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Contents

The Cover: *The cover depicts deformed reinforcing bars which are used in a range of residential, commercial and infrastructure applications from concrete slabs to prefabricated beams, columns and precast products. Deformed reinforcing bar is rolled from carbon steel classified into structural, intermediate and high-tensile grades. This product complies with Philippine National Standards (PNS 49).*

Brought into focus in the recently concluded Strategic Planning Sessions of the Metals Industry Research and Development Center are its five major strategic thrusts, namely: Focus on Customers; Industry Competitiveness; Responsive to National Priorities; Service Improvement; and Technological Self-reliance. An essential output of the Strat Planning activity is the list of identified strategic objectives. One of which is to have a deeper penetration of the local M&E market through the intensification of promotional activities.

The Philippine Metals is one of the DOST-MIRDC's publications aimed to strengthen its drive for more aggressive information dissemination. Featured in this second issue are technical articles on the R&D projects of the DOST-MIRDC: the Development of 120-Passenger per Coach Capacity Automated Guideway Transit (AGT) System; Design and Development of an Automated Guideway Transit System Depot and Passenger Stations; Design, Fabrication and Testing of Pandanus Leaves Slitter-Presser; Development of an Automatic Tool Change (ATC) System for the 3-axis Computer Numerically Controlled (CNC) Router Machine; A Pulse-Width Modulation (PMW) Laser Power Controller for the 3-axis CNC Laser Machine; and Optimization of Machine Process Parameters through 2D Image Layout Enhancing and ArtCAM Post-Processing for 3D Machining. Included also in this issue are some feature articles, aimed to further disseminate information regarding our various initiatives that demonstrate our ardent support to the M&E industries.

The pages of the Philippine Metals present a collection of what the engineers, R&D personnel and other support teams have engaged themselves in during the past several months. Through these articles, we wish to emphasize that we are taking our responsibility to the M&E industries seriously. We earnestly want to communicate to all industry players that we are putting tremendous efforts to science, technology, and innovation initiatives so as to offer the best possible interventions. The outcomes of these R&D efforts are meant to enhance the industries' capabilities and catalyze robust economic activities – all for the benefit of the industries we are mandated to serve.

We are proud to present Volume 2 of the Philippine Metals. We will always be behind the M&E industries, ready to provide valuable contribution to its growth and global competitiveness. The technical articles inside this publication are proof of our commitment. We believe in the capabilities of the industry. We shall remain as champions of local technologies.

Robert O. Dizon
Assistant Secretary, DOST
and Officer-in-Charge, DOST-MIRDC

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Hon. Mario G. Montejo
Secretary, Department of Science and Technology (DOST)

The DOST proudly presents to the Filipino nation the products of the Training Program on Computer Numerical Control (CNC) Machine Tool Programming and Operations. Through the Metals Industry Research and Development Center (DOST-MIRDC), the DOST implemented the CNC Training Program with the aim of pushing for the competitiveness of the metals and engineering industries.

This project is the DOST-MIRDC's parallel move to the Department of Labor and Employment's Memorandum Circular No. 02 in 2012 which identified CNC machining as a 'mission critical skill.' Recognizing that this skill is vital to the industry, requires time to produce, and is not easy to replace, we know that our trainee-graduates who now possess CNC programming and operating skills will fill in the manpower needed in the manufacturing industry, especially in sectors where precision machining is a crucial part of the operations.

Engr. Robert O. Dizon
Assistant Secretary, DOST and Officer-in-Charge, DOST-MIRDC

The implementation of the CNC Training Program is part of the DOST-MIRDC's support to the Makinarya at Teknolohiya para sa Bayan (MakiBayan) initiative of the DOST. Along with our partners from the private sector and the academe, the DOST-MIRDC continues to be a change agent.

As we pursue continuous growth of the metals and engineering industries, we aim to empower the country's workforce. It is our goal to answer the industry's need for skilled CNC machinists. It is our vision to have a technologically self-reliant manufacturing industry. The graduates of the DOST-MIRDC's CNC Training Program are all part of our commitment to stand up to the challenges of the times.

Dr. Rowena Cristina L. Guevara
Executive Director, Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD)

PCIEERD takes pride in the graduates of this program, whom we are certain will survive the competitive world of advance machining because they are now equipped with the necessary preparation, training and skills. We are confident that with these new breed of "seeds" spawned to the local industries, our country stands a better chance in bringing our M&E firms to a higher level of competence. We hope that our graduates will develop the passion of being part of nation-building. With these fresh supply of CNC programmers and operators, we at DOST wish that the industry will nurture our partnership as we address the brain drain challenge head-on together.

The DOST-MIRDC acknowledges all its Partner Support Organizations (PSOs) - industry associations, academe, metalworking firms - who contributed valuable inputs to the CNC Machine Tool Programming and Operations Training Program.

The DOST Fulfills its Commitment to Increase the Country's CNC Talents

Dr. Danilo N. Pilar
Project Leader

Partner Metalworking Firms during Industry Immersions

DOST-MIRDC CNC Project Team

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We at the DOST-MIRDC are committed to implement programs and projects relevant to and have a strong impact on our stakeholders. We have strong faith that as the graduates of our CNC training program become employed in metalworking companies, they will be part of the solution that we intend to bring to the M&E industries.

Reprinted from the Philippine STAR, March 7, 2015.

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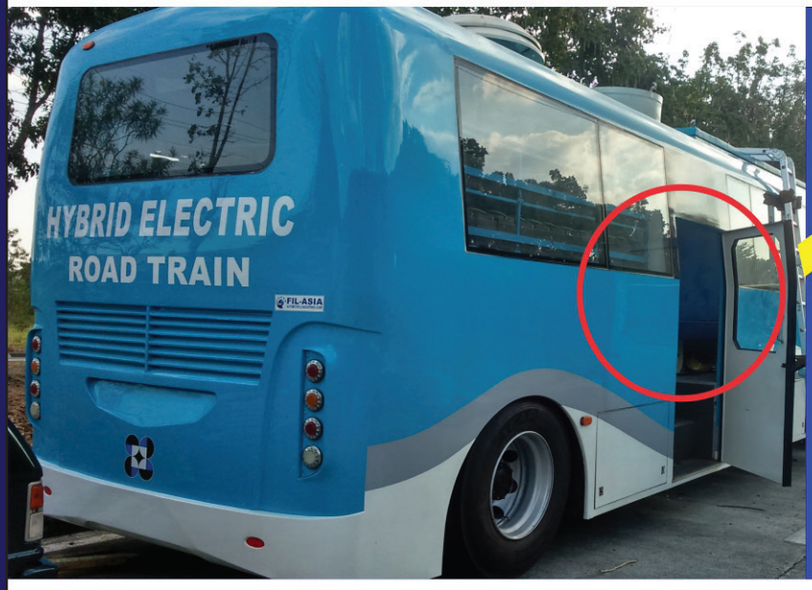

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THE PHILIPPINE METAL STAMPING SECTOR: TOWARDS A COMPETITIVE INDUSTRY

Eldina B. PINCA,*1 Ma. Rodessa Grace A. MERCADO*2

Abstract

The metal stamping sector of the metalworking industry in the Philippines, currently on the platform to vie for its share in the Metals and Engineering (M&E) Industries, continuously evolves to unravel its previously unforeseen substantial contribution in the Philippine economy. The automotive industry, being the bedrock of the metal stamping sector in the country, has recently offered a capital of opportunities as plans of establishing stamping plant emerged concurrently with one of the biggest automotive corporations' acquisition of a new headquarter in the Philippines[1]. The Metals Industry Research and Development Center (MIRDC) conducted a study on the stamping sector in 2013. In particular, the study considers establishing the membership profile of the metal stamping sector as a component of the M&E industries since it was not yet included in the Philippine Metalworking Industry Profiling Study. Direct with its aim to bring to the fore the level of recognition of the metal stamping sector, the study also pays attention to its issues and concerns to be addressed relevantly by the government in order to provide impetus in this industry. The government's proactive strategy in providing incentives has led the majority of investors to have their stamping businesses established in the Philippines particularly in CALABARZON Area. As represented by the increasing annual production trend from 2010 to 2012, the metal stamping industry has been operating effectively towards advancement. Moreover, a remarkable steer of increase in Philippine exports of stamped products in 2012 also signifies an industry that struggles to rebound from a decline in the export market from 2008 to 2011. Though it may be assessed that the metal stamping industry may ramp up as stimulated by the predicted boom in the Philippine automotive industry, the identified issues and challenges of the stamping sector should be given immediate action first as these may impede the continual growth of the industry.

Introduction

The Philippine metal stamping sector, which may now be projected as one of the future forefronts of the M&E Industries, is a highly competitive industry given that stamping is one of the major processes employed in the metalworking industry. The automotive industry is identified as the most catered industry by the metal stamping sector, followed by metalworking, semiconductor, industrial machinery and food. Albeit the different development patterns of the metal working industries in Asian countries, the Philippines was not left behind as being evidently depicted by the continuing plans of expansion of business of most respondent-companies from the recent metal stamping sector study. This business outlook can be attributed to the catered industries' plans to spread out manufacturing process to go along with the global operations. Having this picture, it may be deemed necessary to properly assess how the government can work hand in hand with private sectors to take advantage of the current market trend that will contribute to the economical and industrial development of the metal stamping sector in the country.

While the demands for the metal stamping industry have since evolved, having developed a more realistic demand for production, the only way to feel confident with this progress is to have the industry properly assessed. The rough edges of the industry may not be buffed smooth fully by the pervasive growth of the industry it caters most. From a wider perspective, the evaluation of the stamping sector should be diversified into its ability to match the influence trends that go about with economy change, technology change, as well as changes in skills of the metal stamping workforce. This paper aims to assess this underlying principle through an analysis of MIRDC's Philippine Metal Stamping Sector Study in 2013[2].

The initial purpose of this paper is to highlight the metal stamping sector in the Philippines and to look into its developmental features in the metalworking industry to further extract its strengths and weaknesses. By doing so, subsequent projection rounds can be done by the government to ensure that industrial policies and programs currently provided are parallel with the warranted demands in the metal stamping industry.

The next section presents the industry structure of the metal stamping sector including its industry definition and processes, industry profile, market profile and technical profile. Section III discusses the industry analysis relative to the industry's problems and the

1. Bernie Magkilat. *"Mitsubishi Motors plans P2-B stamping plant".* Manila Bulletin [home page]. January 29, 2015. http://www.mb.com.ph/mitsubishi-motors-plans-p2-b-stamping-plant/

2. Metals Industry Research and Development Center. (2013) *Philippine Metal Stamping Sector Study.* Unpublished Manuscript

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factors contributing to these issues; section IV presents conclusions and recommendations to address the problems of the industry.

II. Industry Structure

Industry Definition

Among the processes involved in the metalworking industry, metal stamping is considered as one of the most important processes in manufacturing since it can produce relatively large volume of stamped products at low cost and in a short span of time. The stamping process is just like it sounds – a sheet of metal is placed between an upper die and a lower die and it is stamped with a use of a press. This process of permanent deformation is particularly done to produce the desired three-dimensional shape. Through cold forming, large metal and alloy sheets are shaped into definite structure as methods such as bending, clipping and molding are carried out.

Stamped products vary from equipment and bigger metal structure to finer parts of larger machinery. Output in metal stamping process may be classified into two: automotive stampings and non automotive stampings[3]. Automotive stampings may include any stamped parts used in vehicles while stamped products used in other non-automotive industries may include products like electronics, household appliances and housing parts, cooking and kitchen utensils, crowns and closures like bottle caps and jar crowns.

In a broader sense, the metal stamping industry becomes a medium in transforming raw materials to finished products that are used in different industries. In order to attend to the demands from various industries, more definite processes to produce stamped products are done which includes blanking, punching, piercing, forming, drawing, embossing, extruding dies and savaging. The metal stamping industry's versatility makes it easy to survive the rapidly increasing demands that arise together with technology.

Industry Profile

In the 2013 Philippine Metal Stamping Sector Study, data were gathered from 5 regions where establishment of 80 stamping-shops were identified. From these 80 respondent-shops, only 70 were included in the study. The other 10 identified respondent-shops were either closed or falls on a divergent category (i.e. produces only stamped foil). The identified stamping shops in the Philippines are located in Region III, IV-A, VII, XI and NCR.

Table 1. Regional Distribution of Stamping Shops

Area / Region	No. of Shops	Percent (%)
NCR	20	29
Region III	2	3
Region IV-A	34	49
Region VII	8	11
Region XI	6	8
Total	70	100

Metal stamping companies have sprung mostly from provinces in Region IV-A. Cavite, Laguna, Batangas, Rizal and Quezon have a total of 34 stamping shops comprising 49% of the total number of respondents, which can be attributed to investors' economic sense of delving into areas considered as good investment hub. Most respondent-shops located in Region IV-A are inside special economic zones and industrial estates wherein different investment incentives are given. Some of these incentives include income tax holiday; incentives under the Build-Operate-Transfer Law, which includes government support for accessing Official Development Assistance and other sources of financing; provision of vital off-site infrastructure facilities; option to pay a special 5% Gross Income Tax, in lieu of all national and local taxes; permanent resident status for foreign investors and immediate family members; employment of foreign nationals and assistance in the promotion of economic zones to local and foreign locator enterprises[4]. Moreover, findings from the recent metal stamping study of MIRDC indicates that most stamping shops were established from 1989-2004, the period when most science parks and economic zones were established.

Most stamping shops in the Philippines are established as corporation. Respondents who disclosed data about their initial capital for putting up a stamping business declared a capital ranging typically from P1,000,001 to P50,000,000. Clearly, metal stamping is a capital-intensive industry, thus, establishing this business as a corporation will allow it to exist with continuity while giving shareholders limited liability and obligations. In addition to this, it was also revealed that between the independent and captive types of business activity, most respondents fall under the independent business category. Captive and independent metal stamping shops differ in terms of technical operations as the former is usually part of larger manufacturing business. Captive shops are more focused on specialized procedures, thus applying limited processes for producing stamped products while independent shops cater to more customers with various requirements and employ less specialized operations.

As with capitalization, stamping shops were categorized into five types: cottage (less than P 100,000); micro (P 100,001-P 1M); small (P 1,000,001-P 10M); medium (10,000,001-P 40M) and large (greater than 40M). As revealed in the study, most respondents fall under the small scale category based on capitalization and at the same time, classified also as small scale based on the size of employment. 35 out of 70 or 50% of the respondent-shops commonly provide work for employees ranging from 10 to 99.

In most cases, the expenditures regarded in the metal stamping in-

3. Standard Industrial Classification Manual, 1972, cited in Brand and Huffstutler (1986). Trends of labor productivity in metal stamping industries. Monthly Labor Review

4. BDO (2012) *Doing Business in the Philippines.* Alba Romeo & Co. www.bdo.net.ph

Table 2. Classification of Shops According to Size of Employment

Classification	No. of Employees
Micro	1-9
Small	10-99
Medium	100-199
Large	More than 200

dustry may include labor cost, material cost, overhead cost, machineries etc. Aside from equipment used in the metal stamping industry, another contributor that makes this business undeniably expensive is labor cost. This could be one of the reasons why numbers of employees are kept to a small number. Labor cost, however, does not only pertain to wage level but also to the cost of the employees' health and safety benefits and also to cost of necessary trainings. On the other hand, the level of skills of the metal stamping workforce as rated by the interviewed respondents remains at satisfactory level. The aggregate data pertaining to personnel information (i.e. training and level of skills) may indicate that the reason why the skills of production personnel do not exceed the satisfactory rating is because of the low level of technological adaptation in most companies, which will be discussed further in the following sections.

Market Profile

Despite the fact that not all respondents who participated in the study were willing to reveal their local production, the data gathered from respondents who disclosed this information are still worth note taking. The average total annual production from the respondents reveals a P 1,000,000-P 50,000,000 range. The breakdown of annual production significantly reports a remarkably improving trend as seen in Figure 1.

As evaluated, upward shift can be observed in Figure 1, which is an indication of profitable growth, prevailing from 2010 to 2012. The robust increase especially from 2011-2012 may be attributed to the strong improvement of business condition in the Philippine metals industry in 2012 as initiated by the growth of automotive industry particularly in the assembly process for vehicle manufacturing which also increase the demand for stamping products.

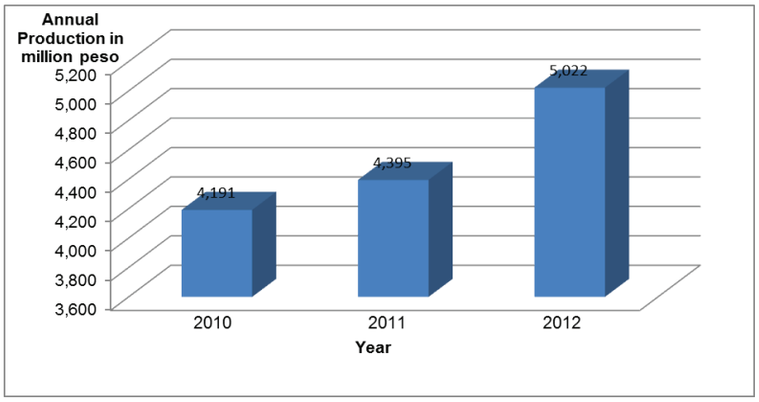
In relation to this, the export and import statistics as derived from National Statistics Office (NSO)[5] spell an increasing reliance for stamped products. The Philippine export of stamped products dropped from 2008 to 2011 but had a significant increase in 2012 with 80% boost over the 2011 level having USD 2.4 million in 2011 and USD 12.2 million value in 2012. The increase in export of stamped products may characterize the industry which is driven by both local and foreign demands. The import statistics on the other hand, also demonstrates a 69% increase from 2011 to 2012 as registered by the amount of USD 48.89 million in 2012 compared to the 2011 amount of USD 25.18 million which could be a hint to the industry's insufficient capability to attend to the current demand for stamped products.

Technical Profile

Of the equipment listed in the study that are used in the metal stamping industry, mechanical press tops the roll at it was listed with 732 units from the 70 stamping shops. Other stamping equipment that are used in most stamping shops are hydraulic press (255 units) and hydro-pneumatic press (195 units)[6]. As with the purchase condition of these main stamping equipment, dominance of brand new equipment was noted but the number of second hand mechanical press and hydro-pneumatic press is still noticeable. The prevalence of secondhand equipment among respondent-shops can be attributed to the consistency with durability of stamping equipment that do not break easily. It is also safe to assume that bigger stamping companies mostly decide to modernize their equipment while small firms decide to stick with considerable investment purchasing old equipment from larger companies. Being stuck on old equipment however may have a profound effect on the industry as it may mitigate not only the capability to attend to the growing demand for stamped products but also the acceleration of skills of the metal stamping workforce.

Mechanical press as compared to its hydraulic counterpart has more flexible force capacity which is determined by flywheel energy. The main reason why this equipment is widely used is because of its speed, consequently allowing higher production. The hydraulic press on the other hand also gains popularity in terms of efficiency. This equipment has better forming and drawing capabilities. The data pertaining to the equipment used in stamping companies in the country describes the tendency of most re-

Figure 1. Annual Production Trend of the Respondent-Companies



5. National Statistics Office. Foreign Trade Statistics. Import and Export Statistics of Stamped Products. 2010-2012

6. Metals Industry Research and Development Center. (2013) *Philippine Metal Stamping Sector Study.* Unpublished Raw Data

spondents to focus more on producing high volumes of products rather than the efficiency.

The quality control equipment commonly used by the respondent-companies are caliper, micrometer and height gauge with a total of 911 units. These equipment are commonly used in the inspection and layout work in order to provide accuracy in measurement.

III. Industry Analysis

Problems

With respect to the problems encountered in the metal stamping industry, the issues identified from the study do not uniquely differ from the problems faced by most metalworking industries. Most common concerns that arise from the metal stamping industry are material-related issues like material defect (e.g.. corrosion) and difficulty in sourcing out of raw materials due to unavailability in the local market; issues with quality control and quality assurance (QA/QC); and human-resource related concerns, particularly pertaining to lack of commitment and fast turnover of employees.

The competition in the industry is also strong, as described in the study. This may be attributed to the reality that most stamping shops in the Philippines are well-established, that newly established stamping shops may find it hard to compete if they do not have substantial capital to modernize and compete fairly through technology advancement.

Industry's Competitive Position

Though the progress in number of stamping businesses' establishment has declined from 2005 to 2012, as shown in the recent metal stamping study, the growth in number of metal stamping shops during the time of establishment of economic zones and science parks still maintains representative significance with its continuous existence. At present, the government recognizes the impressive growth of the Philippine automotive industry and has vowed to continue providing incentives in the form of income tax holidays and reduced taxes and duties. This initiative may therefore attract more investors to engage in industries such as metal stamping that mostly caters the automotive industry.

