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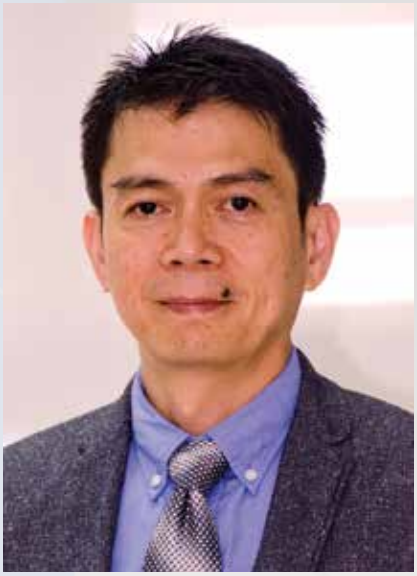
About the cover:

A sheet of metal is formed into a manufactured part through the process of stamping. Stamping technology is the backbone of mass production that drives the industrial age.

Contents

Preface



Our mission is to boost the productivity and competitiveness of the Philippine metals, engineering (M&E), and allied industries. Not many are aware, but it is the M&E and allied industries that support the manufacturing industry. Behind the creation and distribution of consumer products and the effective delivery of services to various markets, are the products and services provided by metalworking companies, engineering solutions services, and all metals and engineering-related enterprises.

Science, technology, and innovation drive various industries toward becoming more resilient and sustainable. Through the years, our experiences and the success stories of innovative countries across the globe underscore the need to pay more attention to the performance of the local manufacturing industry. It then follows that as upstream industries, we need to make the metals, engineering, and allied industries more inclined to research and development and more adoptive of new technologies.

The Center is committed to delivering its mission of carrying out effective and relevant information exchange. Through the papers we write, we intend to provide a significant contribution to national and global efforts to raise the capabilities of the metals, engineering, and allied industries.

For this year's issue, we grouped the papers under the following: Materials Research; Process Research; Product Development; and Equipment Development. Featured also in this issue is a status report of the local metalworking businesses involved in stamping.

I, together with the DOST-MIRDC's researchers, technicians, and support staff, am proud to present the 2020 Philippine Metals.

Robert O. Dizon
Executive Director

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Formulation of Pattern Wax for Investment Casting

Florentino J. LAFUENTE*1, Celso L. AGUISANDA*2, Juanito G. MALLARI*3, Karen C. SANTOS*4

Abstract

Investment casting is known for its ability to produce components with a high degree of surface finish, excellent dimensional accuracy and complex shape. A wax pattern is an essential component in casting to achieve the desired quality of the cast. There are commercially available wax patterns, however, are costly. Technical specifications of these are available, but are limited as these are considered trade secrets of local manufacturers. This, therefore, opens up an opportunity for the MIRDC to formulate its wax patterns from the mixture of different waxes such as paraffin, micro-crystalline, carnauba, and beeswax. Different proportions were tested to obtain the best blend among the trials. Bending strength and fracture were considered as the experiment's quality responses. The combination of 65% paraffin, 10% carnauba, 25% beeswax surfaced to be the optimized blend. It attained the nearest characteristics with the commercially-available wax materials with 31.5 kg/cm2 bending strength and not too brittle for cracks to occur. Also, the pattern can easily be produced since the materials are locally available.

Keywords: investment casting, pattern wax

Introduction

A pattern is a replica of the object to be cast, used to prepare the cavity into which molten material will be poured during the investment casting process [1]. Pattern materials can be grouped into waxes and plastics. Since the use of plastic patterns is usually in conjunction with relatively thin ceramic shell molds known as "replicast," wax patterns are more preferred by local foundries [2].

Pattern wax is considered a valuable raw material in the production of an investment casting. The higher the quality of wax patterns produced by the wax room, the higher the quality of the casting produced [3]. The cost and high minimum order quantity, however, for pattern waxes have been a challenge most especially to the small foundries in the country. In response, many small foundries have attempted to develop and formulate their wax materials in light that most manufacturers only disclose limited technical information as these ingredients are considered a "trade secret." The attempts, however, failed to achieve the desired quality and performance for the pattern wax. To lessen the cost for investment casting, some foundries just resort to using recycled pattern wax resulting in poor quality casting.

Several studies have been made about the blended wax patterns in the investment casting process. Bemblage and Karunakar [4] determined that the blend with proportion of 50% paraffin wax, 30% beeswax, and 20% montan wax gives the better results. The study of Kamboj [5] revealed that a blended wax pattern of 60% paraffin wax, 25% beeswax, 5% microcrystalline wax, and 10% carnauba wax obtained a better linear and volumetric shrinkage.

Pattern waxes are complex mixtures composed of relatively sophisticated, high-priced ingredients that have been formulated and blended to make the best wax pattern possible.

Basic raw materials and additives are combined to achieve desired characteristics and properties [6]: strength; hardness; shrinkage viscosity; toughness: melting point; surface smoothness; ash content; injection temperature; mold release; dimensional stability; and compatibility with mold material.

The solidification shrinkage of waxes can be reduced by mixing in powdered solid materials called "fillers." These are insoluble in and have a higher melting point

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than the base wax. They produce an injectable suspension when the mixture is molten [2]. However, improving the strength and toughness of the formulated pattern wax is beyond the scope of this study.

To ensure that the quality is preserved, it is recommended that the pattern wax is handled properly during the following stages: melting, where the standard meltdown for waxes is typically between 82˚C – 93˚C, while some temperature-sensitive fillers should not exceed 82˚C; conditioning, which is done to ensure uniformity as most waxes are usually injected below their melting point; and injection, where it is important to control the speed of the wax for ideal mold filling.

Materials and Methods

A. Sourcing, Characterization, and Testing of Pattern Waxes

In order to establish a baseline for the formulation of new pattern wax, the project team conducted testing and characterization of different pattern waxes, using the following test equipment: Differential Scanning Calorimeter (DSC), Infrared Spectrometer (FTIR), Auto Viscometer, Inductive Coupled Plasma (ICP) Machine, Karl Fisher Water Analyzer, Needle Penetrometer, Auto-Titration, Particle Size Analyzer, Densitometer, Gas Chromatograph (GC, Lovibond Calorimeter, Drop Melt Point Apparatus, Meter Balance and Bending Strength Tester.

In this study, the wax materials used for the experiment are Paraffin, Micro-Crystalline, Carnauba, and Beeswax. To identify the ratio of the mixture, the team characterized each of the wax materials.

The bending strength of wax material was measured using a Naniwa Bending Strength Tester. A 1x1x5cm wax specimen was placed on two points or support. The pendulum is set to swing in slow motion triggering the hammer to come in contact with the sample, simulating load. The rate of force at which the wax specimen breaks is determined as the bending strength.

Table 1. Characterization of Different Types of Pattern Waxes

Specifications	Casting Wax / B 2025 USA	Virgin Casting Wax (162)	Injection Wax V404F
Manufacturer	Westech Products,Inc.		
Cost	Php 560.00/ kg		
Form	Pellets	Pellets	Pellets
Color	Pine Green	Green Salad	Aqua Marine
Color after melting	Pine Green	Green Salad	Green Salad
Density (gm/cm3)	1.17	1.09	1.21
Bending strength (kg/cm2)	33.42	38.55	59.03
Removal from rubber mold cavity	Easy	Easy	With difficulty
Fracture during Bending	Deformed without fracture at lower load	Deformed without fracture at lower load	Fractured at higher load
Hardness	Soft and Tough	Soft and Tough	Hard and Brittle
Viscosity	High	High	Low

Table 2. Characterization of Different Types of Wax Materials

Wax Materials (100%)	Density (gm/cm3)	Bending Strength (kg/cm^2)	Shrinkage (%) (Hollow Ring)	Fracture	Color After Melting
Paraffin	1.08	24.90	0.91	Brittle	White, Opaque
Micro-Crystalline	0.99	23.63	2.90	Brittle	White, Opaque
Carnauba	0.95	36.75	4.06	Brittle	White, Opaque
Beeswax	1.09	18.23	3.91	Soft	Ivory

Table 3. Trials Using Different Mixtures of Pattern Waxes in Varying Proportions

	Trial 1	Trial 2	Trial 3	Trial 4
Mixture A	Paraffin (50%) Micro-Crystalline (45%) Carnauba (5%)	Paraffin (25%) Micro-Crystalline (75%)	Paraffin (70%) Beeswax (30%)	Paraffin (40%) Carnauba (10%) Beeswax (50%)
Mixture B	Paraffin (50%) Micro-Crystalline (40%) Carnauba (10%)	Paraffin (50%) Micro-Crystalline (50%)	Paraffin (60%) Beeswax (40%)	Paraffin (50%) Carnauba (10%) Beeswax (40%)
Mixture C	Paraffin (40%) Micro-Crystalline (50%) Carnauba (10%)	Paraffin (75%) Micro-Crystalline (25%)	Paraffin (55%) Beeswax (45%)	Paraffin (60%) Carnauba (10%) Beeswax (30%)
Mixture D	Paraffin (30%) Micro-Crystalline (30%) Carnauba (40%)	n/a	Paraffin (50%) Beeswax (50%)	Paraffin (65%) Carnauba (10%) Beeswax (25%)
Mixture E	Paraffin (40%) Micro-Crystalline (25%) Carnauba (35%)	n/a	Paraffin (40%) Beeswax (60%)	Paraffin (70%) Carnauba (10%) Beeswax (20%)
Mixture F	n/a	n/a	n/a	Paraffin (60%) Carnauba (10%) Beeswax (30%)

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B. Development and Testing of Newly Formulated Pattern Waxes

Trials of varying proportions of paraffin, micro-crystalline, carnauba, and beeswax were conducted to formulate the best blend of waxes, as specified in Table 3.

C. Testing of the Developed Wax Patterns in the Actual Investment Casting

The formulated best wax blend was tested in the actual investment casting. Observations were made on the performance of wax patterns using the injection method, on wax patterns after withdrawal from metal die, wax patterns on gravity pouring to the rubber mold method, on the wax patterns during the dewaxing process, and on the final casting.

Discussion of Results

A. Results of Pattern Waxes Characterization

During the bending test, the casting wax specimens, in reference to Table 1, deformed without fracture at a lower load. This implies that the material is soft, tough, and has high viscosity whereas the injection wax specimen was fractured at higher load which indicates that the material is hard, brittle, and has a lower viscosity. This result was used as the basis in the formulation of new pattern wax as a good pattern wax should have low viscosity when melted to simplify its injection and, flow into and fill the thinnest sections of the die. It should also be resistant to breakage, i.e. it is of sufficient strength and hard enough at room temperature such that the patterns can be self-supporting and not easily damaged during handling.

Primarily for this study, the bending strength and the fracture of the wax are the quality responses that were considered to accept the tested pattern wax. The fracture and bending strength of the pattern wax were both tested.

Figures 1-4 show the bending strengths of different pattern wax mixtures.

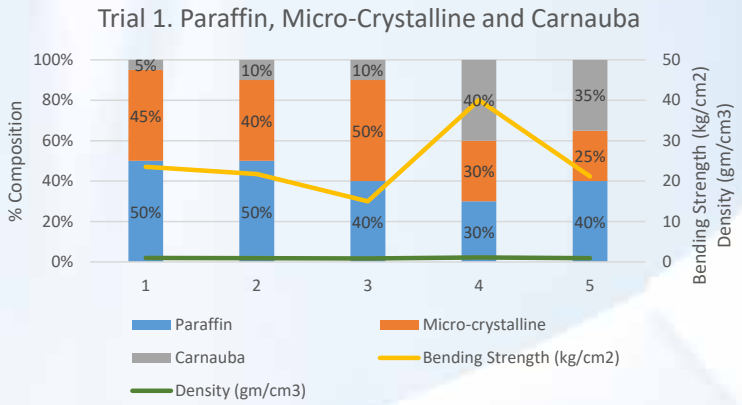

Fig. 1. Bending Strength Results of Pattern Waxes (Trial 1)

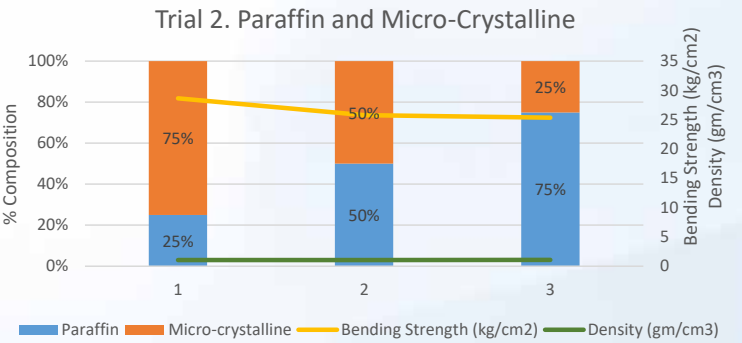

Fig. 2. Bending Strength Results of Pattern Waxes (Trial 2)

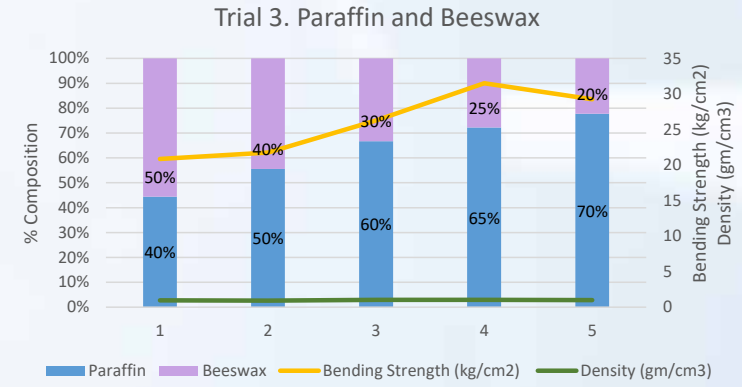

Fig. 3. Bending Strength Results of Pattern Waxes (Trial 3)

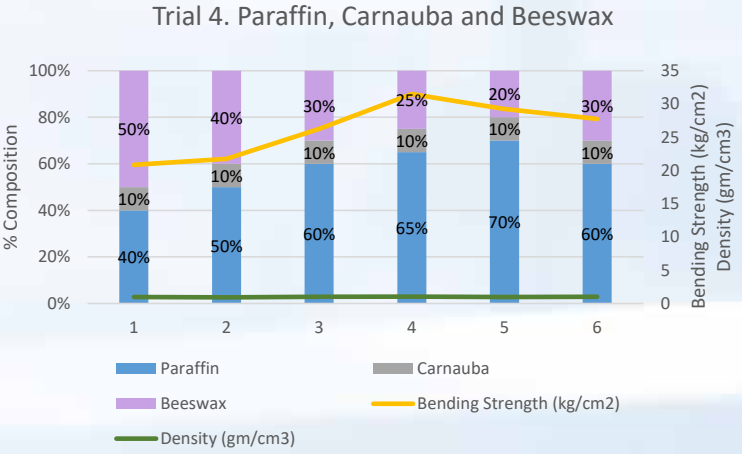

Fig. 4. Bending Strength Results of Pattern Waxes (Trial 4)

Although mixture 4 (30% Paraffin, 30% Micro-Crystalline, and 40% Carnauba) exhibited high bending strength, the resulting pattern wax is too brittle.

The mixture of 25% Paraffin and 75% Micro-Crystalline shows the highest potential. In fact, this mixture is already being used by investment casters. However, with this blend, withdrawal of wax patterns from the metal die using manual wax injection is highly difficult. In addition, the wax pattern is still too brittle and the bending strength is low as compared to commercially available pattern waxes.

Pattern wax made from the mixture of paraffin and beeswax is too brittle. Beeswax can be a viable substitute for microcrystalline but even with its soft property, when it is cold or after the temperature drops and it solidifies, it becomes very brittle and its fracture is dry and granular.

In this trial, Mixture 4 exhibited characteristics and properties closest to that of the purchased pattern wax. The bending strength is not far below and it is not too brittle. Hence, this newly formulated pattern wax which is a mixture of 65% Paraffin, 10% Carnauba, and 25 % Beeswax was used in actual investment casting process to verify if it is a viable substitute for commercially available pattern waxes.

B. Performance of the Formulated Wax Pattern in Actual Investment Casting Process

In injection method, the use of formulated pattern wax showed some advantages: Less injection time, less sticky so it is easier to remove from the cylinder and metal die. It also consumed less silicon mold as compared to commercially available wax.

Surface finishes are similar for both; however, the dimensional accuracy is slightly lower for the formulated pattern wax but still acceptable.

In gravity pouring to rubber mold method, the sprue has shrinkage cavity for the purchased pattern wax. Whereas for the formulated pattern wax, the sprue is almost flat. But the differences in shrinkage level did not affect the quality of wax patterns. Formulated pattern wax is easier to be withdrawn from the rubber mold and easier to clean and remove fins compared to the purchased pattern wax.

During the dewaxing process, less wax was left on ceramic molds for the formulated pattern wax. Paraffin and Beeswax that are both present in formulated pattern wax have relatively low melting temperature and they easily evaporate when subjected to steam (100°C).

No run-out occurred during shell firing and pouring; and both pattern waxes were easily removed from ceramics molds and separated from the returns during fettling. Final cast parts using purchased and newly formulated pattern wax both have the same surface finish quality.

C. Properties and Characteristics of Newly Formulated Pattern Wax

The final properties and characteristics of the formulated pattern wax are described and summarized below:

Table 4. Properties and Characteristics of Newly Formulated Pattern Wax

Composition	65% Paraffin ,10% Carnauba, 25% Beeswax
Form	Block
Color	Ivory
Color after Melting	Ivory
Density (gm/cm^3)	1.01
Bending Strength	31.73 (average)
% Shrinkage (Rubber Mold) Hollow Ring Solid Ring	 3.47 3.59
Fracture during Bending	Fractured at a lower load
Hardness	Soft but brittle
Viscosity	High

The bending strength of the newly formulated pattern wax is lower than the purchased wax. This means that the quality of the pattern wax is more brittle thus requiring extra care when handling in actual investment casting operation.

Conclusion

A pattern wax was successfully formulated using a mixture of 65% paraffin, 10% carnauba, 25% beeswax, and 0% micro-crystalline. It was verified through the identification of the bending strength and fracture of individually formulated pattern waxes. The properties of the developed pattern wax are near its commercially-available counterpart obtaining 31.5 kg/cm2 bending strength and being not too brittle for cracks to occur. Though the bending strength is lower than the commercially-available pattern wax, the newly formulated pattern wax exhibited enhanced performance in terms of ease of use in actual investment casting and ability to produce surface finish quality similar to those produced using the purchased pattern wax.

Recommendation

The scope of this study focused on exploring different base wax materials. For future work, it is recommended to look into mixing additives specified in table II, to improve toughness and bending strength of the pattern wax material. The acceptance criteria the formulated pattern wax concentrated only on bending strength and brittleness. Other important parameters in wax patterns such shrinkage, dimensional stability over time, etc. can also be explored.

Acknowledgment

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Study on the Plating Ability of Different Conductive Paint using Various Carbon Pigments and Binders

Keziah M. DE LA RAMA*1, Geoffrey L. ABULENCIA*2

Abstract

Conductive paint or ink is a type of coating that is produced from the mixture of conductive pigments/fillers and binders. Typically, it is formulated using expensive metallic particles such as gold, silver, and copper. Various electrically conductive form of carbon can be an alternative pigment for conductive paint to lessen the cost. For this study, the plating ability of several combinations of carbon pigments such as charcoal, activated carbon, and graphite; and binders such as glue, acrylic paint, hide glue, and acrylic polymer dissolved in acetone was investigated. On various pigment to binder ratio of 20:80, 50:50, and 80:20, the resistivities of the conductive paint were measured and results were verified using electroplating. The samples were exposed in 5% Salt Spray Test for 24 hours to determine the corrosion resistance of the electroplated samples and if the paint will wear off during the process. Overall, the result shows that graphite in hide glue or acrylic polymer dissolved in acetone can be a viable low-cost alternative for other expensive metal counterparts.

Keywords: conductive paint, resistivity, electroplating

Introduction

Conductive paint or ink is a type of coating that is produced from the mixture of conductive pigments/fillers and binders. To a certain conductivity of the paint, when deposited on non-conductive materials, it becomes fit for electroplating [1]. This kind of paint when applied to a material also reduces its static charge dissipation that may be harmful to electronic devices and creates electromagnetic/radio frequency interference (EMI/RFI) shielding [2]. This can also be used in circuits as a painted resistor element, a capacitive electrode, or can function as a conductor in designs that can tolerate high resistivity [3]. Typically, conductive paints that are available in the market are formulated using expensive metallic particles such as gold, silver, copper, and other precious metals. Silver is an attractive material for conductive ink [4] due to its excellent electrical properties, however, is very costly. Copper is also a good alternative for its abundance and fairly high conductivity, however, poses oxidation issues under ambient condition [5]. Aside from being costly, these metals are also reported not to be environment-friendly and might cause serious problems including water toxicity and cytotoxicity [5].

A good alternative for the above-mentioned conductive pigments is the use of various electrically conductive form of carbon such as graphite [2,3] and carbon black [6,7]. Unlike the metallic material, these pigments are cheap, non-toxic, environment-friendly, and readily available [9]. In fact, several studies have already been conducted in acknowledgment of its advantages over its expensive metallic particle counterpart. In the study of Islam et al. [8], a cost-effective carbon black ink from burned charcoal of dry woods and poly-vinyl alcohol (PVA) binder was utilized for textile applications such as cotton fabric, bend-sensors, and heat-spreading materials. The study of Bhore et al. [9] also utilized carbon-conductive paint for screen printing, of which their electrical properties, rheological properties and screen printability were observed. The printed ink film of graphite was not highly conductive, but the addition of conductive carbon increased the ink's conductivity significantly.

In view of several advantages of a carbon-based conductive paint, this study aims to investigate the plating ability of different combinations of carbon pigments and binders.

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Materials and Methods

A. Experimental Setup

Carbon-conductive paint formulations with various combinations of carbon pigments such as charcoal, activated carbon, and graphite and binders such as glue, acrylic paint, hide glue, and acrylic polymer dissolved in acetone in appropriate amounts were tested in this study. The experiment used the following carbon pigment to binder ratios: 20:80; 50:50; and 80:20. The paint was applied on a small cut of wood and dried as shown in Figure 1.

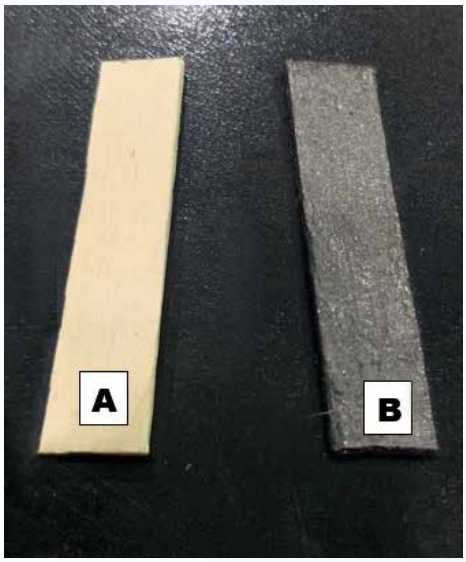

Fig 1: A) Bare Wood, B) With Carbon Conductive Paint

B. Testing Procedure

The resistance of the painted material was measured using a multi-tester. The length of the small cut of wood is around 2 inches and resistance was measured from one end to another. From the identified resistance, the plating ability of the conductive paint can already be concluded. However, to verify further the result, painted samples underwent copper electroplating followed by nickel electroplating. Electroplated samples were examined after each process using visual inspection. The successful samples were exposed to a 5% salt spray test for 24 hours in accordance with ASTM B117-16 using the Cyclic Corrosion Chamber, ATLAS CCX 2000 to determine the corrosion resistance of the electroplated samples and if the paint will wear off during the process.

Discussion of Results

Table 1 shows the result of the various experiments using different combinations of carbon pigments and binders. From the table, for the three (3) different carbon pigment to binder ratios, it can be observed that the samples using charcoal and activated carbon have high resistivities. This was even supported by the result of the electroplating as the plating disposition onto the materials did not occur, as marked in the table as "failed." Only the area in contact with the copper wire jig was copper-plated. Same results were obtained when graphite powder was mixed with glue and acrylic paint. Despite having low resistance of 1k ohm for the mixture of activated carbon – acrylic polymer at 50:50 and 80:20, the specimen, however, failed to be electroplated. The researchers may conclude that this transpired due to the size of the particles of the activated carbon used in the experiment. The large particles affect the closed-packing of the content, hence affecting the specimen's conductivity when dried. On the other hand, the resistivities of the mixture of graphite-hide glue and graphite-acrylic polymer were low enough to materialize electroplating.

Table 1. Resistance of various combinations of carbon pigments and binder

Charcoal			
BINDER	**Mix Ratios (% by weight)**	**Resistance (Ω)**	**Electroplating**
Glue	20%	20 kΩ	Failed
	50%	18 kΩ	Failed
	80%	18 kΩ	Failed
Acrylic Paint	20%	12 kΩ	Failed
	50%	10 kΩ	Failed
	80%	9.5 kΩ	Failed
Hide Glue Solution	20%	6 kΩ	Failed
	50%	5kΩ	Failed
	80%	4 kΩ	Failed
Acrylic Polymer + Acetone Solution	20%	4 kΩ	Failed
	50%	2kΩ	failed
	80%	2 kΩ	failed
Activated Carbon			
BINDER	**Mix Ratios (% by weight)**	**Resistance (Ω)**	**Electroplating**
Glue	20%	15 kΩ	failed
	50%	13 kΩ	failed
	80%	13 kΩ	failed
Acrylic Paint	20%	8 kΩ	failed
	50%	7 kΩ	failed
	80%	6.5 kΩ	failed
Hide Glue Solution	20%	4 kΩ	failed
	50%	3 kΩ	failed
	80%	2.5 kΩ	failed
Acrylic Polymer + Acetone Solution	20%	2 kΩ	failed
	50%	1 kΩ	failed
	80%	1 kΩ	failed
Graphite			
BINDER	**Mix Ratios (% by weight)**	**Resistance (Ω)**	**Electroplating**
Glue	20%	11 kΩ	failed
	50%	10 kΩ	failed
	80%	9 kΩ	failed
Acrylic Paint	20%	6 kΩ	failed
	50%	5 kΩ	failed
	80%	5 kΩ	failed
Hide Glue Solution	20%	1.5 kΩ	failed
	50%	1 kΩ	Success
	80%	900 Ω	Success
Acrylic Polymer + Acetone Solution	20%	950 Ω	Success
	50%	600 Ω	Success
	80%	570 Ω	Success

The sample electroplated with nickel shows moderate tarnishing because of thin coating. The carbon conductive paint was still intact on the wood and did not wash out during the process.

Conclusion

In this study, the plating ability of different carbon conductive paints was investigated. Charcoal, activated carbon, and graphite were used individually as a mixture to different binders such as glue, acrylic paint, hide glue, and acrylic polymer dissolved in acetone. Three (3) pigment to binder ratios were used: 20:80, 50:50, and 80:20. The dried painted samples were assessed based on its respective resistivities. Only the graphite in mixture with hide glue and acrylic polymer dissolved in acetone produced good result as these samples exhibited low resistance. This was even verified using electroplating, of which copper was successfully deposited onto the material.

Recommendation

As future work it is recommended to look at the morphology of the ink to evaluate the distribution of solid particles in the ink film to further investigate the factors affecting resistivity values like the particle size. Other tests like peel test after electroplating is recommended. Thickness of coating as a function of time can be measured as well. Finally, the other properties of the ink such as rheology, viscosity and adhesion can be further tested.

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Effects of Anodizing Time in Tartaric-Sulfuric Acid on the Coating Thickness of Aluminum Alloy 6061

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Abstract

Aluminum alloys have extensive engineering application in the aerospace industry. Anodizing of aluminum alloy in tartaric-sulfuric acid (TSA) electrolyte is recently developed to obtain a more environment-friendly process and to produce an anodized layer with better corrosion resistance. In this paper, the effect of anodizing time on the coating thickness of Aluminum Alloy 6061 anodized in TSA has been investigated. With other parameters held constant, the process was performed with anodizing time variations of 10, 20, 30, 40, 50, and 60 minutes. Coating thickness was determined via a digital device utilizing magnetic and eddy current principles. Corrosion resistance was carried out by 240-hours salt spray test while the microstructure was assessed using a metallurgical microscope. Thickness test results showed that anodizing time has a direct relationship with anodizing time and can be modeled using a second-order polynomial regression at a very high correlation coefficient of 0.9947. At 200x magnification, the microscope revealed that high porosity can be obtained using the TSA electrolyte which is beneficial if the sample will be dyed for better absorption. The TSA anodization specimens also exhibit excellent corrosion resistance as no observable defect or pitting occurred during the 240 hours of exposure.

