disposal problem: salt baths require frequent maintenance
Vacuum	815-1095	1500-2000	75-1525	3-60	50-63		Excellent process control: bright parts: faster than gas carburizing: high equipment costs

uniformity, some of the pegs were carburized using this vacuum carburizing technology. **Table 1** [2] compares process characteristics of different carburizing processes. Pack carburizing is one of the oldest heat treating process, but is still widely used due to simple and low equipment cost. But in terms of process control, vacuum carburizing is superior.

Vacuum carburizing is also often termed as Low Pressure Carburizing (LPC) in many technical papers and references as the “vacuum” condition is not really attained during process. It just denotes that the process is being carried out in the lowest oxygen concentration possible to avoid oxidation and contamination.

The objective of the study is to compare the case-depth uniformity of pack and vacuum carburizing processes.

Review of Related Literature

SAE J423 was the basis used in this study for the evaluation of case-depth and case-depth uniformity. Generally, effective case depth is evaluated using the equivalent 50 HRC criterion. Vickers or Knoop hardness tester are usually used since they produce small impressions.

Gorockiewicz, Adamek, and Korecki [3] studied several steels and the microstructure formed at the carburized layer after low pressure carburizing process. The researchers used the 550 HV (approximately equivalent to 52.3 HRC) as effective case-depth criterion for the carburized Ferrium C61 steel. Two sets of processing parameters were used and the hardness results were plotted against the case-depth in millimeters. The effective case-depths were determined by projecting

*4 *Metals Technologist IV*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*5 *Metals Technologist III*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*6 *Administrative Aide VI*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

horizontally from 550 HV in the y-axis until it intersects the graph, and then from this point projected downward the to the x-axis (depth). In an article of Dr. Kuruvilla Cherian [4], same method was applied in the determination of the effective case-depth, except this time a 50 HRC criterion was used. The material used is AISI 8620 gears and are carburized by conventional gas carburizing and AtmoPlas microwave carburizing. He was able to compare the uniformity of the carburized layer between the two processes by analyzing the effective case-depths measured at different test locations. In this study, same method of determining the effective-case depths shall be applied.

In a paper of Hosseini and Li [5], it was reported that it is difficult to obtain in pack carburizing, even with good process control, a total case-depth variation of less than 0.25mm. The variation pertains to the deviation of the maximum and minimum case-depth values from the mean value. In fact, according to them, commercial tolerances start from +/- 0.25mm up to 0.8mm for deeper case depths. This study will adopt the same case-depth variation analysis in assessing the uniformity of the case-depths.

Materials and Methods

A. Preparation and Processing

Pack Carburizing

Bolts with dimension of 100mm (L) x 10 mm (Ø) were tied with GI wires for subsequent water quenching process and then packed with charcoal in a 300x300x600 (mm) stainless steel box. Barium carbonate was added as energizer. Then the box containing the samples was loaded inside the electric furnace (**Figure 2**). Shown in **Figure 3** is the standard hardening cycle performed in MIRDC. The samples were pre-heated at 650ºC for 1 hour, and then austenitized for two hours at 920ºC, followed by water quenching. Lastly, all samples were tempered to the final hardness.

Vacuum Carburizing

For the vacuum carburizing preparation, samples were tied with GI wires also and then were arranged with adequate spacing to ensure proper flow of gases and allow adequate quenchant circulation during carburizing and quenching respectively. **Figure 4** shows the vacuum carburizing furnace of the MIRDC having a hot zone dimension of 600x750x1000mm, and maximum capacity of 500 kilograms. The furnace comes with a simulation software that calculates the carburizing parameters. For this study, the target case depth was set to 0.4 mm. The carburizing cycle is shown on **Figure 5**. An austenitizing temperature of 950ºC was used. Acetylene was used as the carburizing gas. When the temperature of 950ºC was achieved, acetylene gas was introduced for 235 seconds, succeeded by a diffusion time of 265 seconds, and then another boost of acetylene gas for 60 seconds only and then another diffusion time of 20 minutes 40 seconds. Time interval after carburizing pulses allow the carbon atoms to diffuse below the surface of the samples, otherwise, a carbon potential above 0.8% at the surface might be achieved. When this happens, possibility of forming undesirable brittle carbides and soft retained austenite increases.

Figure 2. Sample were packed in a stainless steel box filled with charcoal and barium carbonate is added as energizer (left). The box is loaded inside the electric furnace (right).

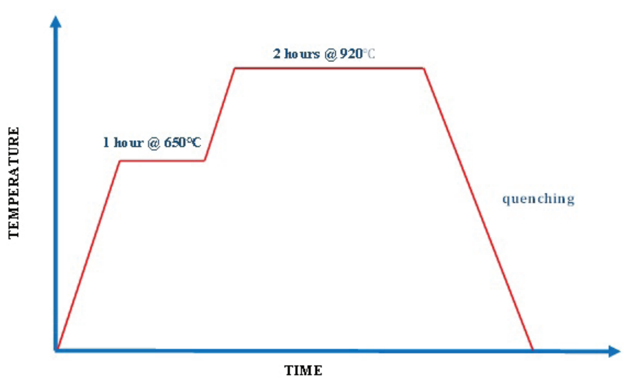

Figure 3. Standard hardening cycle

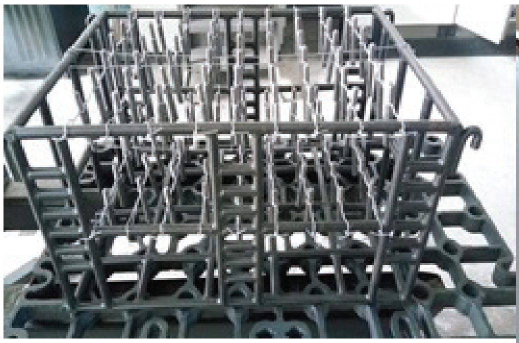

Figure 4. Samples were tied with G.I. wires and arranged with adequate space for subsequent oil quenching (left). MIRDC vacuum carburizing furnace with hot zone dimension of 600x750x1000mm.

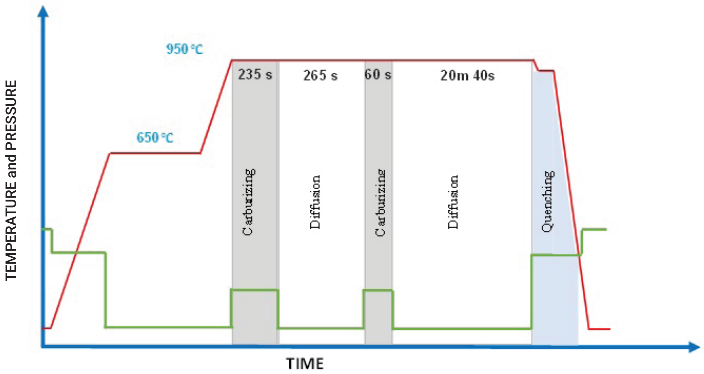

Figure 5. Plot of vacuum carburizing cycle.

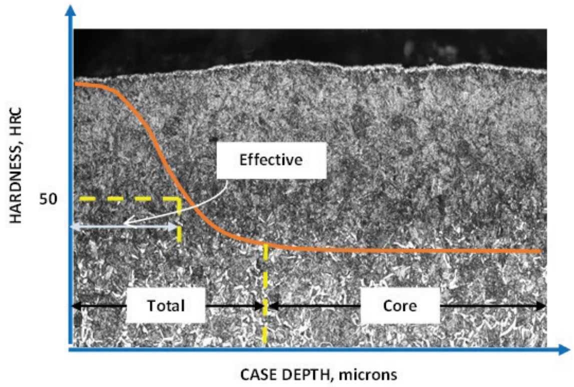

Figure 6. Visual representation of effective and total case depth as defined by SAE J423.

B. Test and Evaluation

For the evaluation of the case-depth, the researchers adopted two of the recommended methods in SAE J423 standard, namely, mechanical (through hardness measurements) and visual or microscopic. Below is the definition of two types of case-depth as defined by the standard [6]:

Effective Case Depth—The perpendicular distance from the surface of a hardened case to the farthest point where a specified level of hardness is maintained. The hardness criterion is 50 HRC normally.

Total Case Depth—The distance (measured perpendicularly) from the surface of the hardened or unhardened case to a point where differences in chemical or physical properties of the case and core no longer can be distinguished.

Shown in **Figure 6** is a visual representation that differentiates the two. The typical hardness profile of a carburized layer decreases with the distance from the surface until a constant hardness is obtained up to the core. For the sample preparation for the visual approach, samples were sectioned, mounted, ground, polished and etched with 3% Nital and then were viewed using Olympus GX53 optical microscope. For the mechanical approach, the hardness was measured using Knoop hardness tester. The obtained data were converted to equivalent HRC.

Results and Discussion

I. Chemical Composition Analysis

One untreated sample was analyzed for its chemical composition. The result did not fall on any standard grade, however, the nearest grade is AISI 5015. Shown in **Table 2** are the actual chemical composition and the AISI 5015 composition based on standard [7]. The customer's material is apparently made of low carbon low alloy steel.

Table 2. Comparison of Actual Chemical Composition and AISI 5015 Standard Limits

	%C	%Si	%Mn	%P	%S	%Cr	%Mo	%Ni	%Cu
Actual	0.18	0.17	0.67	0.020	0.018	0.34	0.0017	0.010	0.014
Standard	0.12-0.17	0.15-0.30	0.30-0.50	0.035max	0.040max	0.30-0.50	-	-	-

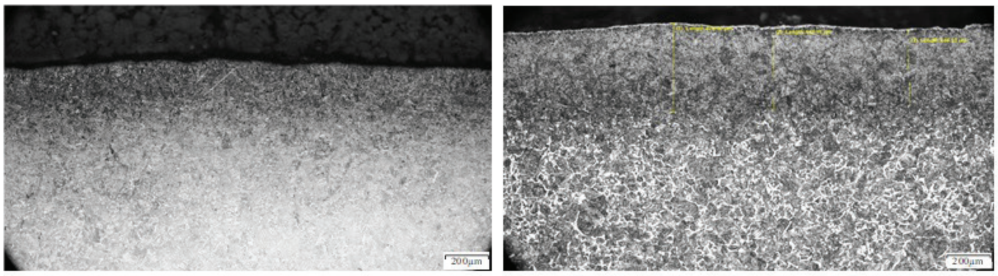

Figure 7. Case hardened layer is more distinguishable from the core in the vacuum carburized sample (right).

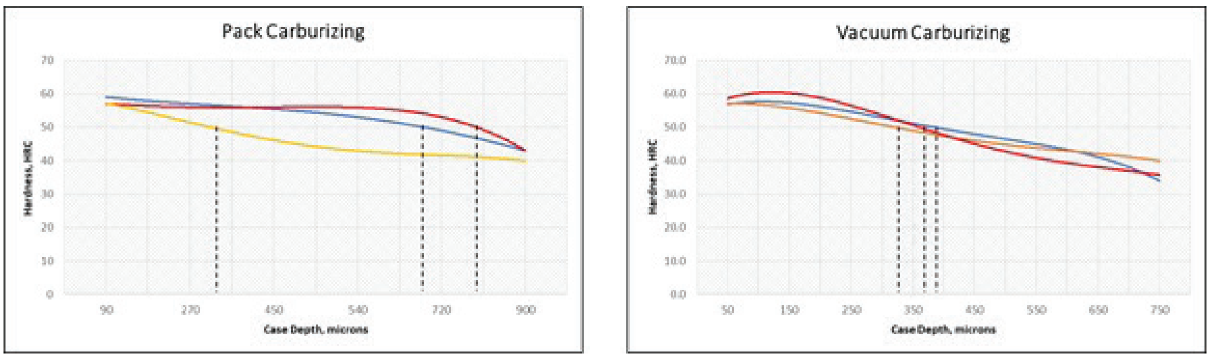

Figure 8. Graph showing the closeness of the measured effective case depth values for vacuum carburized (right) compared to pack carburized (left) samples.

II. Visual Inspection

Determination of the total case depth using microscopic technique is generally easier to apply but still depends on the quality of the preparation to reveal demarcation line between the case and the core. Photomicrographs at 100x magnification for pack and vacuum carburizing were compared. Visually, a demarcation line between the carburized layer and the core is more pronounced on vacuum carburizing. It is therefore easier to measure the total case depth. The three measurements ranged from 446 to 478 microns and are approximately near the 0.4 mm or 400 microns target case depth.

III. Hardness Measurements

To evaluate the effective case depth, linear microhardness measurements at an interval of 90-100 microns were taken starting from the surface up to a certain depth with a hardness equivalent to 50 HRC. Looking at **Figure 8**, the blue, red, and orange lines are hardness measurements of the case at three different locations. The projections to the x-axis are the approximate case depth at which the hardness is 50 HRC. The results gave a range of 330-790 microns or a variation of +/- 230 microns for pack carburizing. While vacuum carburizing has a range of 325-388 microns or a variation of +/-31.5 only.

IV. Impact Toughness

Significant amounts of alloying elements such as chromium increase hardenability of the low alloy steels. In this case, an evaluation of the core microstructure revealed a continuous network of grain boundary ferrite and formation of martensites. This observation is consistent with the obtained microhardness values in the approximate range of 37-43 HRC. This has a direct effect on the toughness of the samples. In fact, a brittle fracture was obtained after conducting a qualitative impact bending test by smashing the bolt with hammer while one end is clamped (see **Figure 9**). This batch of samples having high surface hardness but low impact

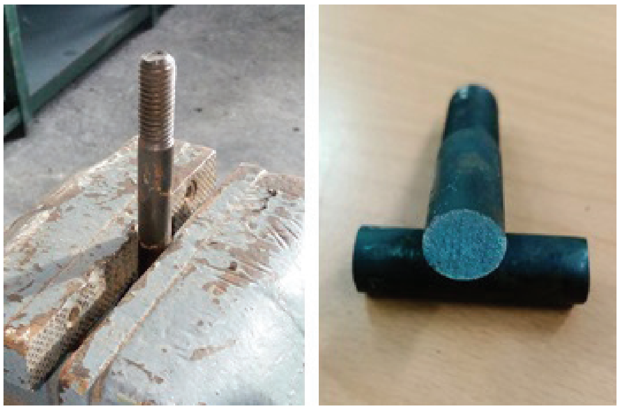

Figure 9. A flat fracture surface (right) indicative of brittleness was obtained by smashing with hammer while one end is clamped (left).

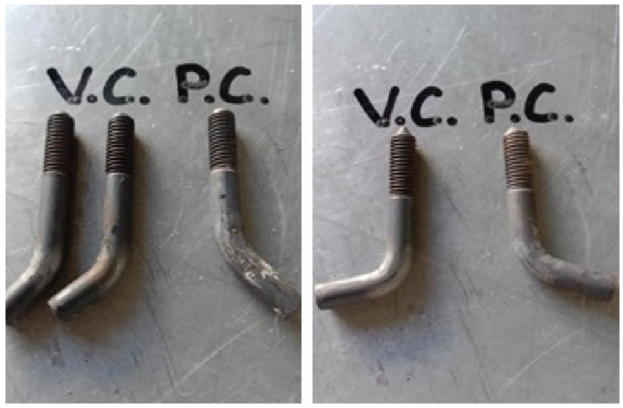

Figure 10. Samples did not fracture when manually tested for static bend test using G.I. pipe (left) and impact bend test by smashing with hammer. Vacuum carburized bolts were labeled as VC, while pack carburized bolts as PC.

toughness properties will be verified if sufficient for their function once subjected to actual operations by Aton Marketing.

To provide an option, a batch of samples was tempered to a final surface hardness of 30-40 HRC (converted from HRA). These values were chosen with the objective of increasing core toughness by bringing down the core hardness to less than 25 HRC. This batch has lower surface hardness, but higher impact toughness. **Figure 10** shows a simulation of static and impact bending test respectively. This time, the bolts did not fracture, hence tougher.

Conclusion

1. The measured total case depth for vacuum carburized specimen is near the 0.4mm case depth set in simulation software. Vacuum carburizing therefore has better process control than pack carburizing.

2. Vacuum carburized specimen has better results over pack carburized in terms of case-depth uniformity. Vacuum carburized has +/- 31.5 variation based on three (3) hardness measurements, while pack carburized has a variation of +/- 230.

3. Overall, the vacuum carburizing produced a more consistent carburized layer than pack carburizing.

Acknowledgment

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)” and “Development of Column-Packed Adsorbent for Chrome Recovery from Tanning Wastewater (PCIEERD Project No. 08517).”

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Process Research

Design and Development of Blanking Die and Forming Die of Blades of a Two-Blade Stainless Steel Propeller for Small Fishing Boat - Alternative Stamping Tools and Methods to Manual Forming

Ronie S. ALAMON*[1], Raymond S. DE OCAMPO*[2], Joein L. LUCES*[3], Isidro D. MILLO*[4]

Abstract

This study presents the design and the development of a blanking die and a forming die of blades of a two-blade stainless steel propeller for a small fishing boat. The use of blanking die and forming die serves as alternative stamping methods to the manual forming of blades in order to maintain the consistency of the geometrical form of the blades and produces a symmetrically balanced two-blade propeller.

