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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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 research 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 research 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/m², the tensile strength was 2.041 MPa, modulus of elasticity was 8.33 GPa and the compressive strength was 4.28 MPa.
ABSTRAK

MPa, kekuatan hentaman adalah 40.682 J/m², kekuatan regangan adalah 2.041 MPa, modulus kelenturan adalah 8.33 GPa dan kekuatan mampatan adalah 4.28 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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TABLE OF CONTENTS

Abstract........................................................................................................i
Abstrak.......................................................................................................ii
Dedication.................................................................................................iv
Acknowledgement....................................................................................v
Table of Contents.....................................................................................vi
List of Figures...........................................................................................viii
List of Tables............................................................................................x
List of Symbols........................................................................................xi
List of Abbreviation....................................................................................xii
List of Appendices...................................................................................xiii

1. INTRODUCTION..................................................................................1
   1.1 Background......................................................................................1
   1.2 Problem Statement........................................................................3
   1.3 Objectives......................................................................................4
   1.4 Scopes...........................................................................................4

2. LITERATURES REVIEW.................................................................5
   2.1 Rapid Prototyping Background....................................................5
       2.1.1 Solid Freeform Fabrication..................................................7
       2.1.2 Three Dimensional Printing...............................................9
       2.1.3 STL File Format................................................................12
       2.1.4 ZPrinter 310 Plus..............................................................13
   2.2 Mechanical Properties Background............................................15
       2.2.1 General Definition of Mechanical Properties.......................16
2.2.2 Mechanical Properties of Investigation ............................................. 17
2.3 Previous Studies ........................................................................................................... 22

3. METHODOLOGY ........................................................................................................... 23
   3.1 Introduction ..................................................................................................................... 23
   3.2 Experimental Design ...................................................................................................... 24
       3.2.1 Specimen Preparation .......................................................................................... 24
       3.2.2 Flexural Test ........................................................................................................ 26
       3.2.3 Charpy Impact Test .............................................................................................. 29
       3.2.4 Tensile Test .......................................................................................................... 34
       3.2.5 Compression Test ................................................................................................. 38

4. RESULT AND DATA ANALYSIS .................................................................................. 41
   4.1 Flexural Test ................................................................................................................ 41
   4.2 Charpy Impact Test ..................................................................................................... 47
   4.3 Tensile Test ................................................................................................................ 51
   4.4 Compression Test ....................................................................................................... 60
   4.5 Final Result ................................................................................................................ 65

5. DISCUSSION ................................................................................................................ 66

6. CONCLUSION ................................................................................................................ 72

REFERENCES ..................................................................................................................... 73

Appendix A
Appendix B
Appendix C
Appendix D
Appendix E
Appendix F
# LIST OF FIGURES

2.1 Mechanism of three dimensional printing 10  
2.2 ZPrinter 310 Plus three dimensional printer 13  
2.3 Stress-strain curve to identify tensile modulus and tensile strength 19  
2.4 Stress-strain curve to identify toughness 20  
2.5 Stress-strain curve for types of toughness 21  

3.1 Three dimensional printing processes 24  
3.2 Three-point flexural test 25  
3.3 Mechanism of flexural test for three point loading 26  
3.4 Geometry for flexural test specimen 26  
3.5 Charpy impact test 28  
3.6 Schematic of the charpy impact test 29  
3.7 Geometry for charpy impact test 30  
3.8 Tensile test 33  
3.9 Mechanism of tensile test 34  
3.10 Geometry for tensile test 35  
3.11 Compression test 37  
3.12 Mechanism of compression test 38  
3.13 Geometry for compression test 38  

4.1 Graph of maximum force versus number of specimens for flexural test 41  
4.2 Graph of maximum stress versus number of specimens for flexural test 42  
4.3 Graph of maximum strain versus number of specimens for flexural test 43  
4.4 Graph of flexural strength versus number of specimens for flexural test 45  
4.5 Graph of impact energy versus number of specimens for charpy impact test 47
4.6  Graph of impact strength versus number of specimens for charpy impact test  49
4.7  Graph of maximum force versus number of specimens for tensile test  45
4.8  Graph of maximum stress versus number of specimens for tensile test  52
4.9  Graph of maximum strain versus number of specimens for tensile test  53
4.10 Graph of tensile strength versus number of specimens for tensile test  55
4.11 Graph modulus of elasticity versus number of specimens for tensile test  58
4.12 Graph of maximum force versus number of specimens for compression test  60
4.13 Graph of compressive strength versus number of specimens for compression test  62
5.1  First maximum force and second maximum force for second specimen of flexural test  65
5.2  Stress-strain curve of third specimen for tensile test  68
LIST OF TABLES

1.1 Composition of zp 130 powder 2
2.1 Comparison of solid freeform fabrication method 8
2.2 Specification of ZPrinter 310 Plus 14
2.3 General definition for types of mechanical properties 16
2.4 List of related previous research 22

4.1 Data collection of flexural test 40
4.2 Data to calculate flexural strength 44
4.3 Flexural strength for each specimen 44
4.4 Data collection of charpy impact test 47
4.5 Data to calculate impact strength 48
4.6 Impact strength for each specimen 49
4.7 Data collection of tensile test 51
4.8 Data to calculate tensile strength 54
4.9 Tensile strength for each specimen 55
4.10 Data to calculate modulus of elasticity 57
4.11 Modulus of elasticity for each specimen 57
4.12 Data collection for compressive test 60
4.13 Data to calculate compressive strength 61
4.14 Compressive strength for each specimen 62
4.15 Mechanical properties for zp 130 powder 64

5.1 Mechanical properties for fused quartz and zp 130 powder 69
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<td>A</td>
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<tr>
<td>b</td>
<td>width</td>
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<tr>
<td>cm</td>
<td>centimeter</td>
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<tr>
<td>d</td>
<td>height</td>
</tr>
<tr>
<td>E</td>
<td>energy</td>
</tr>
<tr>
<td>Ee</td>
<td>modulus of elasticity</td>
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<tr>
<td>f_v</td>
<td>tensile strength</td>
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<tr>
<td>F_max</td>
<td>maximum load</td>
</tr>
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<td>GPa</td>
<td>gigapascal</td>
</tr>
<tr>
<td>h</td>
<td>thickness</td>
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<tr>
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<tr>
<td>ε</td>
<td>strain</td>
</tr>
<tr>
<td>σ_c</td>
<td>compressive strength</td>
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xi
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

Appendix C  Result for flexural test

Appendix D  Result for charpy impact test

Appendix E  Result for tensile test

Appendix F  Result for compression test
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 deflection 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)]

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate by weight (%)</th>
</tr>
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<tbody>
<tr>
<td>Plaster which contains Crystalline Silica at &lt; 1 %</td>
<td>50 – 95</td>
</tr>
<tr>
<td>Vinyl Polymer</td>
<td>2 – 20</td>
</tr>
<tr>
<td>Sulfate Salt</td>
<td>0 – 5</td>
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</table>
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.