Index Terms—anodizing, tartaric-sulfuric acid, aluminum alloy 6061

Introduction

Aluminum alloys have extensive engineering applications and are particularly favored by the aerospace industry due to features such as lightweight, high specific strength, and good workability [1-2]. However, aluminum alloys are susceptible to atmospheric corrosion especially in industrial and marine environments [3]. Anodizing and further protective coatings can be applied to improve their corrosion resistance [4]. Among various electrochemical anodizing processes, the chromic acid (CA) anodizing is considered to be one of the most effective approaches [2,5]. It does not only provide direct corrosion protection but also form a paint base suitable for further protection treatments. Furthermore, CA anodizing has been used because it provides surface protection without affecting component tolerances and fatigue strength [6].

The use, however, of CA anodizing can be detrimental to health and the environment [7] as hexavalent chromium Cr (VI) ions are the major component of the CA electrolyte which is known to be a toxic and hazardous material. There are efforts to develop alternatives of a chrome-free and environment-friendly electrolyte [1-2,5] and among them is the use of dilute sulfuric acid anodization. However, despite an improvement of fatigue strength of the alloy, its corrosion resistance is still lower than that of the alloy being anodized in CA [8].

Anodization of aluminum alloy in TSA is a recent development for anodizing that is regarded as non-hazardous and produces excellent corrosion resistance [1-5]. Studies show that the tartaric acid, as an organic additive, does not only reduce the sulfuric acid concentration but also improve the quality of an anodized film [9]. Compared to CA electrolyte, the TSA electrolyte can make more efficient usage of energy and water with much less liquid waste generation and gas emissions.

Several studies have already been made about the influence of mixing tartaric acid on sulfuric acid as the anodizing electrolyte: Marzocchi et al [10] studied the electrochemical behavior of an anodized aluminum alloy; Curioni et.al [11] wrote that the tartaric acid as an additive to sulfuric acid bath reduces the growth rate of the porous

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anodic film without significantly affecting the mechanism of porous film growth; Boisier et al [8] in the study on the effect of tartaric acid on anodic film morphology stated that sealing is more efficient due to their lower porosity and the properties of the barrier layer are higher.

More researchers conducted studies on the beneficial roles of TSA as well as on the effects of several anodizing parameters on the quality responses of the specimen. Setianto and Korda [3] showed that increasing the anodizing potential also increases the coating weight and coating thickness of AA2024-T3 but has no effect on its corrosion resistance. Mubarok et. al [6] conclude that anodizing temperature, applied voltage, and duration in that order mostly influence the coating weight and thickness of the aluminum.

There is also an increasing number of studies about parametric optimization and post-treatment techniques that can be implemented with TSA anodizing. Terada et. al [12] improved the specimen's corrosion resistance by incorporating cerium ions and sol-gel in the post-treatment process. Regio et al [13] studied the use of post-treatment immersion using Zr-based conversion coating and found out that this resulted to a higher corrosion resistance than that of the sealing using boing water. Bensalah et al [14] used bath temperature, anodic current density, and acids concentration as variables to establish a compromise between maximization of growth rate and micro-hardness and minimization of dissolution rate and weight loss after abrasion.

To date, there are a few studies that tackle the effects of varying process parameters of TSA anodizing of aluminum alloys. Also, the majority of the literature has concentrated so far on AA 2024-T3 as a specimen. The purpose of this study was mainly to investigate the effect of anodizing time on the coating thickness of AA 6061 that was anodized by TSA. Possible future researches may focus on the parametric optimization and post-treatment techniques of the process.

Materials and Methods

A. Pre-Anodizing Processes

The chemical composition of the Aluminum Alloy 6061 used in the investigation was identified via an X-ray Fluorescence (XRF) analyzer. The result is shown in Table 1.

Table 1. Chemical composition of AA 6061

Element	Composition (wt%)
Cu	0.253
Mg	1.361
Mn	0.045
Fe	0.347
Zn	0.032
Si	0.446
Cr	0.357
Others	0.049
Al	97.110

There are six (6) levels of anodizing time in the experiment with four (4) trials each level, hence 28 samples were prepared. The specimens have dimensions in millimeters of 150 x 100 x 2. Sample preparations were done by grinding the specimens using a 600-grit abrasive paper, washing with distilled water, and then air-drying. After which, the specimens were mounted on an aluminum rack for immersion.

Pre-anodizing activities were performed. The aluminum rack with the specimens hanged on it was submerged into a tank bath with de-ionized water containing different concentration of solutions depending on the process being conducted. Cleaning/degreasing using a commercial cleaner bath with 40g/L concentration was carried out for 10 minutes, mainly to remove the oils, soils, and residues form from the previous forming, extrusion, or polishing process and to ensure a uniform and consistent etching with required surface topography. Etching the specimens on a tank bath with 10% caustic soda for 20 minutes was to get rid of the natural oxide layer and alloy accumulations which might be formed during extruding or forming process and to hide surface defects produced during base metal deformation. At the final stage, desmutting using 2% nitric acid solution for 5 minutes was to take away the smut or alloying alkali-insoluble residues formed in the etching and/or polishing process, as well as the natural aluminum and magnesium oxide layer and tenacious scale. After each step of the process, the specimens were rinsed twice by de-ionized water.

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B. Experimentation and Testing

A PVC tank with a dimension (LxWxH) in mm of 840 x 840 x 800 was used as the anodizing bath. The tank has a cathode bar, fumehood with acrylic cover, and complete braces for 200-L capacity. In this study, the solution contained 40 g/L sulfuric acid and 80 g/L tartaric acid maintained at room temperature of 28-30°C for all the specimens during the entire anodizing process. It is also necessary to have a low current density to have thin but tough aluminum oxide. With the current density held fixed at 0.35 A/dm^2, a series of anodizing experiment was conducted under variations of anodizing time (10, 20, 30, 40, 50, and 60 minutes). Lead was used instead of aluminum to act as a cathode in the experiment. Stirring was done during the anodizing process. After anodizing, the specimens were rinsed for five (5) minutes immediately. Specimens were then sealed in hot de-ionized water at 70-100°C for 60 minutes. Finally, the specimens were air-dried in a drying oven at around 90-100°C for 20 minutes. The anodized specimens were examined via visual inspection after each process and were mechanically assessed. Coating thickness of the sample was analyzed using a thickness tester. Pit counts were analyzed using the Cyclic Corrosion Chamber, Atlas CCX 2000, at an angle of 18° from vertical. The specimens were exposed in a 5% Salt Spray Test for 240 hours in accordance with ASTM B117-16 to determine the corrosion resistance. Analysis using a metallurgical microscope was also performed to elucidate the surface morphology of the anodized layer.

Results and Discussion

A. Effects of Anodizing Time on the Coating Thickness

Oxide coating thickness grows directly proportional to anodizing time, as shown in Table 2. To meet different application requirements, for a defined set of anodizing parameters, TSA anodizing coating thickness can be controlled by the anodizing time.

The scatter plot of the anodizing time vs the average of the coating thickness is depicted in Figure 2. Using regression analysis, the scatter diagram has the best equation fit in a second- order polynomial as

$$y=0.0037x^2+0.04x-0.57 \quad (1)$$

where x is the anodizing time and y is the coating thickness of the specimen. The polynomial regression has a very high correlation coefficient of 0.9947.

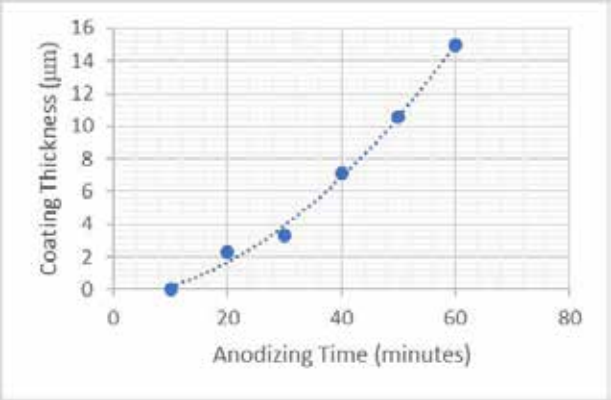

Fig. 2 Scatter plot diagram of anodizing time vs coating thickness

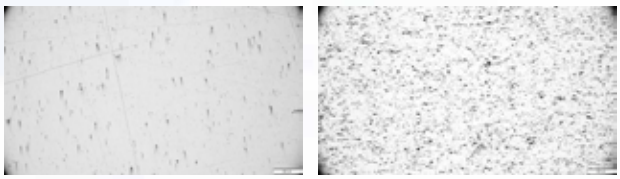

Fig.3 Microstructure using metallurgical microscope at 200x magnification: (a) bare aluminum and (b) anodized aluminum

B. Microstructure and Corrosion Resistance of the Anodized Specimens

Figure 3 shows the plain view images of the surfaces of the TSA-anodized coating at 200x magnification. The results reveal the very distinctive porous structure of the coating surfaces. The image of non-anodized aluminum was also taken to compare the microstructures. It shows that high porosity can be obtained via TSA anodizing. Higher porosity is desired in an anodized aluminum to better absorb dyes.

The evaluation of the samples shows no observable defect or pitting. The samples passed the 240 hours of exposure without evidence of surface corrosion, indicating excellent anodic coating performance.

Table 2. Anodizing Time vs Coating Thickness Test Results

Time (mins)	Coating Thickness (µm)				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
10	0	0	0	0	0.0
20	2.5	2	2	2.5	2.3
30	3	3.5	3	3.5	3.3
40	7	7.5	7	7	7.1
50	10	11	10.5	11	10.6
60	15	16	14	15	15.0

Conclusion

The influence of anodizing time on the coating thickness of AA 6061 was investigated in this paper. The results of the experiments showed that the coating thickness has a direct relationship with the anodizing time which can be formulated in a second-order polynomial regression with a correlation coefficient of 0.9947. The specimens also passed the salt spray test as no observable defect or pitting surfaced during the 240 hours of exposure signifying that the specimens exhibited excellent corrosion resistance. The microstructure at 200x magnification of the TSA-anodized specimens revealed the very distinctive porous structure of the coating surfaces. The data showed that high porosity can be obtained via TSA anodizing.

Acknowledgement

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Capability Building for Testing Weld Shear Strength of Selected Welded Mesh Reinforcing Bars

Edward A. MALIT*1, Rio S. PAGTALUNAN*2, Jerameel F. REYES*3

Abstract

Concrete has been known as a material which has superior compressive property compared to other materials but is very weak in tension. Steel on the other hand, has excellent tensile properties especially the structural grade ones. Reinforcing steel bar or rebar is used to make the concrete stronger and resistant to cracks. Embedded in concrete, this forms a composite material which has excellent compressive and tensile properties. Welded rebar mesh eliminates the traditional tying of every intersecting bars. These intersections were joined by resistance welding where a pressure is applied and current is passed at a specified time. The usual test being conducted to these products is evaluating the compliance of the rebar to its specification, but not the bond of the two welded reinforcing bars. This paper discusses the fabrication of jig/fixture that will be used to test the shear behaviour of welded rebar mesh. Weldable grade rebars will be joined using Shielded Metal Arc Welding (SMAW) to replicate the joining process and two-inch thick mild steel plate will be used for the main material for the jig. The design of the jig will be based from the collaborative requirement of ASTM A 1064 (Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain ad Deformed, for Concrete) and the limit of the universal testing machine (UTM). The fabricated jig will complement to the capability of the laboratory in testing materials and products.

Keywords: rebar, welded rebar mesh, shear test, jig

Introduction

Weldable wire mesh is such a commonly used material because it is the least expensive and most effective tool for so many applications, and it can be found in various styles and designs. It is a convenient and economical steel reinforcement for concrete structures.

This kind of mesh consists of perpendicular bar strands that are welded at each intersection, which makes for a very sturdy product. The use of weldable wire mesh is vital in creating a strong, durable, and well-built structure that will not only ultimately reduce the use of resources over time, but also speed up and simplify the construction process. The use of this product has proven economical. It is seen as a viable option for concrete reinforcement.

The BPS Product Certification Scheme

The Bureau of Philippine Standards (BPS) under the Department of Trade and Industry (DTI) oversees the product certification scheme in the Philippines. All local certified products, prior to market release, must comply with the requirements of the Philippine National Standards (PNS) before given the Philippine Standard (PS) mark. In the case of imported products, the DTI-BPS issues the Import Commodity Clearance (ICC) upon passing through PNS-base testing requirements.

The product certification scheme is a very sensitive task of the government which directly affects both local market and manufacturers for the protection of the consumer. The BPS accredits local testing laboratories, such as the Metals Industry Research and Development Center (MIRDC), SGS, and Intertek, that can conduct the tests needed. Most of these laboratories are accredited to ISO/IEC 17025 and have the same testing capabilities for rebars, angle bars, wires, and LPG cylinders in terms of available facilities. At present, BPS does not have PNS standard for welded wire mesh using reinforcing steel bars. This standard will only be developed once this product enters the Philippine market.

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The testing of various metals is provided by the MIRDC as a third-party service for both government and private organizations. According to the office of Standards Conformity Division of BPS, a government testing laboratory like the MIRDC is most suited for their product certification scheme because of its impartiality.

The most common testing machine used in shear testing is the UTM. However, MIRDC does not have the capability to conduct the said testing due to unavailability of fixtures/jigs. Fabricating this fixture provides the opportunity to develop the MIRDC's capability to test shear characteristics of the welded rebar wire mesh.

General Objective

The general objective of this study is to build the capability to test the weld shear strength of selected welded wire mesh composed of reinforcing steel bars used in the construction. To achieve this, the study specifically aims to design and develop a weld mesh tester jig; conduct shear test of welded wire mesh of reinforcing steel bars using the jig; and train personnel on the operation and maintenance of weld mesh tester jig.

Significance

Upon completion of the project, MIRDC will be able to fill in the gap to conduct tests needed for weldable wire mesh products once circulated in the local market following the ASTM Standard to guarantee the highest level of product quality. The results of this project will provide initial information on the shear characteristics of selected weldable wire mesh used in various construction.

Limitations

The study covered only the weld shear test of welded wire mesh. The design of the jig used to conduct the test is based on the ASTM 1064 standard but most features of the UTM are considered.

The sizes of samples for testing of welded mesh were also limited to what is commonly used by the industry, specifically 12mm, 16mm, 20mm and 25mm, which are much higher than the actual rebar sizes used in mesh which are usually 8mm Ø up to 12mm Ø only. This is to evaluate if the thickness of the plate is sufficient to overcome the tensile load of high strength rebars.

Yield load was not reported in this paper since there is another metal introduced to create the mesh product. Yield strength is not recommended for products with dissimilar materials because of the phenomenon where the plastic deformation exactly starts between the two material is not clearly identified. Also, introduction of heat during the welding process might affect the mechanical property of the material.

Materials and Methods

Jig Design, Fabrication and Assembly

The design was first tested virtually using Siemens NX software (See Figure 1). The weakest portion in the design is displayed so the trial and error during testing is minimized.

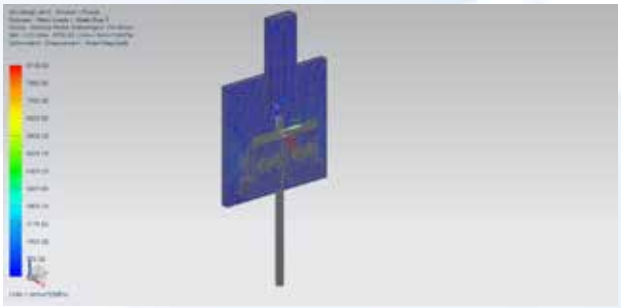

Figure 1. Simulation of Fabricated Jigs/Fixtures

The main body of the prototype jig (Figure 2) is made of mild steel plate. The thickness is based from the ultimate tensile load of the maximum diameter of the wire to be tested. Mild steel plate is used so that the difficulties in welding are reduced and the deformity in the body is observed obviously, in case it is loaded in the plastic region.

Figure 2. Body of the test jig after machining to designed dimension

Another important parameter in the conduct of test is the axiality of the sample to the loading equipment. The centreline of the gripper portion of the jig should be the same with the sample being pulled. In this case, a 50mm thick plate was used for the gripper portion to withstand the load requirement and at the same time, ensure axiality of the testing.

The supports are designed to be adjustable to accommodate different rebar and wire sizes from 8mm Ø to 25mm Ø. The supports were fastened by two A490 Hexagonal Bolts each to ensure steadiness and strength during the conduct of the test.

Preparation of Samples for Testing

In this study, sample wire and rebar mesh (Figure 3) were replicated by joining the rebars by SMAW. This guarantees the welded area to be stronger since there is additional metal on the sample. Samples were cut in 600mm length for better gripping of the equipment.

Figure 3. Welded samples for testing

Results and Discussion

Test Result of Bolts, Nuts, and Washers

The results of hardness test are intended for the verification of the material used for the bolts, nuts, and washers. Test was conducted in accordance with ASTM E 18-08b "Standard Test Methods for Rockwell Hardness of Metallic Materials." The results of the hardness test of each exhibit normal measurements for its specification.

Table 1. Hardness test results of bolt, nut, and washer

Sample Description	Average Hardness, HRC
A 490 Bolt: 22mmØ	34
Nut	34
Washer	42

Shown in Figure 4 is a 25mm Ø sample and the jig loaded at 150kN. Minimal stress is shown on the bolts. As specified in ASTM A1064 *"Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete,"* the design of the jig shall meet the testing requirements.

The shear test was conducted using a non-standard procedure developed and validated by the Mechanical Metallurgy Laboratory of MIRDC. In this test, the maximum load is determined and the location of fracture is remarked.

Figure 4. Test setup for the shear test of rebar wire mesh using the fabricated jig

Based on the ASTM A1064, the minimum average shear value in Newtons shall not be less than 241 multiplied by the nominal cross sectional area in square millimeters. That is, 12mm Ø, 16mm Ø, 20mm Ø, and 25mm Ø rebars shall withstand the minimum values of 27 257 N, 48 455 N, 75 713 N, and 118 300 N respectively. Although each sample exceeds the minimum required shear load, it was observed that there are inconsistencies in result. Most of the samples fractured at the weld portion while some seemed affected by the heat of the welding process. Nevertheless, the fabricated jig withstands the load without fracture.

Table 2. Shear test results of welded rebar samples

	12 mm Ø		
Sample Description	A	B	C
Shear Load, mm	37 800	50 100	47 800
Remarks	*	**	**
	16 mm Ø		
	A	B	C
Shear Load, mm	72 060	68 601	44 745
Remarks	**	*	*
	20 mm Ø		
	A	B	C
Shear Load, mm	98 707	116 003	102 866
Remarks	*	*	**
	25 mm Ø		
	A	B	C
Shear Load, mm	121 560	124 621	122 325
Remarks	*	*	*

*Fracture occurred at the welded part **Fracture occurred at the rebar

It was also observed that during the shear testing of 25mm diameter welded rebar, the jig experienced a permanent deformation on the base plate as shown in Figure 6. The fabricated jigs/fixture showed a permanent deformation at around 98 000 Newtons.

Figure 5. Photo showing permanent deformation after testing 25mm Ø

As for the design and fabrication of the test jig, it was observed during the shear testing of the 25mm diameter welded rebar that the test apparatus experienced a permanent deformation on the base plate. The concluded force direction is shown in Figure 6, Free Body Diagram (FBD). It is also concluded that the welded area of each sample is not consistent that led to inconsistency in the result.

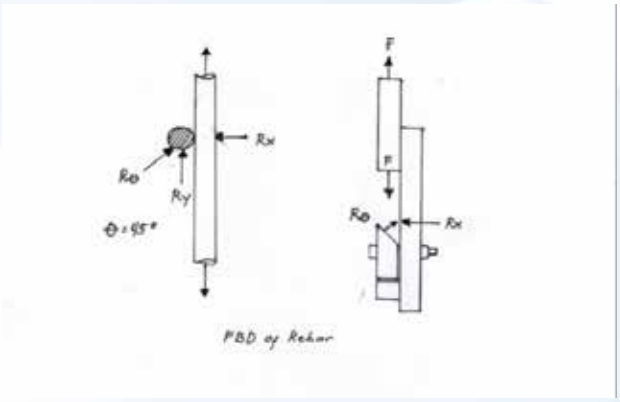

Figure 6. Free Body Diagram

Conclusion

MIRDC supports its customers to achieve quality of materials and products thru analysis and testing. In this regard, the Mechanical Metallurgy Laboratory has developed a new test jig that will be used for the conduct of shear strength of welded rebar wire mesh. This means that the laboratory is now ready to accommodate testing of samples, especially once the BPS regulates this product for construction use.

The jig will also serve its purpose to different samples that require maximum shear strength of the product with the same simulation setup. Usually, testing of samples using non-standard method is based on how the sample is actually used. The availability of the test jig will lessen the testing cost since the customer will not consider the design and fabrication of their own test jig. The error in the testing set-up of similar samples or products will be reduced as well since the test jig will perform as the standard fixture of the laboratory for shear weld test.

All qualified laboratory personnel are trained on the proper use of the developed test jig. The design of the jig is explained and the proper setup of the UTM is actually demonstrated. Limitations on the capacity of the test jig and sizes to be tested are also emphasized for safety of all personnel working in the laboratory and to avoid damage to facility.

Recommendation

It is recommended to change the material of the body of the fixture, particularly the MS plate being used. Using a high strength steel like D2 material, AISI 4140 steel, or other tool steel may be more versatile and have reasonable load capacity. Unlike the mild steel plate, these steels also have enough carbon content to alter its mechanical properties thru heat treatment.

Further study on the angle of inclination shown in Figure 5 also needs to be verified to reduce the force acting tangent to the inclined part. Another one is to install a plate reinforcement at the back of the plate to distribute the force that induced by the bolt.

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The Effect of Pouring Temperature on the Microstructure of As-cast Austenitic Manganese Steels

Stan Kristian G. EJERA*[1], Lemuel APUSAGA*[2], Manolo G. MENA*[3]

Abstract

Hadfield steels is a class of austenitic manganese steels (AMS) known for its excellent toughness, ductility, work hardening capability, and wear resistance. Being widely used in the industry, it is imperative that its service life must be extended in order to fully maximize the benefits of the alloy. This was studied through modification of pouring temperature. Three (3) levels of pouring temperature were used: 13700C; 14100C; and 1450°C. The samples were melted in an induction furnace and sand casted. They were allowed to cool overnight. An optical microscope and scanning electron microscope with energy dispersive spectroscopy (SEM/EDS) were used to characterize the as-cast structures. Results show a direct linear relationship between pouring temperature and the average grain size. Moreover, pouring temperature was conversely found to have an inverse effect on the degree of segregation of both carbides and alloying elements. This study could potentially pave the way for the production of better performing AMS in the industry.

Keywords: Austenitic Manganese Steel, Hadfield Steel, Pouring Temperature, Grain Size

Introduction

Hadfield steels, named after its inventor Sir Robert Hadfield in 1882, is a class of austenitic manganese steel (AMS) known for their excellent toughness, ductility, work hardening capability, and wear resistance [1]. This unique set of properties makes AMS a prime choice for high impact and wear applications. The local mining and quarry industries primarily use Hadfield steels in crusher plates, grinding mill liners, cement mixers, impact hammers, transportation equipment, etc. Having high hardness values and abrasion resistance when work-hardened while still maintaining a very tough interior core prevents impact-induced brittle fracture (a common problem with hard materials) [2].

Through a series of experimentation, Sir Hadfield established that optimum properties can be achieved when steel contained 12% Mn and 1.2% C with a Mn to C ratio of 10:1. This was the original Hadfield steel composition. Manganese steels today normally have manganese content from 12% to 15%. Newer manganese steels have been developed to contain Mn upwards of 20% [1], [3].

Hadfield steel's properties are mainly attributed to its high manganese content. Manganese allows austenite, a tough iron phase normally only stable at high temperatures, to be stable even at room temperature. Austenite is tougher than ferrite because of its face-centered cubic (FCC) structure as opposed to ferrite's body-centered cubic (BCC) structure. The friction stress of dislocations in FCC is much lower than in BCC giving austenite better plasticity, i.e., higher ductility. This allows the absorption of more energy without fracturing. The austenitic structure, together with the formation of dispersed hard carbides make Hadfield steel a superior alloy in the industry.

Although Hadfield steels have widely dominated the industry, they do not come cheap due to their high manganese content. It is therefore imperative that its service life must be extended in some manner in order to fully maximize the benefits of the alloy. This can be done through metallurgical modifications. The principle of materials science, in its simplest form, states that property is a function of internal structure which in turn can be controlled through processing techniques [4],[5]. Thus, by modifying several processing parameters such

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as pouring temperature, an improved AMS should be readily achievable even with only minimal changes to its composition.

Through this study, local industries can get the most value from their AMS by modifying different production parameters to improve the mechanical properties and eventual performance. Moreover, local foundries and heat treatment facilities may also gain appreciable knowledge on the science behind performance enhancement through process modifications. Hopefully, this will help them discover more ways to optimize the mechanical properties of AMS specific to the local setting.

Methodology

General Casting Procedure

The samples were melted in an induction furnace and sand casted. The furnace charge primarily consisted of manganese steel scraps as the base alloy. Target elemental composition was attained through the addition of ferromanganese alloy for Mn adjustment, carbon raiser for C adjustment and mild steel scraps for dilution. The target composition for the alloy is given in Table 1. This is based on the nominal specifications for Hadfield steels [6].

Table 1. Alloy Composition, wt%

	Fe	Mn	C	Cr
Target	85.9	12.5	1.1	0.5
Actual	84.24	12.45	1.54	1.78

The initial charge was calculated based on the raw materials' chemical composition. After a sustained period of melting and homogenization, a sample from the melt was collected and analyzed via Optical Emission Spectroscopy (OES). Prior to pouring, adjustments through appropriate charge additions were made to achieve the target composition. The actual average composition after these adjustments is shown in Table 1.

The molten AMS was then transferred to a ladle for pouring. The temperature was monitored using an immersion thermocouple. Three (3) levels of pouring temperature were used in this study – 1370, 1410, and 1450°C. Upon reaching the required pouring temperature, the melt was cast into sand molds and allowed to cool overnight. A schematic diagram of the casting is shown in Fig. 1. The casting had an overall rectified length of roughly 1500 mm and a cross sectional diameter of 32 mm. Multiple samples for characterization and mechanical testing were cut from this casting.

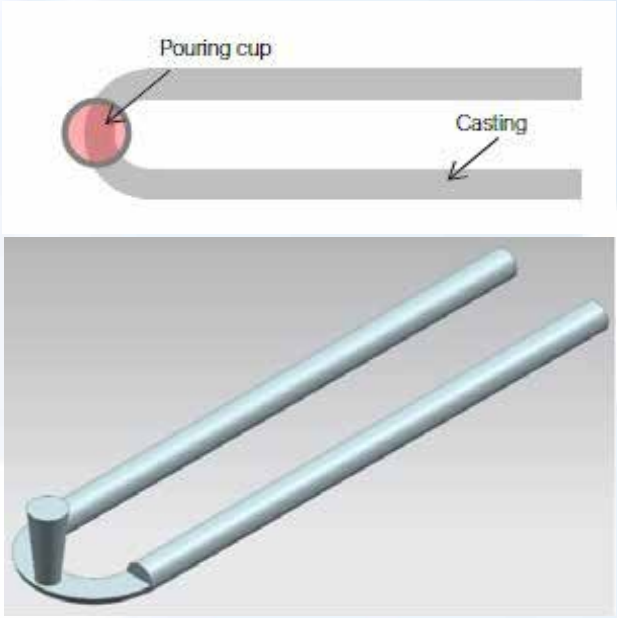

Fig. 1. Schematic diagram and 3D render of casting.

