EFFECT OF ELECTROLESS PLATING LAYER THICKNESS ON MECHANICAL PROPERTIES OF RAPID PROTOTYPING (3D PRINTING)

MUHAMMAD WAZIR SHAFIQ BIN ARIPIN

MASTER OF MANUFACTURING ENGINEERING
(INDUSTRIAL ENGINEERING)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

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Muhammad Wazir Shafiq Bin Aripin

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MUHAMMAD WAZIR SHAFIQ BIN ARIPIN

A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

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DECLARATION

I declare that this thesis entitled "Effect of Electroless Plating Layer Thickness on Mechanical Properties of Rapid Prototyping (3D Printing)" is the result of my own research except as cited in the references. The dissertation has not been taken for any degree and is not concurrently submitted in the candidature of any other point.

Signature : ....

Name : MUHAMMAD WAZIR SHAFIQ B ARIPIN

Date : ....

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion, this dissertation/report is sufficient in terms of scope and quality as partial fulfilment of Master of Manufacturing Engineering (Industrial Engineering).

Signature : ....

Supervisor Name : DR MOHD SHUKOR B SALLEH

Date : ....

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DEDICATION

I dedicate this work to my family, especially my mother Jemaah Bt Md Said, my spouse Nur Ain Bt Sulaiman and my children Muhammad Waarith, Ainul Mardhiah and Ainan Marissa for their continuous love, concern and funding. Thank you. My love for you all can never be quantified. God bless you.

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ABSTRACT

Nowadays, materials that have been extensively used in the automotive industry are low carbon steel, high strength steel, aluminium, plastics and composites. However, plastic materials are not commonly used as a vehicle body part because their properties are much lower than steel in term of tensile strength and impact strength but on the other hand, plastics are very light compared to steel. Several types of plastic that commonly used in the automotive industry are such as acrylonitrile butadiene styrene (ABS) and polypropylene (PP). In order to improve the surface finish of ABS, a thin coating on the top of the surface is needed. Therefore, this study was carried out in order to analyze the effect of different rapid prototyping path on tensile strength, impact strength and surface roughness properties as well as to investigate the effect of different coating on ABS. This study was divided into three sections, that are none coating, spray paint coating, and electroless plating. Two parameters that has been used in rapid prototyping were a vertical and horizontal path of position printing. This study also used a quantitative experiment using an analysis of variance (ANOVA). The results show that the significant factor that affect on ABS 3D printing were vertical path of position printing and electroless plating. Vertical path of position printing contributed significantly in increasing tensile strength and impact strength. Whereas, the surface roughness shows a minimum value when using electroless plating as a coating medium. The results of tensile strength, impact strength and surface roughness obtained from this experiment were 17.14 MPa, 0.03937 J/mm^2 and 0.7533 μm respectively when these two parameters were applied during the experiment.

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ABSTRAK

Pada masa kini, bahan yang digunakan secara meluas dalam industri automotif adalah keluli karbon rendah, keluli kekuatan tinggi, aluminium, plastik dan komposit. Walau bagaimanapun, bahan plastik amat jarang digunakan sebagai bahan komponen badan kenderaan kerana sifatnya jauh lebih rendah daripada keluli dari segi kekuatan tegangan dan kekuatan impak namum begitu, plastik sangat ringan jika dibandingkan dengan keluli. Beberapa jenis plastik yang biasa digunakan dalam industri automotif seperti acrylonitrile butadiene styrene (ABS) dan polypropylene (PP). Bagi meningkatkan kualiti permukaan ABS, salutan nipis di bahagian atas permukaannya diperlukan. Oleh kerana itu, kajian ini dijalankan bagi menganalisis kesan cetakan prototaip yang berbeza terhadap kekuatan tegangan, kekuatan impak serta sifat kekasaran permukaan hasil dari lapisan yang berbeza pada ABS. Kajian ini dibahagikan kepada tiga bahagian iaitu tiada salutan, salutan semburan cat, dan penyaduran tanpa elektrod. Dua parameter yang digunakan dalam prototaip berulang ialah kedudukan cetakan menegak dan mendatar. Kajian ini juga menggunakan percubaan kuantitatif menggunakan analisis varians (ANOVA). Hasil kajian menunjukkan faktor penting yang mempengaruhi ABS 3D adalah kedudukan cetakan menegak dan penyaduran tanpa elektrod. Kedudukan cetakan menegak sangat penting dalam meningkatkan kekuatan tegangan dan kekuatan kesan. Manakala, kekasaran permukaan menunjukkan nilai minimum apabila menggunakan penyaduran tanpa elektrod. Keputusan eksperimen menunjukkan kekuatan tegangan, kekuatan impak dan kekasaran permukaan adalah 7.14 MPa, 0.03937 J / mm2 dan 0.7533 µm masing-masing apabila kedua-dua parameter ini digunakan di dalam eksperimen ini.