Moreover, a positive business outlook has been detailed as depicted by the data gathered from the respondents. The growth of the metal stamping industry may have been hampered by different setbacks but is still able to maintain its position to contend remarkably with the growing demands of the metalworking industry. 68 out of 70 respondents have expressed their plans of having additional product lines, expanding company technical capability and increasing production and personnel. This expression of business goal, when elaborated upon, may suggest a clear direction when creating industrial policy for the metal stamping sector. It is interesting to note that most manager-owners who were interviewed for this study were giving this outlook for their businesses because they can sense a steadily rising industry and they are willing to improve their metal stamping business to match the ongoing trend in production.

Good management, however, cannot be substituted by simply having positive business outlook. In considering plans to expand, one must also take into consideration the current business situation that they have. Assessing the capability of their production based on their equipment and manpower may be a good start. In MIRDC's metal stamping study, it was noted that there is still a number of stamping companies that are dependent on either old or second hand stamping equipment (i.e.. mechanical press and hydro-pneumatic press). As explained by Silva, et al.[7], shifting to virtual manufacturing of automotive stamped components by means of finite element computer analysis is a powerful tool that is capable of helping engineers to solve different technical tasks.

To put the trends in context, most stamping companies are reliant on the use of mechanical presses that were purchased on the date their businesses were established, taking into consideration the fact that the biggest number of companies included in the study was established from 1989 to 1996. Though it may seem outdated, the widespread use of mechanical press as evaluated against hydraulic presses may have a say with the durability of these machines as well as the earlier trainings mostly concentrating in the operations of mechanical presses. In most companies categorized as small industry, budget constraint may be one of the reasons why managers are not sending their personnel to trainings that will update their knowledge in technological advancement pertaining to stamping equipment. Instead, owners and managers who are mostly benefiting from trainings simply pass on their expertise that they have acquired in the earlier stage of their careers to their employees who, in return would simply rely on old equipment that are known to them.

IV. Conclusion and Recommendations

Conclusion

The analysis made for the 2013 Metal Stamping Industry Study of MIRDC may have presented a picture of an industry that is ready to face a promising future in the M&E Industries. This, however, should still be predicted with some caution before proceeding confidently that the metal stamping industry is already moving towards industrial advancement. The depiction depends obviously, on where we are looking. In this review, though it was explained that metal stamping sector employs processes for different industries, there's still a bit of a glitch with generalizing the study as it commonly favors information pertaining to the automotive industry. Though all industries are covered in the study, lack of relevant analysis concerning other industries such as semiconductor, food and other non-automotive industries in relation to its demands and contributions to the metal stamping sector

7. Silva, M. B., et al. (2004). Stamping of automotive components: a numerical and experimental investigation. Journal of Materials Processing Technology, Vol. 155-156, No. pp. 1489-1496, ISSN 0924-0136

is one of the reasons why this review cannot encompass the whole industry and make exhaustive analysis.

In general, the business condition of the metal stamping industry is growing as indicated by the steadily improving production trend in most companies but still needs to fill in the gap of inconsistency with the supply of most needed stamped products that can't be produced sufficiently in the country.

The metal stamping industry, in summary is an important facet of the M&E Industries as the need for stamped products remains strong and the trend for production continues on countries with emerging economies like the Philippines. However, it is still evident that the government is currently focusing on attracting investors, overlooking the possibility of having mismatch between growing demands for stamped products and existing technology on the metal stamping industry. The continued existence of local industries such as automotive industry can be predicted through the competitiveness of the products of its allied industries such as metal stamping sector.

Recommendations

In sustaining high volume of activities, customer satisfaction is also at stake and it may be difficult for the industry to maintain this if they have little control on the accuracy of the machines they use. Upgrading through acquisition of new machines or simply modernizing the manufacturing environment by refurbishing stamping equipment particularly press machines may be helpful in solving this problem. However, as previously mentioned, purchasing new equipment is never easy if the owners of the metal stamping firms do not have the capability to upgrade equipment. In this sense, the government, thru MIRDC-DOST should provide the necessary assistance in modernizing equipment and helping the metal stamping workforce to be updated on new technologies by providing them with relevant training.

Competition, on the other hand was expressed to be one of the major downturns for other companies who can't reasonably compete when it involves stern price competition. Larger companies are mostly winning market share by lowering price of their product offerings since they have the capability to engage in enormous production of stamped products. Logically, smaller companies who see this as a threat may be overlooking the opportunities that may be offered by focusing on the quality of their services rather than focusing on the price itself.

Founding alliance concentrating on the metal stamping industry is also recommended so that those who engage in this business will have the chance to secure the benefits from each other's experience that will allow them to voice to a greater effort any particular concern that will be encountered in this industry.

To properly address concerns with regards to human resources, proper assessment of managing style of owners may also be tapped. Prior to concerns on employees' lack of commitment, one of the areas that should be looked into is how they hire their workers. In some cases, personnel who lack skills are still hired since they do not demand higher wages. One of the most noteworthy observations in this regard is that when employees have little experience or expertise, this may result to lack of interest and motivation towards their job. This could result to labor turnover that will further drive the management to have more expenses for rejected work. It is therefore suggested that in order to solidify the foundation of human resources in stamping companies, one must take into consideration the level of skills of the people they welcome to their company.

More importantly, the government should maintain its support to the Philippine metals industry not only through incentives but also by finding ways on how to cope with the demand structure of every sector such as the metal stamping industry to stabilize the spur of advancement in both technology (i.e. equipment) and manpower (i.e. skills) upgrade.

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Development of 120-Passenger Per Coach Capacity Automated Guide-way Transit System

Jonathan Q. PUERTO,[*1] Joey G. PANGILINAN,[*2] Carla P. SAN DIEGO[*3]

Abstract

The Philippines only invests an average of 2.5 percent of its annual Gross Domestic Product (GDP) to develop public infrastructure, including roads and other transportation structure, in the country. In effect, existing transport fixtures cannot suffice the population of Filipino commuters at present. Taguig, being one of the highly urbanized cities in Mega Manila, faces this problem on a daily basis. Traffic congestions, brought by inefficient public transport system and commuter traffic in the area, contribute to the loss of productivity of Taguig City. To be able to address the problem, MIRDC adopted the Automated Guide-Way Transit (AGT) System in Bicutan. Specifically, the project aimed to develop and demonstrate the AGT along Gen. Santos Avenue in Bicutan as an alternative transport technology and an efficient transportation model in the area. The design of the AGT-Bicutan was improved to consider the observations during the test and evaluation of the AGT situated at the University of the Philippines in Diliman, Quezon City (UP). Also, the development was to make it comparable with the present public mass rail transportation system in the country. Moreover, the AGT-Bicutan can carry 120 passenger-per-coach with its relatively bigger coaches compared to the prototype in UP. AGT-Bicutan also employed a trackrunning from DOST- Philippine Textile Research Institute (DOST-PTRI) to the DOST-National Research Council of the Philippines (DOST-NRCP) grounds. The scope of the project only covered the design and development part of the technology. Testing and evaluation of the AGT will be carried over to the second phase of the project.

I. Introduction

The Philippines loses P2.4 billion a day, or a projected P6 billion a day in 2030, due to the time spent when in daily traffic jams instead of in more productive instances. In a study by the Japan International Cooperation Agency (JICA), it was predicted that the passenger count in Mega Manila may reach a whooping 7.4 million per day come 2030. Hence, there is high need to improve the country's mass transport services, most especially in Greater Manila (JICA, 2013).

Among the highly urbanized city in Metro Manila is Taguig (formerly spelled as "Tagig"), now an important residential and industrial suburb of Manila. From a thriving fishing community along the shores of Laguna de Bay with a land area of 47.88 km and a population of 644,473 in 2010, this number is expected to double in the coming years. According to Taguig City officials, they estimate around 80,000 (2011) commuters per day along one of Taguig's busiest stretch known as Gen. Santos Avenue. It connects Circumferential Road 6 (C-6), M.L. Quezon Street, and the South Luzon Expressway (SLEX). Despite Gen. Santos Avenue being a national road, tricycles are the dominant public transport mode here. They occupy an informal terminal along the sidewalk on either side of the road in front of DOST compound.

To address the aforementioned concerns, the project initially envisioned to build an approximately 1.6 kilometer elevated test track that will run from the DOST-PTRI compound to the Brgy. Hall of Lower Bicutan in C-6, with DOST providing funds for the 500 meters segment of the track and LGU -Taguig sourcing funds for the remaining segment. In an exploratory meeting with Taguig LGU officials headed by Hon. Mayor Maria Laarni L. Cayetano, they showed interest on possible adoption of the technology because of the following reasons:

a. possibility of extending to Rizal province;
b. complements the future developments in C-6 (tourist attraction);
c. alternative to tricycles which highly contribute to air pollution; and,
d. alleviates traffic congestion.

The LGU recommended that the AGT track be built on the same side where most of government owned establishments were situated such as the DOST-PTRI and DOST-NRCP, PUP-Taguig, and the Philippine National Police Camp Bagong Diwa. The demonstration track was shortened to approximately 372 meters in length only along the premises of DOST-PTRI and DOST- NRCP. This meant faster and easier implementation of the AGT- Bicutan project while providing more time for MIRDC to evaluate the impact of the project to other sectors and stakeholders. The AGT system will also serve as a showcase of DOST technology to Bicutan community resembling what the Korea Institute of Machinery and Materials did to their unmanned Maglev technology.

After coming up with a successful AGT prototype in UP Diliman, the Department of Science and Technology embarked on putting up a bigger and more improved

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version of the AGT along Gen. Santos Avenue in Bicutan, Taguig City. The objective was to showcase a locally-developed alternative mass transit system that would directly benefit the Taguig community. The AGT Bicutan prototype was an offshoot of the AGT prototype in UP. Results from the AGT UP evaluations and observations from stakeholders served as the basis of improvements made to the Bicutan project.

The project generally sought to promote the adoption of the AGT System in Bicutan to address the need for public mass transport alternatives that is efficient and sustainable. Specifically, the project aimed to build and demonstrate the AGT system along Gen. Santos Avenue in Bicutan as an alternative technology and an efficient transport model in the area.

The rapid growth of population fleeing to urban cities means increase in number of commuters every day, hence, the need for additional modes of transport and, consequently, the improvement of existing ones. Introducing the AGT in Bicutan will address problems linked to the need for alternative transport modes. AGT is seen to be a safe, reliable, and relatively cheap transport technology that will not only cater congestion problems but environmental problems as well.

The Project Management Team is composed of the following with corresponding responsibilities:

1. Metals Industry Research and Development Center (MIRDC)

- agency assigned to implement all activities from materials/supplier procurement for different components of AGT system; hiring of manpower and consultancy requirement; fabrication, installation and integration of mechanical and electrical assemblies; coordination with different agencies and institutions such as LGU's, the Department of Environment and National Resources (DENR), DOST-PTRI, DOST-NRCP, DOST-Central Office, PUP, the Philippine National Police, MERALCO, Metro Manila Development Authority (MMDA), and other stakeholders; and over-all project management.

2. Project Management and Engineering Design Services Office (PMEDSO)

- Over-all in-charge of the design and specifications requirement of the AGT system. Also, assists in project management and coordination with different agencies and other stakeholders.

3. Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD)

- agency tasked to monitor over-all progress of the project. Also assists in coordination with different agencies and stakeholders.

Project Framework

The AGT project is also in collaboration with different key players in the public and private sector. The framework consists of three stages, namely, Design and Development, Test and Evaluation, and Commercialization of AGT.

Design and Development

- This is in partnership with MIESCOR Builders, for development of elevated test track, and Fil-Asia, for the development of the coach. The output of this project is only up until the completion of the prototype.

Test and Evaluation

- This is the second phase of the project. The prototype and its components will be subjected to a series of test runs from which it will be observed and evaluated. A test protocol earlier drafted for the AGT System in UP will be evalu-

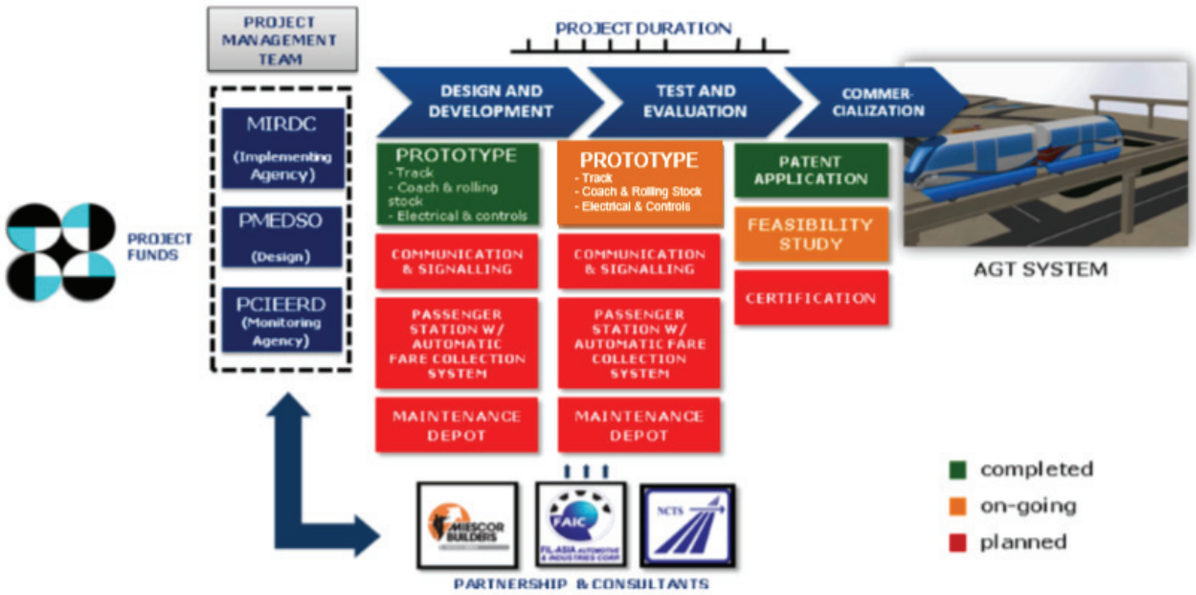

Figure 1. AGT Bicutan Project Framework

ated and modified to suit for AGT-Bicutan project. Other components under this stage will be tested once design and development has been finalized.

Commercialization

- At present, the project team, in cooperation with the DOST-Technology Application and Promotion Institute (DOST-TAPI), is processing Patent applications for the following technologies related to the AGT UP prototype: (1) The entire system (AGTS); (2) The Elevated Track; (3) The Rolling Stock Assembly; (4) The Coach Assembly; and (5) The Electrification System of the rolling assembly and coach assembly.

This project focused on the design and development of the AGT Bicutan prototype only. Test and evaluation of the whole system including will be part of the project's second phase.

Although, AGT-Bicutan generally followed the same design platform of the AGT UP prototype, improvements and modifications were injected. The project team will evaluate if these modifications can also be filed for patent.

Also, a pre-feasibility study is being conducted in partnership with UP-National Center for Transportation Studies (UP NCTS). The study focuses on three identified potential application of AGT system, including the possible extension of AGT-Bicutan down to C-6 near Brgy. Lower Bicutan Barangay Hall. The project team is also having exploratory discussions with TUV Rheinland on the possible safety and reliability certification of the AGT system.

The primary advantage of AGT over conventional railways is that the system occupies marginal space and is less expensive to build. Other advantages of AGT are as follows:

A. Cost effective – reduces the size labor-force required to operate and maintain the system.

B. Safe - AGTs are often above ground level thus accidents with buses, trucks, and other vehicles are almost impossible.

C. Environment friendly - AGTs are non-polluting which reduces carbon monoxide (CO), volatile organic compounds (VOC) and nitrogen oxide (NOx) emissions by more than 58 tons over the year. In addition, its quick construction time results in less disruption to the surrounding environments, whether business or residential.

D. Aesthetically pleasing - The sleek design blends in with modern urban environments and most types run on rubber tires which are very quiet.

Methodology

Coordination and Preliminary Activities

DOST coordinated with the Local Government of Taguig under the leadership of Mayor Lani Cayetano before the commencement of the project. Consultations with Barangay Lower Bicutan officials, National Capital Region Police Office (NCRPO), PNP-Camp Crame, and PUP Taguig and Sta. Mesa branches were also conducted during pre-implementation. These abovementioned stakeholders had expressed their full support to the project. Also, the project team held further consultative meetings with other stakeholders such as the different tricycle organizations plying along Gen. Santos Avenue, the Office of the City Councilor, DOST-PTRI, and DOST-NRCP which also gave their support to the project.

Likewise, all trees that were affected by the construction were identified and documented by the Department of Environment and Natural Resources (DENR). MMDA was tapped to perform the tree cutting, balling, and trimming activities.

Design

The Project Management and Engineering Design Services Office (PMEDSO) of the DOST was in-charge of the overall design of the AGT system. While the AGT- UP was designed to fit in narrow streets and act as a feeder system to existing bigger railways such as the Metro Rail Transit (MRT), Light Rail Transit (LRT), and Philippine National Railway Trains, AGT-Bicutan was designed to accommodate higher capacity, originally around 60 passengers per coach. However, the project team agreed to change the design to accommodate 120 passengers per coach. With this modification, the AGT can now be comparable to the existing MRT and LRT and can be adopted in the country's major thoroughfares in the future. The AGT-Bicutan design is an improved version of the AGT prototype in UP, taking into consideration the observations and findings during test and demonstrations conducted in UP.

Implementation

The development of the elevated test track, rolling stock, and electrical and controls were done in partnership with the private sector.

Elevated Test Track. The development of 372-meter elevated test track was awarded in 2012 to MIESCOR Builders Inc., after having been evaluated as the Lowest Calculated Responsive Bid and found to comply with the technical and other requirements of the project. The actual construction started on February 2013 after the issuance of permit from DENR to cut and/or ball affected trees. Prior to the commencement of construction, a site survey and a geotechnical investigation of the site were performed. Results were incorporated in the design.

Rolling Stock. The fabrication of two articulated coaches and chassis was awarded to Fil-Asia Automotive and Industries Corporation, a local bus body manufacturer. The four bogies, including other assemblies such refurbished differentials, guide-wheel frames and current collector frames, were all fabricated by MIRDC. Variable Frequency Drives and Inverter Duty Motors were bid out and awarded to BJ-Marthel International, Incorporated. Other mechanical, electrical, and electronic parts and components were purchased by MIRDC.

On February 25, 2014, the two rolling stocks (coaches and bogies) were transferred to the DOST-PTRI grounds, the same site where it was lifted and mounted onto its test rack.

Electrical and Controls. The Exponent Controls and Electrical Corporation, under the supervision of engineers and technicians of the AGT project team, provided the manpower and equipment/tools required to carry-out the project. Meanwhile, all needed components were purchased by MIRDC. A power room was constructed to house the 700 kVA transformer, the rectifier, and other electrical components.

Moreover, the application for MERALCO power connection, including payments and other required documents, were completed within the project duration. Conversely, AGT energization will be carried over to the second phase of the project.

Discussion of Results and Findings

Elevated Test Track

A depth of at least 1.5 meters below existing ground level was recommended for AGT foundations for both locations. Actual depth used is at least two meters for each site. Also, a safe bearing capacity of 300 kPa was recommended for adoption for analysis considering dead and codal live loads.

Design. The track was designed to simultaneously achieve two functions: (1) to provide physical support to the rolling stock and guide to the train's guide wheel assembly to keep the train safely positioned, and (2) to carry the electromechanical components of the train including power rails and communication equipment. Figure 6 shows a cross-section of the AGT test track.

Although generally similar to the elevated track in UP in terms of its features and function, the track in Bicutan employed bigger columns, hence, bigger footprints, wider guide-ways, and more massive structure. Table 2 shows the comparison, in terms of features and technical specifications, of the AGT-Bicutan and the AGT-UP. All structural members of the elevated track are cast-in-place concrete with compressive strength (f'c), of 4000 psi. The track is composed of two beams designed to carry a 2-car train (2,200kg per wheel load). Angle bar edge armoring are mounted to prevent the concrete edges to spall or chip due to mechanical contacts of the flange to the train's pneumatic tires and guide wheels.

The distance between every column is 20 meters center-to-center with 1.88 meters lateral spacing. Lateral bracing beams in between the tracks are also placed every five meters along the span to support the beams on side sway forces from the guide wheels.

Due to higher capital cost for pre-cast concretes, it was recommended to employ the cast-in-place method in the project. However, once the AGT system is adopted, thus, longer tracks will be constructed, it may be economically sound to use pre-cast concrete beams.

