



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# Investigation of Mechanical Properties of Parts Produced Using 3D Printing

Thesis submitted in accordance with the partial requirements of the Universiti  
Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering  
(Manufacturing Process)

By

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## APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:



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## ABSTRACT

Mechanical properties for material are important in order to produce high quality product. Rapid prototyping is one of the fields that produce product or prototype by using many types of materials. This reasearch was done focusing on studying about the mechanical properties of parts produced using three dimensional printing which is one of the methods of rapid prototyping. The material for this reasearch is zp 130 powder which was machined using ZPrinter 310 Plus. In order to determine the mechanical properties, the study about the theory had been done by reading the journals. Then, the next step was defined the type of material used to produce parts using three dimensional printing. A study about the three dimensional printing and rapid prototyping also had been done in order to enhance knowledge and skills in term of producing parts or prototype. After that, research about the specimen design and standard dimension for testing specimens was done to manage the designing process by using SolidWork software. There were twenty specimens had been machined using ZPrinter 310 plus. Each type of testing needs five specimens which one specimen took five minutes of machining. The final method in order to complete this project was to test the specimens by using four types of testing which were flexural test, charpy impact test, tensile test and compression test. The testing was obtained to get the data of mechanical properties. After completing the test, all data were analyzed in order to get the actual data for mechanical properties which using specific equation for each data. As the final result, the flexural strength for zp 130 powder was 11.9 MPa, impact strength was 40.682 J/m<sup>2</sup>, the tensile strength was 2.041 MPa, modulus of elasticity was 8.33 GPa and the compressive strength was 4.28 MPa.

## ABSTRAK

Sifat mekanikal sesuatu bahan adalah penting bagi menghasilkan suatu produk yang berkualiti tinggi. Pembuatan prototaip pantas adalah salah satu bidang dalam menghasilkan produk dengan menggunakan pelbagai bahan. Kajian ini adalah berfokus kepada mengkaji sifat-sifat mekanikal bagi produk yang dihasilkan menggunakan percetakan tiga dimensi yang mana salah satu daripada pembuatan prototaip pantas. Bahan yang telah digunakan dalam kajian ini adalah zp 130 powder dan mesin yang digunakan adalah ZPrinter 310 Plus. Bagi mengkaji sifat-sifat mekanikal bahan tersebut, kajian terhadap teori telah dilakukan sebagai permulaan iaitu melalui pelbagai jurnal. Kemudian, langkah yang seterusnya adalah menentukan jenis bahan yang akan digunakan bagi menghasilkan produk dengan menggunakan mesin cetak tiga dimensi. Kajian mengenai pencetakan tiga dimensi dan juga pembuat prototaip pantas juga telah dilakukan untuk memperkayakan pengetahuan dan kebolehan berkenaan dengan penghasilan prototaip. Kajian juga telah dilakukan berkaitan dengan rekabentuk spesimen dan ukuran piawai untuk spesimen-spesimen. Setelah rekabentuk piawai dikenalpasti, bentuk-bentuk spesimen telah dilukis menggunakan perisian SolidWork. Terdapat dua puluh spesimen yang telah dimesin menggunakan ZPrinter 310 Plus. Terdapat empat jenis ujian yang akan dilakukan terhadap spesimen-spesimen tersebut dan setiap ujian menggunakan sebanyak lima spesimen. Bagi menghasilkan satu spesimen, lima minit diperuntukkan untuk masa pemesinan. Sebagai langkah untuk mendapatkan sifat-sifat mekanikal bahan tersebut, empat jenis ujian yang dilakukan adalah ujian kelenturan, ujian hentaman 'charpy', ujian regangan dan ujian mampatan. Kemudian, data-data diperolehi daripada hasil ujian-ujian tersebut dianalisis dengan menggunakan rumus tertentu bagi mendapatkan keputusan sebenar bagi sifat-sifat mekanikal zp 130 powder. Sebagai keputusan akhir, didapati kekuatan lenturan bagi zp 130 powder adalah 11.9

MPa, kekuatan hentaman adalah  $40.682 \text{ J/m}^2$ , kekuatan regangan adalah  $2.041 \text{ MPa}$ , modulus kelenturan adalah  $8.33 \text{ GPa}$  dan kekuatan mampatan adalah  $4.28 \text{ MPa}$ .

## **DEDICATION**

For my beloved mother and father, I would like to thank both of you because of the helps that both of you had gave to me especially for the costing and support in order for me to finish this thesis successfully. I also would like to thank all my friends who have helped me gaining my knowledge about the information of this thesis especially those who have a lot of discussed with me.



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## LIST OF SYMBOLS

A	-	area
b	-	width
cm	-	centimeter
d	-	height
E	-	energy
Ee	-	modulus of elasticity
$f_v$	-	tensile strength
$F_{max}$	-	maximum load
GPa	-	gigapascal
h	-	thickness
le	-	impact strength
J	-	Joule
kN	-	kilonewton
L	-	distance
m	-	meter
mm	-	millimeter
MPa	-	megapascal
N	-	Newton
P	-	load
S	-	stress
%	-	percent
$\sigma_{fs}$	-	flexural strength
$\epsilon$	-	strain
$\sigma_c$	-	compressive strength

## LIST OF ABBREVIATION

ASTM -	American Society for Testing and Materials
CAD -	computer aided design
CAM -	computer aided manufacturing
FDM -	fused deposition modeling
ISO -	International Standards Organization
MOR -	modulus of rapture
RP -	rapid prototyping
SFF -	solid freeform fabrication
SLS -	selective laser sintering
USA -	United State of America



## **LIST OF APPENDICES**

- Appendix A Gantt chart and flow chart
- Appendix B Calculation for flexural strength, impact strength, tensile strength, modulus of elasticity and compressive strength
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# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Mechanical properties for materials are important to be tested in order to make sure the products that to be produced have good quality and good physical strength which depend on the material used. The properties are referring to the ability of the material to get through any stress or defection which can affect the products physically. Three dimensional printing is one of the rapid prototyping process that use powder as main component material to produce a prototype. The machine that used to produce prototype which had been chosen for this research is ZPrinter 310 Plus by Z Corporation. The materials that used to for three dimensional printing normally exists in form of powder and one of the materials is zp 130 powder.