Index Terms: *Blanking die, forming die, two-blade propeller, stamping method*

Introduction

The Philippines is still one of the top fish-producing countries in the world being an archipelago with more than 7,100 islands. Millions of Filipinos are engaged in small-scale marine fishing using fishing nets and small fishing boats [1]. These small fishing boats are classified as motorized municipal fishing boats with lengths ranging from 5 to 18 meters, 0.5 to 2.9 gross tonnage (GT), and powered by a 3-16 HP gasoline or diesel engine. Usually, a Briggs and Stratton or Kohler engine is directly coupled to the shaft to which a two-blade stainless steel propeller is attached. Its rudder is usually controlled by means of a long pole attached to the rudder arm. Gill nets, hand-lines, traps, small ring-nets, and other small gears are usually operated from these boats. [2]

The two-blade stainless steel propeller is a rotating fan-like structure which is used to push the small fishing boat by using the power generated and transmitted by the engine. The transmitted power is converted from rotational motion to generate a thrust which imparts momentum to the water, resulting in a force that acts on the fishing boat and pushes it forward [3]. Some two-blade propellers are made of aluminum alloy, bronze alloys, or even galvanized carbon steel depending on the market availability and price. It also comes in various sizes and thread diameters depending on the size shaft and brand of the engine of the fishing boat. Thin blades require stainless steel material which is known for high strength and durability.

Aluminum and bronze alloy propellers are usually cast and may not be readily available to remote areas of the country. Those materials are also expensive and not popular with fishermen, local boat fabricators, and machines shops. Local fabricators and machine shops commonly produced manually forged mild-carbon steel propellers.

ATON Marketing - a local company and fabricator of propellers for small boats in Antique, Island of Panay, uses a wooden jig with a screw-type propeller blade geometry in their fabrication processes. A 1mm to 2mm carbon steel plate is cut into the size of the wooden jig using a portable grinding machine. Using a hammer or mallets, they manually form the carbon steel plate at the surface of the wooden jig to form the helicoidal face of the blade. The two blades are then

*1 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*2 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*3 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

welded (using Shielded Metal Arc Welding / SMAW process) inversely to an atypical blade boss. The blade boss is formed through series of M10 nuts stack to each. These nuts were initially welded then circularly ground to remove edges.

Based on the described manual process of ATON Marketing, manual forging is susceptible to inconsistent geometry of blade and non-uniformity of blade spacing which cause underwater noise or even hydrodynamics noise. This noise may not be noticed by the local fishermen but the underwater noise of vessels has destructive effects on marine life according to various studies. In addition, this noise affects the health and comfort of the crew and passengers of the boat. Therefore, reducing this noise will significantly decrease the total noise of the vessel. [4]

Besides the geometrical problems on blades, manual forming takes 10 hours on average to complete that would require not less than three (3) workers / person to complete a cycle of tedious processes. The geometrical problems on blades even for the small boat propeller that has the least number of blades, and the tedious processes involved make the manual forming an inappropriate method in making propellers.

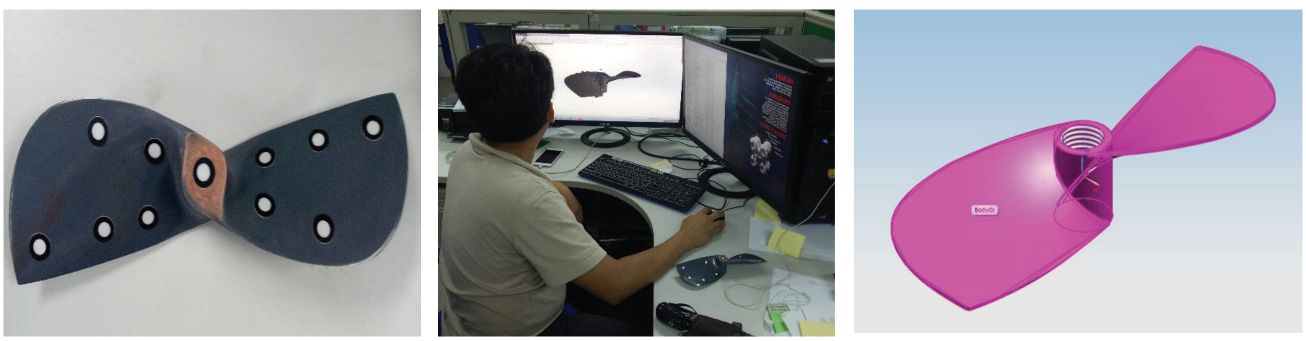
Materials and Methods

A manually formed two-blade propeller referred to as "the specimen" was acquired from ATON Marketing in order to determine its basic characteristics and its geometrical aspects. Visual evaluation and scanning of the specimen were the initial steps.

A. Characterization, Scanning and Measurement of the Specimen's Geometry

The 3D scanning was done through Ceraform Handheld 3D Scanner. This scanner emits some kind of radiation or light and detects its reflection using a camera in order to probe the specimen. The purpose of this 3D scanner is usually to create a point cloud of geometric samples on the surface of the specimen. The point cloud is a large amount of data in the form of a cluster of points, containing the coordinates (x,y,z) of every single point of each surface of the object [5]. These points are used to generate a 3D model of the object using NX CAD software. **Figure 1** (a,b,c) shows some 3D scanning activities.

The 3D scanner works effectively in measuring the complex parts and shapes of the specimen. After scanning, the scanned specimen was adjusted and modified in order to configure a symmetrical and balanced two-blade propeller.



a. The specimen with reference reflectorized dots/ marks

b. Exporting point cloud to NX CAD software for 3D Modelling

c. Exporting point cloud to NX CAD software for 3D Modelling

Figure 1. 3D scanning activities

**4 Supervising Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

Some important characteristics of the specimen were measured and determined using the following techniques/methods:

1. Determining left-hand or right-hand propeller

There are three methods to determine whether the propeller is a left-hand propeller or a right-hand propeller. The first method is the "Blade Angle on Hub" method to determine which way the blades are running from a side angle of the hub. If the blade angle runs from the top left to bottom right it is a left-hand propeller, and if the blade angle runs from bottom left to top right it is a right-hand propeller. The second method is the "Palm Demonstration" in which the hub of the propeller is placed in the palm of a human hand. If the thumb lies comfortably on the blade in your left hand it is a left-hand propeller and if the thumb lies comfortably on the blade in your right hand it is a right-hand propeller. The third method is the "Flow of Material" in which the flow of the material is observed. With a clockwise rotating shaft, a left-hand propeller will direct your material flow downward. A right-hand propeller will direct your material flow upward. A counterclockwise rotating shaft will produce the opposite flow results [6]. Using these methods, the specimen is characterized as a left-hand propeller

2. Diameter Measurement

The diameter of a propeller is the distance across the propeller. If the propeller is viewed from the rear of a small boat and making a solid circle as it spins, the diameter will be the distance across that circle. To measure this dimension measure one blade from the center of the hub to the tip of the blade then double that number to get the diameter [7]. The diameter of the specimen is 215 mm.

3. Pitch measurement

The blades of the propeller extend generally radially from the central hub and have a pitch. The pitch is the theoretical distance a propeller would advance longitudinally in one revolution. Measuring the pitch of a blade is important as blade pitch is a substantial factor in determining the performance of a propeller. This is particularly important where the blades are adjustable as to pitch [8]. The measured fixed pitch of the specimen is 178 mm.

4. Classifying the rake

The propeller skew angle is defined as the greatest angle, measured at the shaft centerline, in the projected plane, which can be drawn between lines passing from the shaft centerline through the mid-chord position of any two sections.

Propeller skew tends to be broadly classified into two types: balanced and biased skew designs. A balanced skew design is one where the locus of the mid-chord line tends initially to be thrown forward of the directrix in the inner regions of the blade span and then backward in the outer regions. In contrast, with a biased skew design, the mid-chord locus tends to predominantly move aft relative to the directrix along the span of the blade. **Figure 2** illustrates these concepts, which tend to be descriptive rather than have any intrinsic quantitative significance. [9]

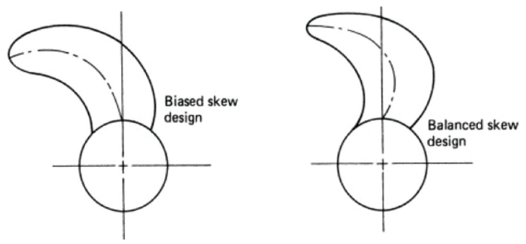


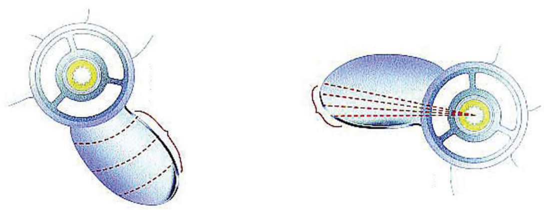
Figure 2. Biased skew design versus Balance skew design

Based on illustrated concepts, the specimen has a balanced skew design.

5. Determining the cup location

When the trailing edge of the blade is formed or cast with an edge curl (away from the boat), it is said to have a cup. Originally, cupping was done to gain the same benefits as just described for progressive pitch and curved or higher rake. However, cupping benefits are so desirable that nearly all modem recreational, high-performance or racing propellers contain some degree of cup. [10]

Determining the cup location would also determine its benefits. If the cupped area intersects pitch lines, as shown in **Figure 3-a**, it will increase blade pitch. Cupping in this area will reduce revolution per minute (RPM) by adding pitch. It will also protect somewhat against propeller "blowout" or "cavitation." If the cup is placed so that it interests rake lines, **Figure 3-b**, it then has the effect of increasing rake.



a. Cupping along with the pitch *b. Cupping along with the rake*

Figure 3. Cupping locations

Based on illustrated concepts of determining cup locations, the specimen has cupping on pitch lines.

6. Material Consideration for the Two-Blade Propeller Blade

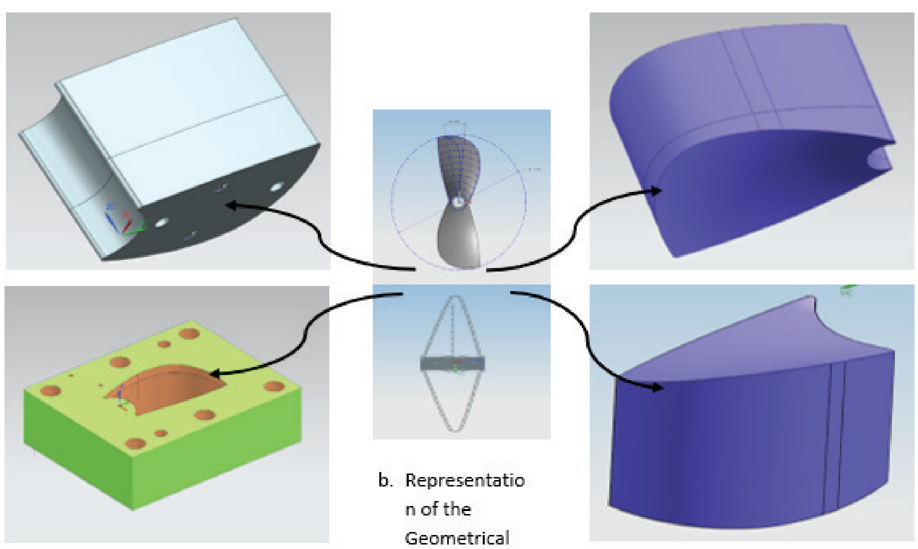
Another choice to make is choosing between aluminum and stainless steel materials. Common with new and commercial packaged boats are aluminum propellers, which are lightweight, salt-water resistant, and repairable. These characteristics of aluminum propeller give the aluminum material an utmost advantage. However, for small boats that use thin propeller blades, stainless steel has an edge over aluminum. Thin stainless steel blade propellers are more durable than aluminum propellers. Considering the thickness, propellers are susceptible to repairs. Stainless steel propellers can be repaired to a like-new condition, while repaired aluminum will suffer from metal fatigue and a loss of strength. Aluminum materials are also expensive and not popular with fishermen, local boat fabricators, and machines shops.

With these considerations, stainless steel (SS304) was chosen to the material for the two-blade propeller.

B. Designing of blanking and forming dies

Dies and molds are composed of functional and support components that generally are cavity and core inserts in injection molding and die casting, die cavities in forging, and punch and die in stamping [11]. In this case, stamping and forging were identified progressions in making propeller blades. From the scanned and characterized specimen, the 3D model of the adapted propeller blade was generated. The 3D model of the propeller is the basis for the designing of the blanking die and the forming die design. Specifically, the geometrical aspects of the propeller blade are reference geometrical definitions of the insert and cavity of both blanking die, and the punches (upper and lower) of the forming die (see **Figure 4**).

The support parts such as stripper plates, forming guide plates, etc. were designed based on the designed inserts, cavity, and punches. Machining tolerances were considered in the design of the support parts. In addition, standard parts such as the MGHP guide, coil spring were determined based on the requirements of



a. Insert and Cavity design of the Blanking Die

b. Representation of the Geometrical Aspects of the propeller 's blade

c. Punches of the Forming Die

Figure 4. References of the geometrical definitions of the insert, cavity and punches

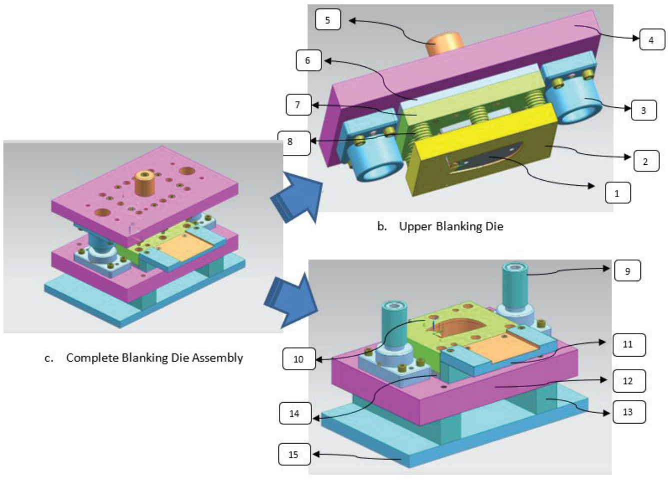


Figure 5. The whole design of the Blanking Die

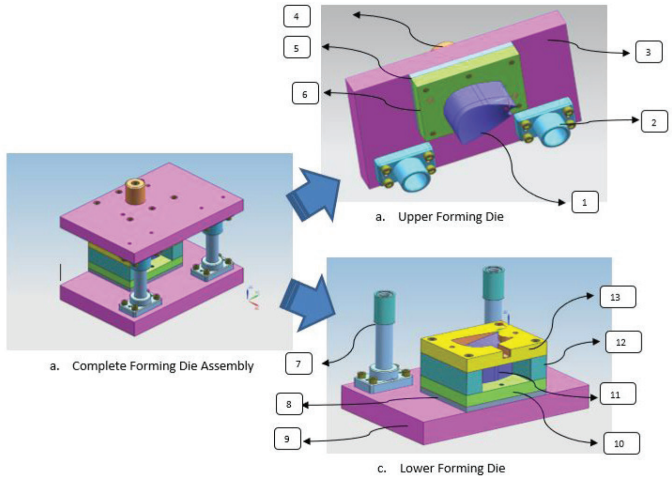


Figure 6. The whole design of the Blanking Die

Table 1. Label of Parts of the Blanking Die and Parts Category

Core Parts	Support Parts	Standard Parts
1 Insert	4 Top holder plate	3 Guide bushing
10 Cavity	2 Stripper plate	8 SWH Coil Spring
	5 Shank	9 MGHP Guide
	6 Insert support plate	
	7 Insert holder plate	
	11 Stopper Guide	
	12 Bottom holder plate	
	13 Riser Block	
	14 Cavity support plate	
	15 Clamping plate	

Table 2. Label of Parts of the Blanking Die and Parts Category

Core Parts	Support Parts	Standard Parts
1 Upper punch	3 Top holder plate	2 Guide bushing
11 Lower punch	4 Shank	7 MGHP Guide
	5 Upper punch support plate	
	6 Upper punch holder plate	
	8 Lower punch support plate	
	9 Bottom holder plate	
	10 Lower punch holder plate	
	12 Riser Block	
	13 Forming guide plate	

the support parts. Standard part means part or item that follows certain International Standards, is readily and commercially available in the market and can be purchased off the shelf. Sizes of these standard parts were based on the applicable product catalogue. **Figures 5** and **6** show the complete list of parts and **Tables 1** and **2** show the category of the parts.

C. Machining, Heat Treatment, and Assembly of Blanking Die and Forming Die

The cavity and the insert of the blanking die and punches of the forming die were machined out of solid blocks of die steel. Unlike large stamping dies and punches which are often cast to near-final geometry with a machining allowance, the size of the blanking die and the forming die are significantly small for the CNC machines of MIRDC. Support components are standard parts and assure the overall functionality of the tooling assembly in such areas as alignment, part ejection, and heating. By using the standard die and mold components such as guideposts, ejectors, etc, the time necessary for manufacturing a die is reduced and machining is mainly devoted to producing the core parts which are the cavities and inserts of both blanking die and forming die. 3-axis CNC machines (Makino KE55 CNC), and 5-axis CNC (Makino F5 milling), and Mazak CNC grinding machine were used on core and support parts that require precision machining. The holes for bolts and dowel pin locations also require precise drilling through Fanuc wire cutting machine.