Table 1

Comparison of Features and Technical Specifications of Elevated Test Track of AGT- Bicutan and AGT-UP.

TECHNICAL SPECIFICATIONS	AGT UP	AGT BICUTAN
Length, meters	465	372
I-beam spacing, meters (center to center)	1.4	1.88
Elevation from NGL, meters	5	5-10
Number of Columns	25	20
Bay lengths, meters (average)	20	20
Column dimension, meters	0.8 x 0.8	1.0 x.1.0
Construction Method	Cast-in-Place	Cast-in-Place

Mechanical System

Rolling Stock Assembly. The rolling stock assembly consists of the chassis, which serves as the skeleton of the car, and two bogies, which carries the weight of the chassis and provides the required mechanical assembly to allow movement of the rolling stock.

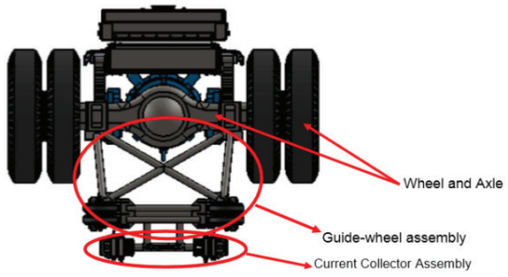

Figure 3. Schematic Diagram of AGT Bogie.

Three major components comprise the bogie—the axle and wheel assembly, the current collector, and the guide wheel assembly.

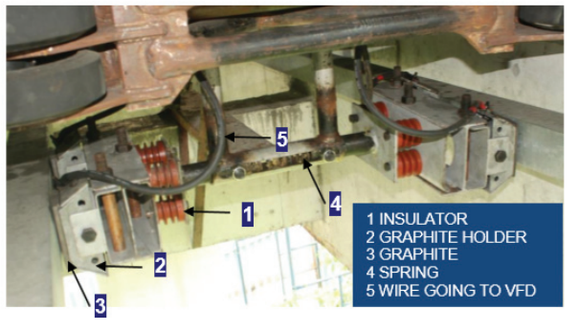

Figure 4. Current Collector Assembly.

The axle and wheel assembly were retrofitted from a refurbished Forward FTR differential and tire. Each bogie is powered by a 125-HP induction motor, connected to a differential axle with a double pneumatic tire on each side. The

suspension is composed of leaf springs with shock absorbers to improve ride comfort. The bogie has its own frame that is connected to the main chassis of the coach through a king pin made from AISI 4140 steel, allowing the coach chassis to pivot to the bogie when running along a curvature.

The multi-axial motion capability of the spring-loaded current collector assembly design (as shown on Figure 4) allows uniform contact between the power rail and the assembly surface. This is to ensure electrical continuity throughout operation without much compromise on the weight. The current collector is also equipped with insulators for proper electrical protection of the coach. The AGT system has a total of eight (8) current collector assemblies; two (2) on each bogie.

Figure 5. Guide-wheel Assembly

The guide wheel assembly serves as the most important component to ensure safe steering of the rolling stock. It is a mechanical system designed to make the bogie wheels travel only along its designated path. The assembly was engineered to extensively boost its strength, thereby ensuring that the coach is at all times properly positioned on the track. It is connected to the differential via U-bolts. Eight (8) solid rubber tires were used per guide wheel frame to ensure stability. Figure 5 shows the guide wheel assembly of AGT-Bicutan.

Coach. The coach is an articulated train system with each car composed of two powered bogies. The design of the coach allows capacity optimization in the size-restricted body without compromising design, simplicity, and aesthetics. Each coach has a capacity of 120 persons. The coach body panel is made up of mainly of Fiber Reinforced Plastic. Figure 6 shows the concept design of the AGT coach prior to its development while Figure 14 shows the developed AGT coaches. Some side skirts were temporarily removed for easier lifting and mounting of the AGT onto its track.

Electrical System

A 650VDC system provides the required power for the electrification of the rolling stock and coach peripherals. A three-phase supply is converted to the required DC voltage which is fed to the power rail. The coach taps on these rails through the current collectors attached to each bogie. Power is then passed to four 150-hp main variable frequency drives that run the four 125-hp main AC motors on the rolling stock and auxiliary VFDs that run the air-conditioning compressors, blowers, and door compressors. Figure 7 illustrates the electrical system overview of the AGT.

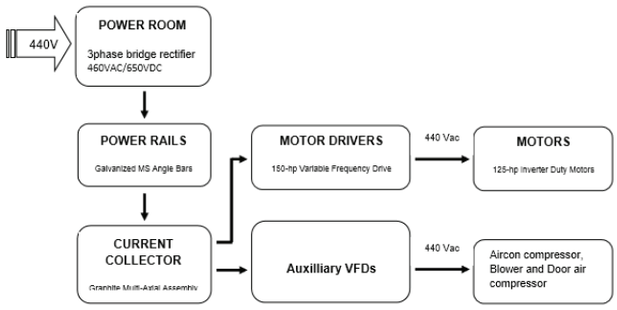

Figure 7. Electrical System Overview

Power Room. Power rail electrification was produced through an uncontrolled six-pulse rectifier setup coupled to a 700kVA Isolation Dry Type 3-phase Transformer housed

Figure 6. A. AGT Bicutan Coach Concept Design
B. AGT Rolling Stocks

inside the power room. The rectifier assembly converts the AC supply to the required 650 DC voltage. Megger test was performed to test the insulation of the system.

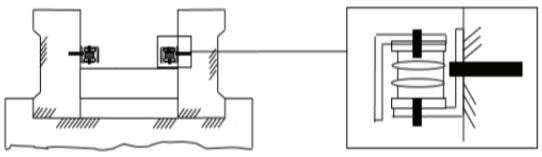

Figure 8. Exploded view of Power Rail

Power Rail. The power rail transports the 650VDC from the power room to the coach. An L-shaped 4"x4"x8mmx6.0m galvanized (double hot dipped) mild steel angle bar acts as the conductor rail of the AGT system. Each rail was mounted on an electrical insulator to isolate the positive conductor to ground. Mounting plate is oriented as shown in Figure 8, to reduce the flexural and shear stress on the insulator. With this configuration, only compressive forces will be experienced by the insulators. Hence, any vibration caused by a passing train can protect the bolt inserts from any damage. Power rails were divided into 6-m sections with each section cut diagonally to make room for thermal expansion due to heat exposure. THHN wires were used to connect section to the next.

Coach. The coach receives DC electricity from the power rails through the current collector assembly. This provided power to the four 150-hp main motor variable frequency drives that powered the four 125-hp motors and ten auxiliary VFDs (2 1-hp for blowers, 4 3-hp door compressor, 4 15-hp for air con compressors).

Controls System

The control system is mainly responsible for controlling the speed and the synchronization of the motors. With this, load is shared and distributed to the four powered bogies of the AGT. The control system receives inputs or commands from the driver and gives corresponding control signals to the other components thereafter. The train may be controlled from either coach, but only one coach at a time may control the AGT. The control system of each coach is mainly made up of the following:

(a) a Programmable Logic Controller (PLC);
(b) a Human Machine Interface (HMI);
(c) 2 Variable Frequency Drives (VFD); and,
(d) 2 AC Electric Motors.

Figure 9. Driver's Control Board

Costing

The development and fabrication of the AGT is much cheaper when compared to the existing railway transit in the metro. The recent awarded contract for the purchase of MRT coaches costs around PhP 80 million per coach, wherein a coach can accommodate 394 passengers (Patria, 2014). The AGT costs cheaper at PhP 33 Million per three-coach rolling stock that can carry about 360 passengers in a single trip. This shows that the AGT can compete with the MRT in terms of passenger capacity while being a cheaper alternative once adopted.

Summary and Conclusion

The development of the AGT system in Bicutan includes the development of the coach, rolling stock, and, elevated test track. The completion of the project resulted to a bigger and more improved version of the AGT prototype located in UP Diliman. Technical specifications and features of the prototype have been improved to efficiently support the more massive AGT Bicutan system structure without compromising simplicity, reliability and, aesthetics, to which AGTs are internationally known for. Results of the evaluations of the AGT-UP prototype were considered in the development of the AGT-Bicutan prototype. Activities such as lifting and mounting, energization, and preliminary test runs which are prerequisite steps to demonstrate to the public the developed AGT is carried over to the second phase of the project.

The traffic congestion in Gen. Santos Avenue in Bicutan has been a perennial problem for commuters and traffic enforcers as well. Through the adoption of the AGT, Taguig commuters will now have an additional mode of transport to avail. This may result to lesser individuals having to wait in long lines to ride jeepneys, tricycles, and the likes to their destination of choice. While the AGT intends to complement and not replace the existing modes of transportation at present, it seeks to be comparable to the current MRT and LRT that are sturdy enough to carry a number of people in a single trip.

Once tested and proven to be efficient and feasible, the AGT system can be an alternative mass transportation technology which can address the problem on traffic that seems to get worse day by day. Through the project, Filipino commuters can now opt to travel through a fast, reliable, and sustainable mode of transportation through the AGT.

Recommendation

The AGT Bicutan prototype is another outcome of the development and optimization of the control system responsible for speed control and synchronization of motors. Two other forms of mass transport systems are being tested/ will be tested using the said control system design, namely, the hybrid electric road train and train set for PNR application.

Moreover, the control system must be verified, evaluated, and certified with applicable standards to ensure the safety and reliability of the system. The project still has several possible R&D areas to research on, namely, (1) Design and Development of the Communication and Signaling,

Passenger Station/ Auto Fare Collection system & Maintenance Depot; (2) Test and Evaluation of the whole AGT system and other facilities; and (3) Certification process.

A Transport Summit is being planned to map out the master plan for AGT until technology is ready for commercialization. Representatives from various transport sectors and consultants may be invited to come up with concrete and comprehensive plan.

If the AGT technology is found to be successful and technically feasible, adoption into existing transportation systems in the Philippines is highly possible. The government agencies involved like Department of Transportation and Communications, Metro Manila Development Authority, and Local Government Units among others is recommended to review their road map on transportation and study where and how the AGT will fit and complement other existing modes of transportation.

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Design and Development of an Automated Guideway Transit System Depot and Passenger Stations

Rodnel O. TAMAYO,[*1] Brian U. RASCO,[*2] Drexler B. SIBAL,[*3] Sarah Mae C. CUATERNO[*4]

Abstract

The project "Design and Development of an Automated Guideway Transit System Depot and Passenger Stations" aimed to produce two (2) Automated Guideway Transit (AGT) System Passenger Stations at the University of the Philippines Diliman (UPD), Quezon City that function as model units for the demonstration of of the AGT System as an operational advanced transport technology. Each of the three-storey station has a total area of 392.0 square meters and a height of approximately 11.0 meters. Firm and functional building materials were selected and used. For the two stations, structural steel I-beams were used as beams and columns, concrete slab for ground floor, and steel plates for the two upper floors. For the roofing system, gable-roofing structure was built at the E. Jacinto Station and tensile membrane fabric structure in funnel-like shapes was constructed at the C.P. Garcia Station. The AGT System passenger stations were equipped with safety features, communications systems, and automated fare collection system. The design of the stations was an output of the collaboration of the MIRDC, Project Management and Engineering Design Services Office (PMEDSO), and the University of the Philippines–Office of the Campus Architect (UP-OCA). The main criteria of the design were functionality and simplicity. The PMEDSO, in consultation with the experts in the transportation research sector, drafted and presented the plans to the UP Diliman as the main stakeholder and collaborator. With the combined expertise of the project team and the UP-OCA, the final designs of the stations were completed. The MIRDC facilitated the bidding and led the supervision of the construction.

I. Introduction

The AGT System at the UPD in Quezon City has been in research and development for more than three years. The project entitled "Design and Development of an Automated Guideway Transit System Depot and Passenger Stations" was carried out under the Department of Science and Technology Disaggregated Grants-In-Aid (DOST-GIA), funded by the DOST–Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD). This is the test track for the mass transit system built and developed by local engineers.

To test and evaluate the AGT system, facilities such as passenger stations and depot are needed. The train stops to load and unload passengers at the stations while the locomotives, multiple units, and rolling stocks are maintained and repaired at the depot. These facilities play an integral role to ensure that the operation of the rail network is safe and efficient.

This project was considered part of the continuous design and improvement of the system that consists of the following components: passenger stations, depot, safety features, communication systems, and automated fare collection systems (AFCS). All of these components are crucial in effectively demonstrating the functionality of the AGT system. Originally, the target deliverable of this project was to come up with full scale AGT stations and rolling stock depot within the six-month project duration. However, it was found that more time was needed by the project team to frame the design of the depot and prepare for the construction. Likewise, resource allocation also became one of the pressing concerns of the project. The project had to overcome challenges such as transfer of funds to other advanced transportation projects and missed targets due to unforeseen factors.

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Prior to proceeding with the design and development of the passenger stations, a system demonstration run was conducted on April 15, 2013 and was attended by possible technology adopters and high ranking government officials including the President Benigno Simeon Aquino III.

The design and development of passenger stations was given full attention. The MIRDC, PMEDSO, and UP-OCA collaborated to produce and conceptualize simple and functional stations. Before the construction of the stations was completed, a public demonstration run was carried out during the University Lantern Parade last December 18, 2013. Free rides were provided to the DOST and UP officials and employees, as well as to the students and residents within the UPD area.

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Transportation Problems in the Philippines

The demand for transportation increases in direct proportion to the living standards in the urban setting. It is important for cities to choose a system that meets their needs. There is no point in choosing a high-cost system if a smaller, less expensive system could do the job. Expensive systems can be a big drain on the public budget, not only for construction costs but also for the annual operating costs.

Some urban areas have suffered physical, environmental, and aesthetic damage from excessive automobile use. As a result, the government is taking steps to arrest further automobile intrusions. The remedies include preservation and improvement of traditional transit service including railways, trams, and bus lines. Railways are too expensive to install in areas of lower density - smaller cities or the suburbs of larger ones - which often suffer the same gridlock problems as larger cities. Buses could be easily introduced in these areas, but do not offer the capacities or speeds that made them an attractive alternative to car ownership.

Accessibility, which is fundamental to transportation systems, is defined as the ability to avail goods, services, and activities such as education, employment, health care, shopping, and recreation. Factors that affect the accessibility are transport demand, basic access, mobility, transportation options, user information, integration, affordability, mobility substitutes, land use factors, transport network connectivity, roadway design and management, inaccessibility, and mobility management (Litman, 2014).

Rachel Kyte (2012) stated in her interview in the Global International Briefing that a good public transportation provides people with a safe, easy, convenient, and affordable transport system. In some urban areas, the requirements for a good public transportation and mobility are not fulfilled. In the third edition of the book, The Geography of Transport Systems, Rodrigue (2013) enumerated the following urban transport problems: traffic congestion and parking difficulties, longer commuting, public transport inadequacy, difficulties for non-motorized transport, loss of public space, environmental impacts and energy consumption, accidents and safety, land consumption, and freight distribution.

Railway Transportation System in the Philippines

In the Philippines, the transportation system is described as underdeveloped (Wikipedia, 2014) but the government is determined to improve the public transport system through various programs and projects (Crisostomo, 2002).

Trains are continuously growing to be a popular means of transportation. The railway network in our country is composed of the Philippine National Railways (PNR), the Manila Light Rail Transit System (LRT-1 and LRT-2), operated and maintained by the Light Rail Transit Authority (LRTA), and the Manila Metro Rail Transit System (MRT-3), run and maintained by the private consortium Metro Rail Transit Corporation (MRTC) in coordination with the Department of Transportation and Communication (DOTC).

The Philippine National Railway (PNR)

The Philippine National Railways (PNR) is a railway company owned by the government operating on a single track in Luzon. PNR's route used to run through La Union to Bicol. In 2010, it started to operate a commuter rail service in Metro Manila and Bicol and in 2011, it re-established its service to cities in the Bicol region. It had 138 stations and used to run to the North Main Line and South Main Line serving different parts of Luzon. Currently, the PNR stations are at-grade, utilizing a side platform layout. Stations were improved along the Metro Manila line by putting ramps for passengers using wheelchairs and several stations have upper platforms that accommodate Diesel Multiple Units services and lower platforms for regular locomotive-hauled services (Wikipedia, 2014)

The Light Rail Transit System (LRT)

The LRT is a rail system in Metro Manila that consists of 2 lines: The LRT-Line 1 (LRT-1) or the Green Line and the MRT Line 2 (MRT-2) or the Blue Line (Light Rail Transit System website, 2013).

The LRT-1 is the first rapid transit line of the LRT. It has 20 stations and runs on 19.65 kilometers of fully-elevated route. This runs from Baclaran to Monumento and Monumento to North Avenue link connecting Quezon City, Pasay, Caloocan, Manila, and Parañaque. Line 2 (MRT-2) is Metro Manila's second rapid transit line and is located along segments of Recto Avenue, Legarda Avenue, Magsaysay Boulevard, Aurora Boulevard, and Marcos Highway. This has 11 stations and operates on 13.8 kilometers which passes through Manila, San Juan, Quezon City, Marikina, and Pasig. It runs 12 trains with a minimum headway of 5 minutes. (Wikipedia, 2014)

The Manila Metro Rail Transit System (MRT)

The MRT-3 is Metro Manila's third rapid transit line and is located along Epifanio de los Santos Avenue (EDSA). It runs on 16.9 kilometers track which commences at North Avenue and ends at Taft Avenue, passing through Makati, Mandaluyong,

Pasay, and Quezon City. It has 13 stations which are above the ground except the Buendia and Ayala Avenue stations and the platform level of Taft and Boni Avenue (Wikipedia, 2014).

According to the MRT website (2012), each station has an average space of 1,300 meters apart; with the closest

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spacing about 730 meters and the farthest, 2,210 meters. It also has facilities like platforms, view-decks, elevators and escalators, and public crossing. The safety of the commuters is valued that the stations are equipped with modern communication systems, closed circuit television for security monitoring, public address system, fire stand pipes and hoses, and wash down bibs.

Methodology

As aforementioned, the Philippine government is pushing to improve the transportation system in the country through various projects (Crisostomo, 2002). The AGT is envisioned to be a more efficient, greener mode of transport that answers the cities' perennial traffic woes. The development of the AGT's elevated train system can serve as a potential solution to the problem of mass transportation in the country. The AGT System will serve as the first model unit for the first mass transit system to be locally built and developed in the country. Sound urban design which addresses all facets of the area being served by a new transit system can help improve the environment. Reducing dependence on automobiles can eliminate many of their unsightly consequences — street congestion, parking lots, gasoline stations, and air pollution, thus making possible urban life styles with more amenities. AGT systems are non-polluting in that the vehicles are electrically-powered. They are presumed more energy efficient than automobiles and competitive with conventional transit.

The design and development of passenger stations was considered as part of the continuous testing, evaluation, and improvement on the AGT System. This served as a model unit for the demonstration of an operational advance transport technology.

This project used the framework that illustrates the scope of work and associates for the design, development, and simulation of AGT System passenger stations, safety features, communication systems, and automated fare collection system.

Project Management Team

The Project Management Team was composed of the following with corresponding responsibilities:

1. Metals Industry Research and Development Center (MIRDC)
- The implementing agency that is responsible for the performance of key activities including materials/supplier procurement for the construction and development of passenger stations, hiring of manpower and consultancy requirement, coordination with the UPD Administration and other stakeholders, and overall project management.

2. Project Management and Engineering Design Services Office (PMEDSO)
- The DOST office in charge of the overall design and specification requirements of the AGT system passenger stations. The PMEDSO assisted in project management and coordination with different agencies and other stakeholders.

3. Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD)
- The agency tasked to monitor the overall progress of the project and assist in the coordination with different agencies and stakeholders.