Metallographic/Microscopic Analysis

Sections, 25 to 38 mm long, were cut from the casting for metallographic examination. The samples were ground at several increasing grit sizes from 80p to 1200p. Polishing was done using suspended gamma alumina. Nital (2-5% v/v) was the etchant of choice to reveal the metallographic features.

Fig. 2. Metallographically prepared samples.

Metallographic examination included grain size determination and phase analysis. Grain size was determined using Jeffries' Planimetric Method as per ASTM E112. An optical microscope with peripherals for contrasting (e.g. illumination control, polarizers) was used for this characterization.

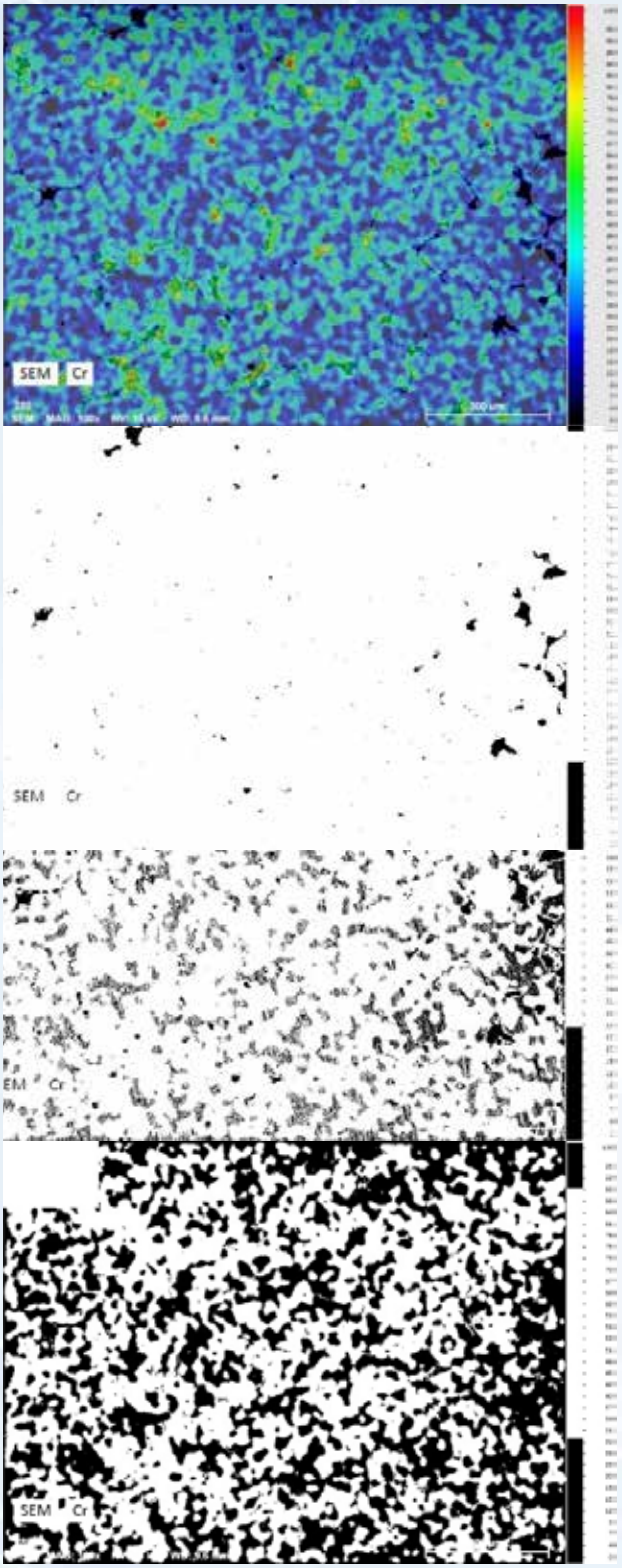

Fig. 3. Image thresholding of an elemental map using different threshold values corresponding to relative abundances of (a) 20%, (b) 25% and (c) 30%.

Scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) was used for elemental mapping and characterization of second phases. From the elemental maps, degree of segregation was estimated by taking the area fraction of depleted regions. The depleted regions were delineated by applying an image threshold corresponding to 30% relative abundance for the element analyzed. The arbitrary 30% value was chosen because this gave the best contrast as seen in Fig. 3. Image analysis were computer-aided using a free and open-source software, ImageJ.

Results and Discussion

Results show that there is a linear relationship between the pouring temperature and grain size of the as-cast austenitic manganese steel (AMS). This can be shown in Fig. 5 where an increase in temperature results in an increase in grain size. Single factor ANOVA in Table 2 confirms that pouring temperature has a significant effect on the initial grain size.

Table 2. Single factor ANOVA for pouring temperature.

Source of Variation	*SS*	*p-value*	*Conc..*
Pouring Temp.	38255.02	0.00088	Sig.
Error	355.09		
Total	38610.11		

To understand how pouring temperature affects grain size, it is necessary to describe the mechanisms involved in grain structure development. Grain sizes can be directly attributed to the rate at which a metal solidifies from the liquid phase. The kinetics of solidification is dictated by two functions – nucleation rate and grain growth. Nucleation rate is the rate at which nucleation sites are made available for the formation of grains while grain growth is the rate at which these grains increase in size before completing the solidification process. When nucleation rate is appreciably faster than grain growth, rapid solidification occurs resulting in finer grain structure. Conversely, the opposite is true for slow solidification which results in coarser grain structures.

At a pouring temperature of 1370°C, the undercooling requirement for incipient nucleation is easily attained as the molten metal is only just above the liquidus temperature. It is important to note that for solidification to begin, a certain amount of undercooling is always necessary. Fig. 4 illustrates how the pouring (or starting) temperature affects the thermal distance/temperature drop (T) needed to reach the same undercooling requirement (TN). The small T allows for numerous nucleation sites to be readily available, thereby, increasing the nucleation rate. Additionally, temperature gradient is also small at lower temperatures. Therefore, slow grain growth is to

be expected as temperature gradient is one of the driving forces for grain boundary movement.

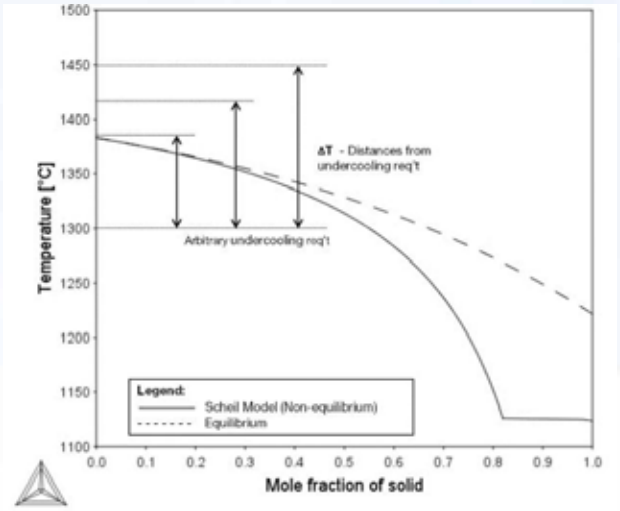

Fig. 4. Theoretical solidification path of AMS showing the thermal distance from an arbitrary undercooling requirement. Generated using Thermo-Calc – Limited Ver. 2018b

With increasing pouring temperatures, T also increases because of the added superheat. The transfer of heat from the melt towards the mold also keeps the melt at a higher temperature for a longer time period. The nucleation rate consequently drops as the availability of nucleation sites is delayed. Temperature gradient becomes higher allowing for faster grain growth. This leads to a larger resulting grain size. This progression of grain sizes with temperature is evident in the microstructures shown in Fig. 5.

Pouring temperature was also found to affect segregation. Fig. 7 shows the development of second phase segregation with . At 1450°C, a mix of intergranular and carbides within grain can be observed. Decreasing to 1410°C, the grain boundaries become more populated with carbides, but some particles can still be observed within the grains. At the lowest temperature, there is little to no second phase within the grains and most particles can be observed at the grain boundaries. As discussed earlier, slow solidification is expected when pouring temperature is high. Through slow solidification, second phases can readily grow or diffuse into favorable equilibrium positions, e.g., vicinities within the grain. The availability of both time and thermal energy allows for this to occur.

With rapid solidification, however, there is not enough time for diffusion producing a more segregated structure. During the solidification process, solute (carbon and other elements) is continuously rejected into the liquid phase which effectively enriches the liquid melt. With low thermal gradient, the liquid gets progressively richer reaching eutectic compositions. This eutectic phase will be the last to solidify and will grow preferentially at high energy areas, i.e., grain boundaries. The eutectic phase for steel is pearlite – a mixture of alpha iron and iron carbide. Images of these pearlite colonies are seen in Fig. 6.

SEM/EDX reveals the same trend for alloying elements. Through color-image analysis of the elemental maps, an estimate of the degree of segregation can be computed. This value measures the overall area of depleted

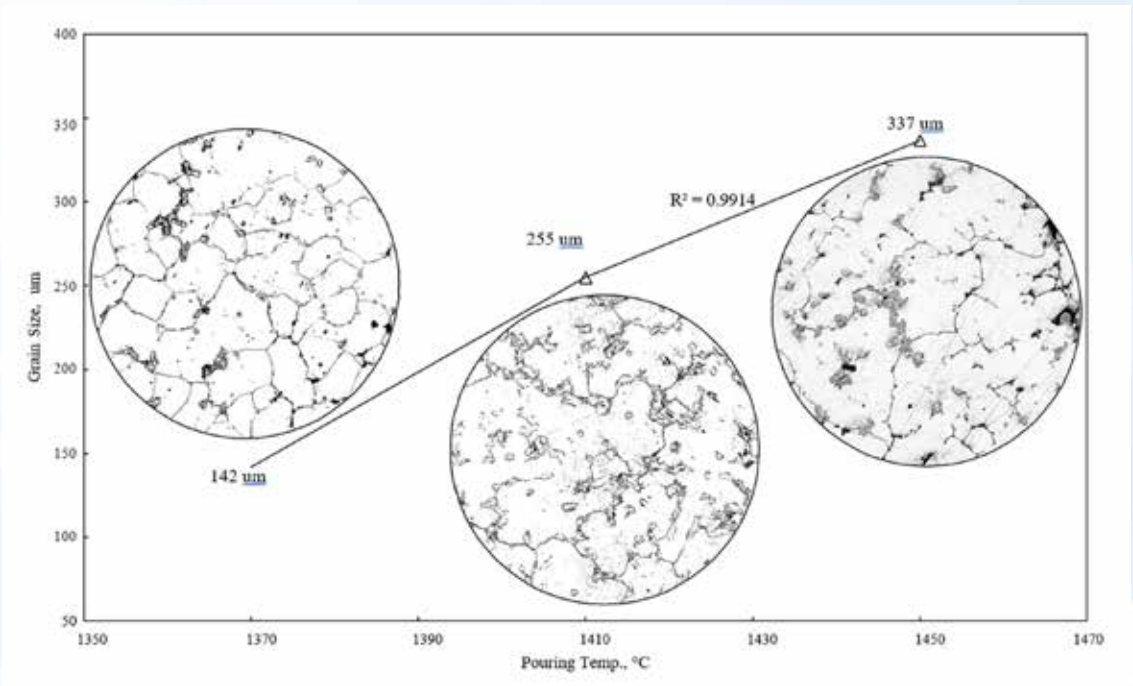

Fig. 5. Relationship between grain size and pouring temperature with corresponding micrographs showing progressively larger grains. Micrographs are taken at 100x.

regions – cooler colors in the elemental map. Larger total areas mean higher degree of segregation. The summary of results is listed in Table 3. Like the carbides, the alloying elements naturally segregate at the grain boundaries as in Fig. 8. At higher temperatures, however, segregation is less pronounced with noticeable long-range dispersion. This difference in segregation behavior can be observed, albeit only slightly, in Fig. 9. Table 3 marks this difference quantitatively.

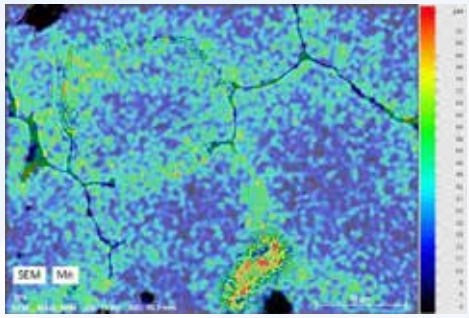

Fig. 8. Elemental map of Mn via SEM/EDX at 1000x showing segregation at the grain boundaries. As-cast sample at pouring temp. of 1450°C.

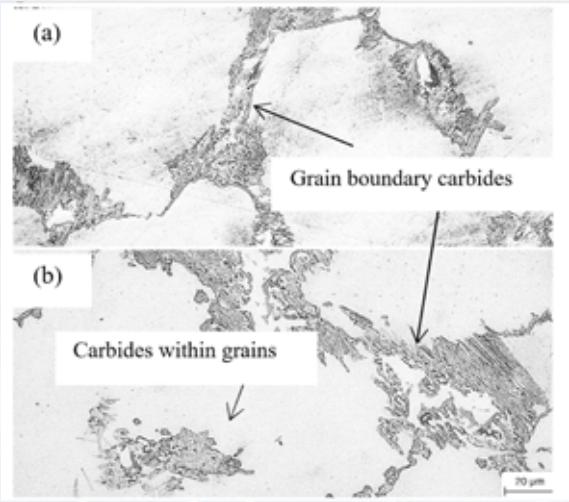

Fig. 6. Micrographs of pearlite colonies for samples poured at (a) 1370°C and (b). 1450°C Images taken at 500x.

Table 3. Degree of segregation of different elements measured in area fraction

Pouring Temp.,°C	Degree of segregation		
	C	Mn	Cr
1370	0.40	0.43	0.42
1450	0.36	0.34	0.37

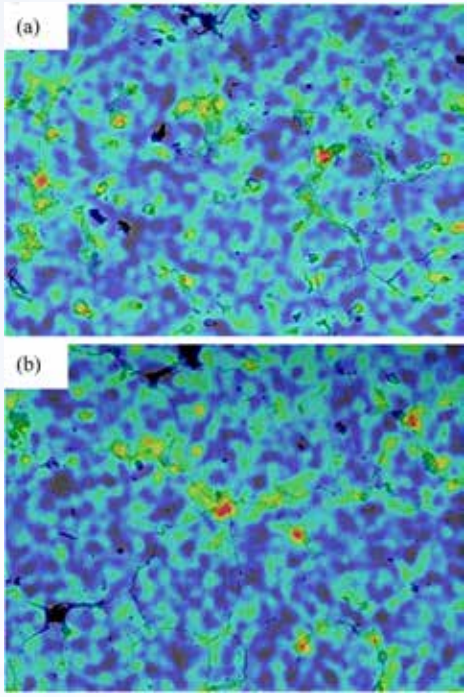

Fig. 9. Comparison of elemental maps of Cr via SEM/EDX at 100x showing long-range segregation/dispersion. As-cast sample at pouring temp of (a) 1450°C and (b) 1370.

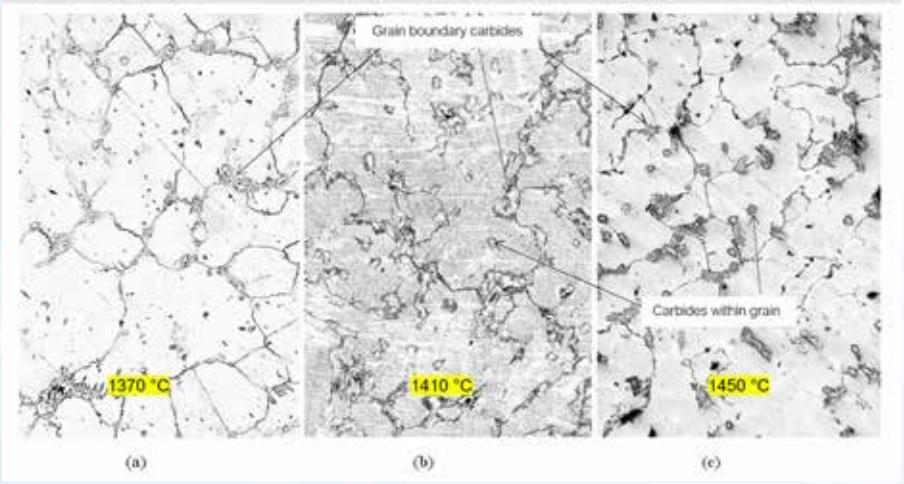

Fig. 7. Microstructures of AMS showing decreasing carbide segregation with increasing pouring temperature. Images are scaled differently to emphasize second phase segregation.

Conclusions

The following conclusions can be made from the results of this study:

1. Pouring temperature has a direct linear relationship with the initial grain size. Decreasing pouring temperature should improve grain size strengthening.

2. However, pouring temperature has an inverse relationship with the degree of segregation of the as-cast structure. Thus, increasing temperature should promote a more homogeneous microstructure.

3. Therefore, an intermediate temperature seems to be optimum as there is a balance between grain size and microstructure homogeneity.

Acknowledgement

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Establishment of Online 3D Printing Service for StrataSys UprintSE Plus

Remartin S. MAGLANTAY*[1]

Abstract

A staggering growth has been shown in the 3D printing market which is shaking the manufacturing sector around the globe. In the Philippines, this technology is mostly available in Metro Manila which is among locations with the worsening traffic conditions in the world. This study established an online 3D printing service that can reach the marginalized and difficult-to-reach population and areas requiring essential parts. A third party software was used to do the remote operation via the online process of the host computer connected to the 3D printer. Access code generated by the third-party software provided security for one-on-one access only and provided for the transfer of files for printing. It is believed that the 3D printing facility's accessibility will be improved through the development of the procedures for data processing, payment, and product handling.

Introduction

3D printing, or additive manufacturing, can democratize the production of parts and the rapid development of ideas into tangible objects. Nowadays, 3D printing machines have made their way into homes, businesses, disaster sites, and soon outer space. As this technology spreads, it could help connect marginalized and difficult-to-reach populations and areas with essential part/s or product/s [1]. All in all, this emerging technology can revolutionize our societies and transform the development sector in a fast-moving phase. For this to happen, there is a need to ensure that this emerging technology gets into the hands or provides access to development practitioners and stakeholders.

Online services are flourishing in the country, from shops to payment of service. Government agencies also adapted the process and have been providing online services to provide ease to the citizen. It became significant and a necessity due to the worsening traffic condition in the country where, based on the survey, the average time of travel commuting is about 45.5 minutes [2].

In 2013, the Department of Science and Technology-Metals Industry Research and Development Center (DOST-MIRDC) acquired rapid prototyping which uses Acrylonitrile Butadiene Styrene (ABS) plastic, a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which plastic manufacturers machine the material [3].

The project aimed to provide an online service for 3D printing. To attain this objective, the specific objectives are to develop an online accessible 3D Printing facility; and to improve accessibility to online 3D Printing. The expected outputs are online 3D printing services and the procedures for online 3D printing.

Normal operation is done where the CAD design is loaded to a computer connected via intranet or LAN cable connected to the 3D printer through its software and process before sending it to the printer.

Remote 3D printing service will provide the service to the client without leaving the comfort of their place and with the capability of delivery of printed products at their doorsteps and avoiding the worst traffic along the way.

The concept refers to the client's created Computer-Aided Design (CAD) data/file, access the remote computer via third party software and code to be provided, upload it to a slicer software and processes to a file format 3D Printer. The processed file is uploaded to the remote 3D printer machine through the network, which will manually start the printing machine after receiving the data. CAD file will be submitted before accessing the third party software for the quotation and pricing.

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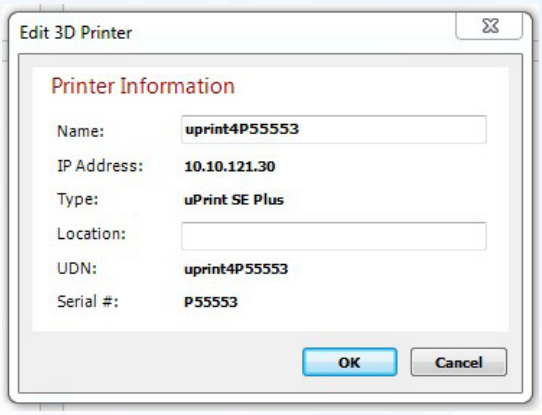

Figure 1. 3D Printer network connection details

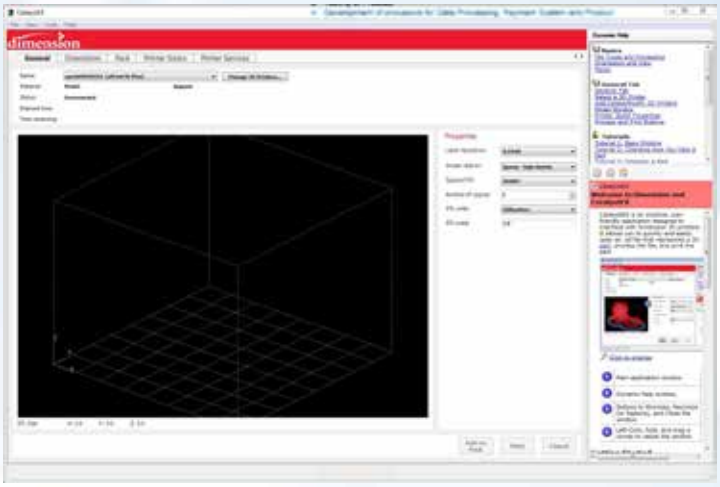

Figure 2. CatalystEX software interphase

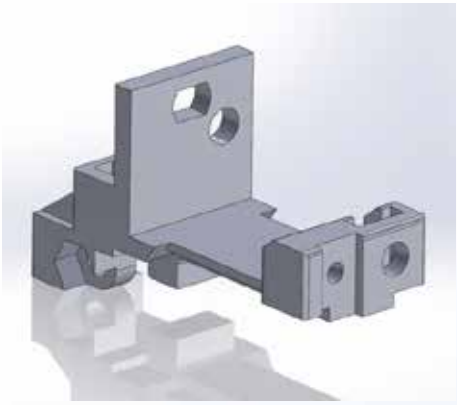

Figure 3. CAD data to be processed

Figure 4. The host computer and 3D printer setup

Methodology

1. Network Configuration

The 3D Printer was connected to the Prototyping Division (PD) Network under the name "uprint4P55553" and with a designated unique IP address. Computers enrolled only in the PD Network can access and send printing jobs to the 3D Printer. Figure 1 shows the information on the 3D Printer connected to the PD network.

UprintSE Plus has a software package called CatalystEX, installed on the computer accessing the 3D Printer. A dedicated computer was proposed for remote access which was configured to access only the CatalystEX software. This is to ensure the safety of the file system of the host computer and the computers connected to the network as a whole. Figure 2 shows the graphic user interface of CatalystEX.

2. Access Link

The client computer (computer of the client accessing the 3D Printer) was installed with the "AnyDesk" software [4]. AnyDesk is a commercial software designed for remote access with fast data transmission and secured using banking-standard TLS 1.2 technology to ensure the computer is protected from unauthorized access and RSA 2048 asymmetric encryption to verify every connection.

Results and Discussion

A trial was conducted to assess the effectiveness of the setup. A CAD model, as shown in Figure 3, was used as the data to be processed. The host computer is placed beside the 3D Printer machine and is configured to be included in the network, as shown in Figure 4.

Anydesk software is downloaded and installed on the client computer. A CAD file is generated using 3D software and is saved as an STL file. It was sent via email to the host computer. This was done to simulate the process of transferring data.

The received file is evaluated and transferred to the host computer. The access code of Anydesk installed in the host computer is sent to the user of the client computer to be used to remote access the host computer.

When the code is keyed in and launched in the client computer, the host computer is prompted to allow access

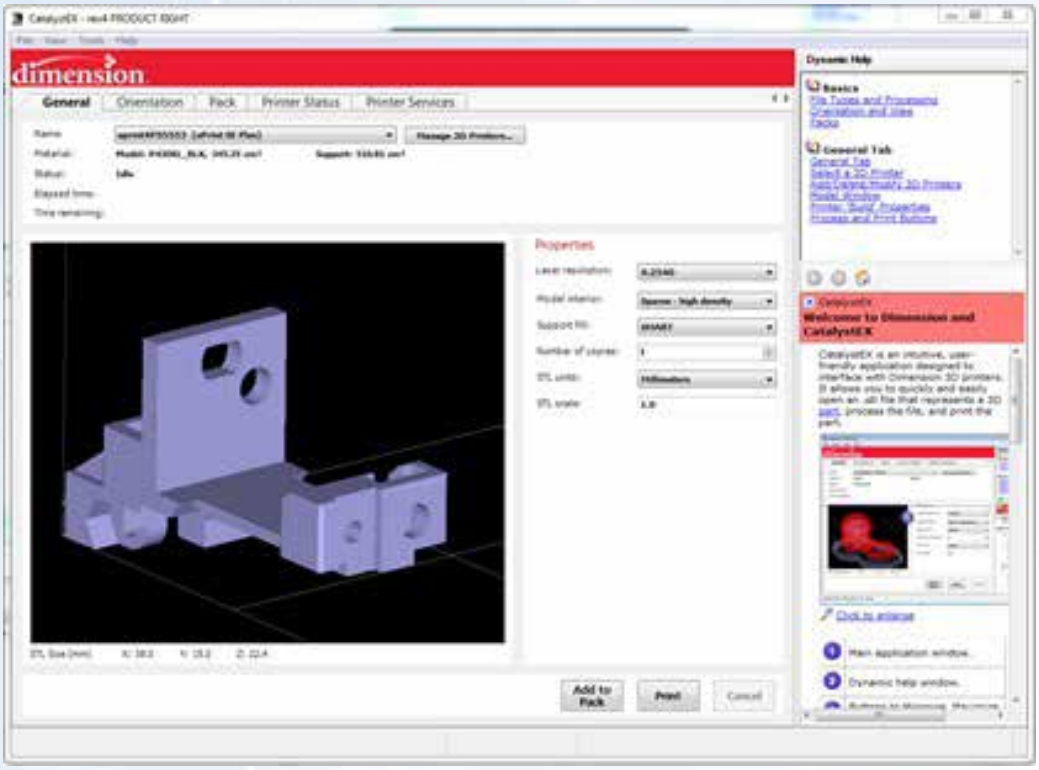

Figure 5. Display in the CatalystEX file with the CAD file transferred from the client computer

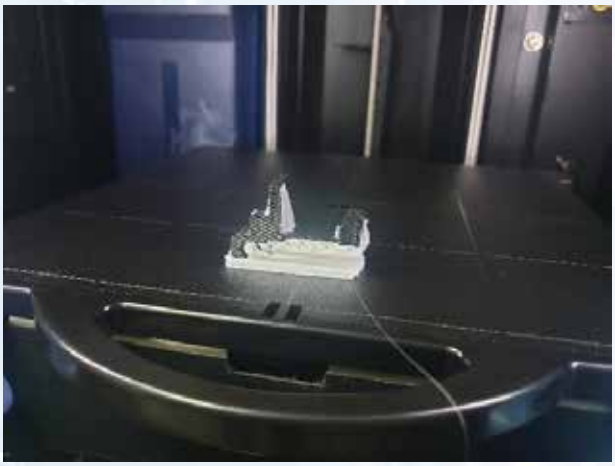

Figure 6. Printed CAD file from the client computer

to the remote user. Allowing so grants the client computer to control the host computer.

There is no data loss encountered during the transfer from the client computer to the host computer through the third party software. The transfer of files depends on the speed of the internet connection. After the transfer is complete, the process is the same as the direct connection setup of 3D printing. Figure 5 shows the display in CatlystEX software with a CAD file from the client computer.

The software package of the printer has no administration and multi-user features. During testing, it was encountered that the next user can alter the ongoing set up of the printer. Therefore, it was ruled that while there is an ongoing printing, the next user will be put on hold until the product is complete and the printer is ready for the next user.

Trained personnel is advised to do the setup for multiple printing per batch to maximize the materials to be used and properly orient the object to be printed.

Overall, an online 3D printing facility is made accessible and have completed a printed product through its set up. No added cost is incurred to the client as the software to be used to access the 3D printer is free and downloadable via the internet. Figure 6 shows the printed CAD file from the client computer.