Figure 7. Wire Cut and 5-Axis machines of MIRDC

Figure 8. Heat treatment and hardness testing in MIRDC

Figure 9. Assembling the dies in MIRDC

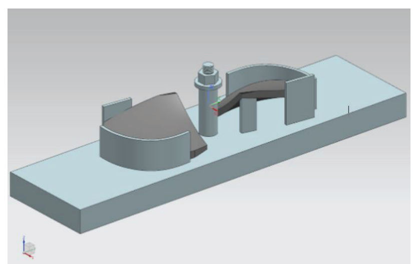


Figure 10. The designed welding jig

Only the core parts such as D2 tool steel (high carbon and high chromium) insert, cavity, and punches were heat-treated using CNVAC Vacuum Heat Treatment Furnace. The target hardness was achieved at 50 to 60HRC. The heat treatment process toughened the die cavity, core inset, and punches of the blanking die and the forming die to prevent chipping at contact during stamping (see **Figure 8**).

Assembling the blanking die and the forming die is also a critical step in the die-making process. All the machined parts, both core, and support parts as well as all the purchased standard parts need to be put together to be functional. Assembling the dies requires a comprehensive understanding of their structure as well as their mechanism to attain the precision and functionality of the die. All parts, including those parts that are interchangeable, were identified for position in a way that assures the location's mark is always clearly visible even after assembly.

D. Design and Fabrication of Welding Jig for the Propeller Blade

The welding jig was fabricated to hold and position the two blades of the propeller prior to their joining/welding to the hub. The welding jig locates or guides the welder (human welder/operator) in welding the workpiece. Using the GTAW (Gas-Tungsten Arc Welding) welding process is the most appropriate and most suitable welding for the propeller for various considerations and reasons. Some of them are the type of material being welded which is stainless steel, the thickness of the blade, and the needed strength of the weld.

With the use of welding jig, setting –up of tools, or sometimes lay-outing were eliminated. Interchangeability of blades is also possible. The welding jig also provides safety at work for the welder as well as for the workpiece.

Results and Discussion

The developed blanking die

Figure 11 shows the structure of the developed blanking die of a propeller's blade. As designed, the blanking die is divided into upper blanking die consisting of a shank, a top holder plate, an insert support plate, an insert holder plate, a stripper plate, and an insert; and a lower blanking die constructed from a clamping plate, riser blocks, a bottom holder plate, a cavity support plate, and a cavity.

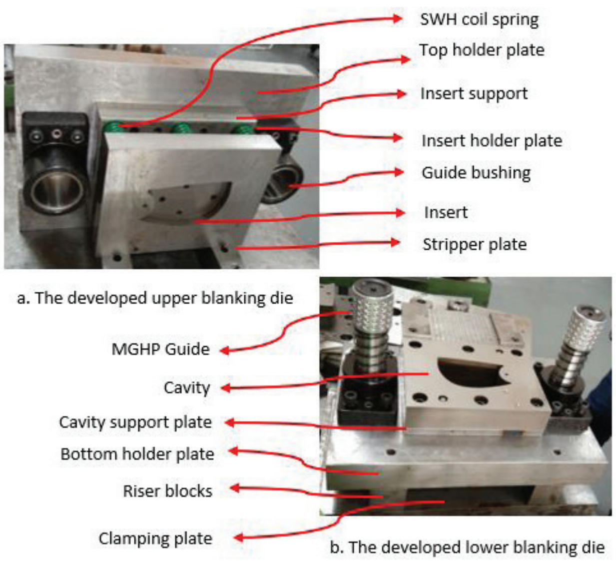
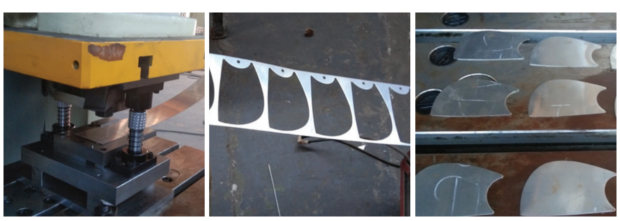


Figure 11. The developed blanking die for propeller's blade

As shown in **Figure 12**, the top blanking die is installed to the slide of the press machine (OCP-110) fixing it using a shank holder. This is a method of installing the top blanking die appropriately for relatively small dies. The bottom die is fixed using clamps on the bolster plate of the press machine. A very important factor in the blanking dies is the clearance, thus, the provision of the guide post is critical so that the relationship between the upper blanking die and the lower blanking die is maintained constantly in the dies themselves.



a. Set-up of the blanking die at OCP- 110 *b. Material/scrap* *c. blank of the propeller's blade*

Figure 12. Set-up and result of the blanking process

The maintained clearance of the upper blanking die and the lower blanking die minimizes if not eliminates the bristly edges or burrs.

The developed forming die

Figure 13 shows the structure of the developed forming die of a propeller's blade. The forming die is partitioned into an upper forming and a lower forming die. The upper forming die is constructed from a shank, a top holder plate, an upper punch support plate, and an upper punch. The lower forming die is constructed from a bottom holder plate, a lower punch support plate, a lower punch holder plate, riser blocks, a forming guide plate, and a lower punch. All parts are constructed based on the design.

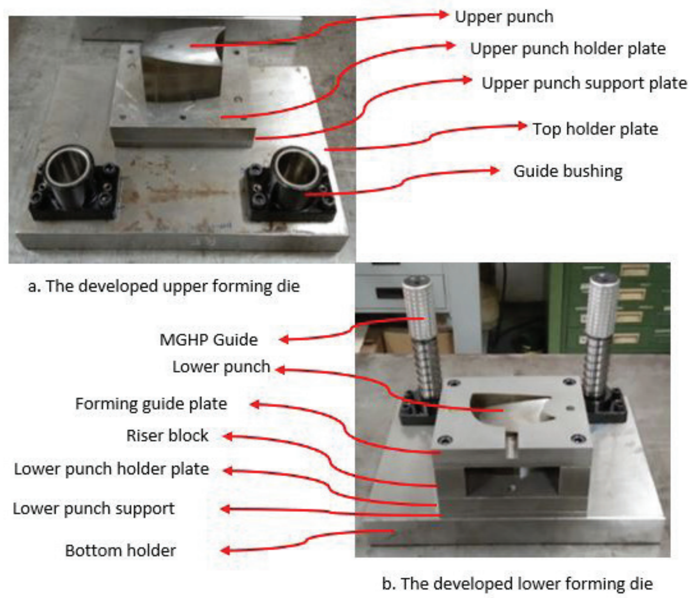
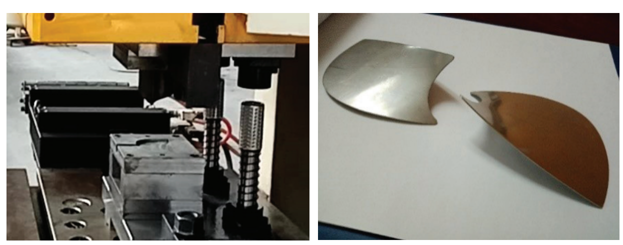


Figure 13. The developed forming die for propeller's blade

Similar to the set-up of the blanking die, the top forming die is installed to the slide of the press machine (OCP-110) fixing it using a shank holder. The lower forming die is fixed using clamps on the bolster plate of the



a. Set-up of the blanking die at OCP- 110 *b. formed propeller's blade*

Figure 14. Set-up and result of the blanking process

press machine. The MGHP guide and guide bushing of the forming die maintained constantly the clearance and the relationship between the top forming die and the lower forming die. (see **Figure 14**).

The constructed two-blade propeller using the welding jig

As shown in **Figure 15**, the welding jig was fabricated based on the design and was intended to hold firmly the two propeller's blades as well M20 x 40mm x 25 mm ø coupling as blade hub in the middle. With the welding jig for TIG welding, the two propeller's blade are welded in symmetrical manner. This results to maintaining the uniformity and consistency of every two-blade propeller. Further, the welding jig minimizes the deflection of the two propeller's blades due to thermal stress.

Activities and Processes Time

Table 3 shows the time for every activity and process using the blanking die and forming die in order to produce 10 pieces of two-blade propellers. The set-up activities are accomplished by two (2) persons but the processing activities needed only one (1) operator / user.

The total time of every activity and process using the blanking die and forming die is significantly lower than the total processing time of ATON Marketing at 10 hours with three (3) persons working.

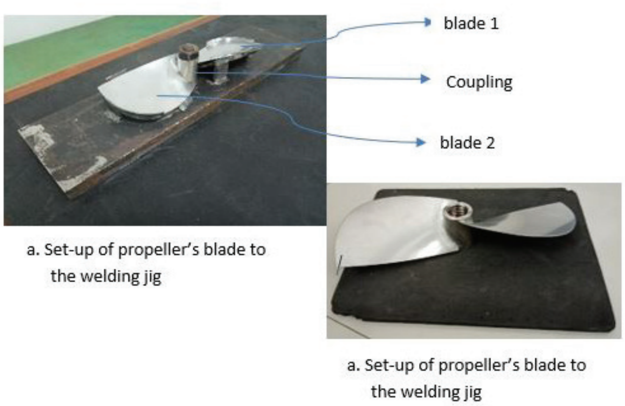


Figure 15. Set-up and result of the blanking process

Conclusion and Recommendations

The development of the blanking die and the forming die demonstrate as alternative stamping tools to manual forming in processing two-blade propellers. Using these dies and the welding jig, the geometry of each blade is uniform and the symmetry of two-blade propeller is maintained. Besides, each blade produced has no burr or bristly edges. Moreover, the use of the blanking die and the forming die significantly lowers the processing time of producing a two-blade propeller when set against the manual forming.

The series of tests conducted on the blanking die and the forming die has favorable results in the manufacturability of the two-blade propeller. However, the comparison on the effect of the two-blade propeller produced from manual forging versus the two-blade propeller produced using the dies on the small fishing boats was not included in this project/study. Similarly, the extent of the advantages or potential disadvantages of using the two-blade propeller produced using the dies on the small fishing boats was not determined. Thus, it is recommended to conduct pilot testing of the two-blade propeller produced using the dies on the small fishing boats to determine actual results.

Table 3. Activities and Processes Time

Activity/ Process	Time
Blanking Die Set-Up	15 min
Blanking	1 min
Forming Die Set-Up	15 min
Forming	2 min
Welding	22 min.
Total Time	**55 min**

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Design and Development of Automated Irrigation Controller for Organic Greenhouse

Isidro D. MILLO*[1], Franz Joseph D. LIBAO*[2], Rodnel O. TAMAYO*[3], Vincent Boy E. MANABAT*[4], Joein L. LUCES*[5], Ronie S. ALAMON*[6], Glen D. ESPEÑA*[7], Von Jansen COMEDIA*[8], Michelle D. NAVARRO*[9]

Abstract

This study describes the design and development of an automated irrigation controller for organic agriculture. A prototype controller featuring a programmable logic controller (PLC) and human machine interface was assembled. The PLC was programmed to control the electric motor that drives the centrifugal pump that supplies water to the greenhouses. A human machine interface was programmed that allows the farm operator to schedule the irrigation of the crops precisely as required by the farm management.

The assembly was encased in an industrial-grade electrical box with ample overload protection to the electric motor. The performance test showed that significant man-hours are saved by as much as 30 percent compared to manual operation of the sprinkler irrigation system. Moreover, water usage has been observed to be significantly regulated due to the fix amount of time allotted due to the automation of the irrigation operation.

Keywords: *Sprinkler Irrigation, Programmable Logic Controller, Human Machine Interface, Automation, Organic Agriculture*

Introduction

Greenhouses are structures that create a controlled micro-climate to allow the cultivation of crops that otherwise will not grow at certain periods in time. This micro-climate is supplemented by various irrigation methods to supply the required soil moisture and humidity inside the greenhouse.

Modern greenhouses and other indoor farming structures often have mechanized systems to deliver available water for the plants. Sprinkler irrigation system is one of the most commonly used due to the ease of installation, relatively low cost, and satisfactory performance. The water is pressured through sprinkler nozzles that deliver water, usually above the foliage of the crops.

Though mechanization is a huge boon to agriculture, it may not always be optimized to the specific application where it is implemented. A common practice in greenhouse systems is to manually operate the motorized pumps to activate the sprinkler irrigation system. Though it effectively improved the irrigation process, the manual operation of motors may be subjected to human error that can cause water wastage due to over-irrigation. Alternatively, under-irrigation can also occur if the amount of water delivered is less than what the crop actually requires.

Introduction of automated controls for water pump activation can provide precise delivery of water, convenience to farm technicians and an opportunity to record various operation parameters through data logging. It can lessen operational costs due

*1 *Supervising Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

*2 *Sr. Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

*3 *Chief Science Research Specialist Metals Industry Research and Development Center Bicutan, Taguig City Philippines*

to optimized usage of water and save manpower, especially in medium to large-capacity farms.

The general objective of the study is to design and develop an irrigation system with automated controls for use in an organic agriculture greenhouse

Specific Objectives:
- Program a user interface and control logic of applicable irrigation operations;
- Conduct functional and performance testing of the developed controller;
- Establish the optimum operational logic of designated control parameters derived from actual performance test(s); and
- Conduct cost-benefit analysis of the integrated controller.

Expected Outputs:
- An automated irrigation operations based on pre-determined irrigation schedule;
- Reduction of manpower;
- Effective use of water resources; and
- Better usage of electric motor and water pump.

Methodology

The project involved technology benchmarking, designing and preparation of materials to be integrated in the existing greenhouse facility of an identified MSME (Costales Nature Farms). From the field testing results, an irrigation program was developed and uploaded to the Programmable Logic Controller (PLC) that will serve as the operational protocol of the automated control system.

The project will run for a duration of two (2) months. Activities that will be implemented are as follows: development of the automated controller (Two (2) weeks), integration and commissioning (One (1) week), functional testing (One (1) week), and performance evaluation (One (1) month).

Implementing strategy for the project is described as follows:
- Develop / prepare engineering plans and bill of materials for the automated control system;
- Purchase of supplies and materials needed;
- Programming of user interface and logic operations;
- Installation and commissioning of the control system in an existing greenhouse;
- Functional testing of the programmed controller;
- Identify areas for improvement: modify design and features/components, if necessary;
- Develop performance criteria;
- Gather feedback from MSME cooperator;
- Evaluate the general performance of the equipment; and
- Prepare Terminal Report.

Figure 1. Costales Nature Farms in Majayjay, Laguna

*4 Science Research Specialist II
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

*5 Science Research Specialist II
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

*5 Science Research Specialist II
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

Functional and *Performance Testing* were done in ***COSTALES NATURE FARMS*** in Majayjay, Laguna. *Costales Nature Farms* is an agro-tourism destination and organic farm involved in the production of organic vegetables and herbs. The company caters to high-end restaurants for the supply of fresh ingredients.

Figure 2. Sprinkler Irrigation System

Figure 3. Cableways to supply the solenoid valves

Most of the farm's crops are produced inside modular greenhouses. Primary method of irrigation was combination of *overhead sprinkler irrigation and manual watering* via watering cans. The farm had previously expressed interest to have their sprinkler irrigation system to be automated. As such, the farm was identified to be the testing site of the AIS prototype due to its existing infrastructure and proximity to DOST-MIRDC

The farm allocated seven (7) plots of greenhouses for the trials. Testing duration is two (2) months. All greenhouses have existing sprinkler irrigation lines powered by a single centrifugal pump. The project team installed the AIS prototype in the farm pumphouse on May 2021 Control cables were installed from the pumphouse to individual greenhouses.

Figure 4. Assembly of Solenoid Valve Bypass to each sprinkler line

The ball valves have been augmented with solenoid valves that will be controlled by the AIS to facilitate the opening and closing of the valves.

The farm operator has been instructed on how to program simple schedule of automatic opening and closing of the valves. The seven greenhouses were programmed to receive five (5) minutes of irrigation in succession.

**4 Sr. Science Research Specialist
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

**5 Science Research Specialist II
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

**5 Project Assistant III
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines*

Figure 5. Solenoid Valve Bypass Setup

Figure 6. Programming of Irrigation Schedules

Table 1. List of Materials used in the Automated Irrigation Prototype

Control Panel Components				
Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Schneider Electric Modicon M221 PLC CPU Mini USB Interface, 10000 Steps Program Capacity, 9 Inputs, 7 Outputs	1	unit	₱ 16,000.00	₱ 16,000.00
Schneider Electric TM3 Series PLC I/O Module 16 Outputs 2 A 24 → 240 V, 90 x 23.6 X 70 mm	1	unit	₱ 9,600.00	₱ 9,600.00
10.1 inch widescreen, Universal model, 2serial ports,1Ethernet port, embeddedRTC	1	unit	₱ 26,000.00	₱ 26,000.00
Control panel/Metal Enclosure	1	unit	₱ 6,000.00	₱ 6,000.00
Circuit Breakers	1	lot	₱ 1,500.00	₱ 1,500.00
DIN rail power supply, 24 VDC	1	Pc	₱ 7,500.00	₱ 7,500.00
Ethernet Switch	1	Pc	₱ 5,500.00	₱ 5,500.00
Panel exhaust filter fan	1	Unit	₱ 360.00	₱ 360.00
Contactor	1	Pc	₱ 400.00	₱ 400.00
DIN rail	1	meter	₱ 120.00	₱ 120.00

List of Materials...(continued)

Control Panel Components				
Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Panel trunking	4	meters	₱ 500.00	₱ 2,000.00
CAT5e Ethernet cable	1	Pc	₱ 100.00	₱ 100.00
Hookup wire, 18 AWG, White	30	meters	₱ 16.00	₱ 480.00
Hookup wire, 18 AWG, Black	30	meters	₱ 16.00	₱ 480.00
Hookup wire, 24 AWG, White	30	meters	₱ 8.00	₱ 240.00
Hookup wire, 24 AWG, Blue	30	meters	₱ 8.00	₱ 240.00
Hookup wire, 24 AWG, Green/Yellow	30	meters	₱ 8.00	₱ 240.00
Earth terminal block	4	Pcs	₱ 130.00	₱ 520.00
Terminal block CDU 2.5	100	Pcs	₱ 20.00	₱ 2,000.00
Terminal block CDU 2.5 endplate	30	Pcs	₱ 16.00	₱ 480.00
10 way cross jumper	10	Pcs	₱ 65.00	₱ 650.00
Terminal block marking tags	10	Pcs	₱ 85.00	₱ 850.00
Screw end blacket 2.5	20	Pcs	₱ 25.00	₱ 500.00
Other consumables e.g. (ferrule, electrical tape, etc.)	1	Lot	₱ 2,000.00	₱ 2,000.00
TOTAL				**₱ 83,760.00**

Auxilliary Field Devices/Components

Description	Quantity	Unit	Unit Cost	Total Cost
Solenoid Valve	1	Unit	₱ 400.00	₱ 400.00
2 Core Royal Cable	1	meter	₱ 70.00	₱ 70.00

Results and Discussion

As of August 31, 2021, the farm has not experienced any difficulties in using the automated system for more than three (3) months after completion of functional tests.