Three dimensional printing is generally faster, more affordable and easier to use compared to other rapid prototyping technologies. This technology consists of an inkjet printing system where layers of powder are selectively bonded by printing a water-based adhesive from the inkjet printhead. The printhead is able to print the shape of each cross-section as determined by a CAD file.

The zp 130 powder is the material that used in three dimensional printing specially for ZPrinter 310 Plus printer. This material consists of three main components

which are plaster, vinyl polymer and sulfate salt. The composition of each component can be illustrated as table 1.1.

**Table 1.1** Composition of zp 130 powder [Material Safety Data Sheet; (2005)]

<b>Component</b>	<b>Approximate by weight (%)</b>
Plaster which contains Crystalline Silica at < 1 %	50 – 95
Vinyl Polymer	2 – 20
Sulfate Salt	0 – 5

## 1.2 Problem Statements

The three dimensional printing is widely use nowadays in field of rapid prototyping. There are many choices of material to be used as the material for three dimensional printing machining. One of the materials is zp 130 powder which is machined using ZPrinting 310 Plus. The composition of the material was provided by the company who produced the material. But, the mechanical properties of the finished part which had been machined were not provided. The mechanical properties for finished part are important in order to choose the best material that should be used for three dimensional printing in order to get a high quality prototype and to know the capability of the three dimensional printer comparing to other rapid prototyping machines.

### **1.3 Objectives**

- i. To identify the material used in producing parts using three dimensional printing
- ii. To identify the mechanical properties of the parts produced using three dimensional printing.

### **1.4 Scopes**

- i. Study the area of rapid prototyping
- ii. Study types of mechanical properties
- iii. Identify the design parts
- iv. Designed the parts using SolidWork software
- v. Produced twenty specimens using three dimensional printer
- vi. Identify types of testing (tensile test, charpy impact test, flexural test and compression test)
- vii. Test all twenty specimens and analyzed the result

## **CHAPTER 2**

### **LITERATURES REVIEW**

#### **2.1 Rapid Prototyping Background**

Rapid prototyping is the automatic construction of physical objects using solid freeform fabrication. The first techniques for rapid prototyping became available in the 1980s and were used to produce models and prototype parts. Today, they are used for a much wider range of applications and are even used to manufacture production quality parts in relatively small numbers. Some sculptors use the technology to produce complex shapes for fine art exhibitions.

In brief, rapid prototyping takes virtual design from CAD or from animation modeling software, transforms them into cross sections, still virtual, and then create each cross section in physical space, one after the next until the model is finished.

In prototyping fabrication, the machine reads in data from a CAD drawing, and lays down successive layers of liquid or powdered material, and in this way builds up the model from a long series of cross sections. These layers which correspond to the virtual cross section from the CAD model are glued together or fused (often using a laser) automatically to create the final shape. The primary advantage to additive construction is its ability to create almost any geometry (excluding trapped negative volumes). The standard interface between CAD software and rapid prototyping machines is the STL file format.

The word "rapid" is relative to construct a model with contemporary machines typically takes three to seventy two hours, depending on machine type and model size. Used in micro technologies rapid is correct, the products made are ready very fast and the machines can build the parts in parallel.

Advances in technology allow the machine to use multiple materials in the construction of objects. This is important because it can use one material with a high melting point for the finished product, and another material with a low melting point as filler, to separate individual moving parts within the model. After the model is completed, it is heated to the point where the undesired material melts away, and what is left is a functional plastic machine. Although traditional injection molding is still cheaper for manufacturing plastic products, soon rapid prototyping may be used to produce finished goods in a single step.

Due to the high degree of flexibility and adaptability required by many rapid prototyping techniques, these applications typically require the use of robots or similar mechanisms.

However, there are currently several schemes to improve rapid prototyper technology to the stage where a prototyper can manufacture its own component parts. The idea behind this is that a new machine could be assembled relatively cheaply from raw materials by the owner of an existing one. Such crude 'self-replication' techniques could considerably reduce the cost of prototyping machines in the future, and hence any objects they are capable of manufacturing.

### 2.1.1 Solid Freeform Fabrication

Solid freeform fabrication is a technique for manufacturing solid objects by the sequential delivery of energy and material to specified points in space to produce that solid. SFF is sometimes referred to as rapid prototyping, rapid manufacturing, layered manufacturing and additive fabrication.

Techniques;

**i. Fused deposition modeling**

Fused deposition modeling extrudes hot plastic through a nozzle, building up a model.

**ii. Laminated object manufacturing**

Sheets of paper or plastic film are attached to previous layers by either sprayed glue, heating, or embedded adhesive, and then the desired outline of the layer is cut by laser or knife. Finished product typically looks and acts like wood.

**iii. Laser engineered net shaping**

A laser is used to melt metal powder and deposit it on the part directly. This has the advantage that the part is fully solid (unlike SLS) and the metal alloy composition can be dynamically changed over the volume of the part.

**iv. Selective laser sintering**

Selective laser sintering uses a laser to fuse powdered metal.

**v. Shape deposition manufacturing**

Alternatingly depositing sacrificial or part material by a printhead and machining it in shape.