The accessibility of the 3D printer has improved as its access can be done remotely. The user was in a remote place and managed to transfer the file and successfully printed the CAD data. In this regard, 3D printing can be achieved without physically going to MIRDC using only the internet connection, communication with MIRDC, and compliance with the other requirements of MIRDC for the service.

Conclusion

The established set up successfully printed remotely the object with no data loss during transfer. The UprintSE Plus Printer was made available online. Accessibility was developed through the use of a third party software AnyDesk. It enables the communication of the host computer and the client computer, which in effect, the client is the one operating the host computer and the 3D printing software CatalystEX.

Accessibility of the 3D printing facility was improved. The developed procedure/system can provide the services to anyone in and out of the country in the comfort of their place.

Recommendations

It is recommended that the 3D Printer should be accessed one at a time and wait until the ongoing printing job is complete to prevent access or control of the cue list. CatalystEX is not designed for a multi-user application. Cue list can be viewed and edited by any user accessing the 3D Printer.

It is recommended that the transfer of CAD file should be done by the TSS personnel to prevent the changing of data by the client to be uploaded to CatalystEX. This is to avoid different print orientations, which will yield different material consumption and printing duration.

It is recommended that MIRDC should have an online account for the payment scheme. It is believed that having one would be convenient for clients who would come from distant places, especially with the worst conditions of transportation and road traffic in Metro Manila.

Acknowledgement

The team would like to thank the Management Information Systems (MIS) staff for making this project possible. They provided the information and assistance needed in the conduct of this research.

Also, the Prototyping Division staff for the support in processing all the project documents for smooth and fast approval. Lastly, we would like to thank God for His guidance. It is because of God's grace that the team was able to complete the project.

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Fused Deposition Modelling of Face Shield Frames for Health Workers Amid the COVID-19 Pandemic

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Abstract

In response to the COVID-19 pandemic, DOST-MIRDC joined with 3D Printing for a Cause PH in efforts of producing face shields to help protect frontliners. The step-by-step production of the face shield frames via fused deposition modelling (FDM), and the easy assembly of the face shields using acetate sheets are presented in this paper. The materials used for the face shields were polylactic acid (PLA) and Acrylonitrile Butadiene Styrene (ABS), with a total printing time of 1.53 h for each set of two units. The nozzle (build plate) temperature was set to 2100C (850C) for the PLA and 2500C (850C) for the ABS. For future works, one may consider using a nozzle with a diameter larger than 0.4 mm, allowing for a print layer height ranging from 0.6 mm - 1.2 mm. If this is achieved, the printing time can be lessened by 32.68%.

Keywords: Additive Manufacturing, Face Shield Frames, Fused Deposition Modeling

Introduction

The Philippines was put under a state of calamity, under Proclamation No. 929 on March 16, 2020, five days after the World Health Organization (WHO) categorized the COVID-19 situation as a global pandemic [1-2]. The general public's response was to stockpile basic commodities and personal protective equipment (PPE), resulting to the shortage of face shields [3]. One of the community initiatives that arose to somehow help in the ongoing global health crisis came from a group named 3D Printing for a Cause PH, where 3D printing hobbyists and business owners took steps in designing face shield frames for the frontliners, printing them, and gathering donations for the printing materials [4].

A face shield, depending on its design and functionality, may not provide full protection and must be used in conjunction with other PPE such as face masks. Nevertheless, it provides extra protection to the face, which is the most susceptible part of the body to infection likely from bodily fluid sprays or splashes [5]. More importantly, it shields the mucous membranes (i.e. the eyes, nose, and mouth), where SARS-CoV-2 could transmit [6]. Furthermore, the use of face shields prolongs the use of N95 masks, which were in shortage especially at the early stages of the COVID-19 pandemic [7].

The step-by-step procedure in 3D printing the face shield frame, and the simple and easy assembly of the face shield using an acetate sheet are presented. How the printing time can be shortened in relation to the layer height a nozzle can generate, as well as temperature setting considerations with respect to the filaments available at this time are likewise discussed in this paper.

Materials and Methods

The DOST-MIRDC joined the initiative of producing face shields and came up with a 3D printed face shield with a production workflow that is broken down to the following steps: (1) acquiring 3D file; (2) slicing the 3D file; (3) printing of the 3D file; and (4) assembly of the face shield.

Acquiring 3D Printable File of Face Shield Frame

The 3D printable file (STL) used came from the 3D Printing for a Cause PH. The 3D design of the face shield was conceptualized after consulting with medical

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professionals, thus, resulting to the closed top design. The rendering of the face shield frame designed used *Solidworks*.

Slicing the 3D Model of Face Shield Frame

The STL file was loaded in a slicer software. The software processed the file and gave certain commands to the 3D printer to produce the part, layer by layer. It can also be used to orient and arrange the parts in the build plate of the 3D printer. The slicer software was used to assign the printing speed, layer height, wall thickness, wall count, infill density, line width, and many other printing parameters. The parameter settings used for printing were 0.32 mm layer height; 0.6 mm line width; 5% infill density; 80 mm/s printing speed, and a wall count of 4.

To maximize the available build area of the build plate, two face shields were laid out in the slicing software as shown in Fig. 1. This saved time in printing by lessening the time needed to reheat the printing nozzles, and to recalibrate the 3D printers every time a print job was started. DOST-MIRDC was able to print, on average, 50 face shield frames per day.

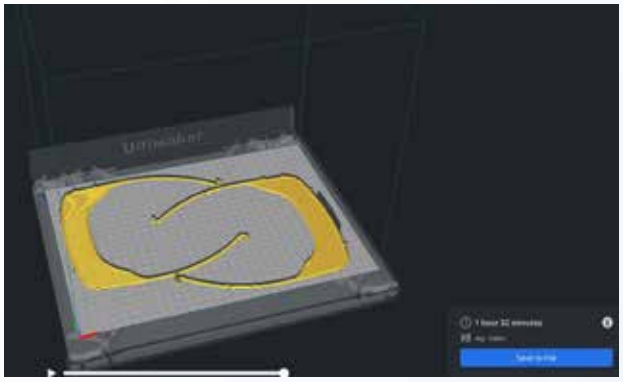

Fig. 1 STL File of the Face Shield Frame sliced via CURA, the slicing software for Ultimaker

3D Printing of the Face Shield Frame

The sliced file is transferred to the 3D printer via USB. The file was chosen from the file menu in the machine interface of the 3D printer, and the printing process commenced thereafter. The layout used for printing is a two (2) piece production with a print time of 1.53 h when using the Ultimaker S5, an FDM printer (Fig 2). There were no supports and rafts used for the print. The materials used for printing were PLA and ABS. To ensure a better bedplate adhesion, a regular stick glue was used.

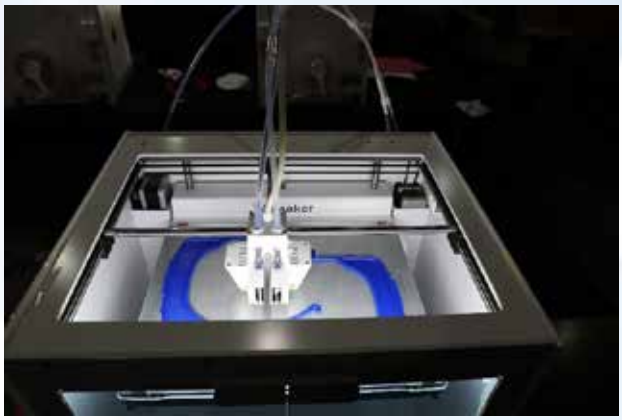

Fig. 2 Actual Printing of Face Shield Frame thru ULTIMAKER S5

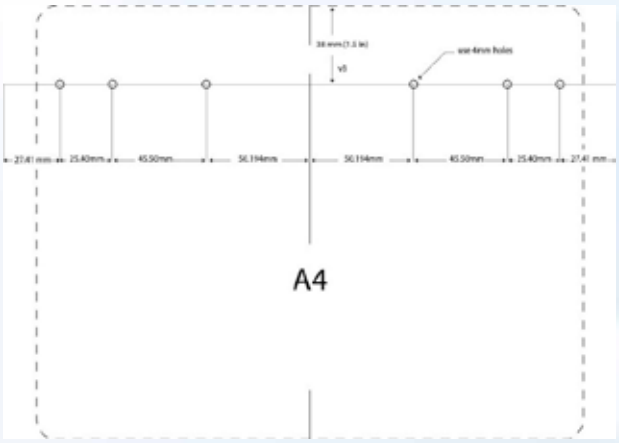

Fig 3. Face Protector Hole Template

Assembly of the Face Shield

The printed part was removed from the build plate by using a scraper. Holes were punched in the acetate sheet using a template from 3D Printing for a Cause PH (Fig 3). The acetate sheet was test-fitted to the frame (Fig 4) to complete the assembly.

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Fig. 4 Face Shield Assemblies

Results and Discussion

Printing time. The printing nozzle diameter used for the printing of the face shield frames was 0.4mm.

The printing time could be lessened by using a printing nozzle with a bigger nozzle diameter. Using a printing nozzle with a bigger nozzle diameter will lessen printing time by allowing a higher layer height and wider line width. In the simulation, printing the said face shield frames using a layer height of 0.6mm and line width to 1.2mm, the simulation revealed a printing time of 30 minutes. In comparison to the print time using the 0.4mm printing nozzle diameter, with a layer height of 0.32mm and a line width of 0.6mm, the printing time will be 67% faster. (Fig 5).

Printing Filament. As mentioned, the 3D printing filaments used were PLA and ABS, as they were the only materials available during the time. The supplied PLA filament was used first. The slicer software already had a recommended temperature setting at 210°C nozzle temperature with 60°C build plate temperature. When the PLA filaments run out, the supplied ABS filaments were used. This changed the recommended temperature setting to 250°C nozzle temperature with 85°C build plate temperature. When the supplied ABS filaments ran out, generic ABS filaments were used. The temperature setting was set to the same temperatures used for the supplied ABS filaments, but some problems occurred with layer adhesion and bedplate adhesion. To address the problem, the temperature setting was increased to 260°C nozzle temperature with a 90°C build plate temperature.

3D Printer. Printing the face shield frames was done on a ULTIMAKER S5.

Clear sheet for shield. A4 size acetate sheets were used because these are readily available.

Optional parts. The frame can have a tighter fit on the head if rubber bands are used on the ends of the frame.

Distribution. The 3D printing run produced 490 face shields. The recipients were the Philippine General Hospital, Army Hospital, Taguig Traffic Management Office, DOST security personnel, and DOST personnel. The face shields were sanitized before distribution.

Conclusion

The step-by-step production of face shields is presented in this paper: 1) digital model acquisition, 2) 3D file slicing, 3) 3D printing via FDM, and finally, 4) assembly. The printing parameters such as layer height, infill density, and nozzle and build plate temperatures according to the filament used were also discussed. The authors also provided recommendations on nozzle size and temperature setting considerations for future works.

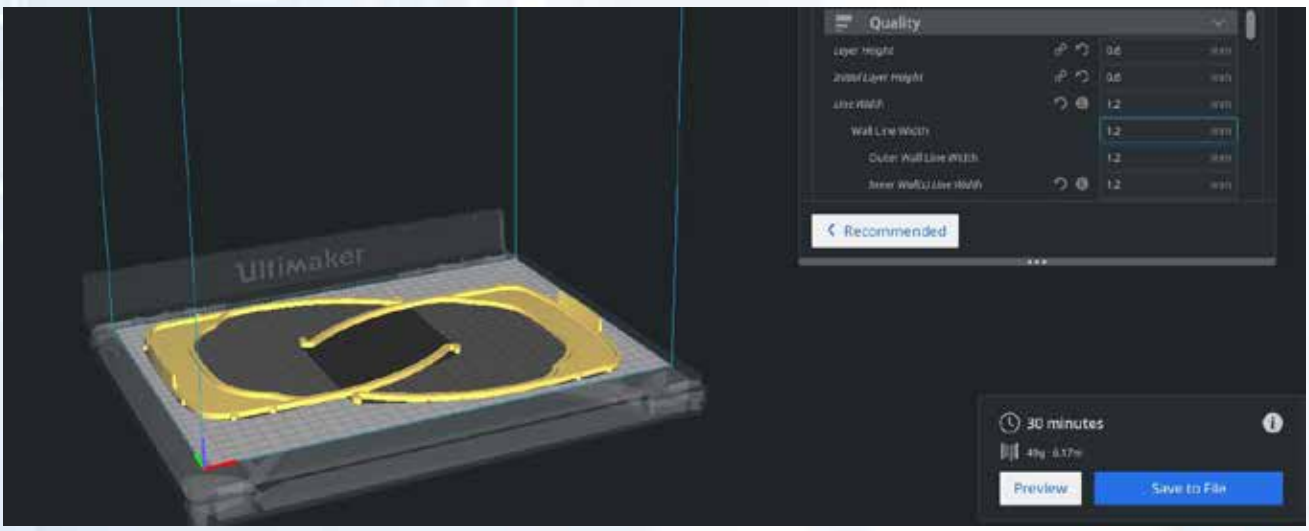

Fig 5. Revised Printing Parameter using 0.6 mm nozzle

This initiative served as a stopgap measure for the shortage of face shields for the frontliners. 3D printing is relatively suitable for low-volume production, but is used to speed up product development and prototyping. The use of injection molding technology is a better option for mass production. Nevertheless, the rapid prototyping capability of 3D printing was demonstrated in providing the country's modern heroes the protection they needed from the SARS-CoV-2 faster while the plastic injection mold for the face shield frames was being developed.

Acknowledgement

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Development of Hand Tractor with Gear Transmission

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Abstract

This study aimed to replace the existing sprocket and chain transmission of the conventional hand tractor with gear transmission without major modification to the design of the said hand tractor. Specifically, the study focused on the 1) design and simulation of the gear transmission system using KISSsoft software; 2) fabrication of the gear transmission system; and 3) conduct of a functional test. Based on the result of this study, the existing sprocket and chain transmission system of the walk-behind type hand tractor can be converted into gear transmission. The gear systems designed using KISSsoft was able to generate precise gear pair specifications which resulted to efficient meshing of gears. The gear transmission assembly is a six-stage gear reducer composed of 12 gears and the speed reduction ratio is 1:9. It is made of helical gears which made the transmission run smoothly due to gradual engagement of teeth. This was manifested through lesser vibration on the machine which has only 74 decibels of measured noise at a minimum engine speed and up to 84 decibels during maximum engine speed while PAES 109:2000 requires <92 decibels. The gear transmission system weighs 85 Kilograms as measured while the sprocket and chain transmission assembly weighs 40 Kilograms. Nevertheless, the increase in weight of the gear transmission system prototype did not affect the configuration of the said walking type hand tractor. Few tests conducted provided favorable results however, it is recommended to subject the hand tractor with a gear transmission system prototype to field testing in order to determine its field capacity and field performance. Also, subjecting the machine to further testing will help the researchers know if the said prototype complies with other PAES requirements. In addition, it is also recommended to revisit the design of the gear transmission system prototype in order to determine modifications that will reduce the weight of the said prototype.

Keywords: hand tractors, gears, gear transmission

Introduction

The hand tractor is the basic workhorse of many small farms (averaging about 2 hectares) in many countries of Asia, especially those in which low-land rice is a major crop like in the Philippines.[1] The hand tractor is also known as the walking tractor, iron buffalo, steel buffalo or 2-wheel-tractors. Hand tractors are used in many rice-producing countries. These tractors have a forward-mounted engine which is counter-balanced by the equipment attached behind the two drive wheels. Philippine Agricultural Engineering Standards (PAES) 109: 2000 classified the walking-type agricultural tractor as a pull-type tractor. This type includes tractors with chain and sprocket transmission system, gear transmission system, and combination thereof. The standard requires that the tractor shall be made of steel bars and sheet metals. The chain shall be at least ISO chain number 10A-1 (ANSI chain number 50) and sprocket transmission system. The handle bar shall be made of Black Iron (BI) pipe (schedule 40) with a minimum diameter of 25 mm. The throttle lever shall be accessible to the operator's right-hand side of the handle bar. The throttle lever is pushed forward to increase engine speed and pulled rearward to decrease engine speed. Moreover, the Standard specifies that the tractor shall be tested in accordance with PAES 111. The peak transmission efficiency of the tractor shall be at least 85%. The manufacturer's specified minimum field capacity of the tractor shall be attained. The noise emitted by the tractor measured 50 mm away from the operator's ear level shall not be more than 92 dB (A). For operator's safety, the Standard requires belt guard or cover, mud guard,

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rubber hand grip, etc. The mechanisms for transmission belt adjustment handle bar height adjustment shall be provided. The hitch of the tractor shall be in accordance with the specifications of PAES 107.

Basic objective of every mechanical drive is to transmit motion and power from driver shaft to driven shaft. Distance between driver and driven shafts may vary based on several factors such as shop-floor lay out, availability of space, safety issues, etc. Each mechanical drive is suitable for a range of shaft distance. Chain drive can be employed for small to medium center distance, typically between 1 – 5m in a single stage. It can also be employed for higher shaft distance by utilizing additional idle supports. On the other hand, gear drive is preferable for small center distance, typically below 1m; otherwise bulk size gears are required to employ, which will consume space and increase system weight. By utilizing idle intermediate gears, power can also be transmitted over longer distance; however, that will increase system weight and power loss and thus efficiency will decrease. [4], [5], [6] Usually the prime mover rotates at much higher speed than it is intended in machine unit. This requires stepping down of rotational speed, which can be done by every mechanical drive. However, each drive has a limit in reduction capacity. A chain drive can provide speed reduction in between 1:1 to 1:5, in a single stage. On the other hand, gear drive can provide a wide range of speed reduction, typically between 1:1 to 1:100. Spur gear and bevel gear are preferred for small reduction, helical gear can provide medium reduction, and worm gear can provide steep speed reduction. [4], [5], [6]

In light of enhancing the capability of MIRDC to develop gear transmission systems for various machines, this project was conceptualized to replace the existing sprocket and chain system of the hand tractor to improve its efficiency and prolong its service life. The initial assumption was to replace the transmission system without major alteration to the design of the machine. The general objective of this study was to design and develop a gear transmission system for hand tractor. Specifically, the study aimed to 1) design and simulate the gear transmission system using KISSsoft software; 2) fabricate the gear transmission system; and 3) conduct a functional test.

Methodology

Evaluation of the Commonly Used Hand Tractor

The parts, mechanism, layout, and assembly of the conventional walking-type hand tractors (Fig 1 and 2) were reviewed and evaluated in order to determine means to incorporate the gear transmission system prototype. These conventional walking type hand tractors were capable of adapting to a maximum of a 12Hp diesel engine.

Evaluation of the Imported Hand Tractor

MIRDC acquired an imported hand tractor with clutch system and reverse motion through another GIA

Figure 1. Common walking type hand tractors manufactured by ACT Machineries and Metalcraft Corporation

Figure 2. Sprocket and chain transmission system of a walking type hand tractor

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project entitled "Piloting of the Hand Tractor-attached Transplanter and Hand Tractor-attached Harvester in Selected Rice Growing Regions." This model has an additional lever in the middle part that shift the gears from low to high speed and set the motion in forward or in reverse. It also uses a diesel engine similar to conventional walking-type hand tractor in the country. The critical parts and the mechanism of a gear system and clutch system were examined and gauged to identify features that may be incorporated into the gear transmission system prototype.

Designing and Simulation of Gear Transmission for Hand Tractor

The concept model of the gear transmission for hand tractor was developed through NX, SolidWorks, and KISSsoft. These CAD and gear simulation software are vital to realize the whole activities of designing.

Machining of Gears

All of the gear components of the hand tractor's transmission system starting from the preparation of materials through gear cutting were done at the Center's machine shop and gear making facility. Said gears passed through the quality inspection as a mandatory process to all machined parts. Other parts of the gear transmission system prototype such as shafts, housing, and cover were machined using various CNC machines available at the MIRDC.

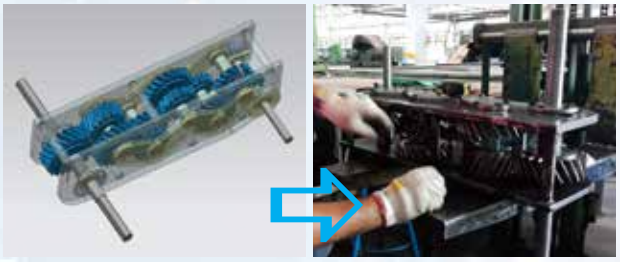

Figure 3. 3D model gear transmission vis-à-vis actual model

Figure 4. Integrating the gear transmission system to a hand tractor

Fabrication and Assembly of Gear Transmission to a Hand Tractor

All components of the gear transmission prototype were assembled based on the simulated drawing. Every gear was arranged in accordance with the drawing to attain the required speed ratio. This gear transmission is a 6-stage gear speed reducer. See Figure 3 and 4.

The assembled gear transmission prototype was integrated into the walk-behind type hand tractor. Minimal changes on the hand tractor was made in order to fit the gear transmission system.

Functional Testing of Hand Tractor with Gear Transmission System

The hand tractor with gear transmission prototype was subjected to functional test run using a 9Hp diesel engine. A smooth transfer of motion from the engine to the number of gears was observed. This was manifested through lesser vibration on the machine which has only 74 decibels of measured noise at a minimum engine speed and up to 84 decibels during maximum engine speed while PAES 109:2000 requires <92 decibels. The said noise was measured 50 millimeters away from the machine, in accordance with PAES 109:2000. Due to limited time frame, the testing was only limited to motion test which was done around the area of Metal Working Shop II (MWS-II).

Results and Discussion

Research and development activities in developing the gear transmission system ran for one and a half years from concept to functional testing. All of the raw materials and standard parts used are available in the local market. Processes involved during fabrication were within the capacity of the country's metals and engineering industries.

Table 1 below shows the reference criteria applied to functional testing. The structure of the hand tractor was not changed even if the gear transmission system was heavier than the sprocket and chain transmission. The gear transmission system weighs 85 Kilograms as measured while the sprocket and chain transmission assembly weighs 40 Kilograms only. With the less vibration on the gear transmission system, the noise was measured at 84 decibels. The operator's safety requirements of PAES 109:2000 such as belt guard or cover, mudguard, and rubber handgrip were not altered with the integration of gear transmission system. Moreover, the hexagonal shaft and changeable tire based on requirements (e.g., to rubber tire when in transport mode) were still maintained. The gear transmission assembly is a six (6) - stage gear reducer composed of 12 gears and the speed reduction ratio is 1:9.

Figure 9. The developed hand tractor with gear transmission prototype

Criteria	PAES 109:2000 requirement	Actual results
Structure of tractor	Made of steel bars and sheet metal	Same / retained
Transmission system	ISO chain number 10A-1 (ANSI chain number 50) shall be used for the chain and sprocket transmission system.	Modified into the gear transmission system.
Noise	< 92 decibels	84 decibels
Operator's safety requirements	Belt guard or cover, Mud guard, Rubber hand grip, etc	Same / retained
Shaft and tire	Hexagonal shaft and changeable tire (to rubber tire when in transport mode)	Same / retained

Conclusion

Based on the result of this study, the existing sprocket and chain transmission system of the walk-behind type hand tractor can be converted into gear transmission. The gear system designed using KISSsoft was able to generate precise gear pair specifications which resulted to efficient meshing of gears. The gear transmission assembly is a six-stage gear reducer composed of 12 gears and the speed reduction ratio is 1:9. It is made of helical gears which made the transmission run smoothly due to gradual engagement of teeth. This was manifested through lesser vibration on the machine which has only 74 decibels of measured noise at a minimum engine speed and up to 84 decibels during maximum engine speed.

Recommendations

The developed gear transmission system weighs 85 Kilograms while the sprocket and chain transmission assembly weighs 40 Kilograms. Nevertheless, the increase in weight of the gear transmission system prototype did not affect the configuration of the said walking type hand tractor. Few tests conducted provide favorable results, however, it is recommended to subject the hand tractor with a gear transmission system prototype to field testing in order to determine its field capacity and field performance. Also, subjecting the machine to further testing will help the researchers know if the said prototype passes other PAES requirements. In addition, it is also recommended to revisit the design of the gear transmission system prototype in order to determine modifications that will reduce the weight of the said prototype.

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Design and Improvement of Gong Fabrication Processes Through S&T Intervention at Bedbed, Mankayan, Benguet

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Abstract

To the natives of Benguet, a gong is a treasure and making gong is a tradition. Gong is a musical instrument played on various occasions like courting, wedding, and festivities. Production of a gong is difficult and labor-intensive. This study on the Improvement of Gong Fabrication Through S&T Intervention in Benguet was implemented in 2017 and was completed in 2019. The traditional method employed by the natives of Benguet involved cutting brass sheet with a chisel into circular blank; lay-outing areas as targets for hammering; hammering into a cup-like configuration; pre-forming the rim and then the bottom; stress-relieving using stove; finishing the rim and the bottom; trimming the edge with a hand grinder and filing. Through the project mechanization of most activities with the use of a metal lathe and forging hammer were introduced to reduce the processing time in the production of a gong. The processing was successfully reduced from 116 minutes to 41 minutes. The introduction of the machines gained the acceptance of women and young ladies and boys to join the project during the training because they did not have to lift heavy hammers with hands. With the introduced methods, fabrication of the gong became much easier. Now even women and youth can make gongs without much effort.

Keywords: gong, brass sheet, rim, edge, stress-relieving, hammering

Introduction

To the natives of Benguet, a gong is a treasure and making a gong is a tradition. It is a musical instrument played on various occasions like courting, wedding, fiestas, etc. [1]. A set of gong consists of 7 to 8 gongs and very often, each gong is played by each individual in a group.

Various materials were considered in gong production but only a few were selected. Aluminum and mild steel sheet were used for training and trial production because of cost considerations. For actual gong production, the brass sheet was used for many reasons. The metal can be formed with ease into desired shapes and forms while retaining high strength. While there are differences between brasses with high and low zinc contents, all brasses are considered malleable and ductile [2].

The usual manual cutting and trimming with a chisel of the brass sheet was replaced by using a metal lathe and the manual hammering was replaced with the use of a mechanized forging hammer.

This study, entitled 'Improvement of Gong Fabrication Through S&T Intervention in Benguet,' aims to reduce the processing time in the fabrication but without a much parting from the usual method of fabricating gong to preserve the natives' tradition and culture. It also aimed to support the Gender and Development (GAD) by providing roles for women and young boys and ladies to participate in the gong-making.

Materials and Methods

The Gong Material

Brass is considered low friction and non-magnetic alloy, while its acoustic properties have resulted in its use in many 'brass band' musical instruments. The metal is valued for its aesthetic properties, as it can be produced in a range of colors, from deep red to golden yellow.

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Traditional Method of Gong Making

In order to introduce an improvement in the process, the project team observed and studied how the gong was made in the traditional way.

Gong Making was extremely difficult and laborious. Traditional gong-making involves several steps. The activities in the preparation of the blank material in making the gong involve the following: lay-outing, cutting, smoothing the edge with a portable grinder, and inscribing boundaries for hammer. The material was brass having 2 mm thickness. The size of the blank depended on the desired size of the gong. After preparing the blank material, hammering is needed to be done near the edge which will result to the desired shape of the material. It was noticed after this step that hammer marks were beyond the inscribed circle that was marked during the blank preparation.

This material goes through another round of hammering. In this step, the hammer had to be held by two hands, while two feet were needed to hold the material against the wooden mold. To do this, the gong-maker has to be highly skilled, otherwise there may be injuries that can be sustained by the gong-maker.

The third and fourth rounds of hammering adjacent to the second round of hammerings are done next.

The large wrinkles at the rim are needed to be removed by hammering the material in a wooden mold.

With all the hammerings on the material, it is stressed and work-hardened or brittle. Further hammering might lead to cracking and spoil the work, so it was temporarily stopped. It was then heated in a wood or LPG stove [3]. To stress-relieve the brass it should reach a temperature of 250-500°C. To check if the material has reached the desired heating temperature, a wooden stick was constantly rubbed on the surface of the material until it started to smoke and char. Wood is chosen because it ignites at around 350°C and after which it starts to char. The brass was then quickly soaked and cooled in water for 2 to 3 seconds.