Through this automation solution, the watering of the crops in the farm is now more efficient. The designated operator simply has to set the timer, and the watering starts and stops automatically after five (5) minutes of recommended watering time. In non-automated setup, the operator needs to dedicate approximately 30 minutes, twice or thrice a day just to open or close the valves of the sprinklers. Time was significantly saved by not making the operator walk around the farm and wait just to open-close the valves of the sprinkler system. Because of the automation of the irrigation system, it is calculated that the farm frees up to 1.5 hours daily, or 45 hours monthly which costs around P1700 a month.

Another issue addressed by this automation solution is the wastage of water. Sprinkler irrigation systems tend to release a significant amount of water over the foliage of crops until it is turned off. The greenhouse in the test site releases an average of 3,500 liters of water

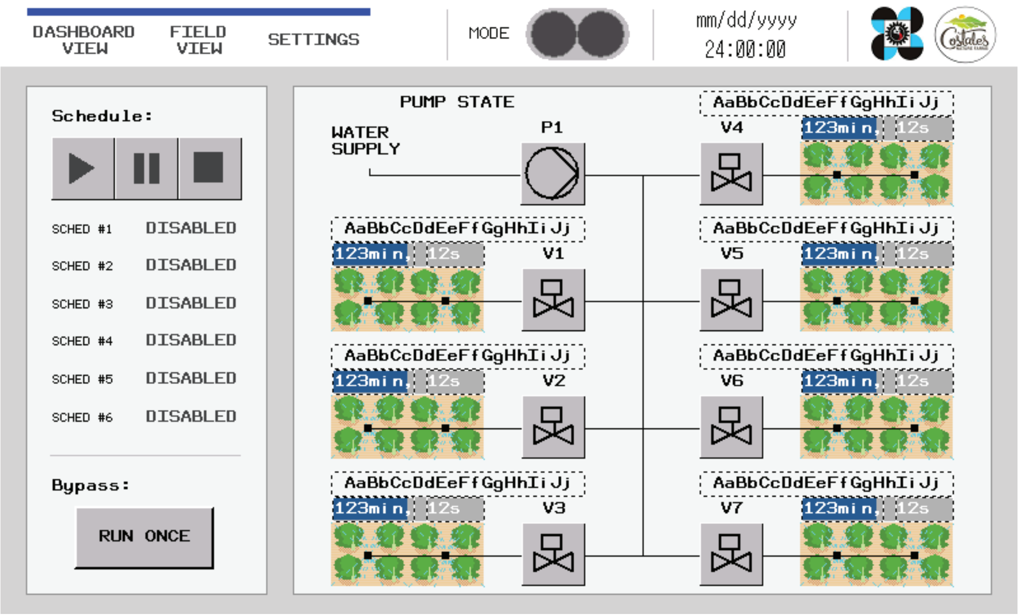

Figure 7. Programmed Interface for the Irrigation Controller Prototype

during its five-minute operation that is sufficient to wet the crop and soil.

If an operator unnecessarily extends the recommended five (5) minutes of sprinkler irrigation for 30 seconds more in a greenhouse either due to human error or it took him more time to get there to close the valve, the amount of water wastage is equivalent to 10% more or as much as 350 liters of valuable water per greenhouse and per scheduled irrigation. This could translate to losses in raw material and energy usage due to wastage and unregulated use of resources.

Conclusion and Recommendations

It can be deduced that automated system can offer significant benefits in terms of manpower reduction in irrigation operation. It can reliably prevent over-irrigation that will result to significant water wastage. Crop quality differences between non-automated and automated system are not statistically significant.

However, the project team also made the following recommendations to further improve the prototype:

- Develop a version or model of the AIS with less cost to further improve market acceptance;
- Test the controller with other features incorporating suitable sensors to maximize the features of the PLC; and
- Test the controller in other agricultural operations to promote the use and benefits of adopting such technologies.

Acknowledgment

The authors would like to thank the project members of the DOST-GIA funded project "Establishment of the Advanced Mechatronics, Robotics and Industrial Automation Laboratory (AMERIAL) in Support of the Metals and Engineering Industry," who worked hard for the development and testing of this project. Acknowledgment is also given to Mrs. Josephine Costales and the staff of Costales Nature Farms for accommodating the project's request to use their farm for the testing of the Automated Irrigation Controller Prototype.

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Optimization of the Control System of the Hybrid Electric Train

Rodnel O. TAMAYO*[1], Pablo Q. ACUIN*[2], Geoffrey L. ABULENCIA*[3], Rolando F. IBUIG*[4], Marion Grejo S. GRAFIL*[5]

Abstract

The Hybrid Electric Train (HET) of the DOST-MIRDC aims to meet the travel needs of local commuters and promote the sustainable development of transportation systems. It has already been turned over to the Philippine National Railways (PNR) to cater transport services for passengers between Alabang and Calamba Stations. This study intends to further improve the train's performance by exploiting the advanced capabilities and features of the Variable Frequency Drive (VFD) currently being utilized by the train. Previously, the operation mode of the VFD was only through a network, in which the PLC and the option boards connected in a daisy-chain command the frequency setting of the VFD. This field bus entails lesser wiring and connectivity; however, it is susceptible to electrical noise interference. The hard-wire counterpart of the field bus has more excellent immunity to noise, and its integration with the present control system enhances the overall performance of the train. The train operator can switch to another operation mode whenever the other gets faulty. Through this, the train remains operational and, in effect, enhances the overall reliability of the train. It was verified when the HET was subjected anew to validation testing on the track segments of the PNR.

Index Terms: *Hybrid electric train, variable frequency drive, optimization*

Introduction

With the expansion of urbanization, the city population is also increasing. This continual growth presents complex challenges to population mobility. Many countries have vigorously switched to rail transit systems to ease the climbing traffic pressure and improve urban mobility [1,2]. Studies also show that railways appear to magnify agglomeration economies and positively affect the growth and spatial structure of population and employment [3-5].

In the Philippines, one of the critical milestones towards transport improvement was the development of the Hybrid Electric Train (HET). The collective efforts of engineers and local partners of the Department of Science and Technology-Metals Industry Research and Development Center (DOST-MIRDC) spearheaded the initiative to meet the travel needs of local commuters and promote sustainable development of transportation systems [6]. The HET consists of several components acting together to operate and run the train smoothly and efficiently. These include the mechanical system about the car body, propulsion, and air conditioning and compressor units; the electrical system relating to the generator set and the battery banks; and the control system covering mainly the Programmable Logic Controller (PLC), Human Machine Interface, Variable Frequency Drives (VFD), and Input-Output (I/O) modules.

At present, the control system of the HET is

*1 *Chief Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*2 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*3 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

interconnected using a dedicated field bus developed by the Mitsubishi Corporation – the CC-Link or the Communication and Control Link. Industrial automation has been applying this kind of networking technology for many years now as connecting the control system components via networks can be centralized and effectively reduce the system's complexity and enhance interconnectivity and remote-control facilities. While field bus is indeed superior and advanced over its hard-wired counterpart, the latter's robustness to electrical noise interference gives it an edge over the former in a control system [7].

This study aims to optimize the operation of the train by integrating the field bus and hard-wire to the control system of the train. The researcher intends to exploit the advanced capabilities and features of the VFD. The optimization activities will be evaluated based on their effects on the reliability and availability of the train during operation on Philippine National Railways (PNR) track segments.

Control System Design Optimization

Alongside with the PLC and HMI, there are 24 stations comprising the control system of the HET as depicted in **Figure 1**. These are interconnected using the field bus CC-Link Industrial Network. The PLC Control Panel is located at the pilot coach while individual HMIs are stationed at each end of the pilot coach and power coach. Two (2) VFDs are placed in each coach to power up the underneath traction motors.

The frequency setting of the VFD can be made via a network and/or an external terminal. The HET is formerly controlled by a network in which the PLC commands the train's speed through the CC-link dedicated cable connected in a daisy chain. It was the better option among the two control methods mainly due to the fewer wires the network necessitates. Its drawback, however, is its inherent susceptibility to nearby significant electrical noise. The speed control through an external terminal of the VFD is relatively less sensitive to electrical noise though requiring more wiring and sets of relays.

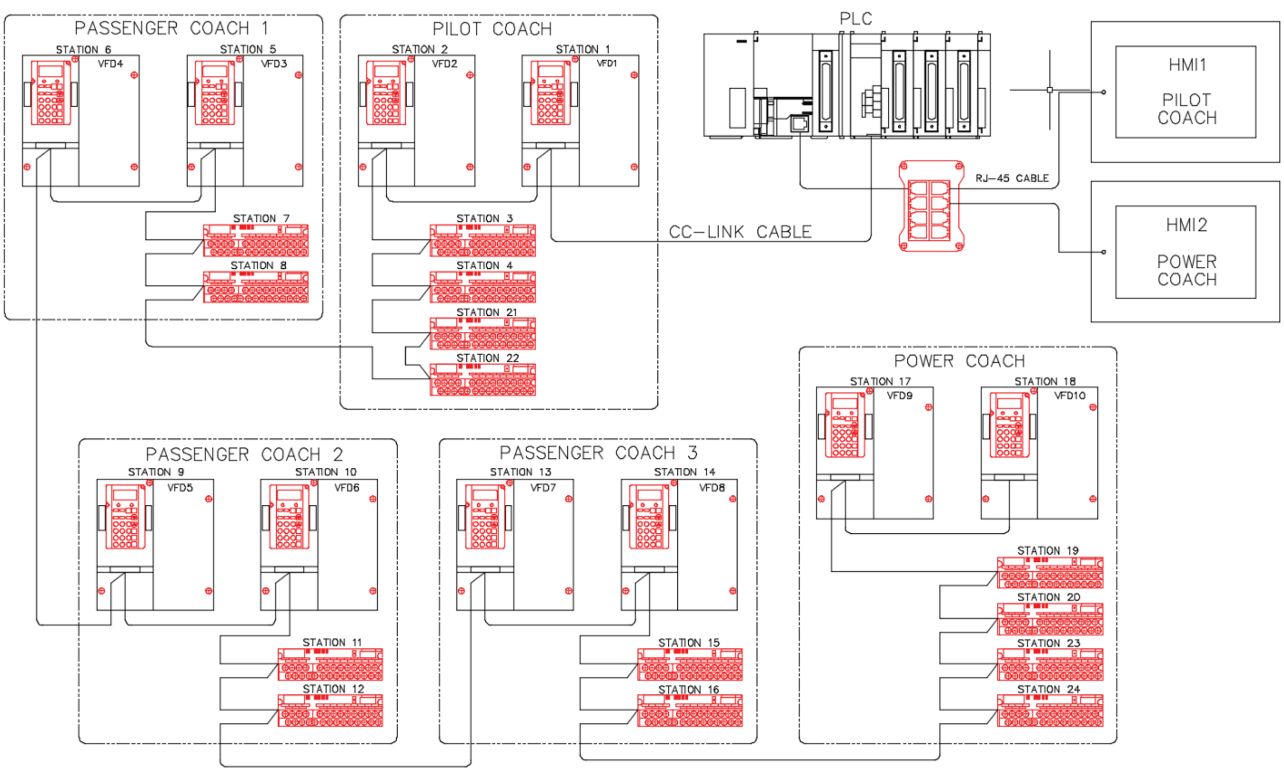

Figure 1. Interconnection of PLC, HMIs, VFDs and I/O modules

**4 Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

**5 Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

Figure 2 shows the overview of the hardwiring for the external terminal control, while **Figure 3** depicts the connection going to the individual VFD's terminal. It can be seen that an additional set of eight (8) relays at minimum was needed to operate the VFD like that when it is connected in network control. In the internal circuitry of the VFD, each external terminal has a positive contact input common since it is using a sink logic. In essence, a signal switches "on" when a current flows from the corresponding external terminal. To complete the relay circuitry of each external terminal, a negative supply must be provided via the SD terminal, as shown in **Figure 3**. The activation of the external relays depends on the actuation coming from the 9-position joystick of the train and the actuators on the control panels located at the pilot and power coaches.

Table 1 summarizes the corresponding function of each external terminal of the VFD being activated. The terminals RL, RM, RH, and REX are used primarily to provide the necessary frequency setting to command the desired speed of the HET. For speeds higher than 15 kph, the distinct combinations of RL, RM, RH, and REX are being activated, as shown in **Table 2**.

Table 1. Corresponding of each external terminal of the VFD

Terminal	Function	Terminal	Function
RL	To give 5 kph	STOP	To give 0 kph
RM	To give 10 kph	RES	To reset the VFD
RH	To give 15 kph	STF	Forward rotation
REX	For speed >30kph	STR	Reverse rotation

Table 2. Distinct combination of RL, RH, RM, and RT for the desired frequency setting

Terminals	Corresponding Speed
RL	5 kph
RM	10 kph
RH	15 kph
RL + RM	20 kph
RL + RH	25 kph
RM + RH	30 kph
RL + RM + RH	35 kph
REX	40 kph

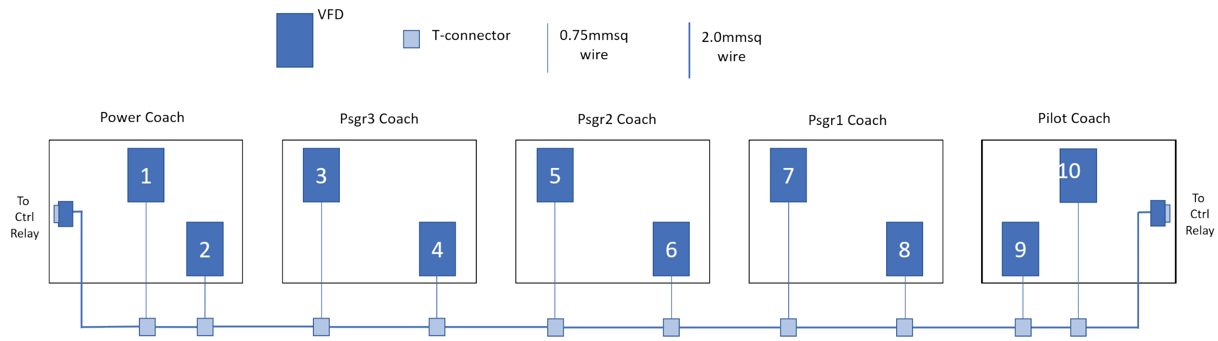

Figure 2. Hard-wired connection of VFD control system

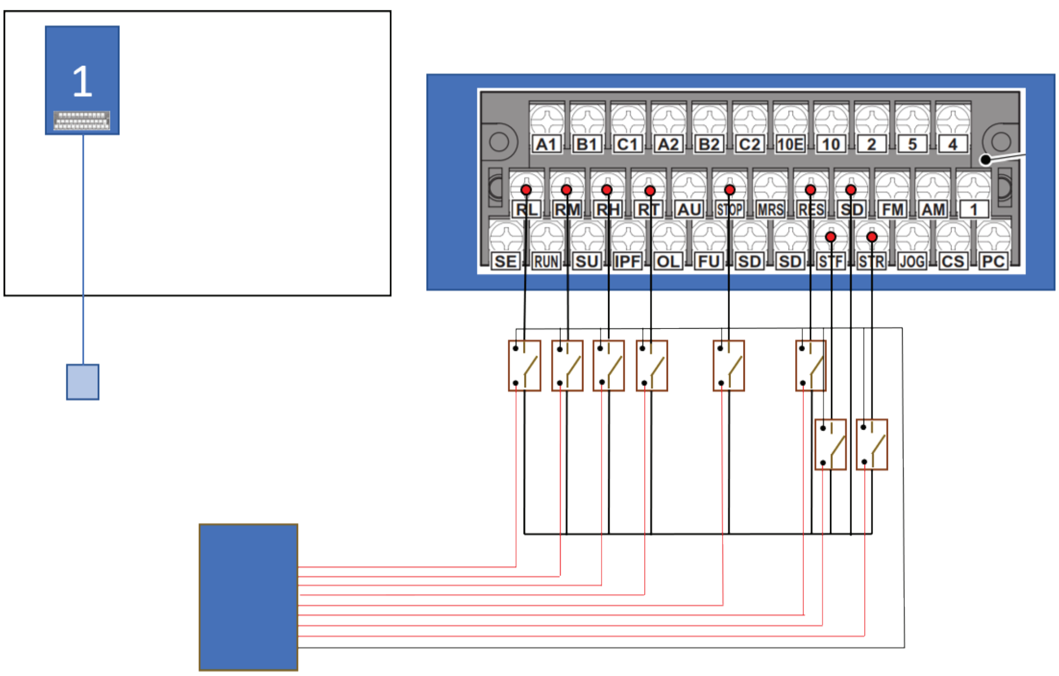

Figure 3. Relay logic for the external terminals of VFD

One of the advanced features of the VFD is selecting the operation mode of the drive between "NET" or network mode or "EXT" of the external terminal mode. If the operation mode is set to "NET" mode, the VFD frequency setting is via the PLC and CC-link option board of the VFD, whereas in "EXT" mode, the VFD frequency setting depends on the actuated hard-wire relay logic. In essence, the other operation mode is disabled with the other operates.