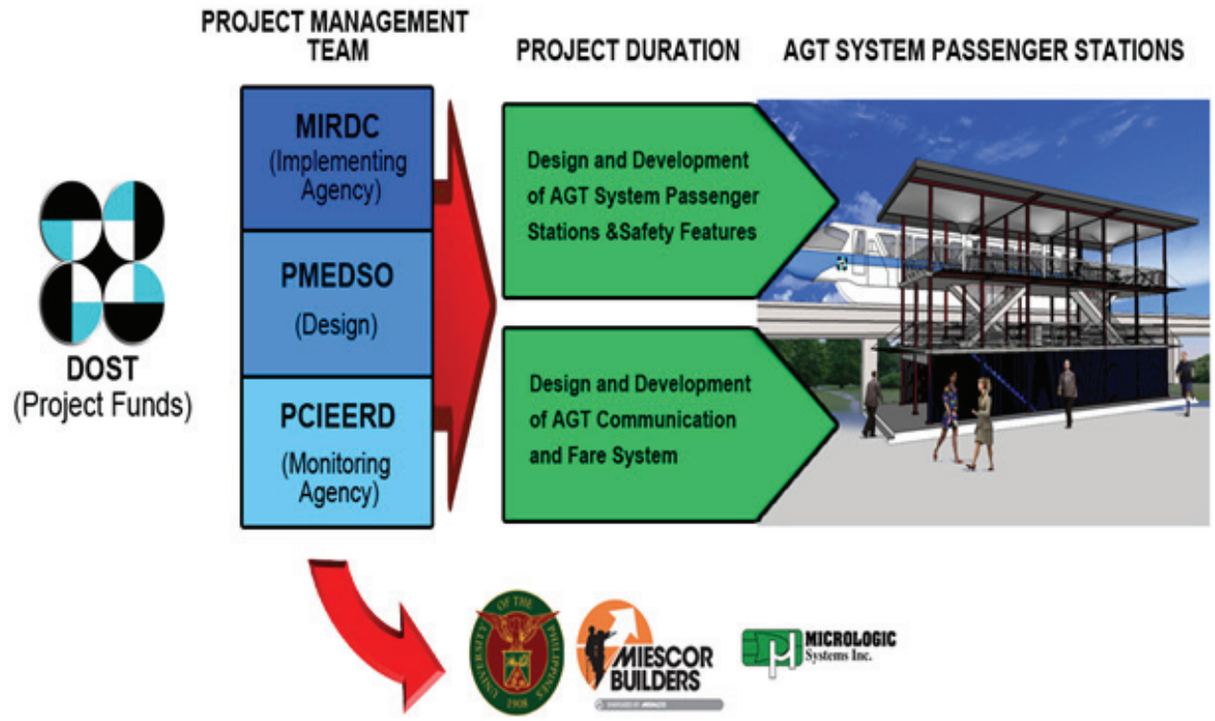

Figure 1. The AGT Project Framework

Design and Development of Passenger Stations

Engineers from the PMEDSO and the MIRDC collaborated to establish a structural design of the passenger stations and selected economically firm and functional building materials to be used. The two AGT System stations were built at the UPD. Station 1 is located at E. Jacinto St. near the UP College of Fine Arts, while Station 2 is positioned in the corner of C. P. Garcia Avenue and University Avenue. Each proposed structure has a total area of 392.0 square meters and a height of approximately 11.0 meters. In consideration of the architectural and aesthetic aspects of the structures, the project team decided to incorporate the roofing details of the design submitted by UP-Office of the Campus Architect (UP-OCA) for Station 2, which integrates the use of tensile membrane structures. However, a simple gable roofing structure with alternate corrugate G.I. sheets and polycarbonate sheets was constructed in the first Station.

The construction of the stations commenced on the 3rd week of November and was completed on April 30, 2014.

i. General Specifications

Each of the three-storey station has a total area of 392 square meters and a height of approximately 11 meters. Each of the stations consists of four roll up doors and a ticketing office located at the ground or first floor. The ticketing office has two windows facing each of the entry doors on the both sides of the stations. The automatic turnstile gates can be installed at the ground floor on a designated area beside the ticketing windows. Going up, the second floor was designed to have the exit turnstile gates for the passengers coming down from the third floor, which is the platform area where the AGT arrives and departs.

ii. Strength and Economy

For both stations, structural steel I-beams were used as beams and columns. These can ensure that the structure is physically sound and well-grounded because they are dimensionally stable. These can also withstand calamities like typhoons.

As for the flooring of the stations, long lasting and durable materials like concrete slabs were utilized for the ground floor while an ideal lightweight materials which are strong and offer good corrosion resistant performance such as steel plates were used for the upper floors.

Compared to the MRT and LRT stations, the two AGT stations are relatively cheaper.
The cost of each station was approximately Php 8,300,000.00

iii. Aesthetics

A simple gable roofing structure with alternate corrugated G.I. sheets and polycarbonate sheets was constructed at the E. Jacinto Station and membrane tensile fabric was integrated in the roofing structure at the C.P. Garcia Station that carried various details borrowed from the iconic UPD buildings and structures such as public transport terminals and train stations around the world.

Figure 2. Completed AGT System passenger station at E. Jacinto Street (Station 1)

Figure 3. Completed AGT System passenger station at C.P. Garcia Avenue (Station 2)

Design of the Automatic Fare Collection System (AFCS)

The proposed AFCS for the AGT System consist of the Automatic Turnstile Gates which used contactless smart card as payment medium. These smart cards were issued at the Point-of-Sale (POS) Stations, which were located in the AGT ticketing office.

The Automatic Turnstile Gates are the gates used in the AGT System which allow passengers to pass one at a time. Figure 2 illustrates the entry gate, located in the first floor of the station, includes a card reader that reads the smart card being tapped by the passenger. In addition, the MIRDC and UPD Information Office supplied the designs of the contactless smart cards as shown in Figure 3.

Design of the Communication Systems and Safety Features

Two-way radios were provided for the communication system of the stations from the power room to the platforms. Manually-operated sliding gates were also installed to avoid the passengers' risk of falling on the tracks while waiting for the AGT to arrive. Safety signages were provided on both

Figure 2. Automatic Turnstile Gate (L) Entry Gate, (R) Card Reader

stations as guide and safety reminders for the passengers. In addition, CCTV surveillance cameras were installed for each floor of both stations for monitoring purposes.

The platform is spacious and is provided with waiting chairs and benches for the passengers. It also has no supporting columns that limit the visibility on the platform.

Unlike Station 1, Station 2 has approach stairs with seven steps and a ramp for Persons
with Disability (PWD) because of the change in elevation. Moreover, a perimeter fence was constructed in consideration of its location being more exposed to the public compared to Station 1.

In addition, the stations are well-ventilated and get enough lighting since these are open
and not enclosed in wall panels. At night, light bulbs and compact fluorescent lamps are used as the lighting of the stations.

Partnership with the Academe (UP Diliman)

The design concept of the passenger stations was made through the collaboration of the MIRDC, PMEDSO, and the UP-OCA. The project team and the UP-OCA, headed by Director Gerard Lico, agreed that the design for the Station 2 would adopt the roofing details of the design concept submitted by Mr. Jeric Rustia, a UP-OCA staff. The roofing system uses tensile fabric as the material for the roof as well as the funnel for storm water draining. To provide updates and give information about the upcoming activities of the project, several meetings with UP Chancellor Caesar Saloma were held. As planned during meetings, MIRDC and UP Diliman agreed to showcase the AGT System during the University Lantern Parade in December 18, 2013.

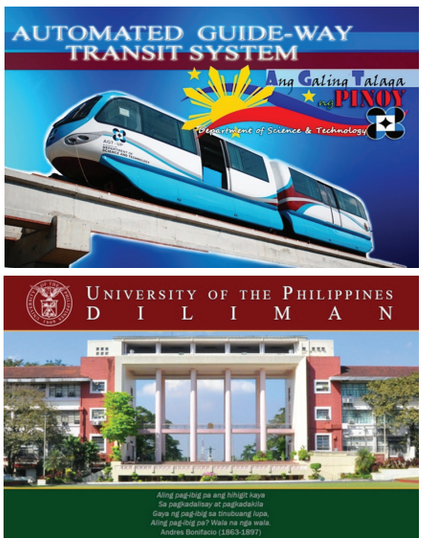

Figure 3. Contactless Smart Card (top) the side designed by the MIRDC, (bottom) the side designed by the UPD

Partnership with Service Industries (MIESCOR Builders, Inc. and Micrologic Systems, Inc.)

The MIRDC engaged a construction contractor for the development of the passenger stations. In line with this, a public bidding was carried out on October 22, 2013 in accordance with the Government Procurement Act (R.A. 9184) and its Implementing Rules and Regulations. The Meralco Industrial Engineering Services Corporation (MIESCOR) Builders, Inc. was awarded with the fifteen million sixty five thousand peso-project (Php 15,065,000.00).

During the actual construction, variations and additional works which were not included in original contract needed to be done. These amounted to one million five hundred six thousand one hundred eighty eight pesos and 54/100 (PhP 1,506,188.54) which was also awarded to the MIESCOR Builders, Inc. Project extensions to complete all the construction works, both from the original contract and variation order, were requested and approved.

The equipment for the Automatic Fare Collection System used in the Public Demonstration last December 18, 2013 was loaned at no charge by the Micrologic Systems, Inc. headed by its President, Engr. Hilary De Leon. These included two Automatic Turnstile Gates with Smart Card Readers. However, the 150 contactless smart cards from Micrologic Systems, Inc. were purchased by MIRDC.

Figure 4. Safety and security features of the AGT passenger stations.

Figure 5. Demonstration run of the AGT initiated with a ribbon cutting ceremony led by DOST Secretary Mario G. Montejo and UPD Chancellor Caesar A. Saloma on December 18, 2013.

Public Demonstration of the AGT Systems

As per agreement between UPD Chancellor Caesar A. Saloma and the project team, the public demonstration run was conducted on December 18, 2013 to showcase the AGT System at the University Lantern Parade. This was attended by the DOST Secretary Mario G. Montejo, DOST Assistant Secretary and MIRDC's Officer-in-Charge Robert O. Dizon, Program Leader of the Advanced Transportation Program, Engr. Jonathan Q. Puerto and the AGT System Passenger Stations project leader Engr. Rodnel O. Tamayo together with the UPD Chancellor Caesar A. Saloma; Jesus P. Francisco, Vice Chairman of the MIESCOR Builders, Inc.; Benito M. Pacheco, Vice Chancellor for Research and Development, UPD; Aura Matias, Dean of College of Engineering, UPD; Carlo A. Arcilla, Head of the National Institute of Geological Sciences; Gerardo Esquivel, Administrator/Vice Chairman, Metropolitan Waterworks and Sewerage System (MWSS); Glicerio Sicat, Consultant for the Advanced Transportation Program; Emil Vergara, Consultant for the Electrical and Controls Systems of the Advanced Transportation Program; and other distinguished guests.

To kick off the demonstration run, a short program was started at 9:00 am with a ribbon cutting led by Chancellor Saloma and Secretary Montejo. Subsequently, the communication systems, safety features, and the ticketing system of the stations, and the AGT itself were demonstrated and was opened to the public until 3:00 pm. Passengers which included UP Students, UP instructors, and residents within the UP premises were assisted by the project staff during the demonstration. Brochures and survey forms were given to the passengers to provide information about the AGT.

In addition, the stations are well-ventilated and get enough lighting since these are open and not enclosed in wall panels. At night, light bulbs and compact fluorescent lamps are used as the lighting of the stations.

Summary and Conclusion

Two AGT System passenger stations were designed and built at the UPD. The design of the passenger stations was planned through the collaboration of the MIRDC, the PMEDSO, the UP-OCA, and MIESCOR Builders, Inc. engineers and architects.

Different factors such as the strength and economy, safety and security, aesthetic, ventilation and lighting, among others, were taken into account in designing the two stations. Each station has a total area of 392 square meters and a height of approximately 11 meters. Structural steel I-beams were used as beams and columns, concrete slabs for the ground floor, and steel plates for the upper floors. A simple gable roofing structure with alternate corrugated G.I. sheets and polycarbonate sheets was constructed at the E. Jacinto Station and membrane tensile fabric was integrated in the roofing structure at the C.P. Garcia Station. The stations were also equipped safety features.

The automatic fare collection system which included turnstile gates and smart card readers, courtesy of the Micrologic Systems Inc., was tested and emphasized in the public demonstration run of the AGT which took place during the University Lantern Parade last December 18, 2013.

In contrast to the major stations of MRT and LRT designed to accommodate as many as 10,000 passengers, the AGT with a capacity of 30 passengers per coach capacity was considered in the design of the passenger stations at the UPD. Each of the three-storey station has a total area of 392.0 square meters and a height of approximately 11.0 meters. The dimension space is enough and can effectively contain the estimated number of passengers in the area. However, the result of the pre-feasibility study on potential AGT routes being conducted may affect the future design of the AGT System Passenger Stations as it includes an assessment on the passenger demand on the proposed corridors of the AGT. Thus, the dimensions of the designed passenger

stations can be modified depending on the travel and passenger demand in a certain area.

Since the AGT stations are only temporary structures, elevators or escalators were not included in the construction. Only stairs leading to the platform areas are available but there is an area in both stations where an elevator can be placed. Comfort rooms were also not built. However, there are provisional areas on the station where comfort rooms can be placed.

Recommendations

Research and Development Breakthrough

The AGT System is a research and development breakthrough in the Philippines. It is the first mass transit system built and developed by local engineers. As part of its continuous development and evaluation, passenger stations with safety features, communication and automatic fare collection system are necessary. Hence, the two passenger stations built at UPD can be used as a model unit for the continuous demonstration of an operational advance transport system.

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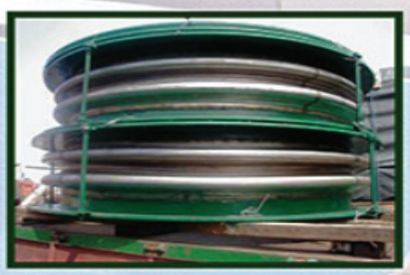

I. PRODUCTS

A. Expansion Joints / Flexible Pipes
(SS Materials) Fabrication
- single and multi bellows
- single and multi-ply bellows
- flange and flangeless flexible pipes
- standard or made to order
(customized)

B. Rubber Products
- rubber pods and gaskets
- rubber impellers, bushings
- O-ring rollers, gaskets diaphragm
- rubber expansion joints
- mechanical seal

II. SERVICES

A. Machining
B. Design and Fabrication
C. Repair of Industrial and Marine Boilers, Super heaters, air heaters, and economizers
D. Marine Hot Works
E. Repair and reconditioning of all kinds of Industrial pumps

Design, Fabrication and Testing of Pandanus Leaves Slitter – Presser

Allan John S. LIMSON,*1 Joein L. LUCES*2

Abstract

The Department of Science and Technology (DOST) – Aklan and Metals Industry Research and Development Center (MIRDC – DOST) designed and developed a manually operated Pandanus leaves slitter – presser as an alternative low cost leaf slitting and pressing device. The main objective is to flatten and even out bariw (Pandanus copelandii) leaves into quality pounded and softened leaf end-product. The pressing mechanism of the fabricated prototype is governed by metal rollers in synchronized rotation using spur gear such that when a metal-to-metal contact is established, the leaves are pressed and consequently flattened. On the other hand, the slitter assembly is comprised of blades which cuts the leaves; and spacer which is adjusted to achieve the required width. The prototype was tested at MIRDC by subjecting sun-dried, air-dried and wet bariw leaves samples to pressing and slitting. The roller gap was set to four micron (almost zero mm) and the thickness of the samples before and after pressing was measured using a digital Vernier calliper. Results showed that air dried bariw leaves had the best pressed condition as they reached the maximum potential for flatness. Sun dried leaves showed crack after pressing and the wet leaves tend to go back to their original form shortly after flattening. Slitting, on the other hand, was done at average strips for 5mm, 10mm and 15mm cuts, respectively. Overall, the prototype passed the functional testing and evaluation conducted and showed potential in providing a more efficient slitting and pressing of pandanus leaves.

I. Introduction

Pandanus, screw pine or pandan is a palm – like plant with variety of uses. Some of its notable importance include culinary, medicinal and industrial purposes. This project focuses on the industrial aspect, specifically on the use of bariw (Pandanus copelandii) leaves for handicrafts.

Craftsmen first collect pandan leaves, slice them into fine strips then sort for further processing. Finished products are ropes, colourful mats, jewelry boxes, decors and other weaved products of high quality. The whole process, from harvesting of raw materials to creating the finished product, is usually a tedious venture as everything is done manually. At the time this project was conducted, there was no existing pandanus leaves slitter – presser. There is a close machine known but is specific in pressing other variety of leaves and the slitter mechanism is not yet commercially available. It is for this reason that the Metals Industry Research and Development Center (MIRDC), an agency of the Department of Science and Technology (DOST), partnered with DOST-Aklan and LGU-Nabas to design and fabricate a prototype Pandanus Leaves Slitter - Presser for pressing and slitting bariw leaves. This project is in line with the aim of DOST – Aklan to establish a Common Service Facility to four barangays of the Municipality of Nabas that will serve as a venue for the process improvement of native bariw products. This is very fitting because Nabas is abundant of bariw plants with around 90 hectares plantation scattered all throughout the municipality and some are growing wildly along the mountain sides and forested areas. Moreover, bariw is the focus commodity of the Nabas Farmers' Information and Technology Services (FITS) Center wherein new technology on production and processing is being employed.

Objectives

The main objective of this project is to design and develop a manually operated Pandanus leaves slitter – presser as an alternative low cost leaf slitting and pressing device.

It specifically aims to:

1. flatten and even out bariw (Pandanus copelandii) leaves into quality pounded and softened leaf end-product ; and
2. test the functionality of the prototype by subjecting sun-dried, air-dried and wet bariw leaves samples to pressing and slitting.

Review of Literature

Pandan as Raw Material for Handicraft – Making

The species of pandan leaves used for weaving comes from the non – edible genus. These species contributes significantly to the traditional handicrafts industry as it is versatile enough to be woven into wide range of quality products such as mats, baskets, hats, wallets and even fancy items among others.

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There are several provinces in the country that engage in pandan weaving handicrafts as a means of livelihood. Some of these include the municipality of Luisiana in Laguna, Baybay City in Leyte, different municipalities in the Bicol Region and many others. In fact, Luisiana Laguna celebrates the Pandan Festival every April to showcase their local artistry through the different line of handicrafts made from pandan (Asian Secrets. Co, Undated; and Laguna Travel Guide, Undated).

Pandan Handicraft Industry in the Philippines

There are several programs implemented by local government and non – government organizations and cooperatives to support the local handicraft industry. For instance, the Non-Timber Forest Products (NTFP) - Task Force was established to address the emerging livelihood needs of upland forest peoples, particularly those who depend on NTFPs as well as to alleviate poverty. The Task Force, which is a collaborative network of Philippine grassroots based non-government organizations and Peoples Organizations, focuses on NTFP development and management issues in the context of sustainable tropical forest management. NTFPs are the resources derived from the forests other than timber. Edible plants such as honey, herbs, spices, bamboo, resins, natural dyes, essential oils, ornamental plants, fibers gums are examples of NTFPs (FAO, 2002; Michelle Arts, 2008).

However, a study titled "Analysis of the Contribution of the Pandan Handicraft Industry to Community Economic" was conducted in 2009 to analyze the perceived degree of contribution of the pandan handicraft industry to community economic development in the municipality of Luisiana, Laguna and the results revealed that the contribution of the pandan handicraft industry to community economic development was low. The said result can be attributed to several factors such as poor production and management system, poor marketing system, inadequate knowledge and technical skills on the adoption of new technology, weak linkages with government agencies and private entities, and inadequate technical, institutional and financial support.

Hence, the implementation of the One Town, One Product (OTOP) program wherein the local chief executives of each city and municipality take the lead in identifying, developing and promoting a specific product or service with a competitive advantage. In line with this, the Uplifted in Baybay City, Leyte, the Plaridel Women's Association for Rural Development (UPWARD) organization in Baybay City Leyte was assigned as the OTOP Center to boost pandan handicrafts-making enterprises (Department of Trade and Industry, 2008; Philippine Commission on Women, 2013).

Roll Pressing

Roll compaction is a form of high – pressure agglomeration. The method requires a roller press, which exerts mechanical pressure on a powder or other dry bulk material as it is forced between two counter - rotating rolls. This pressure compresses the material into compacts, which are either briquettes or sheet, subsequently passed through a mill to produce granules (Wennerstrum, 2000).

Although roll press compaction was predominantly applied in metal sheet or bar rolling, in the early 1960s a new emphasis was placed on rolling of powder metals or briquetting granular materials. At that time, information about the design of a roll press for powders was only of empirical nature. Thus, there existed a need for a mathematical model describing the relationships between the material properties, the press dimensions and operating parameters to aid engineers and operators in design and operation of roll presses for compaction of granular materials. Johanson was one of the first to fill this void by providing the means to determine the press dimensions and roll forces necessary to apply the required pressure to a material with specific properties which were attained experimentally (Balicki, 2003).

The roller press typically consists of a pair of rotating, shaft – mounted rolls of equal diameter. The rolls are mounted on bearing blocks and powered by a motor linked to a drive assembly. The roll gap is the distance between the rolls at their closest point and depends on the pressure applied and the amount of powder passed between the rolls (Wennerstrum, 2000).