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LIST OF ABBREVIATIONS

3D	-	3 Dimension
ABS	-	Acrylonitrile Butadiene Styrene
ACC	-	American Chemistry Council
AM	-	Additive Manufacturing
ANOVA	-	Analysis of Variance
ASTM	-	American Society Testing and Material
CAD	-	Computer-Aided Design
DLP	-	Digital Light Processing
EAK	-	Express Aero Kits
FDM	-	Fused Deposition Modelling
IITB	-	Indian Institute of Technology Bombay
LC	-	Layered Manufacturing
LOM	-	Laminated Object Manufacturing
MJM	-	Multi-Jet Modeling
NC	-	Numerically Controlled
OEM	-	Original Equipment Manufacturer
PC	-	Polycarbonate
PE	-	Polyethylene
PEI	-	Poly-Ether Imide
PLA	-	Polylactic Acid
PP	-	Polypropylene
PPSF	-	Polyphenylsulfone finishing
PS	-	Polystyrene
PVC	-	Polyvinylchloride
RP	-	Rapid Prototyping
SLA	-	Stereolithography
SLM	-	Selective Laser Melting
SLS	-	Selective Laser Sintering
SOP		Standard Of Procedures
UV	-	Ultraviolet

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

A decade recently automobile industry has redefined their product improving the engine performance as well as ripping the new models more comfortable, more dependable, easier to drive, and getting them environmental friendliness**.** Automobile industry does this by means of concurrent engineering methods that enhance the eco-design approach from materials selection to the end of life vehicle treatment. This is a new design approach represent a means of integrating environmental standards in productivity increase as part of the competitive corporate strategy. Eco-design patterns are altering the way cars are being conceived enabling car companies to make do with the most restrictive environmental regulations and even to predict them. In this context environmental friendliness has become an important standard for materials selection. Clean and recyclable materials are responsible for automobile environmental quality, which is becoming a critical issue for the near future.

Multiple material industries, such as thermoplastics, composites, steel, or aluminium, are all working to create lighter weight solutions for the automotive industry. While many solutions will come from a combination of these materials, the plastics and composites industry is leading the way with thermoplastic-based materials. These materials have high strength and rigidity, low density, and tailored thermal expansion properties as well as recyclability.

Thermoplastics are commonly used as the battery-pack systems of electric vehicles. With the added weight of a large battery comes a need to reduce weight in other areas. Resins

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in the battery-pack system help keep the battery stable, regardless of changes in temperature, humidity, and load. Resins also help offset the weight of the battery itself.

While great strides are being made in reducing weight, manufacturing time, and cost; manufacturers continue to develop and test new ideas. Currently, the manufacturer is working to develop hybrid solutions that combine the strengths of thermoplastic and metal. Perhaps the biggest project under development within the automotive industry is creating an all-plastic tailgate.

Future dominant materials will be used as an exterior part in the automotive industry are steel, high strength steel, aluminium, plastics and composites (Mazumdar, 2013). Plastics is a cheaper material but not commonly used as a vehicle body part. It because of their properties lower than steel in term strength and impact. However, plastics very light compared with steel. If the properties of thermoplastic can improve, may have big advantages over steel in automobile manufacturing in the future.