A toggle switch was installed on the control panel board at the pilot coach to switch between the two operation modes. The switch actuates the hard-wired relay going to the "AU" terminal of the VFD, as depicted in **Figure 3**. By this setting, the train driver can easily switch to another whenever there is a malfunctioning situation in one of the modes. This, in effect, can remain the train operational due to the employed backup control system.

Testing and Analysis of Result

Before the optimization activities, the HET was scheduled to complete three (3) loops per day to complete the 150 hours of a validation run along the track segment between Alabang to Calamba of PNR. The train, however, had an insufficient number of trips on some of the days, as summarized in **Figure 4**. During these downtimes, the train experienced sudden stops as the control system malfunctioned and even worsened to the point of towing the train by a PNR locomotive.

The employed optimization activities significantly improve the reliability of the train, as shown in **Table 3**. Despite the CC-Link network being faulty, the train remains operational because of the employed backup control system or the hard-wire relay logic. During the reliability testing, the operating hours of the HET depended mainly on the availability of the testing track of PNR, hence, the significant deviation between testing hours in the table. Nevertheless, the testing was a success as the train did not experience long halts on the track segment.

Conclusion

The study primarily illustrates how the control system of the HET can further improve. This was made by exploiting the advanced capabilities and features of the VFD. Previously, the operation mode of the VFD was only through a network, in which the PLC and the option boards connected in a daisy-chain command the frequency setting of the VFD. This field bus entails lesser wiring and connectivity; however, it is susceptible to electrical noise interference. The hard-wire counterpart of the field bus has more excellent immunity to noise, and its integration with the present

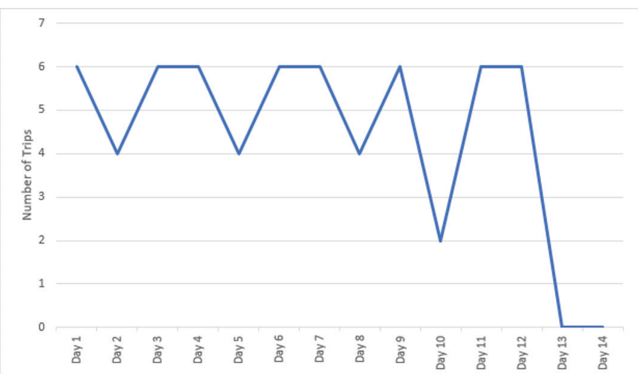

Figure 4. Reliability test result during the HET validation before the optimization activities

Table 3. Reliability testing of the optimized HET

Day	Time Start	Time End	Distance Travel (in km)	Operation Mode	Remarks
Day 1	09:33:56	11:03:21	20.205	External	No error
Day 2	10:34:20	11:52:33	17.906	External	No error
Day 3	8:57:54	14:57:15	59.864	External	No error
Day 4	09:55:40	13:27:32	55.031	External	No error
Day 5	10:40:50	13:04:06	48.944	External	No error
Day 6	9:57:00	12:48:33	38.332	Network	No error
Day 7	08:58:33	12:21:25	59.856	Network	No error
Day 8	9:47:51	11:43:15	28.429	Network	No error
Day 9	8:59:39	11:08:40	30.154	Network	No error
Day 10	10:41:24	12:40:06	25.962	Network	No error
Day 11	9:39:04	11:51:02	35.322	Mixed	No error
Day 12	10:30:34	12:35:05	29.047	Mixed	No error
Day 13	9:54:02	10:44:02	14.193	Mixed	No error
Day 14	11:02:28	12:21:53	23.080	Mixed	No error

control system enhances the overall performance of the train. The optimization activities are generally a success as these heightened the reliability of the train by providing a backup system in case the other operation mode malfunctions. The train operator can switch to another operation mode whenever the other gets faulty. Through this, the train remains operational and, in effect, enhances the overall reliability of the train. It was verified when the HET was subjected anew to validation testing on the track segments of the PNR.

Acknowledgment

The authors would like to thank the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) for entrusting this research, as well as to the researchers of the Prototyping Division (PD) and Materials and Process Research Division (MPRD) for extending their profound knowledge and effort towards the realization of this study.

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Design and Development of a Batch-Type Superheated Steam Treatment System (SSTS) for Stabilized Brown Rice

Dominic S. GUEVARRA*[1], Joein L. LUCES*[2], Melvin L. VISTA*[3], Rosemarie G. GARCIA*[4]

Abstract

This project sought to design and develop a superheated steam treatment system for brown rice. Brown rice has a short shelf life that despite its nutritional advantages and health benefits, remains unappealing to the market. The study conducted by FNRI showed that brown rice, when treated with superheated steam, extends shelf life from one to two months to more than five months. However, the cycle time of the existing steam treatment system takes about an hour making it economically unpractical. The current design and operation of DOST-developed SSTS only take one to three minutes of treatment time. The major components of the system include the treatment machine, boiler, superheater, and controls. Vital parameters, i.e treatment time and temperature were made variable for the flexibility of the system. The equipment has a capacity of 10 kilograms per batch at eight minutes per cycle. The energy, fuel, and water consumption rate were 1.42 kW-hr/hr, 8.66 li/hr, and 71.10 li/hr, respectively. Results showed that the system could generate a superheated steam temperature up to 130ºC evenly spread throughout the treatment chamber implying that the design was appropriate for treating brown rice.

Keywords: *Superheated steam treatment system (SSTS); Stabilized brown rice (SBR); Physico-chemical analysis*

Introduction

Rice (Oryza sativa L.) is considered the main staple food and a major source of nutrients in many parts of the world, especially in the Asian region. Previously, the majority of the Filipinos prefer white or well-polished rice rather than unpolished rice and less vegetables, fruits, and other nutritional foods. As a result, many Filipino children and even adults demonstrate weak immune system, poor growth, and malnourishment.

Shifting to brown rice is seen to counteract the said effects of micronutrient deficiency that is why, at present, many Filipino consumers prefer to eat unpolished rice because of the nutrient value in the bran. Thus, demands for brown rice are increasing because of its reputation for nutritional excellence and health claims associated with eating this type of food. Moreover, statistical report of SL Agritech, a local producer of brown rice, sales are increasing monthly with retail sales of about 25% although well-polished rice still dominates the retail market. Statistics show that brown rice contains essential nutrients that lower the risk of cancer because it contains magnesium that balances the action of calcium in the body by regulating the nerve and muscles to lower bad cholesterol. In connection to this, studies showed that with regards to its health benefits, medical specialists are now recommending brown rice to their diabetic patients.[1]

However, brown rice has slower absorption of liquid due to the fiber present in the bran, which leads to prolonged cooking time. Furthermore, the oil in the bran shortens its shelf life, as the oil becomes rancid in time.

The experiment conducted by Satou et al. showed that when brown rice is subjected to superheated steam for about one (1) minute, significant enzymes were inactivated almost completely without influencing the starch quality. Therefore, superheated steam treatment

*1 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*2 *Science Research Specialist II*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

*3 *Science Research Specialist I*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

can be considered an efficient method for enzyme inactivation. This was due to the rapidity of the surface heating that is one of the features of superheated steam. This report is the first study to quantitatively examine the inactivation of enzymes related to the generation of n-hexanal by superheated steam treatment. It is assured that the inactivation of these enzymes suppresses the decomposition of lipid and the amount of peroxide generation. Therefore, it is expected that stale flavor production in enzyme-inactivated rice, through superheated steam treatment, when stored, will be minimized than in non-treated rice.[2]

In this study, it was shown that enzyme inactivation is possible through a promising new method of the superheated steam treatment. Superheated steam treatment of brown rice requires equipment consisting of a superheated vapor generator and belt conveyor; therefore, initial costs are required in treating brown rice with superheated steam. [2]

Objectives

The general objective of the study is to design and develop a superheated steam treatment system for brown rice. Specifically, it aims to:

1. Design and prototype a superheated steam treatment system that could evenly treat a batch of brown rice; and
2. Evaluate the performance of the superheated steam treatment system for brown rice.

Materials and Methods

In the conduct of this study, the following materials were used: MS sheet, square tube, angle bars, flat bars, wire mesh conveyor, pillow block, electric motor, cable wires, stainless steel sheet, perforated stainless steel sheet, brown rice, diesel, pale, stainless steel pipe, solenoid valve, pressure regulator, relief valve. The testing instruments used were thermocouple, data logger, pressure sensor, flow sensor, and weighing scale.

*4 *Chief Science Research Specialist*
Food and Nutrition Research Institute
Bicutan, Taguig City
Philippines

Design and Development

This stage involves the gathering of technical data (i.e. existing design and operations of superheated steam dryers) and references from patent sites and journals. Internet search of commercially available devices, locally and abroad, was also conducted to acquire in-depth knowledge which aided the researchers in conceptualizing the technology. Additional information was taken from consultants and experts from research agencies, private companies, and cooperatives. Plant visits were also conducted to observe the set-ups and operations of other machines with related applications.

Design conceptualization using a 3-D model was prepared by the project team. The initial design was presented through a focused group discussion, reviewed and finalized with the aid of DOST- Project Management Engineering and Design Service Office (PMEDSO) engineers, FNRI project staff, and the MIRDC technical committee.

Upon approval of the design, a detailed drawing was prepared for the fabrication of the batch-type superheated steam treatment system with a capacity of 10 kg per batch. Assembly, integration, and installation of the SSTS, which was done at FNRI, was supervised and monitored by the project team together with DOST-PMEDSO engineers.

Testing, Evaluation, and Debugging

After the fabrication, preliminary test runs were undertaken to evaluate the functional operations of the mechanical and electrical components, including control, to identify possible technical problems. Likewise, the prototype unit was evaluated in terms of ease of operation, safety, and performance efficiency. Visual examination during operations was made to determine if there were indications of defective parts or problems in the machine. Repair and debugging of any malfunctioned parts and components identified during test were undertaken immediately.

Test Data Gathering

In evaluating the performance of the SSTS, NSIC RC 160 unhusked rice variety was used in this study. This was purchased from JB Aguilar Rice mill located in Nueva Ecija. The unhusked rice were dehulled using rubber rollers and the brown rice produced were fed evenly into the system. Saturated steam was produced and reheated to change its state into superheated steam using a locally fabricated boiler and superheater. The temperature of the superheated steam was set at 110ºC and 120ºC. Treatment time was set at 1, 2, and 3 minutes. Four thermocouples were placed at the four quadrants on top of the wire mesh where the brown rice were laid. Important parameters such as fuel consumption, energy consumption, water consumption, and temperature were recorded.

Results and Discussion

Design and Development

The superheated steam treatment system for brown rice is composed of four (4) major components such as (1) treatment machine, (2) boiler, (3) superheater, and (4) controls. **Figures 1** and **2** display the concept design and the fabricated superheated steam treatment system, respectively.

1. The Treatment Machine is a system component where the brown rice is being treated with superheated steam. It has an overall dimension of 2,750mm(L) x 1,400mm(W) x 1,900mm(H).

a. Support frame and cover. Support frame is made of square tubes cut to each specific length, welded, and bolted together to form the structural support for all the parts of the treatment machine. The overall dimension of the support frame is 2,750mm(L) x 1,400mm(W) x 1,900mm(H). The cover on the other hand is made of S.S. 304, gauge #22.

b. Feeding hoper. It serves as the reservoir of brown rice before treatment. It is made up of gauge #22 stainless steel sheet, cut and bended to form a rectangular shape. It is mounted on the frame with an adjustable slot used for calibrating the clearance to control the thickness of brown rice layer on the conveyor while spreading.

c. Chute. It is located at the end of the conveyor, mounted on the support frame to guide the discharging treated brown rice to the collecting container. It is made of gauge #22 stainless steel sheet cut and bended to its desired form.

d. Conveyor set. It is a part of the treatment machine that holds and conveys the brown rice from feeding hopper assembly to discharge chute. The conveyor set is made of stainless steel wire mesh with 1mm mesh diameter, with both ends connected to form a loop. The conveyor is adjusted by tightening the bolt to push the pillow block that holds the rollers. The prime mover of the conveyor is a 0.745kW 60Hz A.C. motor, equipped with variable frequency drive and gearbox to regulate the linear speed of the conveyor.

e. Treatment chamber. It is the compartment that receives the superheated steam from the boiler. A perforated stainless steel sheet is provided to distribute the superheated steam evenly throughout the entire chamber. The treatment chamber is made of gauge # 22 stainless steel sheet.

f. Steam protection. It is a triangle-shaped funnel placed in the front and rear of the treatment chamber to enclose the escaping superheated steam and protect the operator from accidental exposure to superheated steam. It is made of gauge # 24, SS 304.

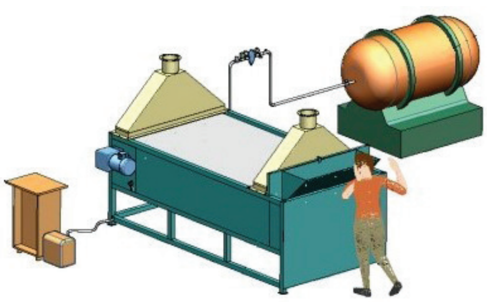

Figure 1. A 3D model of the Superheated Steam Treatment System

Treatment Machine and Controls

Boiler and Super Heater

Figure 2. Prototyped Superheated Steam Treatment System

2. Boiler. It is a steam generator locally fabricated necessary to supply saturated steam to the treatment machine.

3. Superheater. It is a device used to raise the temperature of steam above 100ºC to attain the superheated steam temperature.

4. Controls. This component provides power and a sequential signal in each component during operation.

Testing and Evaluation

The test was conducted to determine the functional operation of each component in the system. The spreading time and variable frequency drive were set to 22 seconds and 30rpm, respectively. The energy, fuel, and water consumption rate (shown in **Table 1**) were 1.42 kW-hr/hr, 8.66 li/hr, and 71.10 li/hr, respectively. Results also show that the system could generate a superheated steam temperature up to 120ºC evenly spread throughout the treatment chamber which implies that the design was appropriate for treating brown rice.

Physico-chemical Properties

The test was conducted to evaluate the preliminary result on the analysis of physicochemical, chemical, microbiological evaluation of brown rice samples treated using the SSTS. Afterward, the brown rice was immediately treated, since enzyme activity will start after the bran layer of the brown rice has been exposed to environmental conditions. The physico-chemical analyses performed for the samples were moisture content, pH, water activity, color, and free fatty acid content.

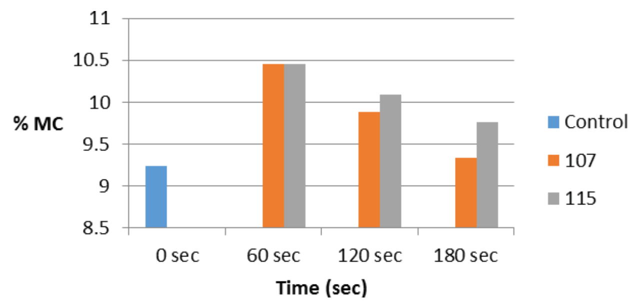

Figure 3. Moisture content (%) of brown rice as exposed to different temperatures and time durations.

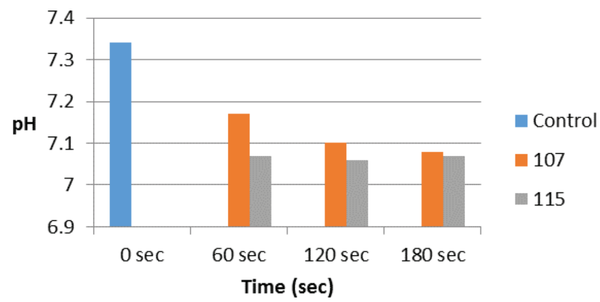

Figure 4. pH value of brown rice as exposed to different temperatures and time durations

1) Moisture content in rice is important since it affects rice texture, taste, appearance, and stability. **Figure 3** illustrates that the moisture content of brown rice treated with superheated steam is higher (10.45%) compared to untreated brown rice (9.24%).

2) The pH of food determines the survival and growth of microorganisms during processing, storage and distribution. **Figure 4** shows that the pH of the treated brown rice was lower than the untreated one, but still near the desired pH for rice which is 7.2.

3) Water activity refers to the amount of unbound water in food that can support the growth of bacteria, yeast, and molds. It was observed that the brown rice exposed in superheated steam in a much shorter time had higher water activity than those exposed to higher temperatures and time (see **Figure 5**).

Table 1. Performance evaluation results of operating the superheated steam treatment system for brown rice.