Slitting

There are three basic mechanical types of web separation, or slit methods employed today. These are the burst or razor slitting which uses only one knife to slit the product; score or crush cut slitting wherein one knife is used to accomplish the web separation such that the web is actually pinched or scored apart by the cutting blade against a hardened plate or bottom roll at about 70 PSI of downward pressure; and shear slitting which makes use of the top and bottom knives working in conjunction to form a scissor cutting action that separates the web. Each of these types has its own advantages and disadvantages. While the first two are less expensive to set up and operate, produces poor quality cut. Whereas the last type is a bit more costly to install and maintain produces fine edge cut quality at high cutting speed rates (Principles of Shear Slitting, Undated).

Methodology

Project Development

The development of prototype was done at the Metals Industry Research and Development Center. The facilities are composed mainly of the machine shop, welding shop, assembly area and painting area for finishing of parts and components.

The prototype was first designed to have both pressing and slitting operations. The pressing mechanism is governed by three rollers, two of which are fixed and the other is adjustable such that the rollers press each other to flatten bariw leaves. On the other hand, the slitter assembly is comprised of blades and spacer. The blade cuts the leaves while the spacer is adjusted to attain the required width. The concept design was created using the CAD Software, NX.

Fabrication was done after a thorough design review. The prototype was fabricated in accordance to the specifications in the Terms of Reference. The materials and their corresponding sizes were all accounted for and strictly followed.

Testing of the Prototype

Like any other test procedures for a newly – develop equipment, the unit was first checked for interference and fits in each sub – assembly. The parts and components were inspected for dimensional accuracy and it was checked for customer's specifications and requirements. Then the equipment was tested without and with load. Results were documented and the roller press manual was prepared for use during the training and operation of said machine. After ensuring that test results are in accordance with the requirements and specifications, the equipment was cleaned and prepared for finishing touches.

As for the testing proper of the workability of the prototype, the initial condition of bariw leaves such as thickness, length and width prior to pressing and slitting were taken. Then, the characteristics of the bariw leaves were tested by subjecting them to pressing and stripping action under the dried and wet condition.

Results and Discussion

Figure 1 shows the concept design, generated from NX, and Table 1 summarizes the technical specifications, materials, major parts and their corresponding description. Figure 2 shows the fabricated Pandanus Slitter – Presser.

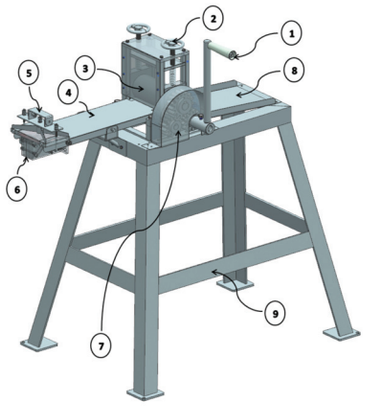

Figure 1. The Pandanus Slitter – Presser concept design generated from NX Software.

Figure 2. The fabricated Pandanus Slitter - Presser

Table 1. Technical specifications and major parts of the Pandanus Slitter – Presser.

MAJOR PARTS	DESCRIPTION	MATERIAL
1 Crank Mechanism	drives the machine. The operator rotates the handle clockwise as the crank mechanism transmits the rotary motion to gears and pressers to start pressing operations.	painted mild steel
2 Plunger	adjusts the compressibility of the roller presser. The operator can select the clearance effect of flatness on the *bariw* leaves.	mild steel
3 Roller Presser	presses the *bariw* leaves.	tool steel
4 Inlet Guide Sheet	supports the slitting assembly and guides the *bariw* leaves during feeding in pressing operation.	mild steel
5 Slitter Cover	covers the protruding blades and guide the *bariw* leaves during slitting operations.	painted mild steel
6 Slitter Assembly	comprises the slitter spacer and blades for slitting *bariw* leaves.	mild steel for spacer; high carbon steel for blade
7 Gear Assembly and cover	transmits rotary motion from the crank to the rollers, and a gear cover to protect the gear assembly.	tool steel
8 Outlet Guide Sheet	guides the pressed *bariw* leaves during pressing operation.	mild steel
9 Base Platform	holds the machine, 700 mm above the ground and made of angle bars welded together.	mild steel
Technical Specifications		
• single – point, metal to metal contact pressing		
• roller diameter: two 60 mm and one 75 mm		
• roller length: 128 mm		
• synchronized roller rotation using spur gear mechanism		
• synchronized adjustment of roller gap up to five millimeter (5 mm) distance		
• manual hand cranking method		
• roller speed: approximately 0.07 m/s		

Pressing and Slitting of Bariw Leaves

Random leaf samples were taken from the bariw roll. Three sun – dried, three normal dried and three wet leaves, respectively were subjected to pressing at ≤ 4 micron (almost zero mm). The roller gap of around four microns was adopted from previous testing since it is at this gap where pressing will likely be done without damaging the samples. Roller gap of more than four microns will be too wide, hence the samples passing through are left unpressed. Using a calibrated digital-type Vernier caliper, each leaf was measured for its initial thickness (before & after pressing) and width at five strategic points in the entire leaf length. Figures 3 to 5 shows the results of the different test conditions.

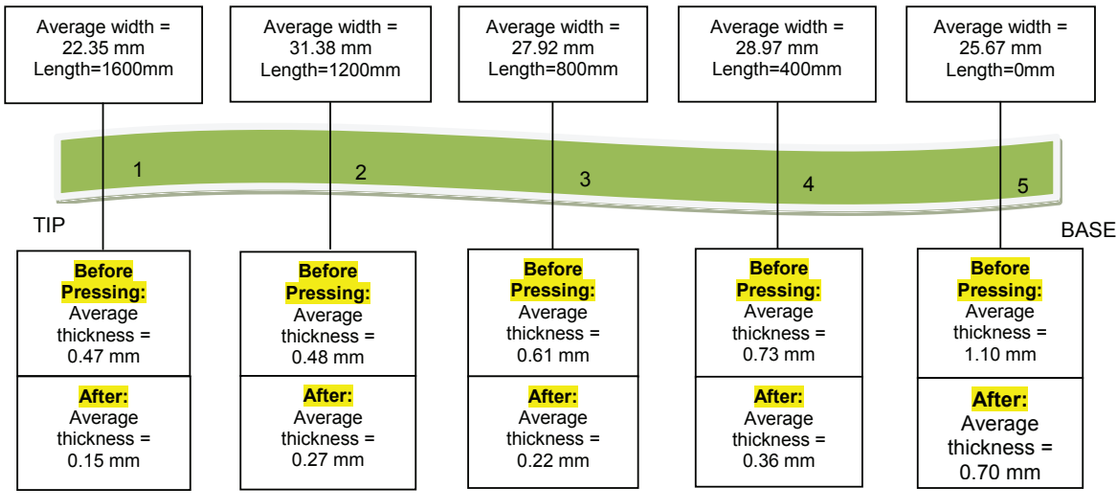

Figure 3. Pressing of sun – dried bariw leaves at ≤4 microns

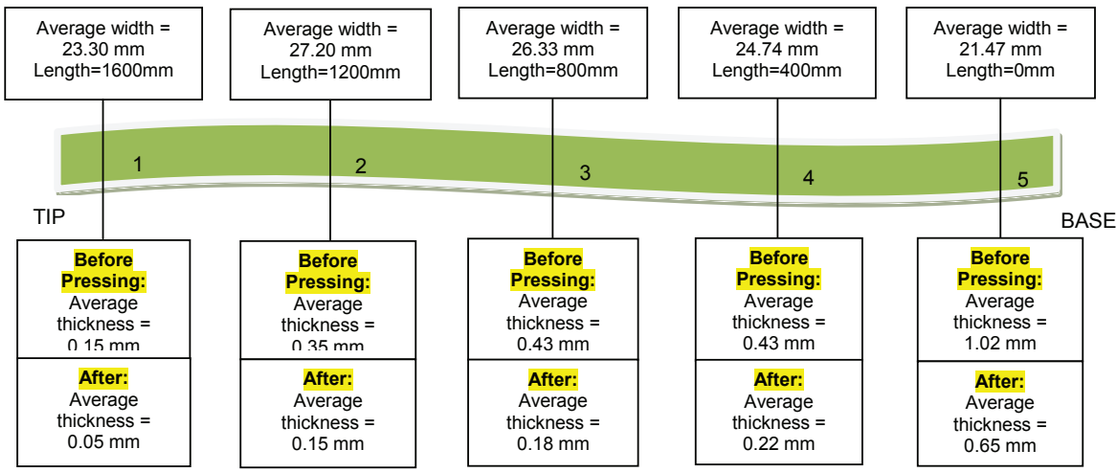

Figure 4. Pressing of air - dried bariw leaves at ≤4 microns

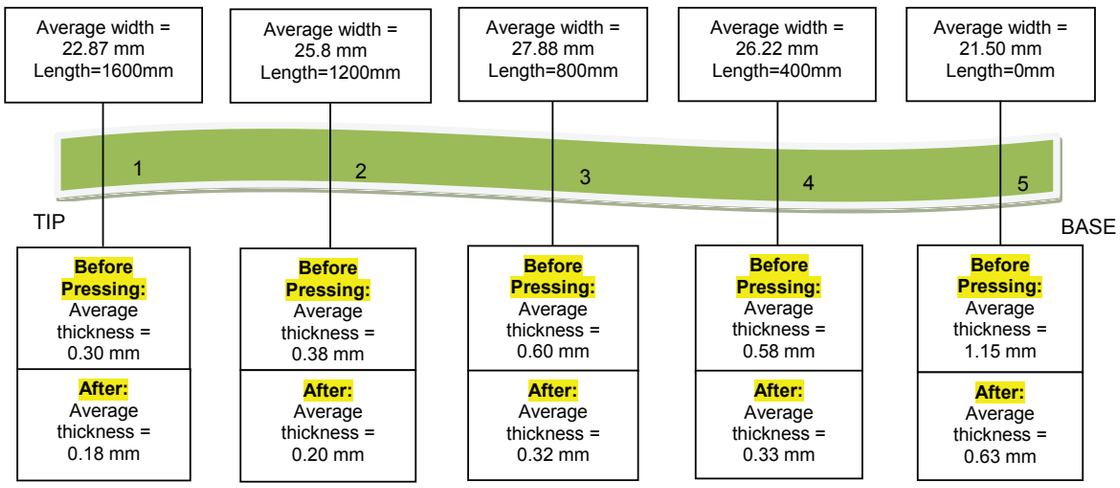

Figure 5. Pressing of wet bariw leaves at ≤4 microns.

Quantitatively, the results showed that the bariw leaves at different conditions had considerable change in thickness after pressing. Based from the feed-back of the stakeholders, the air-dried bariw leaves had the best pressed condition as the maximum potential for flatness was reached. Moreover, the flatness of the pressed air – dried leaves was sustained. On the other hand, the sun dried leaves showed cracks after pressing while the wet bariw leaves tend to get back to its original form shortly after pressing.

Slitting was done after pressing. The slitter spacer was adjusted to different widths to produce five millimeter (5 mm), 10 mm, 15 mm cuts, respectively. In handicraft making, pandan leaves are cut to different widths depending on the product to be woven. More elaborate designs would require shorter width. In the slitting operation performed, a single leaf was divided into an average of three strips when the slitter spacer was set to 5 mm; two strips at 10 mm cut, and one strip at 15 –mm cut, respectively. Figure 6 shows the slitting operation for the 5 mm cut. The strips produced had relatively fine edges.

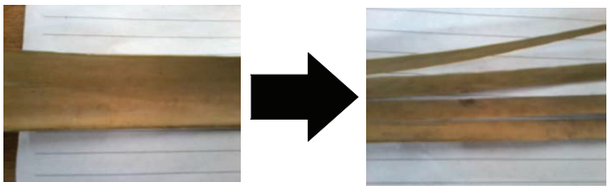

Figure 6. Result of the slitting of bariw leaf at 5 mm cut.

Adoption of the Machine

A week – long training about the developed Pandanus Slitter – Presser was conducted at Nabas, Aklan to test the functionality of the machine and to give the weavers hands – on pressing and slitting operations using the machine. The design, functionality and operation of the machine were discussed and an operations manual was provided. Figure 7 shows the training conducted at Nabas Farmers' Information and Technology Services (FITS) Center - Nabas, Aklan

Conclusion

The study was successfully able to develop a manual bariw leaves presser and slitter. Actual pressing of sun –dried, air – dried and wet bariw leaves were done at roller gaps of ≤ 4 microns, respectively. Results showed that air – dried leaves had the maximum potential flatness. After verification on the functionality and operation of the machine, it can be said that it is useful in improving the texture, unifying the thickness and slitting the leaves at preferred widths.

Recommendations

Based on the results of this study, the following are hereby recommended for future and follow –up research and development studies:

1. Conduct further field testing of the Pandanus Leaves Slitter - Presser in Nabas, Aklan as well as on other provinces that engage in pandan – based handicrafts.
2. Establish standard thickness for flattened bariw leaves that will yield the finest quality raw materials for weaving.
3. Conduct further study on developing pressing processes for bariw leaves.
4. Develop a motorized Pandanus Leaves Slitter – Presser to produce higher leaves pressing and slitting output per operation.

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Figure 7. Training conducted at Nabas FITS Center.

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Development of an Automatic Tool Changer (ATC) System for the 3-Axis Computer Numerically-Controlled (CNC) Router

Jayson P. ROGELIO,[*1] Renann G. BALDOVINO[*2]

Abstract

During machining operations, user safety is a big factor need to consider. The more interaction of the user with the machine, the more the user is prone to accident due to mechanical or tool failures. Like in CNC systems, especially in milling and router machines, user interaction can be seen during manual tool change operations. This study presents the development of an automatic tool changer for the 3-axis computer numerically- controlled (CNC) router machine of the Metals Industry Research and Development Center (MIRDC). ATC reduces the cycle time of tool-change operations, thus, improving the machine productivity. Furthermore, ATC also ensures the user's safety during tool change operations. It allows complete machining where different toolings are required to make different operations like cut, engrave, drill and mill. This includes the use of a pneumatic or quick- change electrospindle and an ISO-20 tool holder system. The tool holder system makes the CNC router adaptable and flexible to different routing operations.

Index Terms—***automatic tool changer (ATC), computer numerically-controlled (CNC), computer-aided manufacturing (CAM), electrospindle.***

I. Introduction

Present day computers are considered as a direct consequence of the progress in the advancement of numerical control (NC) machines. Around 1965, these NC machines were fitted with minicomputers that started the advent of computer numerical-control (CNC) technology in conventional machines. CNC started to develop and grow in meeting the increasing demand to manufacture components or parts of high accuracy in large quantities [1]. As defined by the Electronic Industries Association (EIA), "CNC is the numerical control system where a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programs stored in read and write memory of the computer". CNC has been applied to many mechanical systems like milling, lathe, router, plasma cutting, LASER cutting, etc.

For woodworkers, CNC router has changed their way to deal and approach certain tasks. This machine revolutionized and reshaped the industry in providing solutions to quality of work and productivity issues. With the application of CNC, complicated tasks can be done quickly and efficiently.

Still, some CNC systems utilize manual tool-changing operation like the CNC router developed by the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) for the furniture industry (see Fig. 1).

The machine prototype was named as 'Super Lilok' machine. Lilok, in Filipino, means carver or woodworker. It has the ability to route in all types of wood, acrylic plastic and non-ferrous metals like brass and aluminum. To produce 2D and 3D carvings, the CNC router requires 2 or more cutting tools for engraving, profiling, roughing, etc. As the number of tools used increases, the user interac-

Fig. 1. MIRDC's CNC router machine.

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tion to the machine also increases [2]. Therefore, this study aims to develop an ATC system for the 3-axis CNC router to improve its productivity by reducing the tool-change cycle time. Moreover, it also ensures the safety of operation since integration of ATC decreases user interaction with the machine.

II. The 'Super Lilok' Machine

The CNC router project is under the 'Makinarya para sa Bayan' or MakiBayan program of the DOST. The MakiBayan program aims to strengthen the research and development sector to provide solutions of industry problems in metals engineering, furniture and equipment fabrication. It also aims to work more closely and share resources to work common goals with private R&D partner. The program started with the development of the two (2) machines: the CNC router dubbed as the 'Super Lilok' machine and the CNC plasma cutter as 'Plasmanoy' that uses plasma in cutting sheet metals.

A. Mechanical Motion of the CNC Router

For the CNC router operations, its motion can move and cut in three (3) directions (X, Y and Z) as shown in Figure 2. The X-axis is running left to right. The Y-axis runs from front to back and the Z-axis for the up and down. There is also an optional rotary axis (A-axis) that is integrated in the machine that rotates along the X-axis.

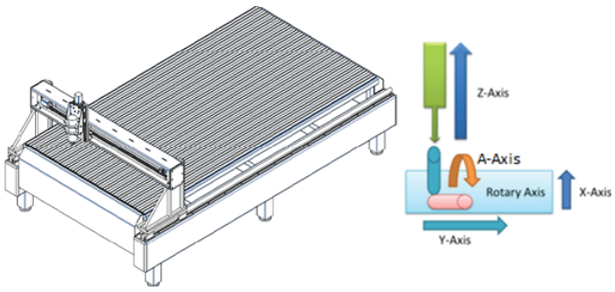

Fig. 2. Motion analysis of the CNC router system.

B. CNC Control Operation

Figure 3 provides an illustration of the signal flow that occurs during transformation of the drawing file to a machine code that will be read and understand by the controller [3].

Just like any CNC machines, the CNC router uses a computing software and breakout board or motion controller (see Fig. 4) to drive a mechanical system [4].

Then, the controller will command the motors to produce a desired toolpath from the g-codes created by the CAM software. The variable frequency drive (VFD) or inverter drive is responsible in controlling the speed of the spindle motor.

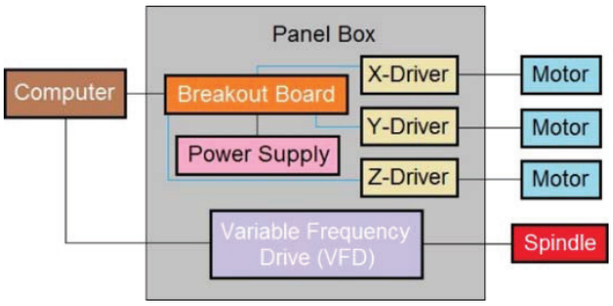

Fig. 4. CNC router machine block diagram

C. Technical Specifications

Table 1 provides the technical specifications of the 'Super Lilok' machine.

Table 1. Cnc Router 'Super Lilok' Specifications

Item Specifications	Item Specifications
Maximum Working Area	1300 mm x 2500 mm
Z-Axis Travel	460 mm
Z-Axis Clearance	200 mm
Maximum Travel Speed	30 m/min
XYZ-Transmission System	20 m/min
Accuracy	0.10 mm
CNC Table	High-Precision Ballscrews
Power Supply	220-Vac, Single-Phase
XYZ-Motors	Stepper Motors
Spindle Motor	2.2-kW Round-Type, Water-Cooled
Maximum Rotational Speed	18000 rpm
Controller Type	USB-Interface, MPG Pendant
Tool Change Operation	Manual

From the specification, the tool change operation currently employed is manual. Figure 5 shows the manual tool change operation using set of tools like a spanner to remove the tool from the spindle motor attachment. The next tool will be secured to the spindle attachment which is the same operation in removing the tool but in the reverse direction.

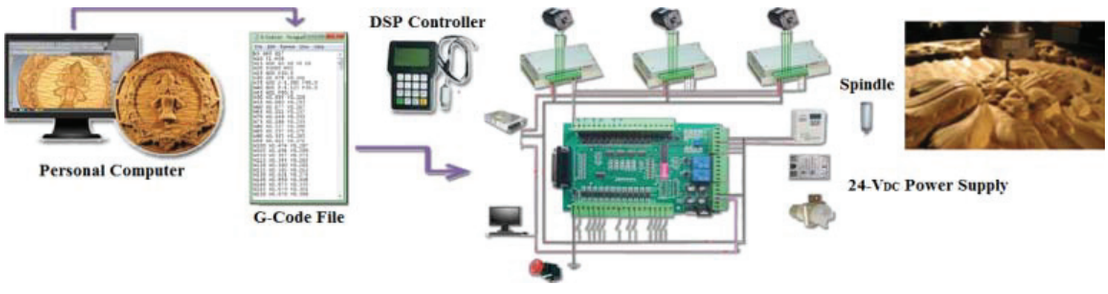

Fig. 3. CNC router system design flowchart.