After stress-relieving, the cup became ductile again and was ready for another series of hammerings. The bottom of the cup was flattened by hammering on a flat metal anvil. Hammering was done in circles and radially away from the center. It was noticed that the cup was wide open and the rim was very much slanting outward. As the flattening went on, the rim turned vertical. The hammering not only flattened the bottom but also thinned and expanded the bottom area causing the outermost periphery of the bottom to become the fulcrum of the rim. It was noticed, too, that the wrinkles turned from large to small wrinkles but plenty in number.

To refine the wrinkles, the cup is hammered at the rim from the inside as shown in Fig 3.

Next step is bending up the rim to its final form. With the property and thickness of the material, it would be hard to make the bend without cracking. However, the material was successfully bent by reducing thickness right at the area where it will be bent. It was done by a gong maker blowing the material with a blunt and radiused chisel right at the circular mark made during the preparation of the blank. The act of blowing, aside from reducing the thickness of the material at that spot, also pushed the corner of the material away from the center of the cup causing the edge of the rim to turn towards the center.

FIGURE 1. The material after the third (a) and the fourth (b) round of hammering

FIGURE 2. Heating to remove stress due to hammering, a) using wood and b) using LPG as fuel

FIGURE 3. Removal of wrinkles

(a) (b)

FIGURE 4. Cornering (a) and grinding (b) results to the basic gong

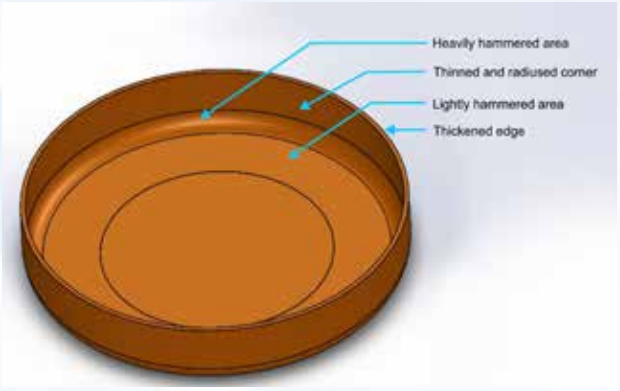

FIGURE 5. Schematic illustration of a typical gong

A series of alternate hammering of the bottom of the cup and its rim creates a remarkably visible corner at the bottom.

After trimming of the edge with the portable hand grinder, the material finally resulted to a basic gong created through the traditional method.

The Gong Product

To further study the created gong, a schematic illustration of a typical gong is shown in Fig 5.

The area bounded by the inner circle was lightly hammered. The thickness of the sheet in that area was almost the same as the original thickness of the raw material. The adjacent area bounded by the inner circle and the next bigger circle were heavily hammered with the thickness of the sheet gradually reducing from the inner circle outward.

The radiused corner which was formed by hammering with a radiused chisel edge was very visible. The thickness of the material in that area was the thinnest in the gong. Thinning that area made it easier to fold the material without cracking as practiced in sheet metal forming [3]. The edge thickened as a result of material compression during folding.

The gong's thickness became thinner from the center towards the corner. That made the Benguet gong look like a diaphragm that made it bouncy when played. The thickness of 2.2 mm at the edge of the gong had thickened from the original thickness of 2 mm of the material as a result of material compression during folding [4].

Changes in the Gong Production Processes

Based on the observed traditional way of making gongs, the team planned how the process can be made easier through other methods. Table 1 presents the introduced method to replace the conventional method.

Gong makers were invited to try and evaluate the methods and determined what were yet to be adjusted or changed. After the adjustments, all the equipment that was used in the production of gong were brought to the production site in Benguet, and training was conducted among the natives. Young men and women were selected during the training to gauge their reception to the new methods. A master gong-maker was asked to make one gong each using the conventional method and the introduced method to compare the production rate.

Results and Discussion

Based on Table 1, lay-outing the blank, cutting the blank with chisel and hammer, and smoothing the edge with a portable hammer were all replaced by using a lathe. All activities requiring manual hammering were replaced with the use of a forging hammer. Trimming the edge with a potable grinder was replaced by using a lathe. Stress-relieving with wood as fuel was maintained because the wood was abundant in the area but introduced the use of LPG fuel as an alternative method especially during rainy days when the wood is not so dry and burning cannot be done inside the building. Manual finishing by sanding is replaced by using lathe.

A master gong maker was asked to produce a gong to compare the production time using the conventional method and the introduced method. The production time is tabulated in Table 2.

Based on Table 2, a gong can be produced in 41 minutes with the introduced method as against the 116 minutes using the conventional method that meant a productivity rate of almost three times. With the introduced method, the qualities of a gong using the conventional method were maintained: no cracks during folding of the rim because of reduced thickness to 1.7 mm at the folding line; and increased thickness to 2.2 at the edge of the gong.

It was also observed that with the introduction of the equipment, an unskilled gong maker could match the speed of a skilled gong maker without experiencing fatigue so he can continue working on the following days. Without the equipment, a skilled gong maker will experience extreme fatigue so that he has to rest for a day or two after a day's

work. When it comes to safety, the gong maker will no longer be using his toes for holding the material, hence avoiding the risk of hitting his toes during hammering with the use of the introduced mechanized forging hammer.

Hands-on Training with Equipment

The new methods were introduced to a local master gong maker, who in return assisted in training other gong makers. The trainees included women and young boys and girls.

FIGURE 6. A young man using brass during training

FIGURE 7. A woman using aluminum during training

Table 1. Changes in Gong Production Processes

Conventional Method	Introduced Method
1. Lay-outing the blank diameter with protractor	Chucking the brass sheet on metal lathe
2. Cutting the blank with chisel and hammer	Turning on lathe
3. Smoothing the edge with portable grinder	Smoothing with lathe
4. Inscribing boundaries for hammering	Marking with lathe
5. Manual hammering near the edge	Mechanized hammering using forging hammer
6. Manual second round of hammering	Mechanized hammering using forging hammer
7. Manual third round of hammering	Mechanized hammering using forging hammer
8. Manual fourth round of hammering	Mechanized hammering using forging hammer
9. Stress relieving by heating with wood	Use LPG fuel during rainy days
10. Manual hammering to flatten the bottom	Mechanized hammering to flatten the bottom
11. Manual hammering to remove wrinkles	Mechanized hammering to remove the wrinkles
12. Manual hammering to highlight the bottom corner	Mechanized hammering to highlight the bottom corner
13. Trimming of edge with potable grinder	Trimming with the use of metal lathe
14. Finishing with manual sanding	Sanding using lathe

Table 2. Gong Production Time

Conventional Method		Introduced Method	
Process	**Time (min)**	**Process**	**Time (min)**
1. Lay-outing the blank diameter with a protractor	5	Chucking the brass sheet on metal lathe	1
2. Cutting the blank with chisel and hammer	15	Turning on lathe	5
3. Smoothing the edge with portable grinder	10	Smoothing with lathe	2
4. Inscribing boundaries for hammering	1	Marking with lathe	1
5. Manual hammering near the edge	6	Mechanized hammering using forging hammer	2
6. Manual second round of hammering	6	Mechanized hammering using forging hammer	2
7. Manual third round of hammering	6	Mechanized hammering using forging hammer	2
8. Manual fourth round of hammering	6	Mechanized hammering using forging hammer	2
9. Stress relieving by heating with wood	8	Use LPG fuel during rainy days	4
10. Manual hammering to flatten the bottom	10	Mechanized hammering to flatten the bottom	5
11. Manual hammering to remove wrinkles	10	Mechanized hammering to remove the wrinkles	5
12. Manual hammering to highlight the bottom corner	8	Mechanized hammering to highlight the bottom corner	3
13. Trimming of edge with portable grinder	5	Trimming with the use of metal lathe	2
14. Finishing with manual sanding	20	Sanding using lathe	5
Total	116	Total	41

(a)

(b)

FIGURE 8. Closer view on the material during processing

During training with the forging hammer, the trainees started by using an aluminum sheet and later used the brass sheet. Hardwood was used as a die during forming. Hardwood was relatively soft compared to metal die, so it avoided the formation of scratches on the underside of the cup. Two hands held the material firmly against the wooden die unlike in the conventional method that the material was held by toes so the possibility of springing out and hurting the gong maker. A footswitch stopped or switched on the forging hammer instantly for safety on an operation.

A closer look at the material showed in Fig. 8 a and b during processing proved they can already make the cup-like shape that is the primary requirement for making gong.

Conclusion

With the introduced methods of gong production, the processing time for one gong was reduced from 116 minutes to 41 minutes, which almost tripled the production rate. The methods were welcome changes to the gong makers due to ease and safety in operation. The methods qualified to the GAD program since they were easily adaptable to young people and women who used to shy away from making the gong. Through the project, it was proven that there is a great chance of preserving the tradition and culture of the gong- making in Benguet.

Recommendation

Tuning the gong was not a part of the study since it requires a highly-skilled ear of the gong master. It is recommended that an electronic sound comparator be considered for tuning gong in a future similar project.

For a higher production rate, it is recommended to use three forging hammers. One will do all the hammering needed to produce a cup-like shape; the second will be used for flattening and stretching the bottom and the last one will be used for hammering the rim. Using additional hammers will reduce the time for setting up tooling for different operations.

When there is higher market demand, it is recommended to study the possibility of using a drawing die and the possibility of time-sharing of a hydraulic press in the production of a gong.

Acknowledgement

Gratitude goes to the DOST-PCIEERD for funding the project; to the MIRDC management for supporting all other requirement of the project especially the use of fabrication facility; and to the project team who worked hard for the project completion:

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Validation of the Hybrid Electric Train (HET)

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Abstract

The Hybrid Electric Train (HET) developed by the DOST-MIRDC underwent validation with the guidance of the Philippine National Railways (PNR) being the identified independent third party. As part of the workflow in a railway vehicle development, validation is a procedure that checks if the train meets requirements and specifications, and if it fulfills its intended purpose. Using the RAMS Model for a railway system, the train was validated for 150-hour run on PNR tracks between Alabang and Calamba Stations, having three (3) loops per day. The PNR inspection team strictly monitored the train performance, logging every malfunction and/or error during the test run. The validation was generally a success, with a validation report from the PNR showing that majority of the findings are related only to car body issues: mostly loose bolts or screws; and damage in the car body and window panels due to the PNR's track condition. Nevertheless, the PNR recommended further optimizations of the HET such as the installation of high-powered headlights and railway-grade horns to be provided by their end.

Keywords: validation, hybrid electric train, RAMS

Introduction

Validation, which is an independent procedure, checks if a train meets requirements and specifications. It also checks if the train fulfills its intended purpose. Clearly, it is a crucial part of the workflow in a railway vehicle development [1]. Typically, validation of this type of safety-critical railway system is performed by means of an on-site test [2].

Several studies have already been made on the importance of performing validation for a railway system. In the study conducted by Chen X. et al [1], validation was used to assess a railway signaling system. Their work enhances the coherence and consistency of the information exchange between the system development and the system verification, to improve the work efficiency. The study of Bonacchi A. et al [3] utilized verification and validation process for railway interlocking systems. The authors showed that the problem has been addressed at the final validation stage of production interlocking system, by means of a model extraction procedure that creates a model of the internal behavior in order to reduce the high costs of direct validation of the target system. Mohod, A. et al [4] made use of the same method for the automated train ticket system. The proposed system helps to allocate seats to the passengers and waiting tickets automatically.

While the DOST-MIRDC intends to secure the performance of the train before its public use, validation was also performed as the final phase of the development. The word "validation" is sometimes preceded with "independent," indicating that it is to be performed by a disintegrated third party. In this study, the PNR was the identified third party.

Methodology

An on-site validation of the HET was conducted on the PNR tracks. Prior to this, the Operation and Maintenance Manual (OMM) for the train was written.

Pertinent preparation procedures also took place to further smoothen the validation. Train optimization mainly includes the installation of railway-standard speed lever, labelling of train components, additional

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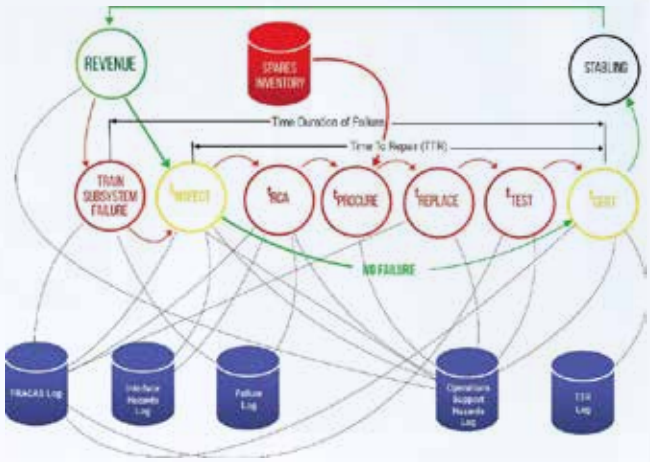

Fig. 1 RAMS Operating Model for HET

Fig. 2. Announcement of the validation test run timetable to passengers at every station

monitoring and safety programming of the HMI and PLC, and scheduled maintenance of train main systems. Training of PNR-authorized drivers was then conducted to familiarize them with the operation of the train.

A. Development of Validation Test Plan

a.1. RAMS Operating Model

The RAMS Operating Model as shown in Figure 1 was developed with reference to Reliability, Availability, Maintainability and Safety (RAMS) in Railway System. It focuses to identify and reduce the safety relevant failures or to eliminate the consequences of the failures throughout the life cycle. The objective is to minimize the residual risk from the safety-related failures in which the tolerability of safety risk of a railway system is dependent upon the safety criteria set by legal authorities or by the railway duty holder in accordance with the rules given by legal authorities.

a.2. Validation Process

The HET was scheduled to run three (3) loops per day to complete the 150-hours of validation run along the track segment between Alabang to Calamba guided by the time table shown on the Passenger Advisory in Figure 2.

During its operation, the scheduled maintenance was carried out to ensure service reliability and availability of the HET. The operation plan of the HET was designed to comply with the existing operational procedure of the PNR. By this, incident of failure during operations were reported by the train personnel and logged through the Control Center.

The inspection team from the PNR performed the side frame, underframe, interior, and function test inspection of the HET based on the submitted OMM by the Project Team. An inspection supervisor certified that the HET underwent inspection prior to turnover to the maintenance team that performed the maintenance activities

The diagram on Figure 3 depicts the overall validation process for every component under inspection.

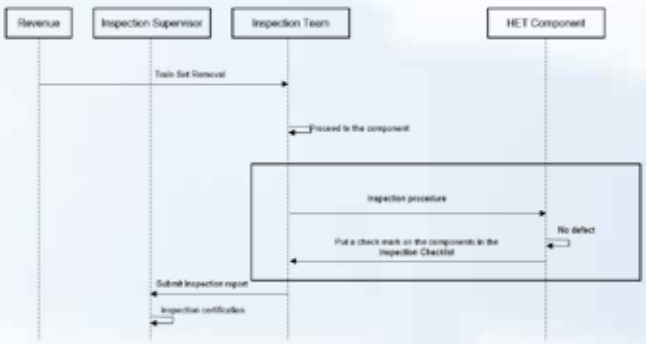

Fig. 3. Validation process of the respective inspection to corresponding HET components

B. Validation Test Run

Guided by PNR's standard operating procedure, the following activities were performed before the actual run.

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- *HET inspection* - the train was inspected using the MIRDC's Inspection Checklist.
- *Diesel Refueling* – the number of gallons of diesel to attain full tank again was recorded to determine the fuel consumption of the previous testing day run.
- *Issuance of Certificate of Rail Worthiness* - MIRDC issued PNR Control Group on a daily basis Certificate of Rail Worthiness informing them HET was operational.
- *Issuance of Line Clearance from PNR* - designated PNR station chief in Calamba issued on a daily basis line clearance for HET to run.
- *Registration of Passengers* - to monitor the number of passengers, registration booth manned by MIRDC Project Staff was set up at every station between Calamba and Alabang. PNR will be using these data to determine the operating hour on rail track of HET upon its turnover.

Ideally, the train should depart and arrive at every station as scheduled. Along the fleet, whenever there was any malfunctioning or sudden stop, its causes were logged by the designated PNR Chief Conductor. Five (5) personnel from PNR formed the daily Inspection Team who monitored every train component. The Inspection Team examined the side frame, under frame, interior and function test of the HET to check for any irregularities. The result of the daily checklist was handed over to the Project Team the following day for mitigation of potential issues.

Discussion of Results

A. Validation Test Report from PNR

a.1. Availability

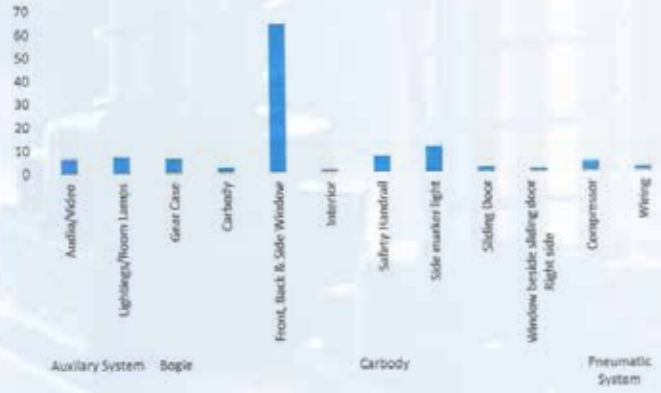
As per the HET schedule, the train must complete a total of 3 loops per day or 150 hours of operation. Based on the operational data, the HET finished a single loop only on the ninth day. This was because the coolant level was too low, which was a generator set radiator issue. The engine temperature was too high due to insufficient ventilation of the genset causing high temperature reading. The Project Team referred the issue to the genset supplier, which was properly and promptly addressed. No reoccurrence of the same findings was logged or reported until the end of the test period.

a.2 Failure Log

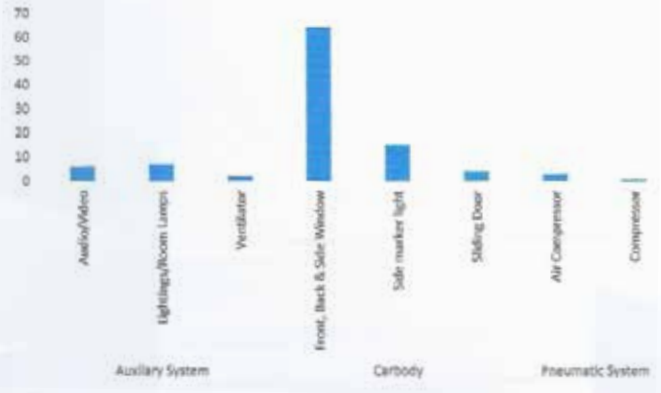
The inspection was made every day after the HET finishes its scheduled trips, the frequency of inspection was designed to increase the chances of discovery of failure.
Based on the data gathered through the inspection, it was found out that majority of the findings are related to carbody issues. Mostly loose bolts or screws, and damage in the carbody and window panels due to the track condition of PNR.

The following illustrations show the breakdown of findings per coach:

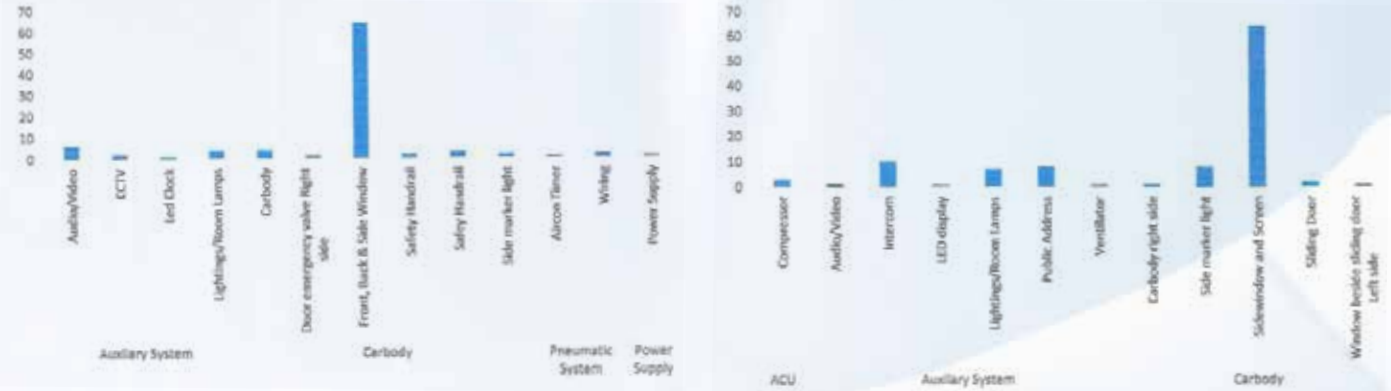
Passenger 1 Coach (P1)



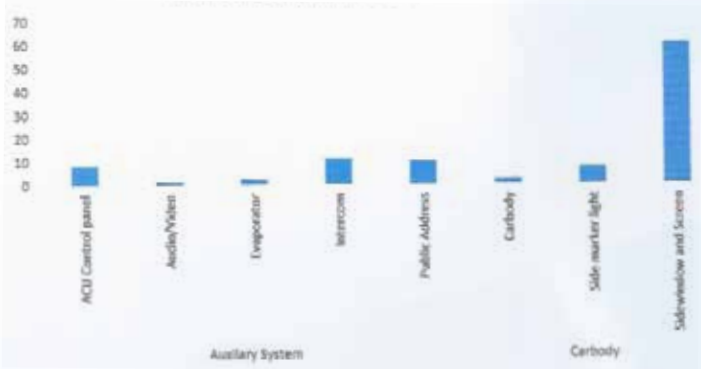
Passenger 2 Coach (P2)



Passenger 3 Coach (P3)



Power Coach



b.3 Finding

As reflected in the validation report, the following operational and safety issues were identified:

- Defective Public Address System (PAS)

This may be caused by its loose wiring connections. It can be noted that the PAS used is not of railway grade, which means it may not handle vibrations during operations. It is hereby recommended that all equipment and connections to be used must comply with the requirements and standards for railway or transportation system to address connection failures caused by vibrations.

- Missing or lost screws of the safety handrails

This may pose a hazard to the passengers using the safety handrails. Safety handrails with missing or lost screws may not be able to absorb the weight or force applied to them when the situation requires (e.g. application of emergency brakes).

Further verification shows that the ends of the handrails were bolted in the carbody which may be sturdy enough to absorb weight or force while providing support to the passengers.

- Deadman's Switch

It is recommended to adopt the existing settings of the PNR Hyundai Rotem's deadman's switch.

- Railway Grade Horn and Headlight

Observation shows that the horns installed were not loud enough and the headlights are not luminous enough. These may pose hazard to ongoing traffic and pedestrians since they may not be noticeable at some distance. It is recommended to adopt existing horns and headlights of PNR to attain an audible horn sound and headlight designed for railway system.

Conclusion

The HET successfully passed the validation testing – the last phase of the RAMS Testing – after completing 150 hours run with no major failure encountered on the rail segment between Calamba and Alabang Stations. The validation report from the PNR shows that majority of the findings are related only to car body issues. Mostly, loose bolts or screws, and damage in the car body and window panels due to the track condition of PNR. Nevertheless, PNR recommended further optimizations for the HET such as the installation of high-powered headlights and railway-grade horns to be provided by their end.

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White Paper: The Hybrid Electric Road Train as Mass Transport Alternative

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Abstract

This paper is intended to present both versions of the Hybrid Electric Road Train (HERT), the Regular HERT and the Light HERT, as alternative to the existing mass transport vehicles like the articulated bus, double decker bus, and regular bus. The comparison focused on the evaluation of maximum capacity per hour per direction and headway. In terms of operational safety, the identified vehicles were compared based on distance before collision in between units during operation. The results of the computation showed that the HERT is a more viable option for higher passenger demand. In-depth analysis in terms of financial viability and environmental impact are not covered in this paper, though estimates of initial costs of investment for the vehicle units were included.

Keywords: Hybrid Electric Road Train (HERT), Regular HERT, Light HERT, Ridership, Headway, Distance Before Collision

Introduction

Countries worldwide have their own mass transportation systems to move people in large numbers at the same time from one place to another. Mass transportation is the movement of people within urban areas using group travel technologies [1]. Its concept is to carry people in the same vehicle, which can be in the form of buses or a collection of attached vehicles like trains. A mass transportation system features movement of people in the same travel corridor with greater efficiency.

This paper presents the Regular HERT and the Light HERT in comparison with the available alternative transport system in the Philippines, all of which are offered as solutions to the country's growing land mass transportation problem. As this paper focuses on the conceptual operational aspect, in-depth economic projections and environmental impacts are not among the factors considered in comparing and selecting the locally-available transportation technology over imported vehicles. The modes of mass transportation compared in this paper are following:

a. Regular HERT – 5 Coaches, with 240-passenger capacity, locally made;
b. Light HERT - 4 Coaches, with 120-passenger capacity, locally made;
c. BRT-MAN – 18m articulated bus with approximately 150-passenger capacity [2], imported
d. Regular Bus – 12.3m length, with 60-passenger capacity, imported or local; and
e. Double Decker Bus – 12.7m length, with 90-passenger capacity, imported.

2. Comparison of five modes of transportation in terms of basic specifications

Table 1 presents the comparison of the five modes of transportation in terms of basic specifications. Data about the developed HERT prototypes are based on actual dimensions and results of performance tests.

3. Salient features of a mass transportation system

The salient features of a mass transportation system are the focus of the evaluation of the identified modes of transportation. Studied for this paper are the following: Maximum Capacity per Hour per Direction (MCPHPD); Time Before Dispatch or Headway; and Distance Before Collision (DBC). Other parameters such as number of

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Table 1. Basic Specifications of the Five Modes of Mass Transportation.

	Parameters	CRT - 5 coaches	LCRT - 4 Coaches	BRT - MAN	Regular Bus	Double Decker
1	Passenger Capacity	240	120	150*	60	90
2	Turning Radius, in m	25	20	12	12	12
3	Speed, in kph	60	60	60	70	60
4	Acceleration time to reach 60kph	20	20	20	15	20
5	Length, in m	43	25	18	12.3	12.7
6	Width, in m	2.5	2.1	2.5	2.5	2.55
7	Height, in m	3.5	3.5	3.6	3.64	4.14
8	Cost per unit, in Million pesos	37 (85% of devt.cost)	22 (85% of devt. Cost)	100/5units	4.2	33M(355UKpounds)

* The value is considered as the average of the maximum capacity of regular 18m articulated bus at 140 passenger and the maximum value of MAN at 158 as stated in the article contained in https://www.mantruckandbus.com.

Table 2. Maximum capacity based on 1-min headway.

Maximum Capacity Based on 1 Minute Headway						
Parameters		Regular HERT- 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Maximum Capacity per hr per direction	14,400	7,200	9,000	3,600	5,400
2	No. of Units Plying	80	80	80	70	80
3	Time Before dispatch of next unit, sec (Headway)	60	60	60	60	60
4	Distance Before Collision, in m	436	436	436	567	436
5	Total Cost of units, in million Php	2,960	1,760	1,600	294	2,640

units required and total cost of units were also considered.

Maximum Capacity per Hour per Direction (MCPHPD). The MCPHPD refers to the measure of the maximum passenger capacity of the transportation mode for a single direction. This terminology is synonymous to passenger per hour per direction, or PPHPD, that is being referred to in various mass transportation articles.

Time Before Dispatch (Headway). The Time Before Dispatch, or commonly known as Headway, is the measure of time in between dispatch of succeeding vehicles. The values computed are highly influenced by the MCPHPD and dwelling time of vehicle in the station. The dwelling time, which is 20 minutes, used in succeeding computations is applied to all identified transportation modes.

Distance Before Collision (DBC). The DBC is an important factor in considering operational safe distance between vehicles. It is a calculated value representing the distance between the front of the incoming vehicle and the rear end of the vehicle that is about to leave the station. The longer the DBC is, the safer the system would be in terms of vehicular collision.

4. Consideration of headway of identified transportation modes

Traffic is expected to build-up on road intersections where the dedicated lanes will cross. The comparison among identified transportation modes is based on the premise that intersections will be free for at least 60 secs on a single direction. Thus, the data presented below are all based on the TBD, or Headway, that was accordingly limited to 60 secs.