PARAMETERS	Trials			TOTAL	MEAN
	1	2	3		
Capacity, kg.	10	10	10	30	10
Steam Flow, m^3/sec.	0.201	0.230	0.189	0.62	0.207
Temperature Generated					
Pipeline, ºC	280	250	290	820	273.33
Treatment Chamber, ºC	130.5	129.75	130	390.25	130
Cycle Time, min	8	9	7	24	8
Energy Consumption, kW-hr./hr					1.42
Fuel Consumption, li/hr.					8.66
Water Consumption, li/hr.					71.10

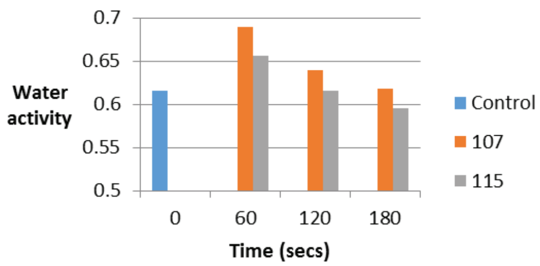

Figure 5. Water activity of brown rice as exposed to different temperatures and time durations.

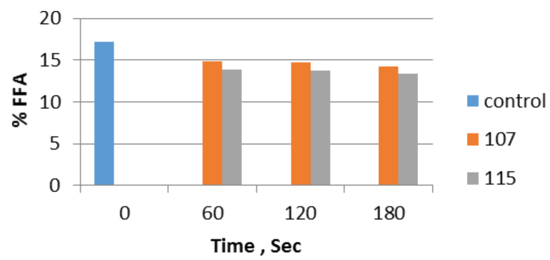

Figure 6. FFA (%) of brown rice as exposed to different temperatures and time durations.

4) Free fatty acid (FFA) is the measure of rancidity caused by the lipolytic hydrolysis in brown rice. Based on FFA results from **Figure 6**, all the treated brown rice samples have lower free fatty acid compared to the untreated (control).

Summary

The study entitled "Design and Development of Superheated Steam Treatment System (SSTS) for Brown Rice" was conducted by MIRDC in cooperation with FNRI. The general objective of the study was to design and develop a superheated steam treatment system for brown rice. Specifically, it aimed to 1) design and prototype a superheated steam treatment system that could evenly treat a batch of brown rice; and 2) evaluate the performance of the superheated steam treatment system for brown rice.

The superheated steam treatment system for brown rice was composed of four major components such as (1) the treatment machine, (2) the boiler, (3) the superheater, and (4) controls.

The treatment machine has an overall dimension of 2,750 mm(L) x 1,400mm(W) x 1,900mm(H). The system has a capacity of 10 kilograms per batch with a treatment time of one (1) to three (30 minutes adjustable depending on the required time. The average steam flow was 0.207 having an average temperature of 273.33ºC on the pipeline and decreases at an average of 112.67ºC when it reaches the treatment chamber. The average operating cycle time was about eight (8) minutes from loading up to cooling of treated brown rice. The energy, fuel and, water consumption were 1.42 kW-hr/hr, 8.66 li/hr, and 71.10 li/hr, respectively.

Conclusion

Based on the foregoing results, the researchers conclude that the designed and developed superheated steam treatment system was able to treat a batch of brown rice evenly

Recommendations

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)" and "Development of Column-Packed Adsorbent for Chrome Recovery from Tanning Wastewater (PCIEERD Project No. 08517)."

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Wringing Error Analysis of Twenty-Year-Old Gauge Blocks

Arvin Yan PACIA*[1]

Abstract

Gauge block is used in the calibration industries as a working standard for the calibration of measuring instruments such as micrometer calipers, dial gauges, height gauges, fixed gauges, and geometrical evaluation of products. Normally, to the required nominal value, it requires a combination of several gauge blocks. The combination will accumulate error, which determines accuracy and application, which is inherent in this practice through the process called "wringing." The wringing quality of gauge block deteriorates as years of usages even after de-burring has been done before wringing. In this study, ethyl alcohol was used as a wringing medium by directly applying it on the surfaces to be wrung together. This paper determined the wringing errors of gauge block with 20-25 years of usage. The objective of this paper will give the metals and engineering industries performing calibration of their quality assurance instrument specific data in addressing their uncertainty of measurement where the wringing quality of gauge block is one of the major components. ISO 17025 an international standard for the "General Competence of Testing and Calibration laboratories" specifically requires that all uncertainty components of measurement must be considered. Besides, this will be used in the decision rule of the instrument is in compliance or non-compliance to a given limit of the provide additional information/components to the metal industries in computing measurement of uncertainties. The Automatic Gauge Block Comparator machine was employed to measure the error of wrung gauge blocks. Five (5) commonly used nominal sizes in calibration were selected by combining several numbers of grades 0 gauge block sizes. The wringing error was measured using the direct comparison method with a single Grade 00 gauge block as a reference standard. The measurement procedure which includes preparation, calibration, wringing, and measurement is as per AS 1457:1998 taking into account all the uncertainty components. The results showed that the minimum and maximum wringing errors for 20-25 years of usage were +0.00004mm and +0.00011mm, respectively. The value represents 6% relative uncertainty of the allowable error for micrometers wringing of three to four nominal sizes but has little effect on caliper (0.40%).

Keywords: *Gauge Block, wringing, wringing error, Central Error, Uncertainty of Measurement, Combined Test Gauge Block Error*

Introduction

Most companies undergo calibration and verification of small tools particularly micrometers, calipers, and dial gauges to maintain the instrument's accuracy and to know if the results are within an acceptable range. The majority of these companies are from the automotive industry, semicon industry, metal fabrication, and testing and calibration laboratories where gauge blocks serve as their basis for maintaining dimensional and length quality control and quality assurance in production; carrying-out applied research and development; calibrating length standards and instruments to achieve traceability to national standards; and developing and maintaining working physical reference length standards. Through ISO 9001

*1 *Sr. Science Research Specialist*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

certification and ISO/IEC 17025 accreditation, these activities will ensure the reliability and traceability of measuring instruments. Several of the calibration laboratories nationwide especially in dimensional metrology incorporate length in their scope of accreditation.

Wringing of gauge block was considered one of the components that affect the accuracy of the result when assessing uncertainty of measurement budgeting. The experience and expert opinions of the laboratory personnel were used as an estimate for the input values to the components of uncertainty measurement. {Suga (1998) published that wringing error of gauge block wrung by a novice and expert ranges from 0.4microns to 0.02microns. This value was conducted using a new set gauge block 1 -5 years of usage.

In fact, the Department of Industry-Philippine Accreditation Bureau (DTI-PAB) reported from the measurement audit, that the participating laboratories involving wringing errors are normally based on conservative estimates 0.0002mm to 0.0005mm. Other calibration laboratories also having similar services were indiscriminately adopting wringing error values.

Gauge block is always used when performing calibration and verification of small tools. It is a combination of different sizes to build the selected nominal size. The process of combining different sizes of gauge blocks is called “wringing.” Wringing is the property of the measuring faces of gauge blocks to adhere completely to other measuring faces or surfaces with a similar surface finish as a result of molecular attraction forces [6], hence, wringing is an inherent characteristic of very smooth and flat surface to “stick together” when one is slid over the other. Gauge blocks with very satisfactory surface conditions will stick to each other for a very long time when wrung together.

The wringing ability of gauge blocks becomes less due to degradation of surface conditions like the presence of scratches, dent, and corrosion stains over the years of usage. This defect can be corrected using available Arkansas Stone, however, in this process, the “sharp burrs,” are not completely removed hence, it is not a guaranty that the quality of wringing will be restored to their original condition. A study of gauge block wringing shows that the surface roughness of gauge blocks can decrease or increase after deburring [17].

In 2001, the DOST-MIRDC Metrology Laboratory performed measurements using an automatic gauge block comparator to determine the wringing error of newly acquired Gauge blocks. The results show a range in wringing error from +0.02µm to +0.17µm.

This paper focuses to find out the wringing errors of the gauge block that was used for 20 to 25 years when wrung using ethyl alcohol as the wringing medium. These errors can be in the industry in correcting their measurements and estimating their uncertainty of measurement budget.

Materials and Methods

In this study, the surface roughness of each block was corrected through deburring. This will minimize the influence of gauge block surface geometrical conditions during usage. **Figure 1** shows that a surface roughness tester is used before and after deburring the gauge block. The method of measuring the gauge block error is by measurement based on Australian Standard (ASI457) using GB100A Automatic Gauge Block Comparator.

The comparative method of measurement compares the wrung Test Gauge Block Size Grade 0 with standard “whole” steel gauge block with grade 00 accuracy. The study was conducted in the laboratory where the environmental conditions were controlled at 20±1°C and 55±10% relative humidity as required by AS1457 using precision air-conditioning unit. The measurement is conducted for the sizes shown in **Table 1** which also includes the combined errors of the individual gauge blocks taken from their calibration results.

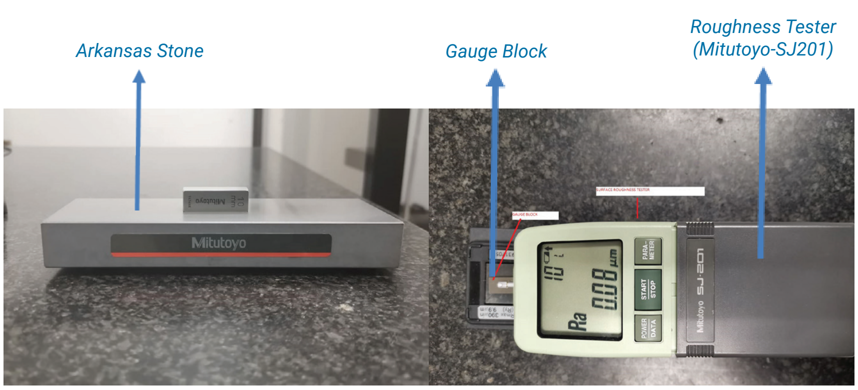

Figure 1. Arkansas Stone used for deburring and Roughness Tester.

Table 1. Steel Gauge Blocks used.

Nominal sizes	Test Gauge Block Grade 0 in mm (Combined)	Standard Gauge Block grade 00 (Whole)	Combined Gauge Bloc[k] error in µm
12.9	10 (SN 949444)	12.9 (SN 060501)	-0.13
	1.5 (SN 950614)		
	1.4 (SN 940252)		
17.6	9 (SN 944588)	17.6 (SN 100170)	-0.07
	7 (SN 944650)		
	1.6 (SN 940295)		
20.2	8 (SN 945445)	20.2 (SN 100343)	-0.26
	6 (SN 946768)		
	3 (SN 940336)		
	2 (SN 950577)		
	1.2 (SN 940356)		
22.8	20 (SN 044070)	22.8 (SN 060210)	-0.04
	1.7 (SN 940857)		
	1.1 (SN 940114)		
75	40 (SN 943158)	75 (SN 730166)	-0.24
	30 (SN 943065)		
	5 (SN 040788)		

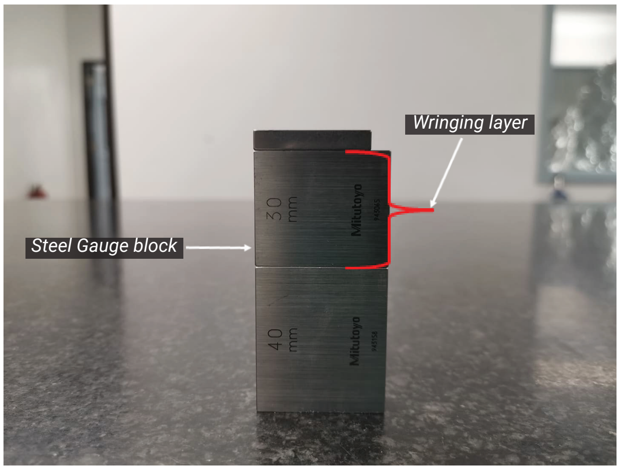

Figure 2. Combined gauge block

In **Figure 2** the wrung gauge block sizes were subjected to the procedure of measurement and evaluation as specified in 2.1 and 2.2.

Wringing Error measurement

The measuring probe of the GBCD-100A measures the central length, minimum length and maximum length. However, only the measured central length was considered. as shown in **Figure 3**.

Each selected test gauge blocks exhibit poor wringability of surface. Though wringing can still be performed through the application of a wringing medium, the ability to stay fixed through time differs from one medium to another.

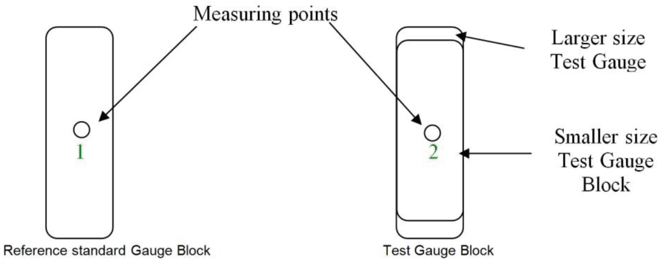

Figure 3. Measuring points of the standard and test gauge blocks. The comparative measurement method of GBCD-100A governed by the following equation. The measured error at measuring point (2) is referred to as the central error of the wrung gauge block.

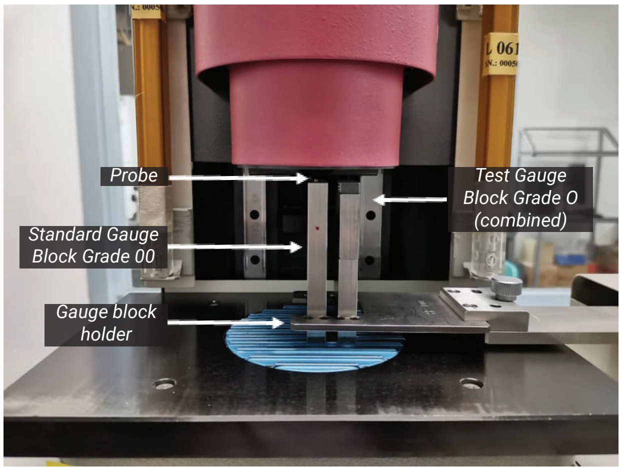

Figure 4. Set-up of measurement using the Automatic Gauge Block Comparator. Gauge blocks were stabilized for 24 hours after cleaning and preparation.

To eliminate the effect of thermal expansion during wringing, the wrung gauge block was stabilized for two hours before conducting measurement. As time elapses after the test gauge blocks have been wrung, the built-up nominal size becomes loose and can be separated with less effort at all, therefore, measurements were started 30 minutes after wringing was made, and succeeding trials were made every 3 minutes for ten trials per nominal size.

After the measurements were conducted, the wrung test gauge blocks were observed for 24 hours for their stability to remain fixed.

Figure 4 shows the position of the standard gauge block and the test gauge blocks in the gauge block holder of the Automatic Gauge Block Comparator.

Calculation of measured wringing errors

Calculation of wringing error was done using Equation 1 shown below.

$$W_e = C_E - \sum e_i$$

Where:

W_E - *Wringing error*

C_E - *Central error*

$\sum e_i$ - *Combined Test Gauge Block Error*

Computed wringing error in μm for nth nominal sizes

$$W_c = \frac{C_E - \sum e_{i_z}}{n - 1}$$

Where:

W_c = computed wringing error for nth nominal sizes

The combined test gauge block error was computed by taking the sum of the calibration errors of each test gauge blocks used to form the required nominal size.

Refer to **Table 1** for the computed combined test gauge block errors. The measured central error is the error value obtained at the center of the measuring face of the combined test gauge blocks which is basically the deviation from the central length of the standard gauge block, indicated as measuring point 1 in **Figure 3**. The values of the Central Error are obtained from the readings of the Automatic Gauge Block Comparator.

Uncertainty of measurement

The uncertainty of measurement was evaluated using ISO Guide to the Expression of Uncertainty in Measurement (ISO-GUM). The uncertainty components identified to have influenced the results of measurement are the uncertainty of measurement of the calibration of standard gauge block, temperature fluctuation of the laboratory, temperature difference of the gauges, and differences in coefficient of thermal expansion.

To attain the accuracy of measurement within the stated/computed uncertainty of measurement, the environmental conditions are maintained at 20±1°C and relative humidity of 55±10°RH, however, the ambient temperature fluctuation before and after each measurement should be within ±0.2°C only. No measurements were conducted outside the prescribed environmental conditions. The equation used for the calculation also included the second order terms as prescribed in ISO-GUM.

Results and Discussion

Measured Wringing Error

The results of measurement are presented in **Table 2**. Individual measurement results are tabulated in **Appendix A**. These results of the computed wringing error were calculated based on Equation (1) using the individual measurement results from Trial 1 to Trial 10 under the conditions stated in 2.1 and 2.2.

For nominal 12.9mm the following sizes that were used 10,1.5 and 1.4mm and the computed wringing error is 0.11μm.

For 17.6mm the following sizes were used 9,7and 1.6mm and the computed wringing error is 0.06μm.

For 20.2mm the following sized were used 8,6,3,2 and 1.2mm and the computed *We* is 0.04 For 22.8mm 20,1.7 and 1.1mm and the computed *We* is 0.11 And for 75mm 40, 30 and 5mm and the computed *We* is 0.10.

The minimum and maximum computed wringing errors are 0.04μm and 0.11 μm respectively as shown in **Table 2**.