The Fused Deposition Modeling (FDM) is a rapid prototyping technique in which a thermoplastic material is extruded layer by layer from a nozzle, controlled by temperature. Compared to other techniques, FDM is a lot cheaper. For the manufacturer, it is very important to know whether producing by means of 3D printing technique is cheaper than utilizing the traditional way of producing. The material that is used in FDM technology, the filament, costs is much lower. For this reason, FDM technology is more attractive to many companies.

1.2 Problem Statement

Vehicle weight reduction is currently the hottest issue concerning vehicles. Vehicle weight directly affects energy consumption. The recent emergence of electric vehicles has focused attention more on vehicle weight (Lyu and Choi, 2015). These means involve

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reducing the size and number of engine related parts by maximizing engine efficiency, producing structurally efficient body design, reducing overall vehicle size by maximizing interior room using space-efficient designs, as well as employing lightweight materials. Lightweight materials can be utilized by developing effectively advanced materials, pioneered moulding processes, and construction technologies. The materials used for vehicle fabrication are largely classified as ferrous metals, non-ferrous metals, and polymers.

Material selection in the automotive industry is an artful balance between market, societal, and corporate demands. The material selection process itself will evolve as vehicle and component development processes change to become more responsive in terms of accuracy, time, and cost-to-market and regulatory demands.

Plastic applications have grown tremendously over the last decade, causing a consistent yearly increase in plastic usage. Plastic fuel tanks, which weight around 30 per cent less than their conventional steel counterparts, and plastic bumpers. It is almost 8.3 per cent of total vehicle weight (Mazumdar, 2013). However, Processing thermoplastic is quite difficult because, during a heated stage, the temperature must be controlled to prevent overheating. As a solution, Rapid Prototyping (RP) will be used as a method to be processing the thermoplastics.

Zolkifly (2013), stated that safety, vehicle appearance, standing charges and resale value play significant roles in influencing satisfaction towards national cars in Malaysia and suggested that local car producer should provide attractive exterior and interior design to cater to customer specific needs by emphasizing on sporty characteristics and design (spoiler, bumper, sport rim, sport meter, sport seats) and metallic paint.

Nowadays, lots of car consumer have their own opinion about vehicle appearance. To fulfil their satisfaction is very difficult but not impossible at a high cost. With Rapid Prototyping (RP) technologies, the landscape of the automotive industry will be change. As

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a result, vehicle manufacturers do not have to worry about designing a vehicle body. Customers will come up with their ideas and produce them through RP technology. The custom design from the consumer will be applied in the design phase. The customer can design their own car's shape with low cost compared with the previous method that needs a large scale of manufacturing. However, how far the RP can be used as a method to replaced conventional method such as injection moulding in term of mechanical properties.

Fused Deposition Modelling (FDM) is best suited for cost-effective prototypes produced with short lead time. Layer lines are generally present on FDM prints making post-processing an important step if a smooth surface is required. Some post-processing methods can also add strength to prints helping to mitigate the anisotropic behaviour of FDM parts.

Surface finishing may be defined as any process that alters the surface of a material or aesthetic or functional purposes. The five major processes that treat better surface finishing such as abrasive blast cleaning and protective coating, anodizing, electroplating and electroless plating. Electroless plating deposits a thin layer of metal on the surface of a part built using the chemical reaction. This metal coating can be both decorative and functional. The coating gives the appearance of production metal or plated parts and provides a hard, wear-resistant surface with reflective properties. However, it electroless plated can improve mechanical properties. With simple finishing techniques, FDM parts are ready for electroless plating with chromium surface.

Combination of all these factors such as the path of RP and types of the coating will influence the result of plastic's strength. The best combination will be given the highest value for strength and impact test and a lower value for the surface roughness result.

The optimization response will be used to design the methodology or technique in plastic finishing manufacturing processes.