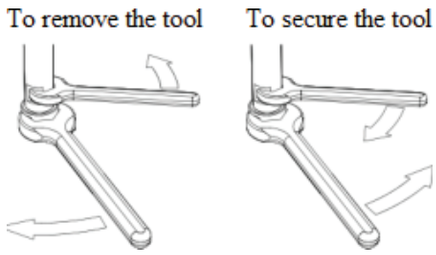

Fig. 5. Manual tool change operation

III. Automatic Tool Changer (ATC)

In manufacturing processes, especially in metal cutting industry, full automation is possible today through the implementation of automatic tool changer (ATC) systems in the machining centers [5, 6]. The smooth run on the tool change operation sequence is defined by two (2) ATC main characteristics: the auxiliary time needed to exchange the tool or the tool-to-tool time and the number of tools it can manage in the magazine [7]. Figure 6 displays the two (2) types of tool magazine used in tool changing systems for

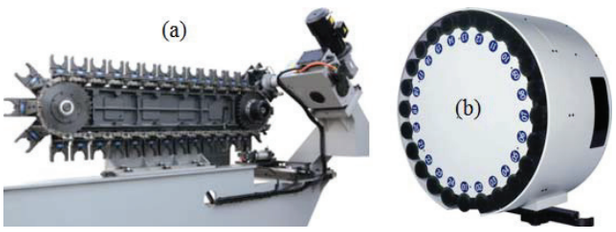

Fig. 6. ATC tool magazine: (a) chain-type and (b) drum-type

CNC machines: chain-type and drum-type magazine.

There are also linear-type magazine used in CNC routers. This type has the simplest configuration compared with the chain- and drum-type. This can be programmed as a stationary magazine wherein the gantry of the CNC itself locates for the desired tool. For the ATC controls [8], microcontroller-based [9] or PLC-based [10] controller can be used.

IV. Methodology

In this study, the ATC system consists of the hardware (see Fig. 7), controls system and software components.

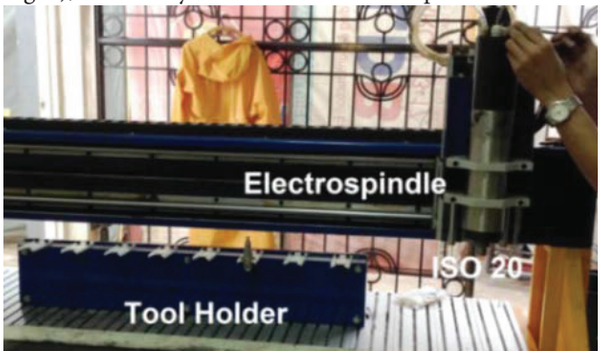

Fig. 7. ATC hardware system

A. Hardware

A 2.2-kW pneumatic electrospindle motor was used. The electrospindle is considered to be the main actuator of the ATC system. The orientation of the electrospindle attached in the machine's gantry system, is vertically-mounted. It runs in a single-phase, 220-Vac line. It uses water- or liquid-cooling as opposed to air-cooling systems. It is supported by an external industrial chiller unit where the water flows in and out during its operation. The maximum rotational speed that the unit can take is up to 24,000 rpm. A variable frequency drive (VFD) is used to adjust and control the speed of the electrospindle.

As seen also in the figure, ISO-20 system is the tool

Fig. 8. ISO-20 tool holder system

holder employed in the ATC system (see Fig. 8).

It consists of the following components: tool holder, chuck, collet and adapter. The tool holder is made up engineering plastic. It is used to manually change or replace the collet and adapter by exerting a strong clamping force when tightened. The collet is used to hold the tool adapter. The adapter is used to hold the specific tool in terms of the tool's shaft diameter. For ISO-20, the maximum shaft diameter that it can accommodate is 6mm. In Figure 9 the tool magazine employed is linear-type consisting of 8 different

Fig. 9. Linear-type tool magazine

tools.

B. Controls System

As shown in Figure 10, the electrical and electronic components in this study consist of the following: DC power supply, inverter drive, stepper drivers and controller pendant.

Fig. 10. Control panel box

• Variable Frequency Drive (VFD) as seen in Figure 11, this

Fig. 11. Variable frequency drive (VFD)

inverter drive is used to control the speed of the pneumatic electrospindle.

• DC Power Supply – As shown in Figure 12, power supply consists of the 24-VDC and 48-VDC. The 24-VDC provides the supply for the motion controller board and the X- and

Fig. 12. DC power supply

Z-axes motor drivers while the 48-VDC is used for the Y-axis motor driver.

• Stepper Drivers – These are used to drive the stepper motors of the three (3) axes.

• Controller Pendant – To transfer the toolpath program files or g-code to the controller, in this study, a digital signal processor (DSP) controller pendant is used (see Fig. 13). It has the capability to set the origin of the machine and workpiece. With the controller, the traverse and process speed value can be assigned.

Fig. 13. Controller Pendant

• Adapter – This is used to hold the specific tool in terms of the tool's shaft diameter. For ISO-20, the maximum shaft diameter that it can accommodate is 6 mm.

C. Software

The software used for the tool-change operation is the ArtCAM (see Fig. 14) and VCarve Pro (see Fig. 15) software using the M6 code, respectively.

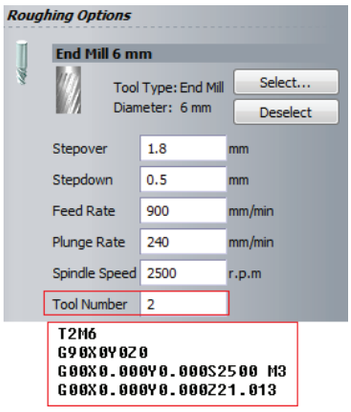

Fig. 14. ArtCAM for tool-change (M6) operation

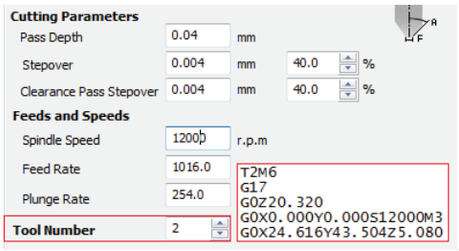

Fig. 15. VCarve Pro for tool-change (M6) operation

V. Testing

Actual testing of the ATC system is conducted in the Super Lilok machine. The materials used were the following:

- 1 mm galvanized-iron (GI) sheet
- 1.5 mm acrylic plastic
- medium density fiber (MDF) board: 3, 4 and 5 mm

A. Test Validation and Analysis

Test was validated using the coordinate measuring machine (CMM-Beyond 504). The cutting accuracy of the machine was computed using the percentage error (% error) formula

$$\% \, error = \left| \frac{actual - reference}{reference} \right| x \, 100\%. \qquad (1)$$

wherein the reference is the CAD-CAM input value and the actual is the measured value.

Table 2. Dimensional Inspection Using Cmm-Beyond 504

Specification (mm)	Tolerance (mm)	Actual Dimension	Tool Used	% Error
GI Sheet (1 mm)				
L = 60		60.00 mm	2 mm	0.00
W = 20		19.96 mm	Endmill	0.20
Acrylic (1.5 mm)				
L = 60		59.90 mm	1 mm	0.17
W = 20		19.86 mm	Endmill	0.01
MDF (3 mm)				
L = 60	± 0.05	60.05 mm	2 mm	0.08
W = 20		20.13 mm	Endmill	0.65
MDF (4 mm)				
L = 60		60.10 mm	3 mm	0.17
W = 20		20.13 mm	Endmill	0.65
MDF (4 mm)				
L = 60		59.98 mm	6 mm	0.03
W = 20		20.02 mm	Endmill	0.10
Average				**0.21%**

Table 2 shows an average percentage error of 0.21% based for the different material samples.

B. Toolpath Simulation

The toolpath simulation was conducted using an ArtCAM software to determine the machining time with and without the ATC system. 3D machining was used to perform different cutting tool operations. In the simulation, four (4) tool-

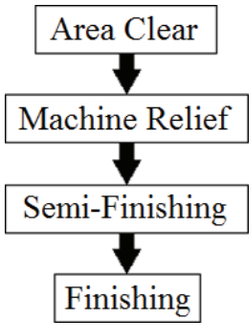

Fig. 16. 3D machine flow process

paths were used: area clear, machine relief, semi-finishing and finishing (see Fig. 16).

Table 3. Result From Artcam Toolpath Simulation

Item Specifications	Item Specifications
Relief Dimensions	Width: 76.20 mm, Height: 127.00 mm Min X: 0.00 mm, Min Y: 0.00 mm Min Z: -3.00 mm Max Z: 0.00 mm
Material Type	Brass
Material Thickness	4.50 mm
Z-Zero	Top of Material
Area Clear Tool Type Feed Rate Plunge Rate Spindle Speed Stepover Machining Time	 6 mm Flat Endmill 900 mm/min 240 mm/min 2500 rpm 1.80 mm 1151 sec
Machine Relief Tool Type Feed Rate Plunge Rate Spindle Speed Stepover Machining Time	 6 mm Flat Endmill 900 mm/min 240 mm/min 2500 rpm 1.80 mm 181 sec
Semi-Finishing Tool Type Feed Rate Plunge Rate Spindle Speed Stepover Machining Time	 3 mm Ball-Nose Endmill 600 mm/min 240 mm/min 2500 rpm 0.20 mm 1287 sec
Finishing Tool Type Feed Rate Plunge Rate Spindle Speed Stepover Machining Time	 2 mm Ball-Nose Endmill 600 mm/min 240 mm/min 4500 rpm 0.05 mm 5124 sec
Machining Time: With ATC With Manual Change	 7743 sec 10443 sec

For the ArtCAM simulation result and the type of tool used, see Table 3.

Results show that the machining time reduces dramatically by 35% when ATC was employed in the system.

C. Reliability Test

Figure 17 displays the reliability test of the ATC system. A difference of 2.7 μm from the target depth value for wood was observed. This is based from the actual series of 40 tri-

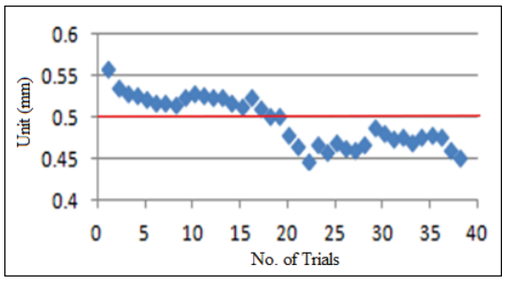

Fig. 17. Actual versus target value for depth of wood

als. In effect, the accuracy is seen to be superior from the 10 μm accuracy of the CNC router without ATC.

VI. Conclusion

In this study, the integration of an automatic tool changer (ATC) system to the CNC router reduces the tool-to-tool change operations. The use of the tool holder system makes the CNC router flexible to different routing operations. This effect can be seen especially to wood machining that utilizes different tools in its operations like profiling, engraving, drilling, cutting, etc. Thus, employing ATC system increases the machine productivity and efficiency. Moreover, ATC reduces the labor intensity and guarantees the safety and security of the operators.

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A Pulse-Width Modulation (PWM) LASER Power Controller for the 3-Axis Computer Numerically-Controlled (CNC) LASER Machine

Support Program for the Productivity and Competitiveness of the Metals and Engineering Industries

Jayson P. ROGELIO,*1 Renann G. BALDOVINO*2

Abstract

This study presents the development of a LASER power controller using pulse-width modulation (PWM) technique for the 3-axis computer numerically-controlled (CNC) LASER Machine. This includes the use of a graphical-user interface (GUI) and a GizDuino board to produce PWM outputs. The GUI was developed in Microsoft Visual Studio. The PWM code was programmed in the Arduino development environment. In this study, PWM is effective in controlling the LASER power of the Synrad firestar f201. Actual tests were conducted to verify its performance in an acrylic plastic material. PWM is also proven to be cost-efficient since it does not require additional modules for analog converters and signal conditioning process. Other features, like motor errors, LASER and chiller temperature, were also incorporated and created in the controls for the safety of the user and the machine hardware.

*Index Terms—**pulse-width modulation (PWM), computer numerically-controlled (CNC), computer-aided manufacturing (CAM), LASER.***

I. Introduction

Computer numerically-controlled (CNC) LASER cutting is an industrial technology that uses a LASER (Light Amplification by Stimulated Emission of Radiation) to cut ferrous and non-ferrous materials [1]. It works by directing the output of a high-power LASER beam, through a PC controller, at the material or workpiece to be cut.

The first LASER cutting machine used for production was developed in 1965. This machine, made by the Western Electric Engineering Research Center, was used to drill holes in diamond dies. Two years after, the use of LASER-assisted oxygen jet cutting in metals began. The application of LASER cutting continue to grow and widen. Even in aerospace applications, this technology become very useful in cutting titanium for structural airframe. Since then, the research on this technology has created a variety of innovations in developing different types of specialized LASER. Some of this optimization includes maximum average output power, efficiency and minimizing the cost. This optimization can be achieved by controlling the amount of LASER power delivered to the load. The efficiency of industrial LASER may range from 5% to 45%. High power consumption is one major disadvantage of LASER cutting. For a particular cutting job, the amount of LASER cutting power or heat input depends on the material, its thickness and desired process rate [2].

LASER power, just like voltage supply and motor, is purely analog in nature. Thus, an analog control is needed to control its level. Analog control, like potentiometer-based, regulates the LASER power supply output, however, analog control is sensitive to small changes in wire resistance and environmental noise [3]. They also generate much heat due to the presence of a potentiometer or variable resistor that carries a lot of current. Moreover, there are also instances that analog-based control cannot be set to its minimum and maximum value. With that, digital control was introduced

Fig.1. CNC Laser Machine

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like the pulse- width modulation (PWM) technique. This study aims to develop a PWM-based LASER power controller for the 3-axis CNC LASER machine. Many studies show that PWM is less sensitive to distortion and noise. This is important especially in high-precision machining like in CNC LASER system. Figure 1 shows the CNC LASER machine locally-designed and developed by the Metals Industry Research and Development Center (MIRDC).

II. CNC LASER System

CNC is a microprocessor-based control system that accepts set of program instructions or machine codes (g-code), processes and sends output control values information to a machine, and receives and analyzes the feedback information from its sensors to accurately ensure the proper machining operation in terms of motion and process speed. Just like any CNC systems available in the market, CNC LASER machine behaves and operates the same mechatronics principle [1, 4].

The CNC LASER machine developed by MIRDC is intended to cut metal and non-metal materials using the 200-W carbon dioxide (CO2) LASER generator from Synrad. CO2 LASER is commonly used in industrial cutting for mild and stainless steel, aluminum, titanium and non-ferrous applications. The machine has three (3) axes (X, Y and Z) of motion driven by stepper motors. It also has a conveyorized- delivery system to transfer the material to the CNC bed. Figure 2 illustrates a block diagram of this CNC system. This can be characterized in terms of three (3) major elements: computer, controller and hardware [5].

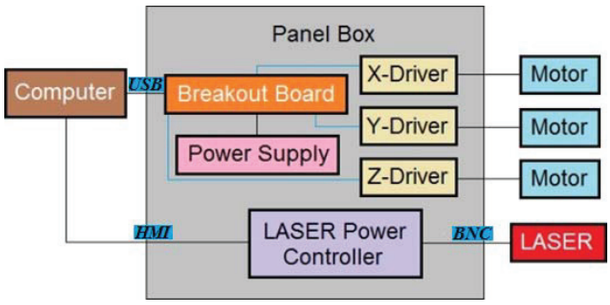

Fig. 2. CNC LASER machine block diagram

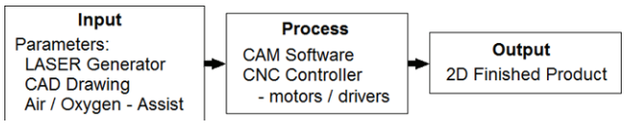

Fig. 3. CNC LASER machine operation parameters

Basically, the computer play an integral part of the control system. Modern CNC systems nowadays are highly equipped with computers that can run computer-aided design (CAD) and computer-aided manufacturing (CAM) programs. Figure 3 displays the operation parameters of the CNC LASER system. The input to the process is the LASER beam produced by the LASER generator, the 2D CAD drawings and other devices like the chiller and air-assist system during cutting.

After the inputs, the process of the system involves the CAM systems and the CNC motion axis controller to drive the stepper or servo motors.

A. LASER Cutting Operations

The generation of LASER beam involves stimulating a material by electrical discharges or lamps within a closed container. Then, the beam is internally reflected by means of a partial mirror or fiber optics. These mirrors are used to direct the path of the coherent light to a focus lens at the material or workpiece to be cut [1].

There have been lot of studies that prove the use of LASER provides an excellent performance compared with other CNC systems (like milling and plasma cutting) in terms of accuracy and precision. LASER operation can cut to the width (kerf) of its beam, which measures 0.01 mm, unlike with milling and router that utilized the diameter size of its mechanical cutter. Moreover, with the cutter, it leaves a rougher edge finish. LASER cutting has the most polished finishing work without warping the material to be cut.

B. Commercial LASER Power Controllers

There are actually many manufacturers of LASER power controllers depending on the type of LASER. Synrad, as the world's leading manufacturer of sealed CO2 LASERS, developed a LASER power controller which is the UC-2000 Universal LASER Controller (see Fig. 4). This controller is design to provide an easy user-interface for the total control of LASER power, duty cycle and modulation frequency [6].

Fig. 4. UC-2000 universal LASER controller

Mach3 also developed a PWM controller integrated in their CNC controller. It allows the user to setup a pin as a PWM output. Figure 5 shows the PWM control setup for Mach3. In motion control, Mach3 is a user-friendly controller but in PWM control, it is quite difficult to setup [7].

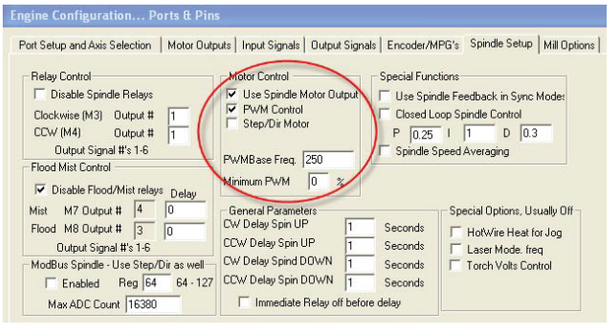

Fig. 5. Mach3 PWM controller

Another commercial digital signal processor (DSP) based controller for CO2 LASER is the AWC608 from Light Object (see Fig. 6).

Fig. 6. LightObject AWC608 LASER controller

The controller comes with a LaserCadd graphic application for simple graphic creation or file importing and exporting. The price of the said controller is $ 750.00 [8].

III. Pulse-Width Modulation (PWM) Technique

Pulse-width modulation (PWM) is a modulation technique used to control the width or duration of the pulse based on the modular signal information. PWM, as digital in nature, has inherent noise-immunity allowing an analog signal to be sent even on a lengthy transmission line [9].

A. Power Delivery

As compared with linear power delivery (resistive means), PWM can be used to control the amount of power delivered to a load without incurring any losses. The average value of voltage or current fed to the inertial load is controlled by turning the switch between supply and load on and off at a fast pace. The power provided from the supply to the load is higher if the switch is on longer compared to its off periods.

B. Duty Cycle

Duty cycle, expressed in percentage, is the term that describes the proportion of on time to the regular interval or cycle period. It can be define simply as the percentage of one period in which a signal is active. Figure 7 shows the different percentage of duty cycle from 0% to 100%.

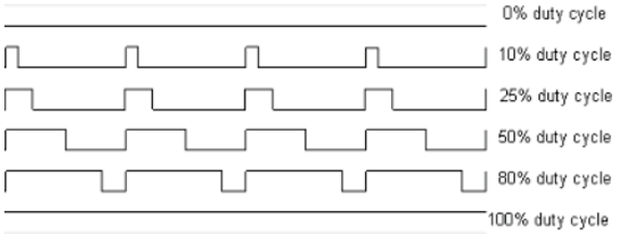

Fig. 7. PWM duty cycle

As the duty cycle increases, the amount of power delivered to a system also increases.

C. PWM Applications

PWM has a variety of industrial applications like in controlling the power supplied to electrical devices such as LED lamps, motors and other inertial loads.

Switching Power Supply – Efficient voltage regulators utilized PWM technique in switching the amount of voltage to the load (see Fig. 8) [10]. With the appropriate duty cycle, the PWM output will provide a voltage approximation at the desired level [9, 11].

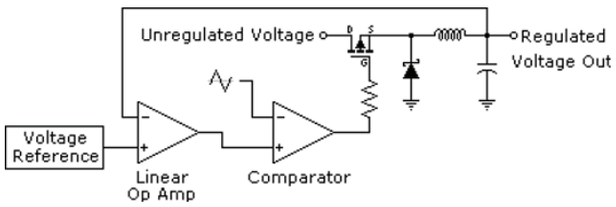

Fig. 8. Switching power supply using PWM

Motor Speed Control – PWM is currently used in motor speed control [12, 13]. PWM control is applied in motor and variable-speed fan controllers since it is more efficient compared to a potentiometer or rheostat. Figure 9 displays the DC motor speed control using PWM technique.