After the wrung test was conducted the gauge block was measured and showed that the gauges remained

Table 2. Computed wringing errors

Nominal Sizes in mm	Ave-Central error in μm	Measured wringing error in μm $W_e = C_E - \sum e_i$	Computed wringing error in μm for nth nominal sizes $W_c = \frac{C_E - \sum e_{i_z}}{n-1}$
12.9	0.09	0.22	0.11
17.6	0.06	0.13	0.06
20.2	-0.09	0.17	0.04
22.8	0.18	0.22	0.11
75	-0.05	0.19	0.10

tightly wrung to each other even after more than 24 hours. This indicates that the error due to the loosening of the wrung surfaces during the measurement is negligible.

The results of surface roughness measurement ranged from Ra 0.03 µm to Ra 0.07 µm These values are considered small as compared with the measured wringing errors. Only, the nominal size of 75 mm has significant changes before and after deburring was made while others are relatively the same. **Table 3** shows the comparison surface roughness before and after deburring of test gauge block.

The Uncertainty of Measurement Associated with the Average Wringing Error

The estimated uncertainties of measurement associated with each average wringing error are shown in **Table 4** which ranges from ±0.063 µm to ±0.122 µm.

Table 4 shows that the wringing quality of a 25 year-old gauge block is within the range of 0.06 to 0.11 microns estimated using a normal distribution curve.

Conclusion and Recommendation

The wringing error of 25 years old gauge block can range from 0.04 microns to 0.11 microns based on the computed wringing error presented on **table 2**. This proves that even the gauge block which is more than 20 years old, can be still used especially when proper handling and maintenance is implemented although it is often used.

The wringing effectiveness of the gauge block was enhanced by ensuring an average roughness of the surface from 0.02 to 0.07 microns. With this surface condition, the gauge blocks will "stay fixed" for more than 24 hours as observed during the experiment. However, there are no data gathered to conclude that surface roughness directly affects the measured central length of the gauge block.

Although the observed time for the wrung gauges to "stay fixed" lasted for more than twenty-four (24) hours, future related studies may focus on the behavior of the errors up to the time of separation of the wrung gauge blocks. Assuming a probability density function (PDF), the range of wringing quality of 25 years' gauge block that can be adopted by the M&E industries is within 0.06 microns to 0.10 microns at 1 sigma probability.

Table 3. Surface Roughness evaluation before and after deburring.

Surface Roughness Evaluation			
Nominal Sizes in mm	Gauge Block use in mm	Average in µm Before deburring	Average in µm After deburring
12.9	10.0	0.11	0.05
	1.5	0.07	0.04
	1.4	0.09	0.05
17.6	9	0.03	0.05
	7	0.03	0.02
	1.6	0.05	0.06
20.2	8	0.04	0.06
	6	0.03	0.05
	2	0.04	0.03
	3	0.04	0.06
	1.2	0.06	0.06
22.8	20	0.02	0.04
	1.7	0.05	0.05
	1.1	0.06	0.06
75	40	0.06	0.07
	30	0.11	0.04
	5	0.17	0.05

Table 4. Computed Uncertainty of Measurement associated to the average Wringing Errors.

Nominal sizes in mm	Average wringing error in µm	Uncertainty of measurement in µm
12.9	0.22	±0.063
17.6	0.13	±0.063
20.2	0.17	±0.063
22.8	0.22	±0.063
75.0	0.19	±0.122

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Appendix A

				Wringing Error = Central Error $- \sum e_i$									
				Where: $\sum e_i$ *- Combined Test Gauge Block Error*									
Nominal Sizes in mm	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Ave-Central error in µm	Measured wringing error in µm	Computed wringing error in µm for nth nominal sizes
12.9	0.10	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.22	0.11
17.6	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.13	0.06
20.2	-0.10	-0.10	-0.09	-0.10	-0.10	-0.08	-0.09	-0.09	-0.09	-0.10	-0.09	0.17	0.04
22.8	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.18	0.22	0.11
75	-0.04	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.19	0.10

Impact of the Covid-19 Pandemic on the Philippine Metalworking Industry: A Phenomenological Approach

Alexander P. GONZALES*1

Abstract

The experiences of the Philippine metalworking industries during the imposition of the government's directives to slow down the spread of the Covid-19 virus in the country need to be given due consideration to determine the necessary actions to be taken in reviving the Philippine economy. A qualitative phenomenological approach is necessary to extract the lived experiences of the different metalworking industry players and identify the essential themes that define their 'lifeworld' concept. The study focuses on the extent of changes experienced by the metalworking industries due to the Covid-19 pandemic, their coping strategies with the new normal, and the assistance needed from concerned agencies and stakeholders. The essential themes that emerged in the extent of changes experienced were abrupt changes in the market condition, severe disruption in operations and mobility, and restricted cash flow while shouldering the cost of health security protocols. The essential themes for coping strategies with the new normal were adjusting to the new health security protocols, creating opportunities in a crisis situation, pursuing survival measures, and contemplating flight reactions. The essential theme for the assistance needed from concerned agencies and stakeholders was needing sound economic policies. The Philippine metalworking industries are one of the drivers of the industrialization and automation of the country. If the government wants to establish a stronger and more resilient Philippine economy, local industries such as the metalworking industries must be revitalized.

Keywords: *Philippine metalworking industries; Phenomenological; Lifeworld; Covid-19; Enhanced Community Quarantine; Pandemic; Health Protocols; Lockdown; DOST-MIRDC*

Introduction

The novel Coronavirus (SARS-CoV-2) or COVID-19, can be considered as the biggest cause of social disruption of the current generation [1] and it leaves a huge impact on the Philippine economy especially in the manufacturing sector.

On March 16, 2020, the Philippines government imposed an enhanced community quarantine (ECQ) on the island of Luzon, which is in effect a total lockdown. After almost two months, through the Inter-Agency Task Force of Emerging Infectious Disease (IATF) Resolution No. 35 dated May 11, 2020, all identified high-risk localities including Metro Manila, Laguna, and Cebu City were placed under a modified enhanced community quarantine (MECQ) from May 16 until May 31, 2020. During MECQ, some businesses are allowed to operate with 50% of their employees on-site [2].

The two months of lockdown in the National Capital Region (NCR), as well as the Greater Metro-Manila Area (GMA), crippled the production of various industries not considered essential. An investigation on the impact of the government's response to the Covid-19 pandemic to the various metalworking industries is necessary to know their experiences and determine their status so that concerned agencies and stakeholders may

*1 *Planning Officer III*
Metals Industry Research and Development Center
Bicutan, Taguig City
Philippines

provide measures, programs, and policies to enable the metalworking industry to survive the present challenges.

Objectives

This study determines the impact of the government's response to the Covid-19 pandemic on the Philippine metalworking industries as experienced by the selected industry players. Specific objectives of this study include:

A. To know the extent of changes caused by the ECQ and other quarantine measures implemented by the government due to the Covid-19 pandemic;

B. To identify the metalworking industries' plans in coping with the new normal; and

C. To determine the assistance needed by the metalworking industries.

Methodology

This study will utilize a qualitative phenomenological research method to determine the extent of the ECQ's effect on the status of the Philippine metalworking industries brought about by the Covid19 pandemic. The ECQ is considered the longest lockdown in response to the Covid-19 pandemic [3]. This study will follow the qualitative phenomenological research approach to trace the shared experiences of the key informants of the study [4]. Phenomenological research provides a platform where the voice of the stakeholders can be heard [5]. Edmund Husserl, regarded as the father of phenomenology, laid down the groundwork for this approach and introduce the concept of 'Lifeworld' [6], which is the sum of the immediate experiences and contacts that defines the world of a person or a corporate life.

The process of phenomenological research applied in this study is shown in **Figure 1**. In order to identify the experiential accounts of the Philippine metalworking industry during the onset of the ECQ, the Metals Industry Research and Development Center through the Technology Diffusion Division – Technology Information and Promotion Section (TDD-TIPS) conducted 12 in-depth interviews facilitated by the author, Engr. Eldina B. Pinca, Ms. Zalda R. Gayahan, and Ms. Lina B. Afable and participated by officials of metals industry associations of the Philippines from July 23, 2020 to November 3, 2020. The officers of the following associations participate in the interviews:

1. Philippine Die and Mold Association (PDMA);
2. Philippine Iron and Steel Institute (PISI);
3. Aerospace Industries Association of the Philippines (AIAP);
4. Metalworking Industries Association of the Philippines (MIAP);
5. Mechatronics and Robotics Society of the Philippines (MRSP);
6. Society of Mechanical Engineers (SME);
7. Philippine Welding Society (PWS);
8. Philippine Society for Nondestructive Testing (PSNT);
9. Philippine Metalcasting Association, Inc. (PMAI); and
10. Philippine Parts Maker Association, Inc. (PMMA)

The key informants of this study are officers of the various metalworking associations in the Philippines. Purposive or judgement sampling is used to identify the key informants of the study [7]. This study requires the extraction of proper data that can only be provided by a selected individual with the following qualifications:

a. Have been engaged in the metalworking industry for more than 10 years;
b. Have a registered metalworking business whose operation was affected by the ECQ; and
c. An elected officer of any recognized metalworking association of the Philippines.

Interviews were transcribed and subjected to the phenomenological approach coding process as stipulated in the literature presented by Edwin Creely [6] such as ontological description, phenomenological reduction, and hermeneutic analysis. Themes were identified and clustered to extract the essence of the observed phenomena. Measures to avoid biases were performed through a series of peer reviews of findings with Engr. Eldina B. Pinca and Dr. Concesa T. Cortez. Validation of findings was conducted through a Focus Group Discussion (FGD) on November 26, 2020, which was attended by various metalworking industry stakeholders. Further observation of findings was done during the MIRDC TDD-TIPS industry dialogue 'Virtual Talakayan' on June 15, 2021.

Results and Discussion

Figure 1: Process of Phenomenological Research

The imposition of the ECQ due to the Covid-19 pandemic greatly changed the corporate and market environment of the stakeholders in the Philippine metalworking industry. The findings of this study will focus on the following:

a. The extent of changes due to the Covid-19 pandemic;
b. The coping strategies with the new normal; and
c. The assistance needed from concerned agencies and stakeholders

The Extent of Changes due to the Covid-19 Pandemic

The extents of changes experienced by the Philippine metalworking industries are abrupt changes in the market condition, severe disruption in operations and mobility, and restricted cash flow while shouldering the cost of health security protocols.

The key informants view the abrupt change in market condition in connection with the dwindling industry market opportunity, fear for an economic recession, and undisrupted essential industries and necessary services.

Even prior to the onset of the Covid-19 pandemic, the Philippine metalworking industries already experienced a dwindling market condition. According to one informant, the non-destructive testing services lost a major client when *"Shell Philippines shut down their operations because they realized that it is more economical to import processed fuel than to refine it in our country."* Likewise, the Philippine metalworking industries serving the automotive sector lost major clients when *"Ford Philippines closed their manufacturing and assembly operations in the Philippines, which was followed shortly after by Honda Cars."*

The market opportunity of the metalworking industries is dependent on the operation of the different sectors they served. One of the sectors that was greatly hit by the Covid-19 pandemic is the transportation sector, specifically airlines operations. As stated by one of the informants, *"the travel ban imposed by different countries greatly decrease the demand for aerospace parts and maintenance services with 70-80% of the airplanes not flying."* The construction sector also had difficulty in terms of the movement of materials, equipment, and personnel which slowed down their operation resulting in a decrease in the demand for iron and steel products. The following statements of the informants reflect the other clienteles of the metalworking industries that slowdown, if not, shut down their operations:

- No one is buying new cars because the banks do not provide new loans.
- To date, the vehicles sales have dropped down by 55% compared to last year. So, that

translates also to a demand reduction whether it's metal stamping, plastic injection, etc.

- Just imagine losing 50% of your income. So, it would not be feasible to operate modern jeeps.
- Our clients in the restaurant industry have very limited operations
- If you will read the papers, a lot of real-estates developers had suspended and reduced their capital expenditures.
- One manufacturing company closed in Laguna and their locally ordered parts were transferred to their mother company in Thailand.
- I am exporting to a client in Australia, but they shifted to China because they already opened up their economy and had implemented sound policies and action plans.

The Philippine metalworking Industries fear the possibility of an economic recession. As one informant recalled, *"the worst crisis was in 1997 and the impact was in 1998, 1999, and 2000. The effect is around 2 ½ years because there was no construction."* The informants are predicting that the recovery period for this pandemic will be longer. They said, *"recovery period will probably start around 2023. So, that means [the metalworking industries have to recover] for the next three and a half years."* They are apprehensive with the uncertainty of the market condition and this is reflected by the following statements *"we had to roll out money without understanding what is coming in the future.;" "It's a different landscape, unlike before, you cannot predict it.;"* and *"We are not availing the loans because we are uncertain of the market condition. If we avail it, we might not be able to pay it back."* They described that the Philippine economy is import-dependent and the Covid-19 pandemic will even worsen the situation because of the inability of the manufacturing industries to operate in the country. One of the informants shared *"I foresee that eventually there will be a lot of imports coming in and competing with the local industries."*

Many players in the Philippine metalworking industries are hampered by the pandemic but a small portion of the sectors they served remain operational. These are considered undisrupted essential industries and necessary services. Food production and distribution are allowed to continue with minimum restrictions as well as power plants that generate electricity. Services such as testing and maintenance in support of these essential industries help some metalworking industry players get by during these trying times. Even in times of crisis, there are some opportunities. An informant states that the *"economic and socialized housing project had picked up because of the virus."* There are still some limitations to those metalworking industry players who are able to operate, they can only serve those that are in close proximity to their shops, as they shared *"we can only serve the costumers who are near to us."*

The severe disruptions in the operation of the Philippine metalworking industries were experienced in terms of forced shut down and restricted operations, problems in workforce management, and difficulty in the movement of workforce, supplies, and outputs.

The government's lockdown policy left the metalworking industries no choice but to comply. A lot of them have totally closed during the two months lockdown from March 15, 2021 to May 15, 2021. The informant shared, *"instead of being reprimanded, we just choose to follow the government's directives."* Most of them have prior commitments and job contacts. Even those with the intention to continue their operations were confronted with a lot of challenges. As the informant stated, *"the problem is the local companies in the Philippines. The barangay won't let them operate and sell their products.;"* and *"when I tried to operate, the suppliers were closed because the government does not consider them as essential."* Most of the shops just continued their operations with the supplies at hand and those without available supplies were forced to cancel. An informant stated, *"we cannot make profit out of 20% to 35% ng operation."*

The problems in workforce management involve the metalworking shops' workspace, because the government requires social distancing, employees such as machine operators and technicians cannot work simultaneously. One of the informants shared, *"the impact is big, out of 80 workers only 20 can work."* The fear of contracting the Covid-19 virus during the total lockdown was so intense that even when there are available job orders and projects, the workers do not report to work. *"There are workers who are afraid to go to work, their family would not allow them,"* said one informant. Boarding workers to continue operations was also a challenge because the landlords do not accept new tenants due to fear of the Covid-19 virus. Some government programs that were implemented during the lockdown further aggravated the workforce problems. As shared by one informant, *"I cannot believe* *how many people choose to go to the province. I think we've lost 60 people because of the 'Balik Probinsya' program."* In order to mitigate the workforce problems, the metalworking companies were forced to implement early retirement schemes and retrenchments. The following statements reflect these experiences, *"The subcontractors lost their works. They are the ones who offer janitorial and maintenance services.;" "We were forced the retrench.;"* and *"Others choose early retirement, while others were laid-off."*

The government imposed a strict quarantine and mobility restriction policy. Transportation of workforce, supplies, and outputs became a challenge to the metalworking companies and severely slow down their operations. *"Our workers cannot report to work because the roads were closed,"* shared one informant. *"Travel pass became a problem for our trucks drivers and our workers,"* shared another. Supplies take a longer time to be delivered, as observed by one informant, *"before, if you order, supplies will be delivered in seven (7) days. Now, it took them fourteen 14 days."* Even maintenance, repairs, and testing services were affected by the restriction in movement and their productivity decreased dramatically, *"our project takes four (4) days to finish, but our people need to be quarantined for 14 days, we are running out of people to deploy."* The uncoordinated implementation of health security policies also added to the burden of transporting metalworking products. The informants shared, *"even the materials, we cannot deliver. The IATF and the LGUs have different policies.;"* and *"we have to pass through three (3) barangays, each with their own barricades and their schedule is not coordinated and unsynchronous."*

The Philippine metalworking industries operate in a certain balance of credits and investments. The government's response to the Covid-19 pandemic disrupted this balance. The metalworking industries experienced moderate to severe cash flow difficulty with the additional burden of shouldering the cost of health security protocols.

The metalworking companies that established good relationship with their suppliers usually enjoy a credit system that extends up to 90 days or three (3) months. As shared by one of the informants, *"if we have a good and long relationship with the suppliers, they won't require us to pay instantly but they ask for a post-dated check (PDC) before pick-up."* In turn, the metalworking companies were able to extend that privilege to their clients. One of the informants shared, *"the big companies do not pay outright in cash. They usually ask for 90 days of payment processing terms. Just imagine how much of our capital is locked with them."* This payment scheme provided the Philippine metalworking industries a buffer capital from the suppliers, while they invest in machines, equipment, and skilled workforce, which in turn gave them the capability to accept the payment terms of their clients.