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1.3 Objectives of Study

The objectives of this study are:

i. To analyze the effect of electroless plating on strength, impact and surface roughness properties.

ii. To investigate the factor that influences the optimization on strength, impact and surface roughness properties.

iii. To validate the effectiveness of the optimization method or technic to achieve high strength, high impact and low value in surface finish.

1.4 Scope of Study

The study will be focusing on the material Acrylonitrile Butadiene Styrene (ABS M30) that been use on rapid prototyping-3D printing coated with electroless plated. This modelling part will be produced based on specimen tensile strength test ASTM D-638-14, impact test ASTM D-256-10e1. The specimen classify into three types of coating which are, raw (naked surface), spray paint and electroless plating. For electroless plating will be followed "The Method of Silver Plating" by Demitrios Roumonis (2012).

1.5 Significance of Study

The significance of this study is to the automotive industry required to improve material of the vehicle body. ABS will be a future dominant material, replace steel as a material with improvement in their strength. The other contributions of this study would be of interest to car designer as well as to design variety shape with low cost of productions. This study will also be beneficial to the aerospace industry. Improvement of strength and impact of ABS also significance to aerospace industry where reduction weight of part is the important criterion.

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Lyu and Choi (2015) stated that a diverse range of polymer materials can be used to make vehicle components and the manufacturing methods in accordance with products and materials vary greatly. Shaping processes must be chosen according to the materials being used and the product design. Consequently, large amounts of lightweight materials, such as polymers, will be greatly used to construct newly developed, polymer-based, vehicles, including electric and electric/hybrid vehicles.

Based on the American Chemistry Council (ACC) (2014), The plastics and polymer composites industry has a long track record of delivering strong performance and continues to pursue transformative innovations. One material class that promises such opportunity is high-performance polymer composites. In addition to potential innovative aerodynamic design and styling aesthetics, polymer composites' high strength-to-weight and stiffness-to-weight ratios have made them the material of choice in industries like motorsports and aerospace for years. Many polymer composites offer an unmatched energy-absorbing capability per unit mass, making them a strong, lightweight choice.

The current developmental infrastructure for plastics and polymer composites used in automobiles is limited by the lack of readily accessible data and design tools developed specifically for these materials. Insufficient material properties databases and design tools that do not effectively model many plastics and polymer composites limit the ability for designers to cost-effectively develop component solutions that take full advantage of the benefits of these materials. The plastics and polymer composites industry should work with automotive Original Equipment Manufacturer (OEM) and Tiers to overcome the following barriers to efficient material selection and part design to encourage further integration of plastics and polymer composites in automotive markets (ACC, 2014).

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CHAPTER 2

LITERATURE REVIEW

This chapter will be discussing in plastic, polymer, and their processing methods. After that, further discussion continues with Additive Manufacturing and how Electroplating is done on the plastic surface. This chapter also lookup the impact Rapid Prototyping – Fused Deposition Modelling on Automotive Industry.

2.1 Thermoplastic and Thermosetting Polymers

The basic structure of plastics (or polymers) is given by macromolecule chains, formulated from monomer units by chemical reactions. Typical reactions for chain assembling are polyaddition (continuous or stepwise) and condensation polymerization (polycondensation). Caused by the macromolecular structure and the temperature-dependent physical properties plastic materials are distinguished into different classes. Figure 2.1 gives an overview of the classification of plastics with some typical examples. (Klein, 2011).

The word polymer literally means "many parts" (Smith et al, 2004). A solid polymer contains more than one chemically bonding become one solid composite. These long molecules are composed of structural entities called mer units, which are successively repeated along the chain. ''Mer'' originates from the Greek word meros, which means part; the term polymer was coined to mean many mers. Sometimes use the term monomer, which refers to a stable molecule from which a polymer is synthesized (Callister and Rethwisch, 2008).