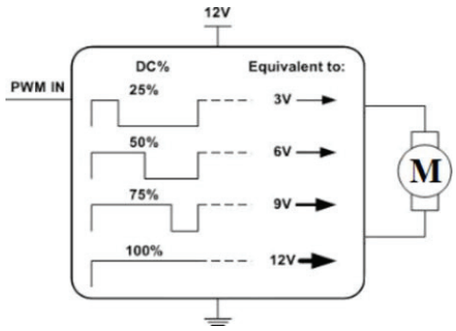

Fig. 9. PWM speed control of DC motor

Telecommunications – In data transmission, PWM is very useful in data encoding and decoding. In Figure 10, the duty cycle has been used to send information over a communication channel. The pulse width corresponds to specific data values encoded at the transmitter and decoded at the receiver [14, 15].

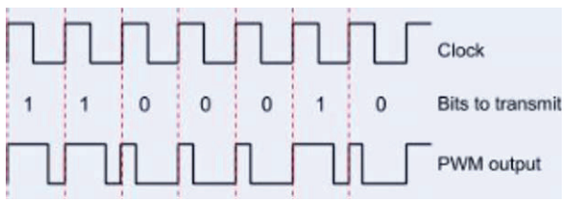

Fig. 10. Data transmission coding using PWM

IV. Methodology

In this research, the controller operations for the LASER power is built with a simple graphical-user interface (GUI) as seen in Figure 11. The GUI was created in Microsoft Visual Studio. In addition, all functions of the LASER generator including the switches, error and safety indicators were incorporated in the controller.

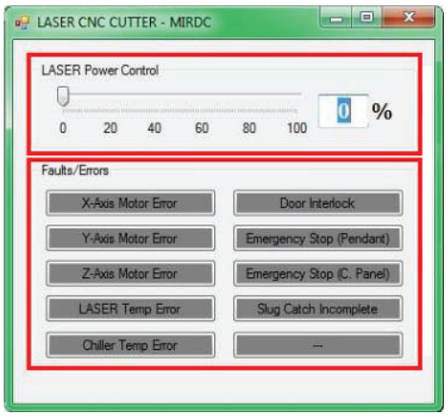

Fig. 11. GUI for the LASER power controller

The interface used to link the GizDuino controller and the Synrad's Firestar f201 CO2 LASER generator is a Bayonet Neill–Concelman or Baby N Connector (BNC) Control Cable. This is a type of coaxial cable that carries the PWM command signal from the controller to the LASER's quick start plug controller.

A. LASER Power Control

In this GUI, a slider and a textbox function was designed and created for the CNC operator to input desired value from 0 to 100%. This function allows the operator in adjusting the desired level of LASER power depending on the type and thickness of the material or workpiece to be cut as shown in Figure 12.

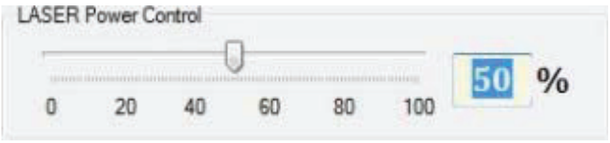

Fig. 12. LASER power control

The Arduino's programming language makes it easy to program the PWM. In this study, a loop program was created in enabling the PWM operation. This operation will only work once the CNC controller and the LASER generator is enabled.

```
void loop( )
{
      updateStatus();
      LaserEnabled = digitalRead(LaserOn);
      if (LaserStatus == false && LaserEnabled == 1)
      {
          PWM_ON();
          LaserStatus = true;
      }
      else if (LaserStatus==true && LaserEnabled==0)
      {
          tickle_pulse_ON();
          LaserStatus = false;
      }
}
```

The code shows that the PWM function or PWM_ON() will only be triggered once the LASER generator is enable in the control panel by the user or operator in preparation for the cutting operation. PWM_ON() operation can be done simply using the analogWrite(pin, dutyCycle). In this function, values of PWM period and pulse width (both in μs) were set. The pulse width is the percentage amount inputted by the user.

B. Faults and Error Indicators

Other safety features (see Fig. 13) were also programmed for different error indicators that can be encountered in the machine before and during LASER cutting operation. In case an error occurs, it will indicate and trigger a red color to alarm the user.

Fig. 13. Fault and error indicators

- X, Y and Z-Axes Motor Errors – These are errors that occur in the three (3) motion axes of the CNC LASER machine.
- LASER Temp Error – Error that indicates if the LASER tube rises above the safe operating limits. The LASER generator itself has an over temperature protection (temperature shutdown) within its circuit element. Moreover, the generator also has a temperature indicator that illuminates green when LASER temperature is within operating limits, changing to red when thermal limits are exceeded.
- Chiller Temp Error – Error that is detected when the chiller encountered a problem. In the system, the chiller used is an intelligent controller that does not need to adjust the controlling parameters according to the ambient temperature for meeting the equipment cooling requirements.
- Door Interlock – This is the error detected if the frame door interlock is left open during operation. Emergency Stop (Control Panel) – This error is detected when the emergency stop in the control panel is activated.
- Emergency Stop (Pendant) – This error is detected when the emergency stop in pendant is activated.
- Slug Catch Incomplete – This error is detected when the slug catch bin is not fully inserted or incomplete

V. Results and Discussions

Here are the results of the PWM-controlled LASER output in a 10 mm clear acrylic plastic (see Fig. 14) in four (4) different duty cycles: 10%, 20%, 30% and 40%.

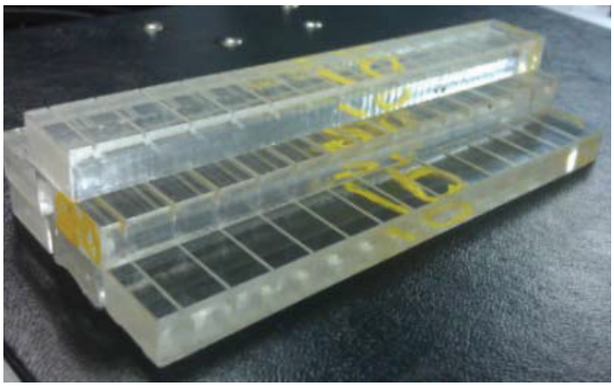

Fig. 14. Sample cut for testing in different duty cycles

In Figure 15, a Mitutoyo Toolmaker's microscope was used to visually inspect and measure the depth of cut. Figure 16 displays the graph of cutting depth versus the amount of duty cycle (10%, 20%, 30% and 40%). The LASER cut produced a clear, polished and mirrored finish on all samples.

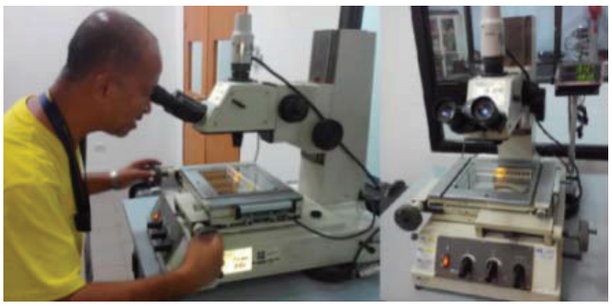

Fig. 15. Mitutoyo Toolmaker's Microscope

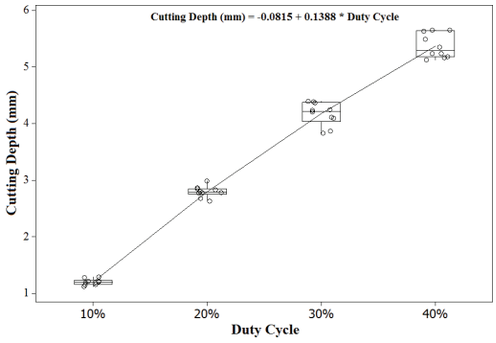

Fig. 16. Depth of cutting (mm) versus the amount of duty cycle

Table 1. Experimental Results

Duty Cycle	No. of Samples	Mean	Standard Deviation	Min.	Max.	CV
10%	10	1.2049	0.0521	1.1250	1.2930	0.0432
20%	10	2.7993	0.0980	2.6310	2.9900	0.0350
30%	10	4.1763	0.2015	3.8330	4.3990	0.0482
40%	10	5.3719	0.2144	5.1270	5.6500	0.0399

Result shows that increasing the duty cycle, increases also the depth of cut by the LASER beam. This only shows that the depth of cut is directly proportional to the duty cycle. This is based from the ten (10) samples run per each duty cycle. The coefficient of variation (CV) or relative variability was used to measure the consistency of the samples across each run (duty cycle). CV is simply the ratio of the standard deviation to the mean. The lower the CV is, the higher will be the consistency in the data. As seen from Table 1, the values obtained from their standard deviation and CV were low. As seen also from the boxplots of Figure 16, the data are less dispersed in every duty cycle. No outliers were seen in the experiment. Moreover, a linear relationship between the duty cycle and the depth of cut can be observed. This shows that amount of cutting can be predicted for any specific material and thickness. For the acrylic plastic, the relationship is:

Cut Depth (mm) = -0.0815 + 0.1388 * Duty_Cycle (1)

VI. Conclusion

In this study, the LASER power controller using PWM technique provides an efficient and effective method to control the amount of LASER beam. As seen from the results, LASER power was controlled successfully using PWM technique. Moreover, the developed PWM controller is cost-efficient. It does not require signal conditioning and additional modules for digital-to-analog converters. Using only a BNC connector to link the LASER generator to the controller board, the amount of LASER beam can be controlled.

Acknowledgement

The authors would like to thank the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) for funding this research. This research is under the "Makinarya para sa Bayan" or MakiBayan program launched by the DOST.

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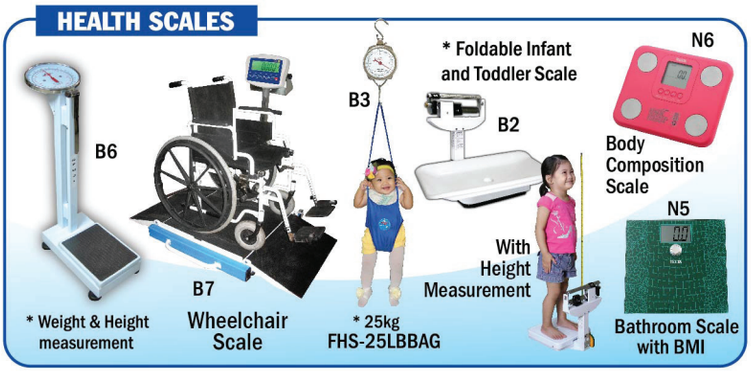

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Optimization of Machine Process Parameters through 2D Image Layout Enhancing and ArtCAM Post-Processing for 3D Machining

Support Program for the Productivity and Competitiveness of the Metals and Engineering Industries

Renann G. BALDOVINO,[*1] Jayson P. ROGELIO,[*2] Geoffrey L. ABULENCIA,[*1] Virgilio Y. MACANIP, JR.[*2]

Abstract

3D machining has been one of the challenges in CNC milling and CNC router machines. It's quite difficult to create 3D relief from plain 2D image. To provide a very clean 3D relief, lot of resources, like software programs, machines, tools and time, is needed. This study provide an optimized way how to enhance the 3D output without sacrificing other factors like the machining time and tool life. Image layout enhancing and the use of ArtCAM postprocessing were applied in the study. As compared with the traditional machining strategy, machine relief was added in the operation. From the results, this strategy helps in the preparation of the 3D model for the engraving toolpath and reduces its machining time operations.

Index Terms—***computer numerically-controlled (CNC), computer-aided manufacturing (CAM), 3D relief.***

I. Introduction

Computer numerical control (CNC) is a microprocessor based control system that accepts program instructions, reads, processes and sends signal information to an actuator or machine tool. It also accepts feedback data information from a sensor placed on the tool to assure the proper motion, speed and operation.

These machines are programmed using a computer-aided design / computer-aided manufacturing (CAD/CAM) software to produce precise and accurate patterns even over a number of identical pieces [1]. Machining 3D face artwork is one of the challenges that advanced CAD/CAM programs need to address and these problems can be seen both in the hardware and software side.

In the software, creating 3D relief model is a lengthy-task for a CAD/CAM designer. A relief is a 3D representation, materialized as a physical artifact, usually of a terrain or facial features. The designer must also be aware of the type of material, tools used and the time of machining. The time of machining is dependent on the process speed, stepover and stepdown. Moreover, the resolution of the 2D image is a very important factor to consider in obtaining a high quality 3D relief. Therefore, this study aims to optimize the machine process parameters of 3D machining through 2D image layout enhancing and ArtCAM post-processing.

II. CAD/CAM Technology

CAD/CAM or virtual product design (VDP) is a concept that provides a unique process based approach in enabling a seamless digital design-through-manufacture environment [2,3]. CAM is the use of a computer program to control machine tools and machineries in the manufacturing industry [4]. This technology has been considered as a numerical control (NC) programming tool in 2D and 3D models generated in CAD software.

A. CAD/CAM Operation

Figure 1 provides an illustration of the signal flow that occurs during transformation of the drawing file to a machine code that will be read and understand by the controller [5]. This can be characterized in terms of three (3) parts: CAD, CAM and CNC control [6].

First, the computer play an integral part of the control system. Modern CNC systems nowadays are highly equipped

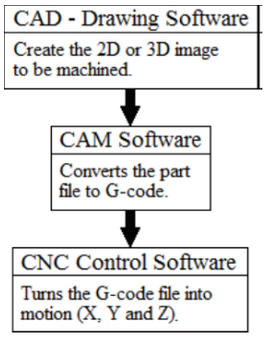

Fig. 1. Signal flow for CNC position control

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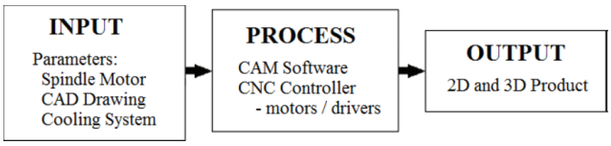

Fig. 2. CNC router machine operation parameters

with computers that can run CAD-CAM programs [7, 8, 9]. As shown in Figure 2 is the operation parameters of the CNC router system. The input to the process is the rotational speed produced by the spindle motor, the 2D CAD drawings and other devices like the chiller during routing operations.

After the inputs, the process of the system involves the CAM systems and the CNC motion axis controller to drive the stepper or servo motors in producing 2D and 3D output.

B. 3D Machining

3D machining usually involves 3 or more progressive stages. Each of which is implemented by a variety of basic and sophisticated process depending on the material and the program available [10].

- Roughing – This process begins with raw stock, known as billet, and cuts it very roughly to shape the final model usually by an endmill. Common processes are zig-zag clearing, offset clearing, plunge roughing and rest-roughing.

- Semi-Finishing – After the roughed part, this process approximates the model and cuts to within a fixed offset distance from the model.

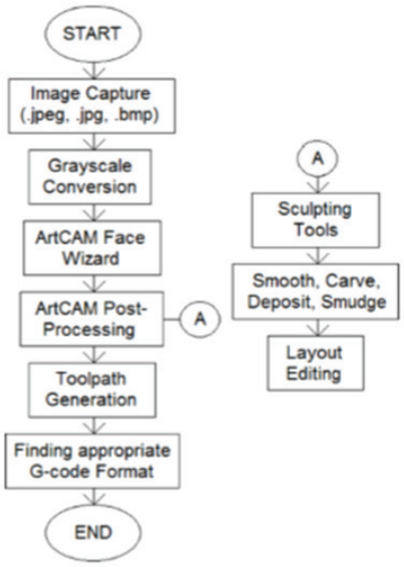

Fig. 3. ArtCAM 3D process flow

- Finishing – This involves the use of a slow pass across the material in very fine steps to produce the final output.

II. Methodology

Fig. 4. Image in (a) raw and (b) grayscale format

Figure 3 shows the proposed process flow of converting a 2D image taken from a digital camera into a 3D relief file.

The captured image or picture (see Fig. 4) was converted into high-grayscale format using Adobe Photoshop before it will be sent to ArtCAM Face Wizard. ArtCAM Face Wizard is a digital tool used in creating 3D face profile model. The 3D model will then be saved as a relief file (.rlf) and will undergo CAM post-processing to digitally enhance the layout.

Interactive sculpting tools, like smooth, carve, deposit and smudge, are used to dynamically smooth and shape the model. The final process will be the generation of an appropriate g- code toolpath.

A. Toolpath Generation

As seen in Figure 5, the 3D machine process flow consists of four (4) stages: area clear, machine relief, semi-finishing and finishing. Brass is the material used for the simulation.

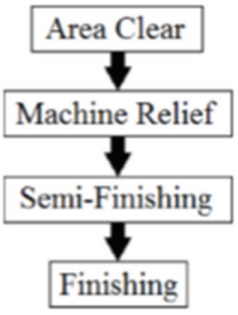

Fig. 5. 3D machine flow process

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• Area Clear – In generating the toolpath, area clear or initial roughing is the first step (see Fig. 6). In this study, a carbide 4-flute flat end mill with 6 mm diameter is used (see Table I).

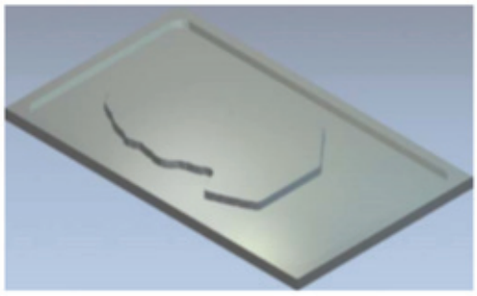

Fig. 6. Area clear toolpath

Table 1. Details of Clear Area

Item	Description
Machining Type	Area Clear
Tool Type	Carbide 4-Flute Flat Endmill
Tool Diameter	6 mm
Tool Clearance Strategy	Offset
Spindle Speed	2500 rpm
Initial Stepover	2 mm
Stepdown	0.75 mm
Feedrate	900 mm/min
Plunge Rate	240 mm/min
Allowance Offset	0 mm
Machining Time	1151 sec

• Machine Relief – In Figure 7, the machine relief is almost similar in terms of operation to initial roughing or area clear. The difference of machine relief is that it uses raster in tool clearance strategy. The stepdown value decreases to 33%. The allowance offset from 0 mm become 0.5 mm to machine relief (see Table II). This roughing tool focused only on the 3D face model in preparation for the engraving toolpath (semi- finishing and finishing). Increasing the offset of machine relief, also helps the smaller toolbits to make large stepover and faster process speed.

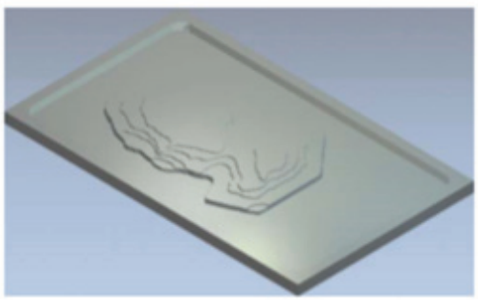

Fig. 7. Machine relief toolpath

Table 2. Details of Machine Relief

Item	Description
Machining Type	Machine Relief
Tool Type	Carbide 4-Flute Flat Endmill
Tool Diameter	6 mm
Tool Clearance Strategy	Raster
Spindle Speed	2500 rpm
Initial Stepover	2 mm
Stepdown	0.5 mm
Feedrate	900 mm/min
Plunge Rate	240 mm/min
Allowance Offset	0.5 mm
Machining Time	181 sec

• Semi-Finishing – This is the machining part where a carbide ball-nose endmill is used (see Fig. 8). This is where almost the engraving process is done. The allowance offset decreases to 60%. This allowance is necessary to prepare the next toolpath with a smaller ball-nose endmill. For more details regarding this parameters, see Table III.

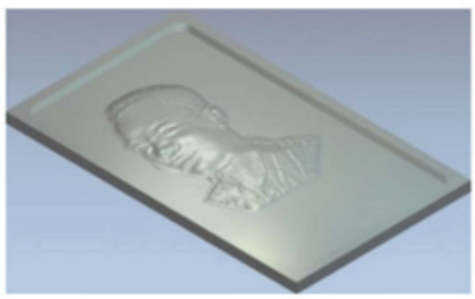

Fig. 8. Semi-finishing toolpath

Table 3. Details of Semi Finishing

Item	Description
Machining Type	Semi-Finishing
Tool Type	Carbide 4-Flute Flat Endmill
Tool Diameter	3 mm
Tool Clearance Strategy	Raster
Spindle Speed	2500 rpm
Initial Stepover	0.3 mm
Stepdown	0.2 mm
Feedrate	600 mm/min
Plunge Rate	240 mm/min
Allowance Offset	0.2 mm
Machining Time	1287 sec

- Finishing – This is the final toolpath of the engraving process as shown in Figure 9. It uses a smaller diameter (2 mm) ball-nose endmill for a more detailed machining. Among the toolpaths, finishing has the highest spindle speed (see Table IV).