Comparison of MCPHPD Based on One (1) Minute Headway

Table 2 below shows the comparison of the identified transport systems. In limiting the headway to approximately 60 secs, the Regular HERT–5 Coaches is seen to have the largest MCPHPD of 14,400. This is followed by BRT-MAN and Light HERT at 62% and 51% of the Regular HERT-5 Coaches' capacity, respectively. The distance before collision is about 0.436km for the four systems, except for the regular bus which is 0.567km. Based on an 18-hour operation, the cost per passenger for the BRT-MAN is computed to be P4,900, while for the Regular HERT-5 Coaches, it is computed to be P5,700/ passenger. The P800 difference, however, may still be subjected to further in-depth analysis to determine if the Regular HERT-5 Coaches' being locally- developed can offset its higher computed value of cost per passenger.

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Table 3. Headway based on 8,889 MCPHPD.

Maximum Capacity Based on 320,000 ridership per day (based on Feasibility of BRT in Cebu City)						
Parameters		Regular HERT - 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Maximum Capacity per hr per direction	8,889	8,889	8,889	8,889	8,889
2	No. of Units Plying	50	99	79	171	132
3	Time Before dispatch of next unit, sec (Headway)	97	49	60	24	37
4	Distance Before Collision, in m	>1000	246	448	Collision	100
5	Total Cost of units, in million Php	1,850	2,178	1,580	718	4,356

Comparison of Headway at Given MCPHPD

Comparison of the five modes of mass transportation using a fixed MCPHPD further emphasizes the significance of headway. By setting the capacity at 320,000 passengers as baseline data, the MCPHPD is computed at 8,889 based on an 18-hr per day operation. Table 3 below shows that with the given figures as basis, headway is determined to be 9 seconds, 60 seconds, and 49 seconds for the Regular HERT-5 Coaches, the BRT-MAN, and the Light HERT-4 Coaches, respectively.

Table 3 also indicates that as the MCPHPD is further increased, the more the headway will be reduced up to a point where the identified transport mode is no longer operationally viable. This is illustrated in Figure 1 where the values of MCPHPD were increased arbitrarily up to the point where the headway is almost 30 seconds. Headway lesser than 30 seconds will result to a shorter distance between vehicles, that will lead to possible collision. The tables of computation are shown in Appendix A.

Figure 1 shows that only the Regular HERT -5 Coaches is more appropriate at higher passenger demand. The BRT-MAN and Light HERT-4 Coaches may be applicable, however, the risk of vehicle collision is high. This will be shown in the succeeding sections. The regular and double decker buses are no longer applicable at higher passenger demand.

The 2010 report of Cebu City indicates that the daily passenger demand will reach 320,000. This demand is equivalent to 8,889 MCPHPD for an 18-hour operation. The information presented in Figure 1 may be applied to this scenario. If the BRT-MAN is used to transport the passengers, the headway is 60 seconds, while the Regular HERT-5 Coaches will have a 97 second headway. The MCPHPD of the Regular HERT-5 Coaches can be increased up to 14,662 at 58 seconds headway. This is equivalent to a passenger demand of 527,832 per day. For the BRT-MAN to be comparable with the capacity of Regular HERT-5 Coaches at 14,662 MCPHPD, its headway will have to be reduced to 36 seconds. However, it must be noted that the identified route of BRT system in Cebu City includes a number of vital intersections that will be affected by this very short headway.

Although the BRT-MAN is cheaper in terms of initial investment, the Regular HERT-5 Coaches offers a more realistic operational headway of 97 secs which favors other motorists that are crossing the dedicated lanes of the mass transportation system.

5. Critical consideration on safe operational distance

In the previous section, the analysis focused on the headway which is a factor affecting the road and traffic systems that will intersect or run parallel to the transportation system. Another vital factor in comparing the identified mass transportation modes is the safe operational distance between vehicles. This is a critical factor that contributes to the safety of both the riding public and the motorists traveling along and crossing the transportation system route.

This section considers the stopping distance of the identified vehicle where the evaluation dwells on the

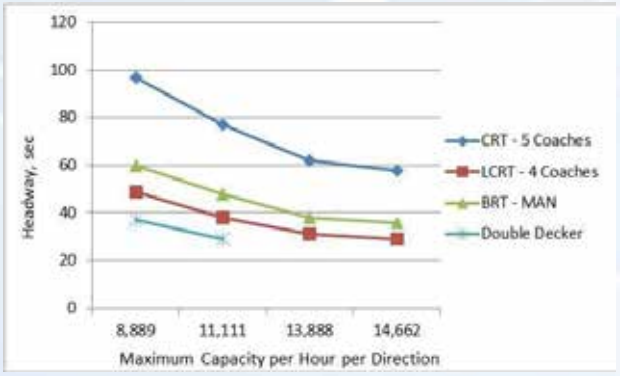

Figure 1. Comparison of how various MCPHPDs affect the headway of the modes of mass transportation.

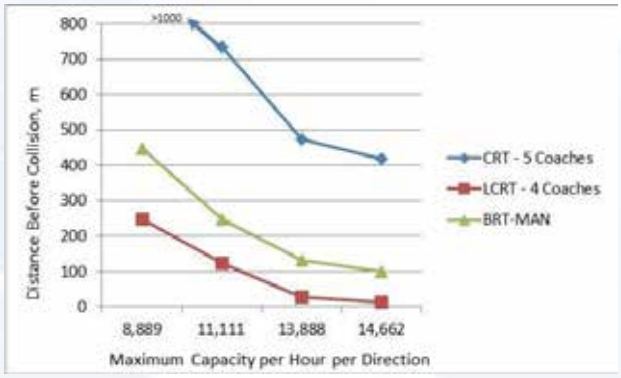

Figure 2. Comparison of how various MCPHPDs affect the DBC of the modes of mass transportation.

Table 4. Comparison of the HERT units and the BRT-MAN in terms of various parameters when maximum capacity is based on 695,433 ridership per day along the Lerma-SM Fairview via Quezon Ave. and Commonwealth corridor.

Parameters		Regular HERT- 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)
1	Maximum Capacity per hr per direction (MCPHPD)	19,317	19,317	19,317
2	No. of Units Plying	107	215	172
3	Headway, in sec	45	22	28
4	Distance Before Collision (DBC), in m	181	Collision	8
5	Total Cost of units, in million Php	3,959	4,730	3,440

DBC at every increase in MCPHPD. Using the results of computation presented in Appendix A, Figure 2 is constructed to present the graph of the decrease of DBC as MCPHPD is increased for the three identified transportation modes. The regular bus and double decker bus were no longer included in the analysis since the baseline capacity used is 320,000 and above. Appendix A shows that Regular and Double Decker buses will have zero DBC at 320,000 passenger demand for a 1-km distance of stations.

According to the state of Utah, the typical stopping distance of a light truck travelling at 40mph (65kph) is about 169ft (51.5m). The stopping distance is the combination of braking distance and the reaction time to bring the vehicle to a complete stop. Following the same concept, a typical BRT-MAN can adopt a stopping distance of about 50m. However, by using a factor of safety of 2, this paper considers 100m stopping distance as the limit for the BRT-MAN. In the case of Regular HERT-5 Coaches and Light HERT-4 Coaches, the maximum stopping distance using only the electronic brakes is 200m based on actual tests. Since the Regular HERT-5 Coaches and Light HERT-4 Coaches have an additional mechanical brake system similar to the one used by the light trucks, it follows that the factor of safety for the stopping distance of both HERT units is approximately equal to 2.

Considering that the minimum DBC is 100m, Figure 2 shows that BRT-MAN is only capable up to 14,662 MCPHPD while the headway is lowered down to 36 seconds. On the other hand, Regular HERT-5 Coaches is considered safe with more than 400m DBC at 14,662 MCPHPD and headway of 58 seconds.

6. Comparison of MCPHPD based on identified corridors

MCPHPD of identified transportation modes based on ridership along Manila to Quezon City corridor

The National Center for Transportation Studies (NCTS) identified a route from Manila to Quezon City via Lerma-Quezon Ave-Commonwealth corridor to be having 695,433 ridership per day. Table 4 below presents the comparison of MCPHPD, headway, and DBC of the Regular HERT-5 Coaches, Light HERT-4 Coaches, and the BRT-MAN to evaluate their suitability. The same methods previously used were applied in this section. Having low MCPHPD, the regular bus and the double decker bus are no longer included in the comparison.

Table 4 shows that only Regular HERT-5 Coaches can meet the required ridership since the DBC is a little below 200m with a Headway of 45 seconds.

Operational Doability in Terms of Headway

In considering actual operation wherein safety of passengers and headway play a major factor, the BRT-MAN has serious issues to consider. Table 4 shows that the headway (or time before dispatch of next unit) is only 28 sec. This time interval would prove to be disadvantageous on intersections and U-turn slots for other vehicles along the identified route due to increased traffic hazards. Forcing vehicles to cross every 28 sec on critical intersections such as Welcome-Rotunda, Quezon Ave. Delta intersection, and various U-turn slots along Commonwealth Avenue, among others, will create serious traffic congestion. Secondary roads will be affected as well. It will be disadvantageous and hazardous for the motorists to cut across the dedicated lanes of the mass transport system with less than half a minute time interval.

Operational Doability in Terms of Safe Operating Distance

In the aspect of safety of passengers and motorists during operation, one most common consideration is the safe distance between bus coaches or units. The distance between vehicles must be ensured in such a way that collision does not occur in any event. For the ridership considered in Tables 4, the BRT-MAN has issues on possible danger of collision as it offers only an 8m distance. The computed values can be interpreted that as a BRT-MAN unit starts to leave a station, the incoming unit is only 8m away which is even shorter than the actual length of a BRT-MAN of 18m and much shorter than the safe stopping distance of 100m.

Table 5. Comparison of the HERT units and the BRT-MAN in terms of various parameters when maximum capacity is based on 541,313 ridership per day along C5 (SLEX Commonwealth corridor).

Parameters		Regular HERT - 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)
1	Maximum Capacity per hr per direction (MCPHPD)	15,036	15,036	15,036
2	No. of Units Plying	84	167	134
3	Headway, in sec	57	29	36
4	Distance Before Collision (DBC), in m	394	7	87
5	Total Cost of units, in million Php	3,108	3,674	2,680

7. Maximum capacities of available transport system based on ridership along C5 through SLEX-Commonwealth Avenue corridor

The NCTS estimated a ridership of 541,313 passengers per day along C-5 Road via SLEX-Commonwealth Avenue roads. Table 5 presents the results of comparison of the HERT units and the BRT-MAN using computation methods applied in previous sections. As shown, the BRT-MAN and the Light HERT-4 Coaches can both fulfill the required MCPHPD. However, only the Regular HERT-5 Coaches is capable of providing the safest distances of 394m, and the safest headway as well. Given these comparisons, the Light HERT 5-Coaches is more favorable than BRT-MAN.

8. Comparison of identified transport mode with MRT

The previous sections showed that the Regular HERT-5 Coaches is most appropriate in terms of MCPHPD, headway and safe DBC. However, these comparisons are still inconclusive without benchmarking from an existing transportation system in the country, in this case the MRT. The classification of MRT falls under the railway system which is considered an efficient mode of mass transportation worldwide. Presentations in Sections 2 to 4, identified the Regular HERT-5 Coaches as advantageous over other modes of transportation such as BRT-MAN (18m). To show how these advantages are comparable with proven a system, Figure 3(a), (b) and (c) illustrate the comparison of MRT with the top two alternatives, the Regular HERT-5 Coaches and BRT-MAN.

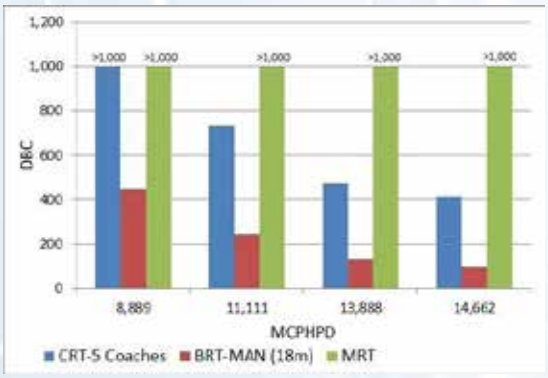

Figure 3(a). Comparison of the DBC of the Regular HERT-5 Coaches the BRT-MAN, and the MRT

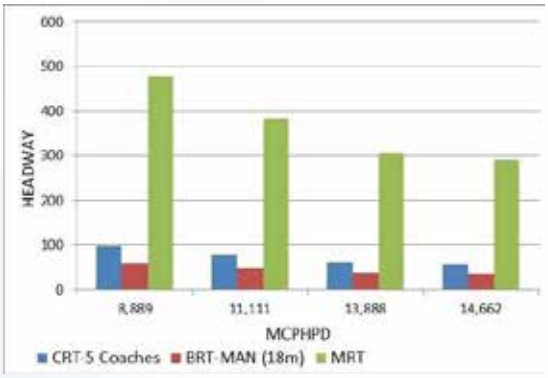

Figure 3(b). Comparison of the Headway of the Regular HERT-5 Coaches, the BRT-MAN, and the MRT

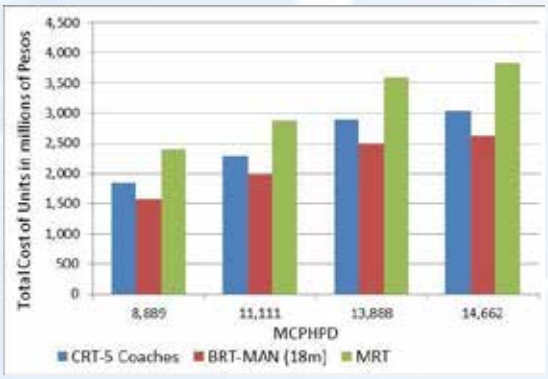

Figure 3(c). Comparison of the initial cost of coach units of the Regular HERT-5 Coaches, the BRT-MAN and the MRT

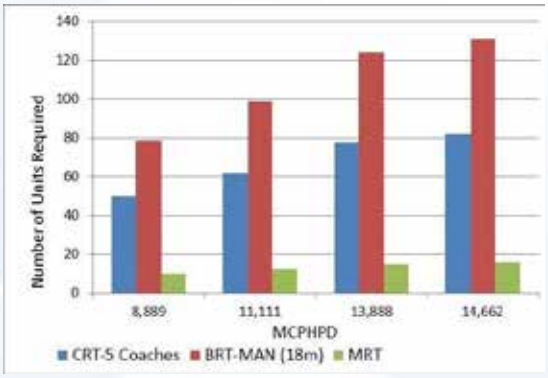

Figure 3(d). Comparison of the Regular HERT-5 Coaches, the BRT-MAN, and MRT in terms of the number of units required

Figure 3(a) shows that both the Regular HERT-5 Coaches and the MRT still have a safe distance before collision of more than 1,000m at ridership less than 320,000 (or 8,889 MCPHPD). On the other hand, the DBC of the BRT-MAN is already less than half of that of both the MRT and the Regular HERT-5 Coaches, and still continues to decrease as the MCPHPD increases. Due to larger capacity of MRT at 1,182 passengers per train set, the headways at different MCPHPD are far above than Regular HERT-5 Coaches, as shown in Figure 3(b).

Despite all the advantages, the MRT has its own downside if comparison of initial cost per vehicle is considered. Figure 3(c) shows that in every MCPHPD set, the initial cost of MRT is larger than the Regular HERT-5 Coaches and BRT-MAN although the number of units required is far less as shown in Figure 3(d). This is due to the cost per set of MRT that amounts to about P240,000,000 excluding infrastructure cost. Computed values in Figure 3 are tabulated in Appendix B.

9. Summary and Conclusions

Various types of mass transportation have their own inherent advantages and disadvantages, be it in terms of safety, maximum capacity and initial cost of investment. With the comparison results presented in Tables 2 to 5 and Figures 1 and 2, the Regular HERT-5 Coaches offers a more practical option in terms of operational considerations like headway, distance before bus/coach units, and maximum capacity. Considering that the computed headways represent single direction only, a road intersection will be heavily affected if both directions will be used by the transportation system since the coach/bus units on both directions will not always pass the intersections at the same time. Hence there exists the possibility that during actual operation the intersections will be stopped longer than the computed headways.

It was further established that the Regular HERT-5 Coaches is more suitable and advantageous for high passenger demand over other modes of transportation like the BRT-MAN, Regular Bus, and Double Decker Bus due to operational do-ability in terms of realistic estimates of Headway and Distance Before Collision. Moreover, the flexibility of the Regular HERT-5 Coaches allows the number of coaches to be increased or decreased to suit passenger demand.

In terms of initial cost of investment, the Regular HERT-5 Coaches may appear to be disadvantageous as compared with BRT-MAN. However, this should not be the case as the HERT is built using locally-available technology unlike the BRT- MAN which is completely dependent on foreign technology. The local HERT opens opportunities to develop and enhance local capabilities in mass transportation system. The adoption of the HERT as an alternative mass transportation system in the country will create new job opportunities and develop expertise in this field of technology as well.

Opting for the HERT as an alternative mass transport system will lessen the problem on availability of imported parts which most of the time are limited to the country where the units were procured. The design of both the Regular HERT and the Light HERT is not dependent on specific brand or manufacturers, therefore the technology adopter/licensee can have a pool of suppliers when it comes to corrective and preventive maintenance problems.

The computations further showed that ordinary and double decker buses are not appropriate for high ridership demand, such as above 300,000, due to limitation in the passenger carrying capacity. The computation of headway already includes dwelling time of 20 secs. In this case, regular and double decker buses will have longer dwelling time for loading and unloading during peak demand hours due to their narrow doors and stairs which are inherent design limitations. The HERT and the BRT-MAN have designs that already address these limitations.

The HERT ridership estimates presented in this paper were purely based on the actual capacity of the prototype. This positively indicates that the capacity of both the Regular HERT and the Light HERT can still be increased by re-designing the position and location of the drive motors and the articulation link system in order to allow passing through in- between coaches.

In addition to all of these, why is the HERT an efficient transportation system?

The HERT is considered an efficient transportation system. Taking into consideration the basic definition of mass transportation system, the HERT has the following features: it is composed of modular connected coaches designed to accommodate more passengers; its doors are designed wide enough to allow fast loading and unloading of passengers to reduce on-station dwelling time; and its operation is designed very similar to that of regular trains which has designated stops and definite schedules.

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Appendix

Appendix A. Computation of Headway at various MCPHPD.

Computation of Headway and Distance Before Collision at 320,000 ridership per day

Maximum Capacity Based on 320,000 ridership per day (based on Feasibility of BRT in Cebu City)						
Parameters		Regular HERT- 5 coaches	Light HERT- 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Maximum Capacity per hr per direction	8,889	8,889	8,889	8,889	8,889
2	No. of Units Plying	50	99	79	171	132
3	Time Before dispatch of next unit, sec (Headway)	97	49	60	24	37
4	Distance Before Collision, in m	>1000	246	448	Collision	100
5	Total Cost of units, in million Php	1,850	2,178	1,580	718	4,356

Computation of Headway and Distance Before Collision at 400,000 ridership per day

Maximum Capacity Based on 400,000 ridership per day						
Parameters		Regular HERT- 5 coaches	Light HERT- 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Maximum Capacity per hr per direction	11,111	11,111	11,111	11,111	11,111
2	No. of Units Plying	62	124	99	214	165
3	Time Before dispatch of next unit, sec (Headway)	77	38	48	19	29
4	Distance Before Collision, in m	732	123	246	Collision	22
5	Total Cost of units, in million Php	2,294	2,728	1,980	899	5,445

Computation of Headway and Distance Before Collision at 500,000 ridership per day

Maximum Capacity Based on 500,000 ridership per day						
Parameters		Regular HERT - 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Maximum Capacity per hr per direction	13,888	13,888	13,888	13,888	13,888
2	No. of Units Plying	78	155	124	267	206
3	Time Before dispatch of next unit, sec (Headway)	62	31	38	15	23
4	Distance Before Collision, in m	472	26	130	Collision	Collision
5	Total Cost of units, in million Php	2,886	3,410	2,480	1,121	6,798

Computation of Headway and Distance Before Collision at 527,850 ridership per day

Distance before Collision - 527,850 ridership per day						
Parameters		Regular HERT - 5 coaches	Light HERT- 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
1	Distance Before Collision, in m	418	12	100	Collision	Collision
2	No. of Units Plying	82	163	131	282	218
3	Time Before dispatch of next unit, sec (Headway)	58	29	36	14	22
4	Maximum Capacity per hr per direction	14,662	14,662	14,662	14,662	14,662
5	Total Cost of units, in million Php	3,034	3,586	2,620	1,184	7,194

Summary of computed data based on MCPHPD

	Distance Before Collision (DBC), in m				
Maximum Capacity per Hour per Direction	Regular HERT - 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
8,889		246	448	Collision	100
11,111	732	123	246	Collision	22
13,888	472	26	130	Collision	Collision
14,662	418	12	100	Collision	Collision

	Headway, in Sec				
Maximum Capacity per Hour per Direction	Regular HERT - 5 coaches	Light HERT - 4 Coaches	BRT - MAN (18m)	Regular Bus	Double Decker
8,889	97	49	60	Collision	37
11,111	77	38	48	Collision	29
13,888	62	31	38	Collision	Collision
14,662	58	29	36	Collision	Collision

Appendix A. Computation of Headway at various MCPHPD.

	Distance Before Collision (DBC), in m		
Maximum Capacity per Hour per Direction	Regular HERT - 5 coaches	BRT - MAN (18m)	MRT
8,889	1,000	448	1,000
11,111	732	246	1,000
13,888	472	130	1,000
14,662	418	100	1000
		- greater than 1000m	

	Headway, in Sec		
Maximum Capacity per Hour per Direction	Regular HERT- 5 coaches	BRT - MAN (18m)	MRT
8,889	97	60	478
11,111	77	48	382
13,888	62	38	306
14,662	58	36	290

	Total Cost of units, in million Php		
Maximum Capacity per Hour per Direction	Regular HERT - 5 coaches	BRT - MAN (18m)	MRT
8,889	1,850	1,580	2,400
11,111	2,294	1,980	2,880
13,888	2,886	2,480	3,600
14,662	3,034	2,620	3,840

	Number of units or sets required		
Maximum Capacity per Hour per Direction	Regular HERT - 5 coaches	BRT - MAN (18m)	MRT
8,889	50	79	10
11,111	62	99	12
13,888	78	124	15
14,662	82	131	16

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Improvement and Testing of a Sugarcane Juice Extracting Machine for Muscovado Sugar Production

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Abstract

A small-scale sugarcane juice extracting machine comprised of three (3) crushing rollers was re-constructed, improved, and tested. This research takes into consideration the small and medium-scale sugarcane processors who have special needs for machines for muscovado production. This study involved the improvement of the design and structure of the crushing roller assembly. To optimize the said assembly, the crushing rollers were fastened to the shafts; and the crushing gap between the rollers was adjusted. This study also aimed to improve the juice yield and crushing capacity through the improvement of the pairing and adjustment of the scraper with the serrations of the crushing roller. Based on the testing results, the sugarcane juicer was improved as it showed remarkable higher output capacity at about 580 kg/hr with juice yield of 52%, as compared to its previous output capacity of 200 kg/hr with a yield of 25%.

Keywords: sugarcane, juice extracting machine, crushing rollers, muscovado, bagasse, juice yield

Introduction

The MIRDC delivered a prototype Sugarcane Juicer to RU Machine Shop Corporation for functional testing in 2017. Figure 1a is an exploded view of the machine showing the vital component including the bridge which cannot be seen in a 3D Model presented in Figure 1b.

In 2019, RU Machine Shop reported that the sugarcane juicer can hardly process 200 kgs of sugarcane stalks per hour and that juice extracted is only 25%. RU also observed that there was an overflowing of extracted juice due the clogging of the filter on the juice collecting basin. The prototype hardly gripped and fed sugarcane stalks having more than 25 mm diameter and hardly crush the hard skin of sugarcane stalk having a diameter below 20 mm between the feeding and top rollers. Lately, the rollers no longer rotated, although the prime mover was working perfectly. This situation eventually led to RU to stop the operation.

The knowledge of the basic design and operation of the sugarcane juicer provided basis for any improvement. In order to crush and extract juice, a sugar cane has to pass between at least one pair of rollers. However, feeding will not be easy if there is only one pair of rollers because of varying size of sugarcanes. The operator will always adjust the gap between the rollers to accommodate the biggest size in a given batch of cane that will be fed in single pass. For another pass, the gap will be made smaller and so on until the amount of extracted juice is optimized.

In a three-roller sugarcane juicer, the rollers can be arranged in triangular formation such that one roller become a common partner of the other two rollers. The gap between the first pair is big enough to let cane pass through with initial crushing and then the second pair do the final crushing and extraction of juice.

Based on the report of RU, the MIRDC decided to redesign the bridge between the feed and discharge rollers to prevent the bagasse from going into the collecting basin, increase the efficiency of collecting the juice extracted by the feed roller and to maintain the contact of the bridge (scraper) with the feed roller at all times.

It was also deemed necessary to restructure/revise the design of feed roller to improve its crushing performance, make the gap with the top roller adjustable to suit the size of the sugarcane and improve the extraction rate of the sugarcane juice.

Furthermore, it was suggested to strengthen the connection between the shaft and the drive roller to

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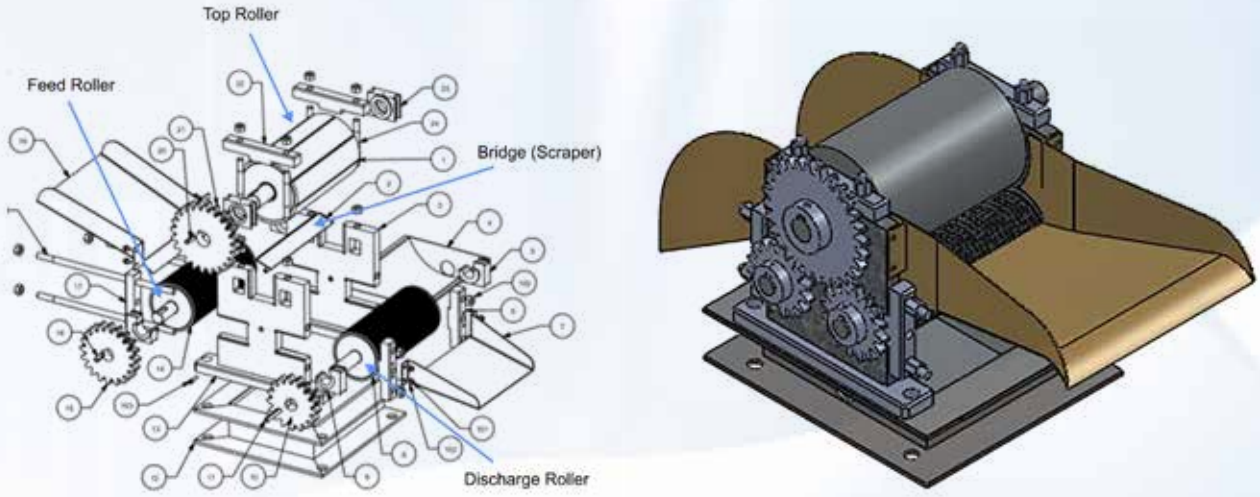

(a) Exploded View (b) Assembled Unit

Fig. 1 3D Model of Sugarcane Juice Extracting Machine

increase its load carrying capacity and also reinforce the feed roller to prevent the possibility of failure as experienced with the discharge roller. Ultimately, this research aims to improve the mechanical strength of the sugarcane juicer and increase its juice extraction efficiency.

Methodology

In this study, the project team examined the important parts of the sugarcane juicer particularly the three (3) rollers and how they affected the low production rate including the poor yield and investigated why the sugarcane juicer failed during the operation. Finally, the team made some modifications in the designs and tested with the actual sugarcane stalks to see if there were improvements in its performance.

Bridge Between the Feed and Drive Rollers

The bridge is similar to a comb because the presence of serrations, as shown in Fig. 2. Its main function is to facilitate the transfer of the bagasse from the feed roller to the discharge roller. Without this part, it is likely that bagasse gets into the juice collecting basin.

The newly designed bridge, as illustrated in Fig.2, replaced the existing bridge having 1.2 mm thick stainless steel with a 4 mm thick sheet. The thickness was increased to prevent distortion due to the pressure of bagasse passing on top of it. With the thicker material, flatness of the bridge was maintained avoiding large gap with the roller and avoiding the entry of the bagasse onto the filter. For better performance, the bridge was also provided with holes along its length that allowed the juice to drip instantly and prevented the reabsorption by the bagasse.