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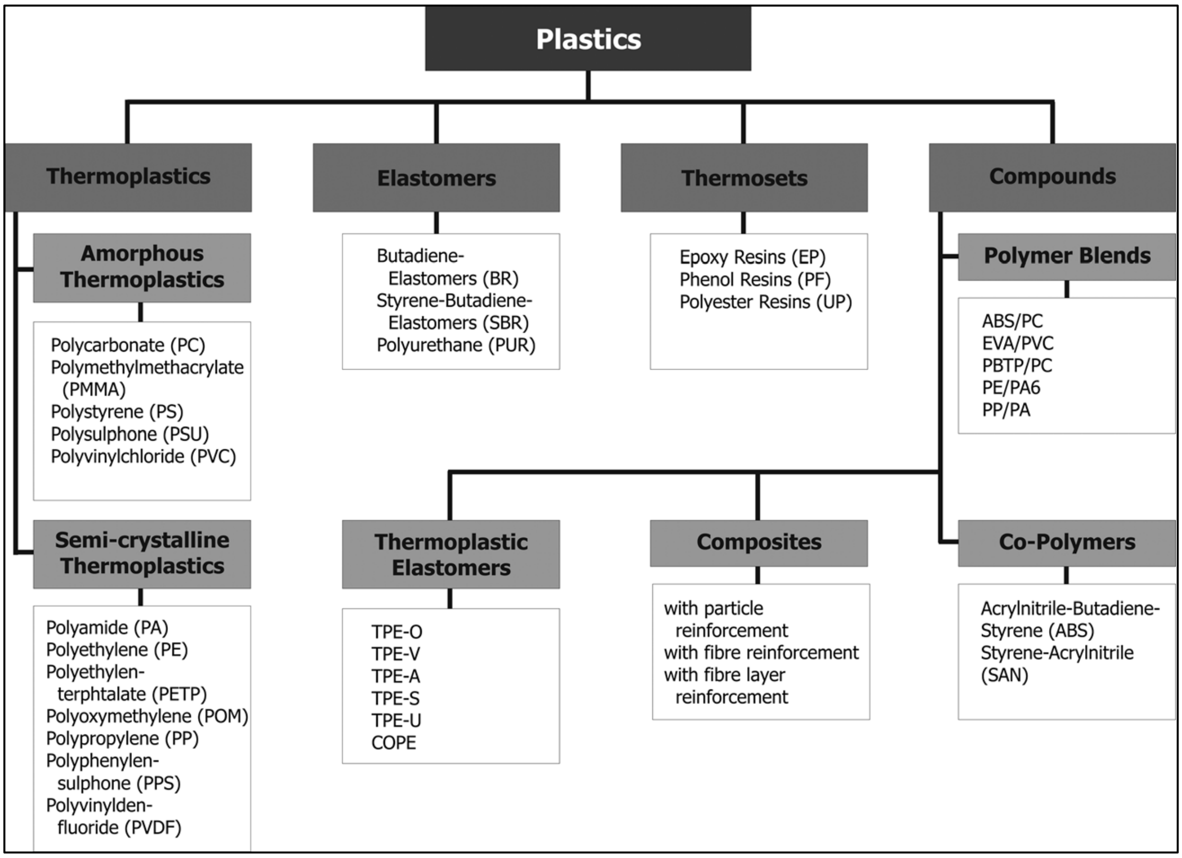

Figure 2.1: Classification of Plastic.
(Klein, 2011)

Have two important material that has been used for a long time in polymer’s family is: Plastics and Elastomers. Focusing on the requirement in the automotive industry, plastics one of potential material that will be used widely in the future. Plastic can be divided into two classes: Thermoplastic and Thermosetting Plastics / Thermosets.

Thermoplastics soften when heated (and eventually liquefy) and harden when cooled-processes that are totally reversible and may be repeated. On a molecular level, as the temperature is raised, secondary bonding forces are diminished (by increased molecular motion) so that the relative movement of adjacent chains is facilitated when a stress is applied. Irreversible degradation results when the temperature of a molten thermoplastic polymer is raised to the point at which molecular vibrations become violent enough to break the primary covalent bonds. In addition, thermoplastics are relatively soft (Callister and Rethwisch, 2008).

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