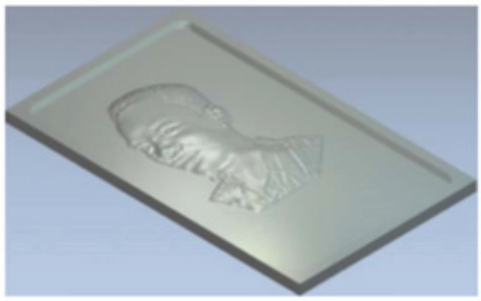

Fig. 9. Finishing toolpath

Table 4. Details of Finishing

Item	Description
Machining Type	Finishing
Tool Type	Carbide Ball-Nose Endmill
Tool Diameter	2 mm
Tool Clearance Strategy	Raster
Spindle Speed	4500 rpm
Initial Stepover	0.05 mm
Stepdown	0.1 mm
Feedrate	600 mm/min
Plunge Rate	240 mm/min
Allowance Offset	0 mm
Machining Time	5124 sec

IV. Results Interpretation

As seen from the details of each toolpath, here are the interpretations of the cutting parameters used in the study.

A. Machine Relief

With this operation, the machining time for the engraving toolpath was decreased by 50% since the focus of this toolpath is in the 3D area unlike with the area clear.

B. Allowance Offset

Providing an allowance offset prior 3D engraving toolpath is very important. The offset itself provides the details of the 3D relief. Without it, it will be difficult for the semi-finishing and finishing to perform engraving process.

V. Conclusion

In this study, the effect of 2D image layout enhancement and ArtCAM post-processing provides an effective way of demonstrating 3D simulation before actual runs. This can be seen from the results of the 3D digitally sculpted output after the finishing stage.

Moreover, with the aid of machine relief, it decreases the amount of time for the engraving toolpath. Thus, also helps in increasing the tool life of the small cutters even run in high process speed.

Acknowledgement

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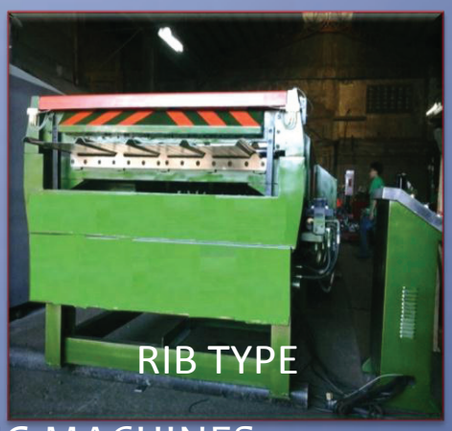
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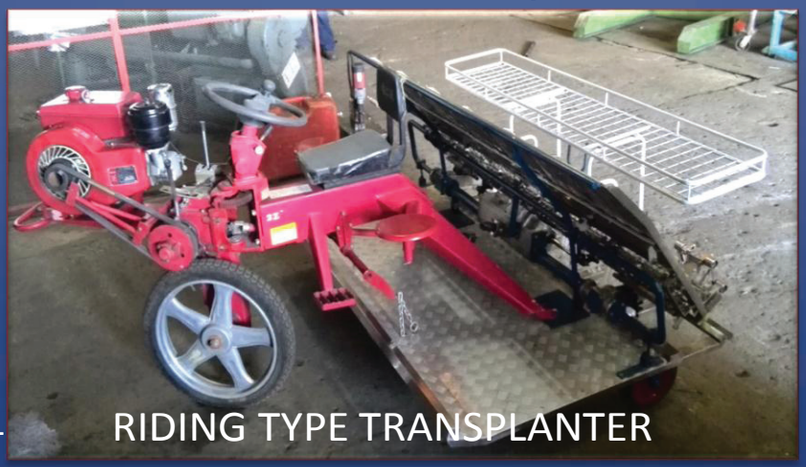
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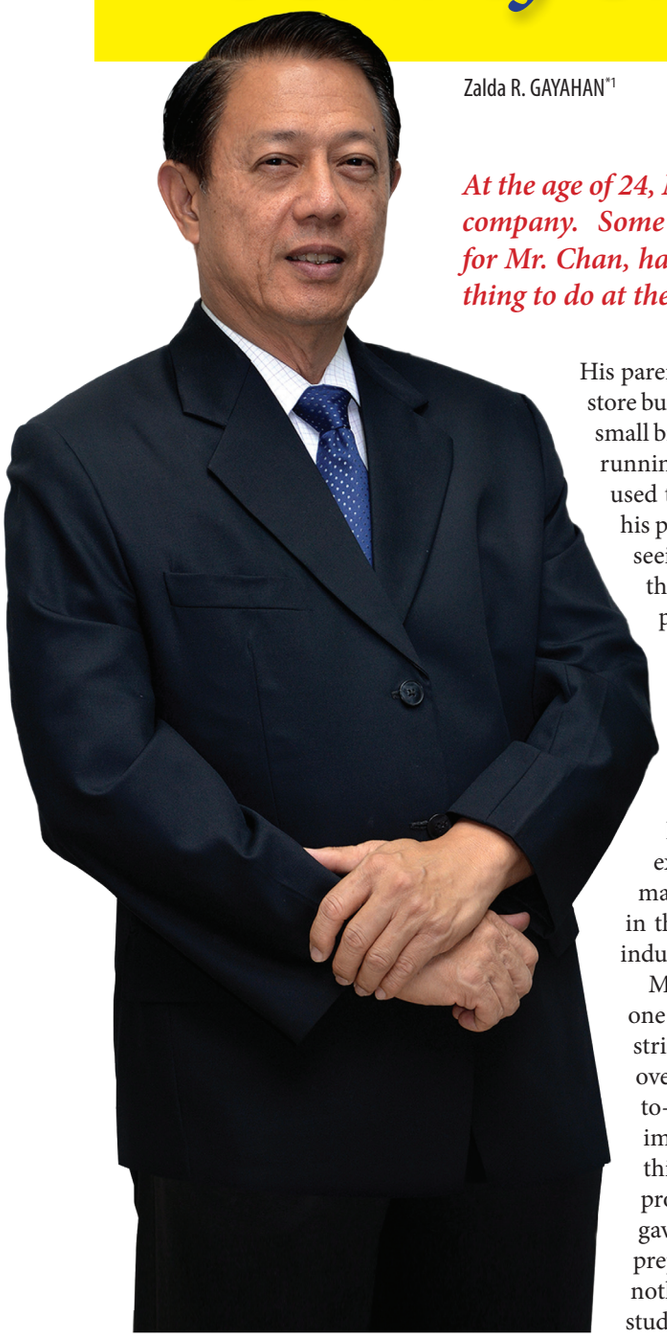

Zalda R. GAYAHAN*1

At the age of 24, Mr. Jimmy Chan already put up his own manufacturing company. Some people may think this might be a little too early. But for Mr. Chan, having his own business just seemed the most predictable thing to do at the most appropriate time.

His parents were into the hardware store business. Selling items, fixing small broken electric appliance, or running errands are tasks he got used to doing while helping out his parents. He was brought up seeing the value of hard-work through his parents' examples. He watched their family business grow, and his parents took him along when they had to go out of the country for business trips. The young Jimmy was slowly being groomed by his experience for a career in manufacturing, particularly in the metals and engineering industries.

Mr. Chan does not only own one company. He has put up strings of different companies over the years. Coming face-to-face with a man of high importance, one is bound to think that his childhood is probably extraordinary that gave him quite a remarkable preparation for success. 'I was nothing special when I was a student,' tells Mr. Chan. He just breezed through school as he earned his Business Management degree. He shares that, as a student, he was not too fond of reading. Although he was not an honor student, he got the grades he wanted.

There were many existing companies in the same field of manufacturing that he was in. Fortunately, his college degree gave him a big advantage when he started his company. He was confident with his decisions concerning strategic planning, and resources allocation. But he also acknowledged the fact that there are many existing companies in the same field of manufacturing that he was.

He gave attention to the in-depth requirements of the industry and studied the priority areas where he wanted to compete. He is fortunate to have a hand at the computer distribution business and was well- versed in computer applications and hardware. He decided to that the way to boost the business is through the introduction of computers in manufacturing. They harnessed some software like auto-CAD for drafting, and eventually came up with their own application

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software and generated CNC codes. Mr. Chan's strategy was to fill the voids of the industry where servicing was concerned. His vision of where he wanted to take his business was clear. His strategies were technology-driven.

His first business was in manufacture of aluminum tubing for toothpaste. His degree in Business Management gave him confidence in running the business, but he knew he needed technical background in engineering. According to Mr. Chan, he learned the basic principles of metalworking, heat treatment, systems production process through 'sipag at tyaga.' Eventually, he became technically adept with machining and tooling, which are 'essential foundations of manufacturing.' He focused the company's initial period of learning into production of precision tools – a move that led to the ability to produce more challenging products.

Mr. Chan attributes his success to all his learning experiences. Asked to share some mistakes that taught him big lessons, he said: 'Mistakes can only be corrected. It was a mistake, but after some time it is not a mistake anymore. It became an opportunity. What enhances my capability are the mistakes I encountered.'

Mr. Jimmy Chan is among the well-known and respected names in the metals and engineering industries. He has affiliations with various industry associations where he also holds key positions: he is one of the founders of the Philippine Die and Mold Association (PDMA), a Trustee of the Philippine Exporters Confederation, Inc. (Philexport) representing the metal manufacture sector, a Past Chairman of the Society of Manufacturing Engineers (SME), former President of the Metalworking Industries Association of the Philippines (MIAP), both National and Manila Chapter, currently a Director at the Philippine Iron and Steel Institute (PISI), and a member of the DOST-MIRDC's Governing Council representing the private sector.

Based on all that he has done, he says that his biggest contribution to the M&E industries is really on being 'able to bring the private manufacturing sector and the government to understand each other.' He believes that industry associations need more interaction and more avenues to be of help to one another. He mentioned that credible linkage with government agencies like the DOST-MIRDC, the Department of Trade and Industry-Bureau of Investments (DTI-BOI), the Department of Labor and Employment (DOLE), and the Technical Education and Skills Development Authority (TESDA) is crucial to the creation of more programs and more effective exchange of information.

'I am very fortunate to be one of the MIRDC's Governing Council (GC) members,' he comments because through his involvement in the GC, he is able to continually contribute to bring the public and private sectors together.

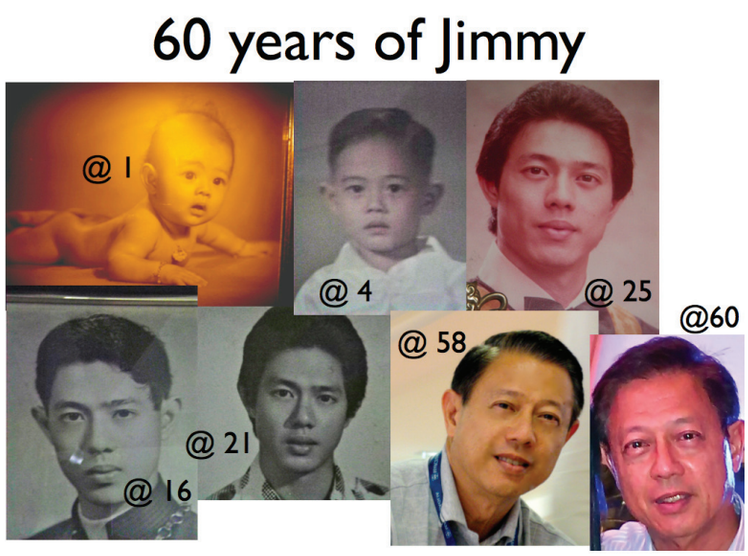
He is thankful for the achievable goals and targets set by the DOST Secretary Mario G. Montejo. Mr. Chan is grateful that the Secretary is very supportive of the MIRDC. To Mr. Chan, plans for longer programs are needed by the industry. 'The only way that we can move forward is to look beyond the political term of the President or the Secretary. If the industry can push this idea, given a ten-year or twenty-year time frame, then we can achieve things that we have not done before.'

Looking at the bright side, Mr. Chan believes in the strength of our manpower. He said that Filipino workers make up the teams in high precision machining centers in other countries because Filipinos are known to be 'hard-working, capable, and trustworthy.' He recognizes that the only problem we need to deal with is how to offer opportunities to make the good people stay. 'Unless we have a very good plan to enhance our manufacturing industry, all the good people in our manufacturing will go elsewhere because they can pay better and there are more opportunities. But if we can offer those opportunities here, then we can keep them.'

Mr. Chan does not only have his eyes focused on the local scene. Like all successful men, he extends his vision to include global markets. 'The world is getting smaller because of communication and good access to transportation.' That is why he sees the ASEAN integration as a challenge. As a nation, we have to set-up more communication channels so that the consumers, the manufacturers and the government will understand and have faith in one another. He believes that we have to push the 'buy Filipino' movement and trust our own capabilities. In this way, there will be more progress.

Mr. Chan is still very much involved in the business and the industry. How long does he plan to stay in the industry? He said: 'If the industry still needs me, I will be of service. But,' he follows this up with a grin, 'I should do something else beside what I do on my idle time.'

Mr. Chan's wife and four children, all of whom have earned college degrees already and are into their chosen fields, are his life's inspirations. What started his journey into the M&E industries was his dream of outdoing his parents. Where they were hard working, he wanted to work harder. All the successes that he has made are attributed to all the people he met and worked with along the way.



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The Philippine Aerospace Industries Roadmap

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This is an overview derived from the Philippine Aerospace Industries Roadmap[1] which was presented to Business Communities at the "Trade and Industry Updates" at BOI Penthouse, DTI, Makati on July 15, 2014.

The Philippine aerospace manufacturing industry envisions the country to be the hub of original equipment manufacturing (OEM) and maintenance, repair and overhaul (MRO) of aircraft and parts in ASEAN. While presently the country trails its ASEAN neighbours, Malaysia, Thailand, Singapore and Indonesia, in aerospace exports and imports, it has the potential to become a competitive force to service the requirements of major aircraft manufacturers such as Boeing and Airbus. Its strategic location, the quality of its human resources, and the presence of three (3) Tier 1 suppliers in its PEZA zones provide a stable platform against which the country can leverage itself to create a market niche in the global aerospace supply chain. To realize the vision of becoming an ASEAN aerospace hub, the aerospace manufacturing industry must be supported by the government not only in terms of infrastructure but also in investment incentives so that the fledgling industry can grow to become a sustainable positive contributor to the economy.

The aerospace manufacturing sector is an essential component to sustainable aerospace development. It will contribute to the generation of export revenues and taxes, conservation of foreign currency reserves through reductions in imports, and reduce unemployment through the utilization of manpower in OEM and MRO activities.

Table 1 summarizes the economic and societal benefits that could be generated by Philippine aerospace.

Table 1. Socio-economic Benefits[2]

PARTICULARS	AMOUNT			SOCIO ECONOMIC BENEFIT
	2013	2022		
		Private Lead	With Positive Program Intervention	
Contribution to GDP	.15% of the estimated $257 billion GDP	.32% of the estimated $448 billion GDP	.57% of the estimated $448 billion GDP	Improve GDP; create more jobs; enhance exports and minimize imports; shore up dollar reserves
Direct employment	2,200 jobs	8,300 jobs	14,932 jobs	Improve GDP through greater consumer spending; lesser unemployment
Income tax from compensation	$2 million	$11.68 million	$21.01million	Estimated $7 million (P 307 million) and $12 million (P 521 million) for private lead and with positive program intervention, respectively, in average of annual income tax revenues from compensation
Salaries of direct and allied workers	$10 million	$58 million	$105 million	Estimated $36 million (P1.548 billion) and $61 million (P2.623 billion) for private lead and with positive program intervention, respectively, in average of annual salaries ; with multiplier effects
Export Projections	$385 million	$1.429 billion	$2.573 billion	Shore up dollar reserves; create jobs; improve GDP
Gains through localization of special processing, inspection and fine machining.	$82 million	$306 million	$551 million	Generate additional income through cost savings with localized materials and processes

1 Public version of the presentation is accessible from http://www.boi.gov.ph/files/roadmaps/TID/9th%20TID-Mr.%20Estoque%27s%20Presentation%20on%20Aerospace.pdf
2 Extracted from Business Projections of the Aerospace Roadmap

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The global aerospace industry is vast in scope and dependent on technological innovations to drive it. The standards are high because of the demands for safety. It is highly influenced by government policies which govern defense budget allocations and support for civil aviation. Trade agreements and trade regulations such as defense treaties and sky travel reciprocities significantly affect the industry.

An aircraft requires thousands of spare parts which provide large opportunities for OEM and MRO companies. Large numbers are precision parts which entail testing with sophisticated instruments. With globalization of aerospace manufacturing, it is estimated that the amount of manufacturing outsourcing is almost 80% of the airplane.[3] Approximately $140 Billion of aerospace manufacturing was outsourced in 2008 because of globalization.[4] According to a survey of aerospace firms the most important criterion for selecting an outsourcing partner is technical expertise. Thus, for the local aerospace manufacturing industry, sharpening the technical expertise through education, transfer of technology and training is crucial to success.

One assistance that the government may provide to strengthen the aerospace industry is to establish an aerospace center either in Clark or in Calabarzon to attract and locate players in one major area where they can enjoy incentives in terms of support facilities and tax holidays. These locators are expected to include ten (10) additional Tier 1 suppliers and 100 Tier 2 suppliers over a ten (10) year period up to 2020. The government thru TESDA/DOST/MIRDC can likewise provide the infrastructures for manufacturing and testing with the relevant skills trainings and aerospace certifications that will fill in the supply chain gaps identified in the aerospace roadmap.

The private sector through the initiatives of the Aerospace Industries Association of the Philippines (AIAP) can help elevate production and manpower standards through collaborative alliances with educational institutions and government agencies. It can also initiate policy reforms through dialogues with the Department of Transportation and Communication (DOTC) and its instrumentalities such as the Civil Aviation Consultative Council (CACC) and the Philippine Aerospace Development Corporation (PADC). Through the help of the Department of Trade and Industry (DTI), it can market its services globally and through the Board of Investments, it can obtain critical incentives of a preferred nature to hasten its growth.

Pursuant to the desire of AIAP to create a blueprint to guide the development of the aerospace industry in this country, this industry roadmap is presented. It is intended to bring to the attention of the government the need to have a robust and exceptional aerospace industry as one of the pillars for sustainable economic development. It presents the global and regional realities prevailing in the industry against which the country has to compete and assert its presence. It outlines the opportunities and threats posed by the environment, identifies the industry's strengths and weaknesses in terms of resources, capabilities, and support systems. It puts together a set of prerogatives and programs that are designed to close the gaps in infrastructure and logistics. This set of goals, objectives, strategies and work plans may well usher the fledgling industry on the road to achieving its full potential and thus become a force to reckon with in the region. However, any successful and sustainable aerospace manufacturing industry invariably must fully engage the cooperation and support of the government. Without the government's economic and technological support, the private sector will be hard-pressed to put together a program that will grow and develop the aerospace industry. It is in this light that this industry roadmap is submitted so that the government will appreciate the need to create a holistic strategy to fully optimize all available resources within the ambit of a public-private partnership.

Products Profile of the Aerospace

3 http://www.wipro.com/documents/insights/aerospace-manufacturing-transfer-systems.pdf (p.3)
4 Ibid.

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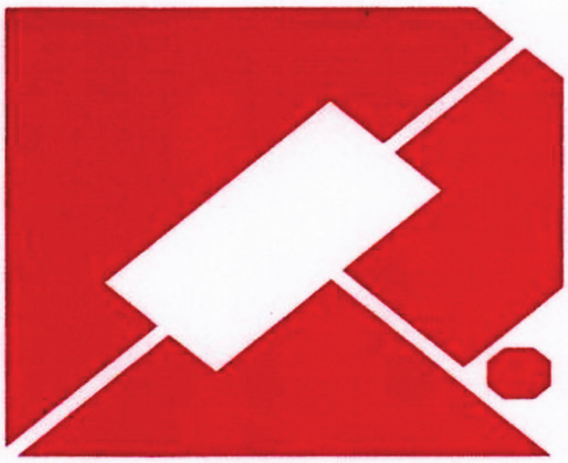

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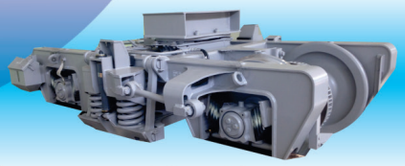

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