Unfortunately, during the ECQ, suppliers only accept cash transactions while their clients stick to the agreed payment terms. This scheme trapped the metalworking companies in a situation where they have to invest more capital. These experiences were reflected in the following statements, *"our suppliers want to clear all pending transactions, while the new ones they gave in shorter terms.;"* and *"suppliers do not grant credits for materials anymore. They require 50% to 20% down and no extension of credit."* Most of the metalworking companies were caught out of cash which restricted them to venture into different business activities and they have to address their outstanding loan obligations. The informants shared these experiences, *"with a limited budget, it is hard for us to venture into other business.;"* and *"it's the same with [loaned] machines, the bigger the machine capacity, the bigger your problem in terms of payment if it is not operating."* The Philippine banking system that could have helped the metalworking companies cope with their current cash flow problems also added to their burden. As one informant shared, *"the banks just delayed their collection. When they did, they asked for the whole amount."*

During and immediately after the ECQ, new health security protocols were established [3]. This additional cost further aggravates the cash flow difficulty of the Philippine metalworking industries. The following statements reflected these experiences:

- If we have a new project, they would require our people to undergo a rapid test, and we have to show the results to our clients.
- If you have 20 people, you have to shell out P120,000.00 for the test. The project has not started yet but the company already has to give a large sum of money.
- It should be a complete medical, every person you have to spend P2,500.00. That is good for one month only, shouldered by the company.

- The barracks, food, personal protective equipment (PPE), shuttle services, and testing have an impact on the contract cost.
- Most of these large companies have the funds to sanitize. They were able to take measures to prevent the virus. They were able to provide shuttle service to their employees. Some were able to implement the protocols but a great majority does not have the means.

The metalworking companies felt responsible for the safety and needs of their workers. They implemented measures to help their workers get by during the ECQ. Some provided them cash advances and released the 13th month early. They even provided food packages and vitamins to their workers.

The Coping Strategies with the New Normal

The Philippine metalworking industries tried to cope with the new normal policies of the government. The new normal is characterized by strict social distancing, health, and hygiene protocols [8]. The metalworking industries' coping strategies can be categorized as adjusting to the new health security protocols, creating opportunities in a crisis situation, pursuing survival measures, and for some contemplating a flight reaction.

Adjusting to the new health security protocol was not simple with the restricted cash flow stated earlier. There were challenges because the measure to be implemented is still based on a trial-and-error scheme. These experiences were shared in the following statement:

- Initially, we bought face masks that are a washable type for economical reasons. But we found out that most of our people were lazy. After they use it, they don't wash it, and it will complicate things.
- We had a problem. One of our employees tested positive. Although, the test is not that accurate. So, we rented a house to segregate the person. But after a week, there were no symptoms. So, we have that person re-swabbed, after 10 days. The result was negative.
- Some temperature scanners that you can commonly purchase have a setting accuracy that is 1.5 degrees Celsius which should not be sold to the public.
- You cannot implement the protocol 100% because people perspire in the shops especially the welders. Due to the nature of their work, we are having issues with the mask and the face shield.
- It is not safe for welders to use alcohol inside the factory. Gel sanitizers are even more dangerous.

Some companies with ample resources were able to implement health security measure that surpasses government standards. They implemented strict entry policies. Even with the slightest symptoms, they don't let their employees report to work. They implemented a strict social distancing policy, as they shared, *"we came out with a plan that everybody is assumed positive."* They implement contact tracing and sanitation measures. One informant shared, *"We have hypochlorous acid, pulse oximeter, CO_2 monitoring. I think those are things that were not implemented by other companies."*

According to Albert Einstein, *"in the midst of crisis, lies great opportunities."* Some of the metalworking industry players were able to think of opportunities to survive amidst the Covid-19 pandemic. One informant shared, *"we try to develop on items that are needed for these situations. It is not easy to develop, especially now, it takes a lot of engineering and resourcing."* The following innovative opportunities were expressed by the informants:

- Now we are trying to develop an air purifier for industrial use.
- We develop a misting booth.
- Fully automated manufacturing is a boom in the food and semiconductor company.
- Industry 4.0. is the new normal. Not all have the capability to adapt, at least we have shared the idea that it can be done here in the Philippines.
- An opportunity came, autonomous robot. It became an advantage to them.
- A company was able to thrive. The company manufactures springs for the hospital beds.
- We called it pre-fabricated items. When the items were delivered to the construction site, they just assemble them. That's another business opportunity.

Pursuing survival measures during the Covid-19 pandemic is not easy. As the saying goes, you have to *"bite the bullet."* Some of the metalworking companies relied on their long experience and the resiliency of their companies. Some of them have survived through tough times, as they shared, *"My father started three (3) years before the Japanese time, I'm working as the second generation.;"* and *"I have been handling business for more than thirty years now, so, I have been through a lot."* Most of the informants shared that they do not see any profit in their operations, they just want to survive. As they shared, *"Actually, what we do is for survival, we don't need to make money.;" What we are thinking right now is how to survive our finances, provide salaries to our employees, and pay the utilities;"* and *"Our concern is to survive this year. Meaning to say, our health keeps us alright. I think, that is already our profit."* Some of the measures they implemented were to cost cut and control their overhead expenses. One of the informants shared, *"we do cost-cutting. We removed our security guards because it is taking a big portion of our overhead expenses. We removed them because they are equivalent to four (4) employees. Our security is 24 hours."* Some of the metalworking companies, in order to survive, do whatever it takes to accept job orders and sell their items even at a break-even price. As they shared, *"we do not choose, if a customer brings it, we have to do it.;" "Our expenses are high and the returns are most often in terms, but sales are sales. So, no matter how small it is, as long as it is in cash, we will accept it.;"* and *"even if it is almost at a loss, you needed cash, you have to sell."*

Unfortunately, not all metalworking shops have enough resources to survive the health crisis situation. Some of them are contemplating if not have decided to pursue a flight reaction. The informants shared, *"eventually, if this continues, a lot of companies will just stop operating, they could not compete.;"* and *"well, I think there's about 4 or 5 that close down already. I believe there's going to be another 4 or 5 if there's really not much activity and the trend will continue until probably midyear next year."* The metalworking firm that closed down sold whatever machines they have to have enough funds to provide separation pay to their workers. The informant shared, *"I will liquidate my equipment, especially in the machine shop. Or I will give the machines as separation pay to my workers."* Some are planning to move into a different location or a different business activity. The informants shared, *"I think, I will just engage in farming.;" "It's better to engage in a trading company, no more local manufacturing.;"* and *"I have to divert my engineering and construction project in Mindanao."*

The Assistance Needed from Concerned Agencies and Stakeholders

Government intervention can make a difference in the Philippine metalworking industry. The intervention does not have to be a bad experience for the metalworking industry players. As one informant shared, *"we tried to help and develop a misting booth, but unfortunately, our project was shot by the Department of Health (DOH). So, no one bought it because they don't recommend the misting booth."*

Unfortunately, metalworking industry players have experienced unsupportive policies even before the pandemic. Since numerous metalworking companies are serving the automotive and transportation sector, policies and programs of the government affect their operations and investment venture. The following statement reflects sentiments *"Department of Finance (DOF) is the one blocking the programs and proposals being done by the Department of Trade and Industries (DTI), the Department of Transportation (DOTr), and even the Department of Environment and Natural Resources (DENR) [regarding modern jeep].;"* and *"The bill was passed to exempt the excise tax of the electric vehicles and that is to promote the production or sales of electric vehicles. But at that time, they included the pickup trucks. When the excise tax was exempted, then it became cheaper to import the completely built unit (CBU) of the pick-up trucks from Thailand than those with assembled parts in the Philippines."*

Import and export policies of the government and the operations of the Bureau of Customs affect the competitive capabilities of the local metalworking industries. The share the following statements on this matter, *"The opportunity and support for the local foundry to be more competitive is so limited. Such that we have to accept the fact that certain markets will be dominated by Chinese products.;" "We need the government support to promote the local products;"* and *"The Customs is always having problems with their manpower and processing of their work. So, there is always a delay in the importation [of raw materials]."* In line with these observations, industry players are also concerned with the entries of low-cost but substandard iron and steel products in the country, which limits the capability of the local industries to compete in term of pricing because the local industries abide with strict quality standards. As one informant shared, *"So, the important thing is the vigilance of the industry in cooperation with the government in policing the market and promoting the importance of the standards. The problem is that we do not have standards. It's free for all."*

The need for sound economic policies is very important to help the Philippine metalworking industry to rise after the Covid-19 pandemic. The Covid-19 pandemic exhausted the resources of most metalworking industry players. For them to recover and be competitive, support from the financial institutions and government incentives are sought for by the industry players. As they shared, *"we have to infuse money to the small and medium companies so that the people can work again. This is a win-win solution. They should lend them in a long term and with meaningful interest.;" "Provide incentives for a local assembler, whatever ways we can provide, even tax holiday. So, they can make the vehicles cheaper.;"* and *"Actually, there is a program. Part of the equity program of Board of Investment (BOI) is to have a shared testing facility, shared painting, Electrophoretic Deposition (ED) coating, and even shared facilities for chassis building."*

Research and development (R&D), technical services, promotion, and training support are also sought by the Philippine metalworking industries to improve their capabilities. Process and operation improvements are necessary to incorporate the health protocols with the least possible financial burden to the metalworking companies. As one informant shared, *"I think the most important is the practical approach, how can we overcome Covid-19 pandemic without additional cost and additional effort that will be put on to the companies."* R&D support from the DOST is necessary to augment the R&D cost of developing new products and machines. Some respondents shared their R&D needs, *"The Department of Agriculture (DA) wants to mechanize. We are hoping DOST can help.;"* and *"It's a high efficiency particulate air (HEPA) filter, it's a very fine filter fabric. We do not have local manufacturers. I don't know if they [DOST-Philippine Textile Research Institute] have this HEPA filter."* The DOST-MIRDC is also enjoined to provide support the metalworking industries. Some of the informants expressed their willingness to have their employees trained, as one of them shared, *"This is the time to train the employees. So that when the economy opens up, we will have a pool of skilled workers."* The metalworking industry also expresses their need for marketing and promotional support, as reflected in the statement, *"We are engineers and technical people, not marketing experts. We can create products. Selling them is a different thing. So, that is also one area that we have to address."*

Conclusion

The experiences of the Philippine metalworking industry during the ECQ and the succeeding quarantine measures of the government should be taken into consideration in the formulation of plans to revive the economy. The metalworking companies are our partners in promoting locally manufactured products. They are one of the drivers of industrialization and automation.

The government's policies to combat the spread of the Covid-19 virus took a heavy toll in the metalworking industries in terms of operations and mobility. Even prior to the onset of the pandemic their market opportunities are dwindling coupled with a steep competitive environment. Most of the metalworking micro, small, and medium enterprises (MSMEs) find it difficult to produce the necessary capital to stay afloat during and immediately after the lockdown. Most of them feared that an economic recession will follow the aftermath of the pandemic. Some of their workers were driven by fear and choose to move to the provinces. Not to mention, that they have to shoulder the cost of the imposed health security protocol without assurance that they will be able to add it up to their clients' contract price.

Most of the metalworking companies tried to survive and cope with the new normal. Some of them were able to find opportunities to provide products needed to help our country to secure the public, such as providing parts for medical equipment and facilities. They even provided a mold for the production of face shields to address its shortage. With the help of the DOST-MIRDC, face shields were produced and distributed to selected hospitals and local government units.

As more metalworking companies shut down or venture into a safer investment, assistance from concerned agencies and stakeholders is imperative. The government needs to convince the various financial institutions to provide support to the Philippine metalworking industries. Government policies should be reviewed, repelled, or created to make the metalworking industries a rewarding and profitable venture. DOST-MIRDC should conduct further studies and dialogues to determine the specific needs of the metalworking industries that will improve their status and competitiveness. By supporting the local industries, we provide jobs and sources of livelihood to the people. Which in turn, creates quality and cheaper products for the Filipino consumers and the local manufacturing industries. A win-win solution for the Philippine economy.

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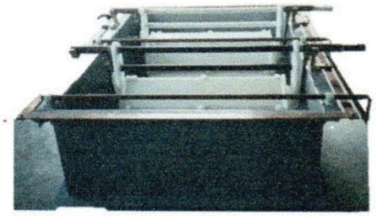
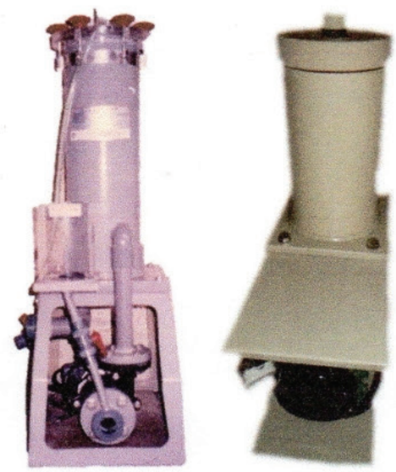
2nd Flr., #2 Mabini Ricarte St. San Antonio, San Pedro
Email add. thoben.industrial@gmail.com
Contact Nos. 8546-9251 / 09298003769



MANUAL PLATING BARREL

BARREL PLATING FOR SEMICON



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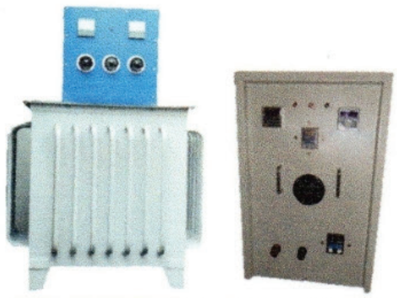
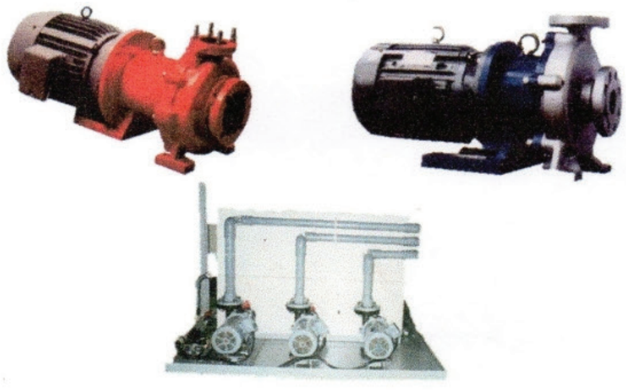


SILICON RECTIFIER

PULSE RECTIFIER

PP & PVC PLATING TANK



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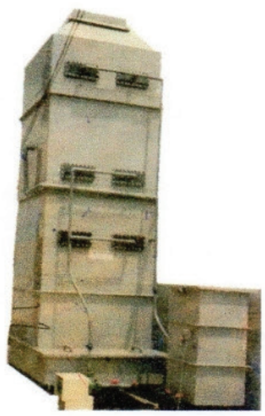
PH METER



FUME SCRUBBER

Metals Industry Research and Development Center

VISION

Center of excellence in science, technology and innovation for a globally competitive metals, engineering and allied industries by 2025.

MISSION

We are committed to provide both government and private sectors in the metals, engineering, and allied industries with professional management and technical expertise on the training of engineers and technicians; information exchange; quality control and testing; research and development; technology transfer; and business economics and advisory services.

CORE VALUES

Professionalism	We adhere to the highest ethical standards of performance. We value our work and are committed to perform to the best of our ability.
Responsiveness	We spearhead implementation of projects that address the needs of the metals and engineering industries. We find solutions to real-life problems through science, technology and innovation.
Integrity	We act responsibly, work honestly, and encourage transparency.
Dynamism	We perform our jobs with vigor and enthusiasm. We welcome change as an opportunity for growth and continual improvement.
Excellence	We adhere to world-class performance and continuous improvement in all we do. We always do our best in every task/endeavor.

QUALITY, ENVIRONMENTAL, and INFORMATION SECURITY POLICY

We are committed to provide products and services to both the government and the private sectors in the metals and engineering and allied industries with the highest standards of quality and reliability within our capabilities and resources and aligned to our strategic direction, to comply with applicable statutory and regulatory requirements to plan and implement actions to address risks and opportunities and to continually improve the effectiveness of our Quality, Environmental and Information Security Management Systems in order to enhance customer satisfaction at all times.

We shall manage and control our activities in order to minimize adverse impacts on the environment, prevent pollution and safeguard the health and safety of all employees, stakeholders, customers, external providers, and the surrounding community.

PRODUCTS AND SERVICES

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MIRDC Compound, Gen. Santos Avenue
Bicutan, Taguig City, 1631 Metro Manila
P.O. Box 2449 Makati, 1229 Metro Manila, Philippines
Telephone Nos.: (632) 8837-0431 to 38
(connecting all departments)
Fax Nos.: (632) 8837-0613 and 8837-0430
Website: http://www.mirdc.dost.gov.ph
E-mail: mirdc@mirdc.dost.gov.ph

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- Gear Making

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- Vacuum Heat Treatment

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- Electroplating
- Anodizing
- Pulse Plating

1.5 Metalcasting
- Conventional Casting
- Investment Casting

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- Nondestructive Testing*
- Mechanical Testing*
- Calibration and Metrology*
- Corrosion Testing*
- Metallurgical Analysis
- Auto-Parts Testing

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- Periodic analysis of industry status
- Extension of S&T services to the regions

B. Industrial Training

C. Industry Linkage

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- Industry and sectoral studies
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DEPARTMENT OF SCIENCE AND TECHNOLOGY
METALS INDUSTRY RESEARCH AND DEVELOPMENT CENTER

MIRDC Compound, Gen. Santos Avenue, Bicutan, Taguig City, 1631 Metro Manila
P.O. Box 2449 Makati, 1229 Metro Manila, Philippines
Telephone Nos.: (632) 8837-0431 to 38 (connecting all departments)
Fax Nos.: (632) 8837-0613 and 8837-0479
Website: http://www.mirdc.dost.gov.ph
E-mail: mirdc@mirdc.dost.gov.ph