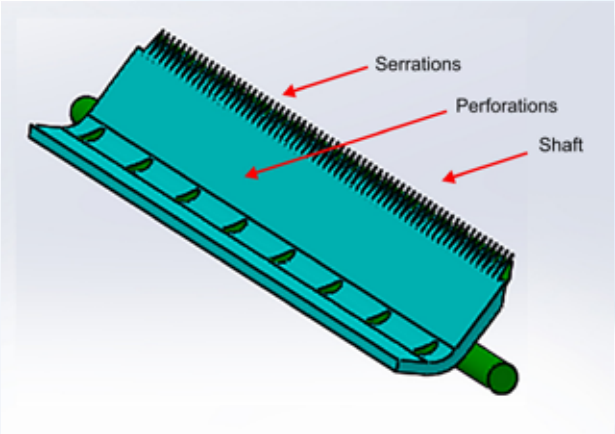

Fig. 2 The Bridge (Scraper)

In addition, the serrations of the bridge were modified to mesh exactly with the serrations of the feed roller. With the exact meshing, the juice clinging on the roller was wiped off effectively thus increasing the juice going to the collecting basin.

The bridge was welded to a shaft before it was installed into the machine. Not shown in the illustration are two set screws that can be adjusted to maintain the fitting of the bridge with the feed roller.

Feed Roller

The feed roller before had serrations that had almost flat surfaces in contact with the skin of the sugarcane. Because of the flat surfaces, the skin of the sugarcane could hardly get broken resulting in poor extraction of juice. The roller was modified by making the serrations which easily penetrated through the hard skin of sugarcane to expose the soft core of the sugarcane. With the skin broken, the

cane was spread further apart for better crushing and extraction of juice at the discharge roller.

The feed roller was machined with some horizontal slots. The slots facilitated the feeding of even the large-diameter sugarcane stalks by biting on the hard skin.

Connection of Shaft, Feed Roller, and End Flanges

The feed roller consists of an outer cylinder made of stainless steel pipe with mild steel forced-fitted to the inner wall; the end flanges were made of cast iron while the shaft was made of AISI 4140 steel. The mild steel pipe was welded to the cast iron end flanges, and the end flanges were welded to the AISI 4140 steel shaft. Because of the differences in the kind of materials, failures occurred at the welded joints. The length of the weld between the shaft and the flange is also short, so it failed easily and obviously. On the other hand, the length of the weld of the end flange with the roller was four times longer so the failure became visible only with the penetrant test.

The team decided to change the material of the end flanges with AISI 4140 steel and maintained the other materials.

The flanges were secured to the cylindrical stainless steel with eight 12 mm diameter by 40 mm dowel keys and secured to the shaft with four special keys having a basic dimension of 6mm x 10 mm x 60 mm. The dowel keys were spot welded to the flanges and to the cylindrical stainless steel. The special keys prevented the axial movement of the flanges without the use of setscrews.

Connection of Discharge Roller

The discharge roller acted as the driver for transmitting power to the top roller and the feed roller so it carried most of the load when in operation. Prior to the modifications, there was an extensive welding damage. The repair of the discharge roller was done was in the same way with the feed roller.

Feed Roller Gear

Another cause of the low production rate was the large gap between the top roller and the feed roller. A large gap made the initial crushing of the sugarcane stalks ineffective for crushing stalks having a small diameter.

To accommodate varying sizes of sugarcane stalks, the feed roller gear shown in Fig. 6 that was connected to the feed roller was redesigned to have one tooth less than the previous gear. The modification effectively decreased the outside diameter of the gear, and created a gap between the feed roller and the top roller that allows processing of smaller size adjustable between 12 to 8 mm. With this gap, the sugarcane juicer was able to crush the stalks having diameters ranging from 16 to 32 mm.

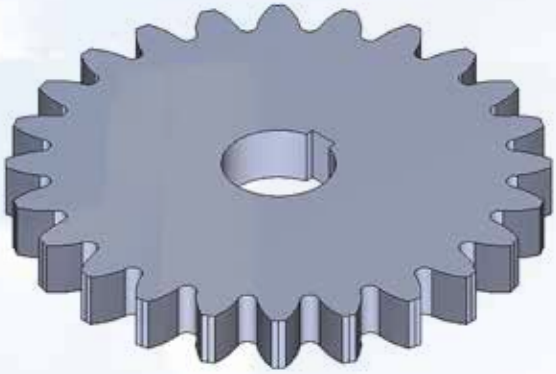

Fig. 6 Feed Roller Gear with 24 Teeth

Fabrication

The serrations of the bridge were machined using CNC wire-cut EDM. After machining, the bridge perfectly fitted the mating grooved of the feed roller. The tooth profile of the gear was conveniently formed with a CNC milling machine. The machining and assembly of the discharge roller required specific flow of activities to ensure concentricity and alignment: (1) Counterbored concentrically both ends of the cylindrical stainless steel pipe (2) machined 4140 steel flange to an outside diameter closely fitting the inside diameter of counterbored of stainless steel pipe, and the inside diameter closely fit the outside diameter of the shaft; machine the keyways with slotting machine; (3) machine keys by milling; (4) sub-assemble one flange and keys at one end of the shaft; then insert to one end of the stainless steel pipe; (5) sub-assemble another flange and keys at the other end of the shaft (6) drill for four dowel holes equally spaced at the parting line of the stainless steel pipe and the flange and insert the dowels and weld to fix.

Testing

1. Gap Between Discharge Roller and Top Roller

An initial test was conducted to determine the optimum gap between the discharge and top rollers. The gap affects the amount of juice that can be extracted and the performance of the motor. The optimum gap was found to be the smallest size of the gap that allowed the sugarcane stalk to pass without damaging the motor. During adjustment, the motor was being monitored until it was operating as close to the amperage rating marked on its nameplate. From the preliminary test, it was found out that the optimum gap was 0.6 mm.

2. Gap Between Feed Roller and Top Roller

The gap also dictated the performance of the crusher. A smaller gap was not favorable for feeding since the pair was not able to bite the cane. Bigger gap was also

not favorable because the pairing between the discharge and top rollers hardly crushes the canes resulting to less extraction of juice. An appropriate gap was determined as the size where there was a crushing effect on the cane with sufficient grip to transfer the cane to the discharge roller. It was determined that the appropriate gap was 10.5 mm.

3. Size of Sugarcane

The size of sugarcane varied from a large diameter near the root to a small diameter near the stalk. The smaller diameter end went first during feeding. When the roller still could not grip the stalk, the gap of the rollers was increased.

Results and Discussion

Test for Appropriateness of Roller Gaps

It was observed during the functional test that the gaps between rollers affected how the driving electric motor works. When the gaps were too small, the electric motor worked hard to crush the canes. This resulted to more juice being extracted, but there was the danger of burning the motor. When the gaps are too big, the motor did not work so hard but the juice extracted was lesser. The degree of work by the motor was monitored by measuring its amperage with a clamp ammeter.

To test the appropriateness of the gaps between rollers, sugar canes provided by RUFMSC were used. From the bulk of canes, it was found that the largest diameter of the cane was 32 mm. The team adjusted the gap between the top roller and the discharge roller to 0.6 mm which was the smallest gap that the machine can attain. The gap between the top roller and the feed roller was adjusted to 10.5 mm which was found to allow sizes of stalks from 16 mm to 32 mm during a preliminary test. The team started the testing with the aim of finding if the machine can work safely with the set gap. Two canes having diameters of 31 and 32 were selected and fed to the machine. The amperage of the motor was monitored at the same time. The result was that the amperage ranged from 18.4 to 22.2. Comparing those results with the 26 rated ampere of the motor, it can be said that the machine can work well and safely with the set gaps and with the largest diameter of the sugarcane. Having observed these, the team proceeded with the next tests.

Test for Extraction Time

To find how long will it take to pass a cane through the machine, six (6) canes were taken from the bulk. Individual and average diameter, length, and weight were measured. The canes were fed to the machine one by one and the resulting bagasse were weighed. The weight of the juice was computed by subtracting the weight of the bagasse to the weight of the cane. For each cane, the ampere reading was taken as well as the processing time. The test results were shown in Table 1.

Due to difficulty of weighing the bagasse of each cane, all the bagasse was collected and weighed as one and obtained 1.36 kgs.

It can be noted from the table that the processing time is proportional to the length of the cane but not to the ampere reading. The ampere reading is proportional to the diameter of the cane. From the results, the yield can also be computed as 1.14/2.5 = 45. 6%.

Test for Juice Yield

Another similar test was conducted but focused on the yield after second passing. Second passing was done by re-feeding the bagasse to the machine to extract remaining juice. Yield is computed as the difference between the

Machine Condition:

1. Motor Rating: 26 2. No Load Ampere: 7.4 3. Gap of Rollers at Feeding: 10.5mm
4. Gap of Rollers at Discharge: 0.6mm 5. Roller Speed: 12rpm

Table 1. Individual Cane Extraction Time

Trial No.	Sugarcane Data					Ampere	Time (Sec)
	Ave. Dia. (mm)	Length (mm)	Wt. of Cane (kgs)	Wt. of Bagasse (kgs)	Wt. of Juice (kgs)		
1	16	930	0.24	0.175	0.065	8.1	13
2	20	810	0.26	0.15	0.11	9.5	10
3	22	730	0.28	0.175	0.105	10.2	9
4	28	880	0.56	Note: No data gathered due to difficulty of weighing crushed bagasse		10.6	11
5	30	650	0.48			11.3	7
6	32	900	0.68			13.4	13
Total			**2.5**	**1.36**	**1.14**		**63**

Machine Condition:

1. Motor Rating: 26 2. No Load Ampere: 7.4 3. Gap of Rollers at Feeding: 10.5mm
4. Gap of Rollers at Discharge: 0.6mm 5. Roller Speed: 12rpm

Table 2. Yield with Second Passing

Trial No.	Sugarcane Data					Ampere	Time (Sec)
	Ave. Dia. (mm)	Length (mm)	Wt. of Cane (kgs)	Wt. of Bagasse (kgs)	Wt. of Juice (kgs)		
1	20	820	0.28	-	-	8.2	8
2	22	900	0.36	-	-	10	18
3	25	870	0.44	-	-	10.3	27
4	28	1060	0.68	-	-	10.8	38
5	29	1130	0.86	-	-	14	48
6	29	1270	0.88	-	-	14.7	63
Total, 1st Pass			**3.48**	**1.78**	**1.70**		
Total, 2nd Pass			**3.48**	**1.62**	**1.86**		

weight of the sugarcane and the bagasse divided by the weight of the cane where the results are tabulated in Table 2.

From the results, the following are computed:

Yield after 1st pass= (3.48-1.78)/3.48 = 48.85%

Yield after 2nd pass = (3.48-1.62)/3.48 = 53.44%

Production Rate

Data obtained from the previous tests did not consider to maximize the canes fed to the machine. Hence, two tests were conducted to find the production rate of the machine. The remaining bulk of canes amounting to 19.3 kgs were divided into two batches. As much as possible, maximum amount of canes were fed to the machine at a time while taking care not to exceed the 26- ampere rated capacity of the machine.

In Table 3, it took 85 seconds to process the 9.65 kgs of cane while in Table 4, it took 60 seconds to process the same amount of canes.

The difference can be said to be normal for an operator doing a job for the first time because he is undergoing the "learning stage". It is possible that the 60 seconds production time in batch 2 can still go lower for succeeding batches.

Considering the data in collected from Batch 2, the production rate will be 579 kgs/hour or 4,632 kgs per day of 8 hours of operation.

From Table 4, yield can be computed as 5/9.65 = 51.81%. That was without a second passing.

Table 3. Batch 1 Production Rate

Gap w/ Top Roller		Sugarcane Data			Ampere	Time (sec)
Discharge (mm)	Feed (mm)	Wt of Cane (kgs)	Weight of Bagasse (kgs)	Weight of Juice (kgs)		
0.6	10.5	9.65	4.73	4.92	Not to exceed 26 amps	85

Table 4. Batch 2 Production Rate

Gap w/ Top Roller		Sugarcane Data			Ampere	Time (Sec)
Discharge (mm)	Feed (mm)	Wt of Cane (kgs)	Weight of Bagasse (kgs)	Weight of Juice (kgs)		
0.6	10.5	9.65	4.65	5.00	Not to exceed 26 amps	60

Conclusion

Based on the test results, the improvements and modifications carried out on the machine were successfully demonstrated. The results showed that the machine performed satisfactory wherein the gap between the discharge and top rollers was set at about 0.6 mm and the gap between the feeding and top rollers was about 10.5 mm. Furthermore, the machine can crush four sugarcane stalks with diameter ranging from 16 to 32 mm at the same time without risking the motor. The outcome proved that the improvements made on the sugarcane juicer were effective and useful in increasing output for muscovado sugar production.

The outcome of the improvement resulted to the increase of capacity from 200 kg/hr to 580 kg/hr as well as increase in yield from 25% to 52%.

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Philippine Metal Stamping Industry 2019: A Status Report

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Abstract

Metal stamping, if not the cheapest, is one of the cheapest processes of producing identical metal parts. The history of the metal stamping industry in the Philippines is tied with the Philippines's economic policies towards industrialization. In 2019, the Department of Science and Technology - Metals Industry Research and Development Center (DOST-MIRDC) conducted a study on the Philippine metal stamping industry. A review of the 2019 study was conducted through quantitative survey database analysis. It presents a comparative analysis of the condition of the Philippine metal stamping industry based on the quantitative responses of 94 metal stamping companies. This study clustered the metals stamping industry into micro, small, medium, and large companies according to the capital classification as defined in Republic Act No. 9501. The large metal stamping companies currently dominate the industry in terms of employees and revenue. The metal stamping companies generally supply stamped parts to the automotive or transport sector, the metalworking sector, and the semiconductor or electronic sector because they offer greater incentives in terms of revenue and volumes of works. Statistical analysis shows that investing higher capitalization provides metal stamping companies a significant degree of control over the internal factors affecting their operations and they generally experienced the same degree of external incentives and pressures. The present industrial landscape shows that the metal stamping industry remains to be a good investment even for starting entrepreneurs.

Keywords: survey databased analysis; metal stamping; DOST-MIRDC; metals industry; MSME; ANOVA

Introduction

Metal stamping, if not the cheapest, is one of the cheapest processes of producing identical metal parts. The history of the metal stamping industry in the Philippines is tied with the country's economic policies towards industrialization. The Americans jump-started the industrialization of the Philippines during the American colonial period from 1920 to 1938. The Philippines then shifted its policies to import-substitution-industrialization (ISI) from 1950 to 1972 [1]. The number of metal stamping businesses in the Philippines increased during the American period with the influx of stamping machines in the country, some of which are still being used today [2]. An export-oriented industrialization (EOI) strategy was intensified during the term of President Ferdinand E. Marcos led by the country's intellectuals known as the technocrats [3]. This strategy was coupled with increased foreign investors, local manufacturers, and assembly plants. During this period, metal stamping businesses had a lot of project opportunities which allowed them to proliferate. After the Marcos administration, the most significant economic policy that promoted the increase of manufacturing companies was the establishment of the Philippine Export Processing Zones and the Philippine Economic Zone Authority on February 21, 1995, during the administration of President Fidel V. Ramos [4]. The economic policies of the administration of President Rodrigo R. Duterte include the promotion of agricultural productivity and industrialization [5]. This necessitates a closer look at the status of the metal stamping industry in the Philippines for proper policy formulation and planning of programs and projects of the government.

The 2019 study of the Philippine metal stamping industry conducted by the DOST-MIRDC utilized a convergent parallel mixed-method research design. It

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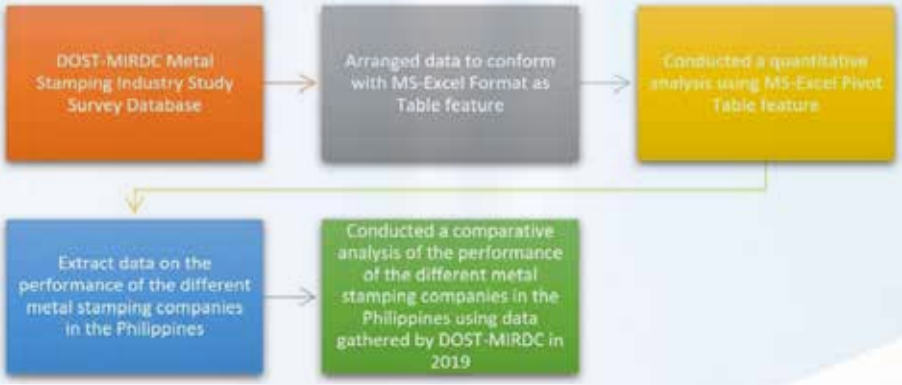

Figure 1. Conceptual Framework

produced quantitative data gathered through a survey using a questionnaire approved by the Philippine Statistics Authority. The survey was administered to 94 metal stamping companies. Qualitative data was gathered through interviews and focus group discussions (FGD) [2].

Figure 1 shows the conceptual framework of the study. The primary source of data for review in this study is the DOST-MIRDC Metal Stamping Industry Study survey database. The database was arranged to conform with the Microsoft (MS)-Excel Format as Table feature and it was processed using the MS-Excel Pivot Table feature. The setting enabled the researcher to extract quantitative data on the performance of the different metal stamping companies in the Philippines, which the researcher used for comparative analysis.

Objectives of the Study

This paper aims to perform a comparative analysis of the performance of the different metal stamping companies in the Philippines using data gathered by DOST-MIRDC in 2019. The specific objectives of this study are to (1) provide an assessment of the Philippine metal stamping industry in terms of its industry profile, (2) present a comparative analysis of the Philippine metal stamping industry in terms of market competition, production, and revenue, (3) identify issues and concerns of the Philippine metal stamping industry; and (4) determine the significant difference in the internal and external factors affecting the performance of the Philippine metal stamping industry.
The objectives required hypothesis testing. The null hypothesis, there is no significant difference in the internal and external factors affecting the performance of the Philippine metal stamping industry, was tested.

Methodology

This study utilized a quantitative survey database analysis from the Philippine metal stamping industry study conducted by DOST-MIRDC in 2019. The database was analyzed using MS-Excel Format as Table feature to process a large quantity of numerical inputs to produce data for comparative analysis. This study clustered the metals stamping companies according to the capital classification as defined in Republic Act No. 9501: micro companies have a capital of not more than P3,000,000; small companies have a capital of P3,000,001-P15,000,000; medium companies have a capital of P15,000,001-P100,000,000; and large companies have a capital of P100,000,001 and above.

Results and Discussions

This study presents a comparative analysis of the condition of the Philippine metal stamping industry for 2019 based on the quantitative responses of 94 metal stamping companies in the survey administered by DOST MIRDC in 2019. Based on the data presented in the MIRDC 2019 study, there are surviving metal stamping companies from 1900 to 1970s. There is a significant increase in the number of metal stamping companies from 1990 to 2000 [2]. The increase can be attributed to the establishment of PEZA in 1995 which encouraged the establishment of manufacturing companies within a designated economic zone. Companies within PEZA are given tax incentives. There are metal stamping companies within the Economic Zones but more importantly, there are metal stamping companies outside of the Economic Zones that are surviving mainly by supplying the companies within the Economic Zones their needed parts and components. This system implies that whatever economic policies of the Philippines that will affect the operation and incentives of the PEZA-registered companies will eventually affect the operation of a significant portion of the metal stamping industry. At present, the main concerns of the PEZA-located companies are the implementation of the Republic Act No. 10963 also known as the Tax Reform for Acceleration and Inclusion (TRAIN) law, and the current Congress laid on the table Corporate Income Tax

and Incentives Rationalization Act (CITIRA) [6]. These policies will affect the tax incentives and purchasing benefits enjoyed by PEZA-located companies which might lead to the relocation of these companies to other economic zones within the Southeast Asian Region. If ever the CITIRA will push through, PEZA needs to repackage its incentives to retain existing locators and attract future investors in our economic zones.

Table 1. Business Location of Companies Classified According to Capital

Classification According to Capital	Business Location				Grand Total
	Owned	%	Rented	%	
Large	11	69	5	31	16
Medium	23	64	13	36	36
Micro	7	64	4	36	11
Small	19	61	12	39	31
Grand Total	**60**	**64**	**34**	**36**	**94**

Table 1 shows the business location of metal stamping companies classified according to capitalization. As observed in Table 1, the percentage of the large, medium, small, and micro-companies who owned or rented its business location is relatively the same with a standard deviation score of 2.71%. It can be concluded that capitalization is not an issue for owning or renting a business location.

Table 2. Business Location of Companies based on Regions

Region	Business Location				Grand Total
	Owned	%	Rented	%	
III	4	57	3	43	7
IV-A	22	49	23	51	45
NCR	25	83	5	17	30
VII	9	75	3	25	12
Grand Total	**60**	**64**	**34**	**36**	**94**

Table 2 shows the business location of metal stamping companies classified regions. As seen in Table 1, the percentage of companies who owned or rented its business location in Region III, Region IV-A, National Capital Region (NCR), and Region VII varies with a standard deviation score of 13.72%. It can be concluded that the geographical location of metal stamping companies is a factor for owning or renting a business location. Metal stamping companies owning their business location is significantly higher by percentage in NCR and Region VII. Generally, the real estate value and leasing cost in NCR and Region VII, specifically in Cebu City, is high. It will be more ideal in the long run for established metal stamping companies to own their business location in these areas.

Table 3. Exporting Companies Classified According to Regions

Region	Exporting		Grand Total
	No	Yes	
III	7	0	7
IV-A	29	16	45
NCR	25	5	30
VII	12	0	12
Grand Total	**73**	**21**	**94**

Table 3. shows the number of exporting metal stamping companies classified according to regions. Based on table 3, 21 metal stamping companies in Region IV-A and NCR are direct exporters. Their locations are ideal because they are close to the ports and export processing zones. Generally, the main strength of metal stamping companies is to supply metal stamped parts to the nearest manufacturing or assembly plants. By doing so, the metal stamping companies are most competitive. They can deliver the needed parts faster and cheaper than their foreign competitors. That is why majority of the metal stamping companies are not exporters. The company location provides proximity advantage but it also comes with a disadvantage in some areas. In localities with limited manufacturing or assembly plant, the market condition forces companies to engage in cutthroat pricing competition, which eventually led to metal stamping companies shutting down operations if they cannot compete. In order to improve the condition of the Philippine metal stamping companies, it is imperative for the Philippine policy makers to create policies that will promote the development, maintenance,

Table 4. Total Number of Employees and Per Plant Average Classified According to Capital

Classification According to Capital	Number of Companies	Total Number of Employees	%	Average Per Plant Number of Employees
Large	16	6975	58	436
Medium	36	3906	32	109
Small	31	916	8	30
Micro	11	202	2	18
Grand Total	**94**	**11999**	**100**	**128**

and establishment of manufacturing industries in the Philippines because the current policies are driving them to Thailand or Vietnam [2].

Table 4 shows the total number of employees employed by the metal stamping industry and the per-plant average. Large companies control more than half of the workforce of the metal stamping industry. Their per plant average is 436 workers. The metal stamping industry in the Philippines is labor-intensive. More employees are necessary if a company owns more stamping machines, especially those with a larger capacity.

Welding, machining, and die and mold processes are the most common processes that go hand-in-hand with the metal stamping process [2]. Metal stamped parts are usually joined together using the welding process. Stamped parts are machined to conform to the specifications required by clients in terms of measurements and dimensions. Press machines used by the metal stamping industry need dies and fixtures to produce the required stamped parts by their clients.

The products and services of metal stamping companies are upstream to a variety of sectors. The top three sectors served by the Philippine metal stamping industry are the automotive or transport sector, the metalworking sector, and the semiconductor or electronic sector [2]. Currently, there are demands for metal stamped parts for private cars, public transport, logistic vans and trucks, motorcycles, and vintage jeeps. This demand is the reason why the majority of metal stamping companies serve the transport sector. Most of the time, the stamped parts need additional processes such as welding, rustproofing, electroplating, heat treatment, and machining. These processes are services offered by the metalworking sector. There are also numerous semiconductor corporations in the Philippines. They require small to micro-sized precision metal-stamped components for cellular phones, computer components, and other electronic gadgets.

Figure 2 shows the total production of the Philippine metal stamping industry in 2018 categorized by region.

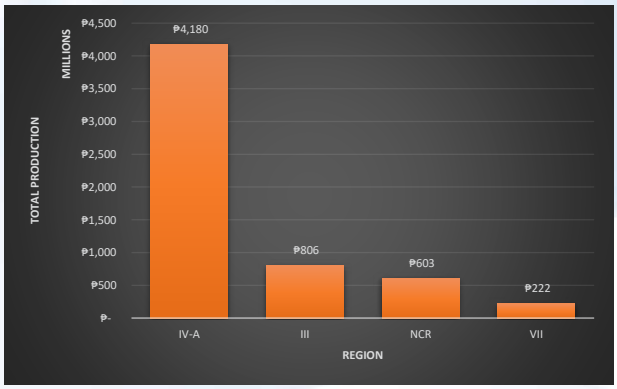

Figure 2. Metal Stamping Companies' Total Production in 2018 by Region

In terms of total production, Region IV-A has the highest production in 2018 amounting to P4.18 Billion. Region IV-A or the CALABARZON tops the production of metal stamped parts because it is the location of most of the economic zones located near Metro Manila. As presented on Table 2 and Table 3, the number of metal stamping companies included in the study from Region IV-A is 45 compared to 30 from NCR, 12 from Region VII, and seven 7 from Region III.

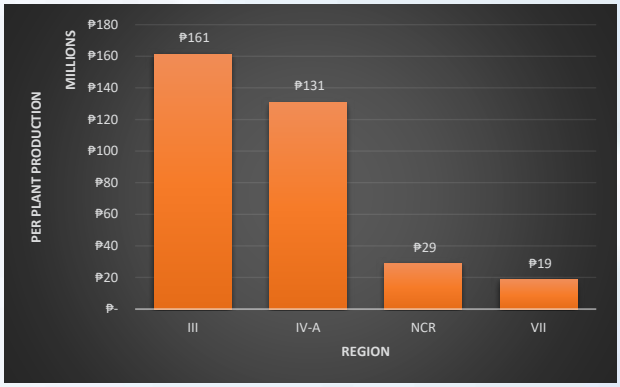

Figure 3. Metal Stamping Industry Per-Plant Production in 2018 by Region

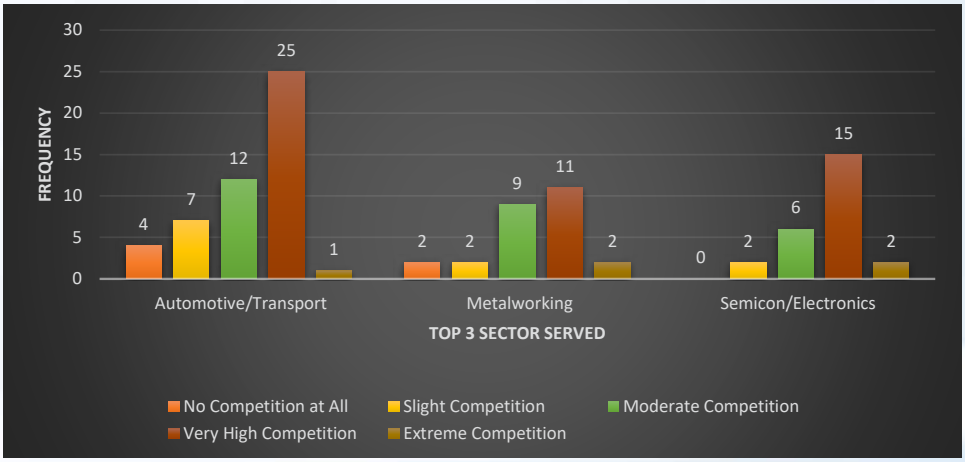

Figure 4. Level of Competition in the Top 3 Sector Served by the Metal Stamping Industry

Figure 3 shows the per plant production of the Philippine metal stamping industry in 2018. Metal stamping companies in Region III top the per-plant production with P161 Million. Region III and Region IV-A can produce metal stamped parts on a large scale because their manufacturing plants are larger compared to those in the NCR and Region VII. For metal stamping companies to produce on a large scale, they require larger storage for raw materials and output metal stamped parts. At present, metal stamping companies in the NCR and Cebu City (Region VII) have limited areas for expansion due to space congestions. Their option is to relocate or establish a satellite manufacturing plant in the special economic zones or nearby provinces.

Figure 4 shows the perception of the metal stamping companies on the level of competition in the top three sectors they served. Figure 7 shows the same curve in the perception of metal stamping companies on the level of competition in the automotive or transport sector, the metalworking sector, and the semiconductor or electronic sector. The majority of the metal stamping companies who serve the automotive or transport sector, the metalworking sector, and the semiconductor or electronic sector perceived the competition to be moderate and very high. This data implies that the top three sectors served by the metal stamping companies are already saturated.

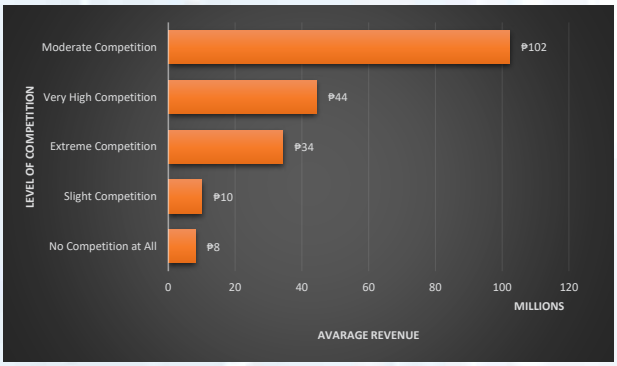

Figure 5. Average Per-Plant Revenue of the Metal Stamping Industry in 2018 Categorized on Level of Competition

Figure 5 shows the average per-plant revenue of the metal stamping industry in 2018 categorized according to their perception of the level of competition. Metal stamping companies who categorized the level of competition as moderate have the highest average per-plant revenue in 2018 amounting to P102 Million. This data suggests that even if the competition in the target market is perceived to be moderate to extreme, metal stamping companies will still enter such a marker because it provides greater incentives in terms of revenue than pursuing a market with slight to no competition at all. This market system could result in a cut-throat competition where the companies with the most resources will survive in the end. Business model innovation can be adopted by competing companies to sustain competitive advantage, regulatory changes, and technological shifting [7].

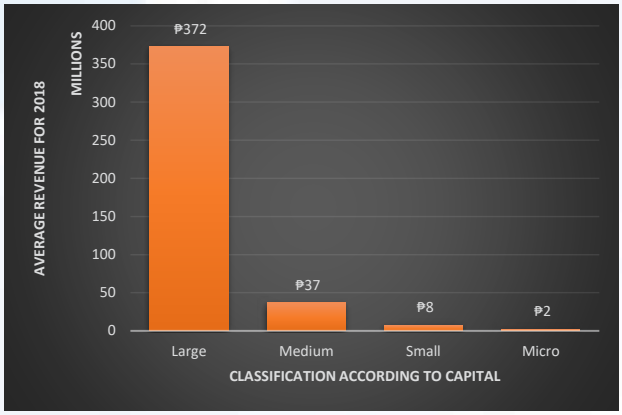

Figure 6. Average Per-Plant Revenue of the Metal Stamping Industry in 2018 Categorized According to Capital

Figure 6 shows the average per-plant revenue of the metal stamping industry in 2018 categorized according to capital. Large companies dominate the metal stamping industry in terms of per-plant revenue in 2018 with a per-plant revenue of P372 Million. The metal stamping industry at present is ruled by the titans. It will take time and great investments before medium companies could reach the level of performance of the large companies in the current market setting. The data also suggest that the metal stamping industry is a good investment for starting entrepreneurs with a small investment on a couple of stamping machines and a little technical know-how can reward them with revenue of P2 to P8 Million annually.

Generally, only a small portion of the 94 metal stamping companies have issues and concerns. The top 3 issues and concerns of the metal stamping companies are human resources, raw materials, and equipment [2]. 34 metal stamping companies have issues and concerns regarding human resources. Attritions of stamping machine operators are common in the metal stamping industry. Skilled workers such as stamping machine operators leave the company to find higher salaries offered by other metal stamping companies in the Philippines and abroad. Resignation of skilled workers can be a concern to micro and small metal stamping companies because they have a limited workforce but for medium and large metal stamping companies, it is not much of a concern because they can easily train unskilled helpers and promote them to stamping machine operators. Substandard raw material is a reality in the Philippine market which concerns 27 metal stamping companies. The Philippine Product Safety and Quality Foundation (PPSQF) noted that there are about 25% of steel suppliers that are selling cheaper products with substandard quality [8]. The Department of Trade and

Table 5. ANOVA Result for the Internal Factors Affecting the Performance of the Philippine Metal Stamping Industry

Internal Factors

Groups	Count	Sum	Average	Variance
Large	12	49.46	4.12	0.11
Medium	12	47.08	3.92	0.07
Small	12	44.35	3.70	0.10
Micro	12	41.57	3.46	0.13

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.91	3	0.97	9.36	0.000067	2.82
Within Groups	4.55	44	0.10			
Total	7.46	47				

Table 6. ANOVA Result for the External Factors Affecting the Performance of the Philippine Metal Stamping Industry

External Factors

Groups	Count	Sum	Average	Variance
Large	12	42.29	3.52	0.15
Medium	12	42.89	3.57	0.08
Small	12	39.67	3.31	0.27
Micro	12	39.73	3.31	0.29

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.71	3	0.24	1.21	0.32	2.82
Within Groups	8.68	44	0.20			
Total	9.39	47				

Industry (DTI) through the Bureau of Product Standard (BPS) with the product testing result from DOST-MIRDC, suspended the Philippine Standard (PS) licenses of six steel manufacturers in 2019 [9]. Substandard materials can be a major cause of rejection in the outputs of metal stamping companies. Metal stamping companies employ experienced quality inspectors who detect substandard materials. There are also times when clients of metal stamping companies require a third-party certification, which is one of the services provided by DOST-MIRDC to ascertain compliance of with standards and specifications [2]. Equipment downtime due to malfunctions is a concern for 14 metal stamping companies. Metal stamping companies experience downtime with mechanical stamping machines especially the old ones but they can easily troubleshoot the problem using minor machining processes. The respondent companies shared that they also experienced problems with modern computerized or programmable stamping machines. Unfortunately, they cannot easily fix the problem if it involves the software or programming. Resolving the problem usually takes time because the companies have to contact the supplier or manufacturers for after-sale support.

The 2019 study of the DOST-MIRDC identified 12 internal factors that affect the performance of the Philippine metal stamping industry. The internal factors are company reputation, company location, market reach, output capacity, quality of products and/or services, facilities and equipment, financial resources, a pool of skilled workforce, internal quality control system, internal research and development, production efficiency, and marketing strategy [2]. Internal factors are variables in which the company has control. Table 5 shows the analysis of variance (ANOVA) results for the internal factors affecting the performance of the Philippine metal stamping industry. Large companies have the highest average score with 4.12. Medium companies have an average score of 3.92, small companies with 3.70, and micro-companies with 3.46. The ANOVA result for internal factors provides a P-value of 0.000067 which is less than the 0.05 alpha (α). The computed F value of 9.36 is greater than the F critical value of 2.82. The result signifies that the null hypothesis is rejected. There is a significant difference in the internal factors affecting the performance of the large, medium, small, and micro metal stamping companies. This result suggests that large companies, with their high average score, have a significant degree of control over the internal factors when compared with the other groups.

The 2019 study of the DOST-MIRDC identified twelve (12) external factors that affect the performance of the Philippine metal stamping industry. The external factors are as follows: the market for products and/or services, demand for products and/or services; customer satisfaction, complementing products and/or services, substitute products and/or services, external research and development, partnership/linkages, government assistance and subsidies, supplier chain/raw materials, local competitors, foreign competitors, and tax policy. External factors are variables in which the company has limited control. Table 6 shows the analysis of variance (ANOVA) results for the external factors affecting the performance of the Philippine metal stamping industry. Based on Table 5, medium companies have the highest average score with 3.57. The large companies have an average score of 3.52 while the small and micro companies have the same average score of 3.31. The ANOVA result for external factors gives a P-value of 0.32 which is greater than the 0.05 alpha (α). The computed F value of 1.21 is less than the F critical value of 2.82. This result signifies that the null hypothesis is accepted. There is no significant difference in the external factors affecting the performance of the large, medium, small, and micro metal stamping companies. All of the four groups are generally experiencing the same degree of external incentives and pressures even with medium companies having a slightly higher average score.

Conclusion

The metal stamping industry is a good indicator of the Country's industrialization status. There are metal stamping companies today that existed for more than 50 years. The business location is one of the main strengths of the Philippine metal stamping companies because it enabled them to supply metal stamped parts to the nearest manufacturing or assembly plants. The geographical location of metal stamping companies is a factor for owning or renting a business location. The large metal stamping companies currently dominate the industry in terms of employees and revenue. Even with intense market competition, the metal stamping companies would generally supply stamped parts to the automotive or transport sector, the metalworking sector, and the semiconductor or electronic sector because it offers greater incentives in terms of revenue and volumes of works. Higher capitalization provides a significant degree of control over the internal factors affecting the performance of metal stamping companies. The metal stamping industry generally experienced the same degree of external incentives and pressures. All and all, the metal stamping industry remains to be a good investment even for starting entrepreneurs.

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Competitiveness and Survival Strategies of the Philippine Metal Stamping Industry: A Multiple Case Study

Alexander P. GONZALES*1

Abstract

This article is a multiple case study on the competitiveness and survival strategies of the Philippine metal stamping industry. Porter's typology of generic strategies is a useful tool in defining an organization's competitive advantage. These strategies aim to help companies gain higher profit than their competitors. The two dimensions of competitive advantage are the competitive scope and the source of competitive advantage. Competitive scope is determined by targeting either a broad or a narrow market. The source of the competitive advantage is gained by providing differentiated products or services or by providing the lowest price for similar products or services. There are four typologies under these generic strategies: cost leadership; differentiation; cost focus; and differentiation focus. The Philippine metal stamping companies that implement a cost leadership strategy do so by being practical and by adhering to the cost standard of their clients or customers. Philippine metal stamping companies whose approach lean toward the differentiation strategy implement practices such as being responsive to client needs, meeting clients' output and delivery requirements, and establishing a reputation of quality and expertise in their market segment. The metal stamping companies that apply a cost focus strategy secure a constant supply of parts and materials and establish streamlined production and integrated marketing system. The metal stamping companies that implement the differentiation focus strategy establish client partnerships, maintain supply control, and develop niche leadership. The survival strategy of the metal stamping companies, exemplified by those which have endured the ups and downs of various prevailing economic conditions of the country, revolved around coping with the technology gaps, operation constraints, and market challenges.

Keywords: multiple-case study; Porter's typology of generic strategies; metal stamping; DOST-MIRDC; metals industry

Introduction

Michael Porter is an authority when it comes to strategic management and competitive advantage. His works on the generic types of competitive advantage such as cost leadership, differentiation, and focus strategy are the foundation to corporate competitiveness analysis [1]. According to Michael Porter, competitive advantage lies within the value a firm provides its buyers that exceed the cost of production [2]. "*Value is what buyers are willing to pay. Superior value stems from offering lower prices than competitors for equivalent benefits or providing unique benefits that more than offset a higher price* [1]." A firm pursuing a cost leadership strategy exploits all possible cost advantages such as lean production, new technology, and supplier relations, enabling the firm to sustain the lowest price possible for certain goods or services. Differentiation strategy anchors on the uniqueness of the goods and services provided by ensuring higher quality, brand recognition, reliable distribution, and the likes. Focus strategy narrows the market segment in which a firm competes and applies cost leadership or differentiation strategy to such a market.

In this paper, the researcher has provided a multiple case study on the competitiveness and survival strategies of the Philippine metal stamping industry. Maintaining a metal stamping business is not an easy task even for experienced entrepreneurs. There are a lot of factors to consider to keep the business afloat. The researcher observed that most of the metal stamping business owners in the Philippines have no formal background in business management, particularly the small and micro-enterprises. The Philippine metal stamping industry is an enduring legacy of the country's golden age of industrialization

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[3]. In some cases, skills and machinery were handed down from one generation to the next. The majority of the metal stamping companies in the Philippines belong to the micro, small, and medium enterprises (MSME) category according to the capital classification as defined in Republic Act No. 9501. In the study conducted by the Department of Science and technology – Metals industry Research and Development Center (DOST-MIRDC) published in 2020, 79 out of 94 metal stamping companies were MSMEs and the areas included in the survey were areas with established economic zones [4].

Method

A qualitative multiple-case study approach was used by the researcher [5]. The advantage of a multiple-case approach is it captures the complexity and entirety of the phenomenon being observed [6] as compared to a single-case study approach. The market condition of the Philippine metal stamping industry is facing challenges both from the local and foreign competitions. A survey questionnaire cannot uncover the strategies used by the different metal stamping companies that enable them to thrive or survive in this kind of market condition. Key informants for this study were owners and personnel of 14 metal stamping companies from different regions as shown in Table 1. An in-depth interview using researcher-made guide questions was used to extract the needed data for the study. Interviews were digitally recorded and transcribed. The coding process was performed manually by the researcher. Thematic analysis was used to permit the researcher to combine the analysis of the frequency of codes with an analysis of their meaning in context [7].

Table 1. List of Informant Companies

Company Name	Region	Established
Accuform, Inc.	VII	2008
Amantech Corp.	NCR	1996
Centro Manufacturing Corp.	III	1996
Cherimel Phils. Inc.	NCR	1994
CMG Metalcraft	NCR	1970
FAG Engineering Group	VII	1997
Golden Dragon Metal Products, Inc.	NCR	1950
Maximetal Industries, Inc.	NCR	1981
MD Juan Enterprises, Inc.	NCR	1967
P & R Parts and Machineries, Inc.	IV-A	1969
RAS Tooling Specialist	NCR	2000
Santos Power Press	III	1996
Sobida Motors Corp.	NCR	2007
Sohbi Kohgei (Phils.), Inc.	IV-A	1999

Results and Discussions

Results in this study were presented in a narrative form which includes the generated thematic concepts and testimonies extracted from the interviews.

Porter's typology of generic strategies [8] is one of the widely recognized concepts in strategic planning for competitive advantage [9]. Competitive advantage for a company refers to an area of the business that enables it to gain a higher profit than its competitors. According to Porter, there are two dimensions to establish a competitive advantage. First, the firm needs to determine its competitive scope. The firm needs to determine if they will target a broad or a narrow market. Second is the actual source of the competitive advantage which is to determine if the firm will provide differentiated products or services or will provide the lowest price for similar products or services. There are four typologies under these generic strategies: cost leadership; differentiation; cost focus; and differentiation focus. Figure 1 shows the identified thematic strategies used by the Philippine metal stamping companies included in this study.

Overall Cost Leadership

Overall cost leadership strategy involves the provision of standard products or services with aggressive pricing [8]. The idea is to amass an economy of scale to attain a competitive advantage over the competition. A small or minimum per-unit profit over a sustainable volume of orders can still generate enough revenue for the firm. The Philippine metal stamping companies that implement a cost leadership strategy do so by being practical and by adhering to the cost standard of their clients or customers.

The metal stamping companies are practical in the sense that they were able to minimize their overhead expenses by maintaining machines and a workforce that will satisfy their client's demands. If they feel that it is not practical for them to maintain additional machinery or processes, they will have it subcontracted. They are practical in their investment in additional machines. They are also practical in terms of acquiring a workforce and selecting their raw materials.

		Competitive Advantage	
		Low Cost	Higher Cost
Competitive Scope	Broad	**Overall Cost Leadership** • Being Practical • Adhering to Client' Cost Standard	**Differentiation** • Being Responsive to Client's Needs • Meeting Output and Delivery Requirements • Establishing Reputation for Quality and Expertise
	Narrow	**Cost Focus** • Securing Constant Supply of Parts and Materials • Establishing Streamlined Production and Integrated Marketing System	**Differentiation Focus** • Establishing Client Partnership • Maintaining Supply Control • Developing Niche Leadership

Figure 1. Strategies of the Philippine Metal Stamping Industry

The following statements reflect this observation:

- *Instead of having to worry, we will just have the plating subcontracted by our accredited company.*
- *Plating and heat treatment, we subcontract it.*
- *You must be bold and invest. If you do not have a metal stamping plant, you will not gain.*
- *We acquire an additional machine that is priced per kilo (scrap metal), we just need to fix the motor.*
- *We get our workforce through an agency. It is much easier and the workers we get are easy to train.*
- *We do not use copper in making medals anymore. It is too expensive. We use brass sheets.*
- *If they (customer) aim for lower cost, we could settle for thinner sheets.*

Generally, clients of metal stamping companies have a standard cost for their required stamped parts or products. As stated by one key informant, *"when they (client) come to us, they already have an existing price, so we will just negotiate if we will be able to give them an equal or better price."* The metal stamping companies strategize to accommodate their client's demands while keeping a workable profit margin. They were able to accomplish this by securing a lower cost of raw materials and demanding from their clients a significant volume of outputs.

The following statements reflect this observation:

- *We locked them (suppliers) to a quarterly PO*
- *Normally, we have a pool of 3 suppliers as a pre-requisite before we purchase.*
- *As long as we have a volume of works, from time to time, we can work up to Sunday.*
- *Our die (medals) usually cost P3,000. We do not profit from the dies.*
- *When we give our quotation and they requested for discount, as long there is still a profit for us, we accommodate them.*
- *In our stamping work, the profit per press amounts to centavos.*
- *We can do 10 thousand pieces per day at 22 centavos.*

Differentiation

Differentiation strategy requires the provision of a unique or different product or services than what is available in the market or at least perceived to be different or unique [8]. This can be done by providing higher quality products or services, better brand recognition, a wider distribution system, and improved after-sale services. This strategy allows the firm to enjoy a better profit margin than its competitors.

The Philippine metal stamping companies' approach to the differentiation strategy includes being responsive to client needs, meeting clients' output and delivery requirements, and establishing a reputation of quality and expertise in their market segment.

Being responsive to the needs of their client is very important because it results in the client's continuous patronage of the products and services offered by the company. The metal stamping companies do this by accommodating rush job orders and appealing to nationalist sentiments.

The following statements reflect this observation:

- *If it is a rush work, about a week. If they already have the die, much faster.*
- *Why would you get it from China when Filipinos can do it?*
- *When it comes to China products, they will find shipping and maintenance difficult.*

Meeting clients' output and delivery requirements sort out the market players. When it comes to volumes of work and their complexities, only a handful of metal stamping company could rise to the challenge. This strategy can be done by investing heavily in additional machines and facilities.

The following statements reflect this observation:

- *We are one of the biggest truck-body builders in the country today.*
- *You can consider us as a one-stop-shop.*

The reputation of quality provides clients peace of mind that the products and services they purchased will not give them problems or if ever they do, they are assured of firm accountability through after-sales support. Expertise, on the other hand, is sought by clients because there are some production problems that only those people or companies with long experiences can address.

The following statements reflect this observation:

- *We are giving a warranty on the body. Instead of one year and P20,000, we can give them 3 years and P100,000 on the body.*
- *It's good if you are the die maker and will do the stamping, when it comes to maintenance you can do it.*
- *The current executives are already the 3rd generation from the company founder.*
- *It's just experience, 20 years of experience.*
- *Any metal parts that we need, we do it by ourselves. Not only that it is much cheaper but we can control the quality and delivery time.*
- *Their cost might be lower or same as ours, but our stamped products' quality is much higher. We are being audited by our principals.*

Cost Focus

Generally, the metal stamping industry serves a focused market because metal stamping machines and equipment are designed to process a specific stamped part based on its size and material [4]. An automotive stamping com-

pany would find it difficult to address the needs of the electronic industry and vice-versa.

Cost focus strategy is simply establishing cost leadership in a specific segment of the market [10]. The metal stamping companies apply this strategy by securing a constant supply of parts and materials and establishing streamlined production and integrated marketing system.

The metal stamping companies secure a constant supply of parts and materials by forecasting their consumption and establishing a partnership with their suppliers.

The following statements reflect this observation:

- *Probably six months before, we should make our order, three months before delivery. The 160 tons probably is good for six months' consumption.*
- *We have a constant supply of engines, our partners in Japan are collecting them.*
- *We are self-sustaining sir, chassis and other parts.*

The metal stamping companies implement streamlined production by instituting process improvement, controlling the production line, and avoiding extra charges to the clients whenever possible. An integrated marketing system is being implemented by partnering with third-party financial institutions to pump-up sales and partnering with clients on product marketing.

The following statements reflect this observation:

- *We implement Kaizen improvement*
- *Well, one of our styles is an end-to-end line. We don't rely much on outsourced work. So, we control our own costs.*
- *They (costumers) pay in cash or we endorse the to a 3rd party financing company.*
- *Our production will go up as long as our boss (client) is enthusiastic about marketing our product.*
- *Sharpening, we do it. We don't charge. It will be cheaper for them.*

Differentiation Focus

Differentiation focus strategy is the same as differentiation strategy except that it focuses on a narrow market. The metal stamping companies implement this strategy by establishing client partnerships, maintaining supply control, and developing niche leadership.

In the metal stamping industry, companies establish client partnerships by establishing their base of operation near their client's location, offer after-sale services, and customizing their operations with their clients.

The following statements reflect this observation:

- *We implement a Centralized Purchasing System*
- *If you buy our products, we provide technical support, service support, and warranty.*
- *Our customer requires that we must be within the area. In PEZA, there are a lot of documentations for ingress and egress materials. So, we establish a sister company in PEZA.*
- *We've been with them for more than 20 years already.*
- *If the clients are Japanese, especially big companies, they want us because we follow their standards.*
- *The skills of our people are tailored fitted. They have been with us for more than 10 years.*
- *We consistently have zero defects and zero recall.*

The metal stamping companies maintain supply control by having the expertise in die making, partnering with suppliers, and involving their operations with their clients' supply chain.

The following statements reflect this observation:

- *Our own product is our dies, which are the ones we use.*
- *If we will not be the ones to produce the part, we will not make the dies and molds for you… We cannot make money. We will just be the hero because we were able to make it. It's very complicated, but there's limited profit in it.*
- *Our supplier here, they cut the metal sheets, then they will store them for us. They control the pricing but we are also aware of the going rates.*
- *What is good with the Japanese, they do not care about other metal suppliers because they revolve only with their own metal industry sphere.*
- *They have what they called a supply chain. That is the reason why there is no delay. Their basis for pricing is international rates.*
- *We are part of a Kanban system. We implement 3 days stocking.*

It is extremely difficult to be a niche leader in the current industry competitive environment [4] but some of the metal stamping companies were able to produce highly specialized products that they are being sought after by clients or customers. They implement this by addressing a specific market need, focusing on trends and clients' attitude, and developing a top of the class production and distribution facility.

The following statements reflect this observation:

- *There are still companies or heavy equipment manufacturers who would prefer the old design.*
- *We do not mass produce. We cater to the market needs of one or two units only. So, the business of our competitor is that if we cannot absorb the demand, the clients go to them.*
- *For the past 2 years, the trend is increasing the service, distribution, or logistics industry.*
- *We always anchor on the buying attitude.*
- *We do not accept body (vehicle) from outside, we make our own body.*
- *The government is imposing euro 4 engines. The engines*

that we get from Japan are actually euro 6.

- *They will get the 4 top body-builders and top 4 flatform suppliers. We are one of them.*
- *Since we are the biggest one, the client will go to us first because we can deliver the volume. If they go to the backyard industry, they can produce 30 units in a day, we can make 300 units with assured quality.*
- *Whenever there is a big project, they will go to the big ones. If we are busy, then we distribute some works to the small players.*
- *There are only a few players because the entry-level is so high for you to really compete.*
- *Global Sir, we have dealers in Europe, we dealers in the States, Southeast Asia, South America, and North America.*
- *We are utilizing social media, website. Americans Sir, actually, the 1st world countries are mostly dealing online.*

Survival Strategy

There have been studies on firm survivals but they mostly focused on the firm's incubation or gestation period with factors such as physical location, strategic focus, and industry affiliation [11]. Another study also includes firm size, sector, export activity, and innovation intensity [12]. Firms included in this study are way past their incubation period (see table 1), but it does not mean that they are not facing survival challenges. The survival strategy of the metal stamping companies revolved around coping with technology gaps, coping with operation constraints, and coping with market challenges.

The metal stamping industry is facing challenges regarding technology gaps. They are coping by informing clients regarding the technology process, augmenting labor force training deficiencies, and acquiring advanced technology.

The following statements reflect this observation:

- *We will still have to design it through engineering work. Prototypes have cost. There are a lot of expenses that the client doesn't know. All they see is the unit price.*
- *Our school is not producing highly skilled people. It's the industry that carries that.*
- *We train them here. They get experience in working with machines. After 2 years, they will resign and go abroad.*
- *It's the industry that provides state-of-the-art technology.*
- *We do not have people who are skilled in die making.*
- *We do not have the capability of creating axels, engines, and transmission.*

The metal stamping companies with operation constraints cope by making-do with what is available, looking for ways to maintain profit, shouldering the ever-increasing operational cost, and dealing with operation problems.

The following statements reflect this observation:

- *Our machines are quite old.*
- *There are times in stamping that we only make a profit out of scraps.*
- *Materials are not consignment. It's cash. So, you must have a revolving fund.*
- *The electricity cost is expensive. Whenever we operate the machine, we make sure that there is enough work.*
- *When you deal with Japanese customers, they want you to periodically reduce the price. But here, everything is going up… labor, material, etc.*
- *When we started the salary of workers is P100-P200 per day. Now, it's P500.*
- *There are times when people are tired and disoriented, an accident happens. They are losing their fingers or hands. It is really pitiful.*
- *We cannot work during rest time. The community is complaining. The machine creates load noise because it's metal to metal.*

The metal stamping companies are coping with the current market challenges by enduring the current government policies, surviving with the left-overs of foreign competitors, and adjusting to seasonal market demands.

The following statements reflect this observation:

- *We do not have a clear-cut governing policy for a sustainable automotive industry.*
- *It is my suggestion, that if it is already a finished product from China, the government should impose higher taxes for us in the metals industry to survive.*
- *In the ease of making business, 100 countries they surveyed. The Philippines is number 95.*
- *In Thailand, they can give it as low as P5 per press, but they are operating at 100,000 units per day. We do not have such demand here.*
- *In Vietnam, the taxes are low, the labor cost is low, and they provide more incentives.*
- *It's consistent. There are Chinese companies that provide very low charges. They tend to favor their fellow Chinese in job orders.*
- *The schools are also implementing cost-cutting. Instead of medals, they gave computer-printed certificates and ribbons.*
- *Job orders come from January to October. November to December is very limited. We don't earn in November and December.*
- *Our Peak season is January-March. We can earn about P300,000. For the rest of the year, it's famine.*

Conclusion

Most of the metal stamping companies are probably unaware of Porter's typology of generic strategies but they are manifesting behaviors consistent with the principles of a certain strategy. Some companies may have reached market dominance [4] but not all metal stamping companies have the resources to compete in a broad market. In fact, most of the metal stamping companies are serving a particular segment of a narrow market. For example, a single car has about 30,000 parts [13]. One metal stamping company would specialize in creating brackets for the seats. With this observation, it can be concluded that most of the metal stamping companies are leaning towards a cost focus strategy. They tend to serve a segment of a narrow market and provide the lowest price possible. The problem with this strategy is that cost leadership or cost focus strategy can only be advantageous to a certain firm if it reaches an economy of scale in its production. Unfortunately, the Philippine market is not that big for a firm to reach an economy of scale. Countries like China, Thailand, and Vietnam have already established cost leadership in the international market, thanks to their conducive economic policies. There is very little room for differentiation in the metal stamping industry because stamped parts are meant to be uniform and true to the specifications of the clients. The only differentiation strength that the Philippine metal stamping industry could exploit is the perception that Filipinos are highly skilled and qualified workers. This trust in skills and quality attacks countries with very high-quality standards such as Japan to invest in the Philippines and partner with the Philippine metals industry. The Philippine metal stamping companies are industry survivors. They have endured the ups and downs of the Philippine economic conditions. They are currently facing challenges such as technology gaps, operation constraints, and market challenges.

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