INVESTIGATE THE EFFECT OF LAYER THICKNESS ON MECHANICAL PROPERTIES OF PARTS PRODUCE USING RP 3D-PRINTER MACHINE

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Investigate the Effect of Layer Thickness on Mechanical Properties of Parts Produce Using RP 3D Printer Machine

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

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ABSTRACT

Mechanical properties for material are something which can be defined as important terms of producing high quality product. In rapid prototyping, there are many kinds of material used to produce the product or in details; to product prototype. In this research, the main focus is to investigate the mechanical properties of parts produce by using three dimensional printing. To be more specific, the investigation is about on how the layer thickness affects parts produced by three dimensional printing. The layer thickness defined in producing the testing specimens was 0.1000mm and 0.0875mm. By referring to several journals or other sources like books and manuals, theoretical studies on determine the mechanical properties has been reviewed. All the fabrication process was carried out by using ZPrinter 310 Plus printing machine. Material use in this process was zp130 powder-based material. Before that, the specimens have been designed according to ASTM standards. For each part, there were differences between designations and geometries in order to match with types of test conducted. Then, all the specimens shape have been drawn by using SolidWork software and saved in STL format. 30 specimens were totally produced; five testing specimens each test and layer thickness involved as mention before. Final method in completing the research was to test each specimens produce by using three types of testing method; tensile, compression, and hardness test. From the test, expected result in determine the mechanical properties of the parts produce by three dimensional printing was obtained. Parts produced in 0.0875 mm of layer thickness obtained the highest value in all data; with 1.0260 MPa of tensile strength, 12.5825 N/mm^2 for modulus of elasticity and 218.94 MPa for compressive strength. As for final result, the affect on layer thickness of part produced by 3D-printer have been identified. Parts produce in 0.0875mm of layer thickness having greater tensile and compressive strength compared with parts made from 0.1000 mm of layer thickness. But opposite from that it became more brittle.

ABSTRAK

Sifat mekanikal sesuatu bahan adalah penting dalam meenghasilkan sesuatu produk yang berkualiti tinggi. Dalam 'Rapid Prototyping' atau teknologi pembuatan prototaip terpantas, terdapat pelbagai jenis material digunakan untuk menghasilkan produk; iaitu prototaip. Kajian ini memberi fokus kepada mengkaji sifat-sifat mekanikal bagi produk yang dihasilkan melalui kaedah percetakan tiga dimensi (3D-printing). Secara spesifik, penyelidikan adalah berkenaan bagaimana ketebalan lapisan binaan mempengaruhi produk yang dihasilkan melalui kaedah percetakan 3D ini. Ketebalan lapisan binaan tersebut yang digunakan dalam menghasilkan specimen adalah 0.1000 mm serta 0.0875 mm. Proses fabrikasi dibuat menggunakan mesin ZPrinter 310 Plus. Melalui rujukan beberapa jurnal serta sumber-sumber lain seperti buku dan manual, kajian secara teori dilakukan; berhubung kait dengan sifat-sifat mekanikal. Spesimen telah direkabentuk mengikut standard yg ditetapkan oleh ASTM. Setiap spesimen adalah berlainan dari segi bentuk dan geometri bagi menyesuaikannya dengan jenis ujian yang akan dibuat. Walaupun bentuk serta geometri setiap spesimen berlainan, bahan yang digunakan dalam prosess ini adalah sama; iaitu zp130 – material berasaskan serbuk. Kemudian, rekabentuk setiap spesimen dijana menggunakan perisian SolidWork dan disimpan dalam format STL. 30 spesimen telah dihasilkan; lima spesimen bagi setiap ujian serta ketebalan lapisan binaan seperti yang telah dinyatakan sebelumnya. Kaedah terakhir dalam menyiapkan kajian ini adalah dengan menguji setiap spesimen melalui tiga jenis kaedah ujian; iaitu ujian regangan, mampatan serta kekerasan. Daripada ujian tersebut, nilai bagi sifat mekanikal sesuatu produk yang dihasilkan melalui kaedah percetakan 3D ini dapat ditentukan. Produk yang dihasilkan dalam 0.0875 mm ketebalan lapisan binaannya mendapat jumlah tertinggi bagi setiap nilai data; dengan 1.0260 MPa bagi kekuatan regangan, 12.5825 N/mm^2 bagi modulus kelenturan serta 218.94 MPa bagi kekuatan mampatan. Keputusan akhir menunjukkan ketebalan lapisan binaan mempengaruhi kekuatan mekanikal sesuatu produk yang dihasilkan melalui kaedah percetakan 3D. Produk yang berketebalan 0.0875 mm lapisan binaannya adalah lebih kuat dalam kekuatan regangan dan mampatannya berbanding 0.1000 mm. Tetapi, ianya akan menjadi semakin rapuh.

DEDICATION

To my beloved father; Basir bin Md. Rejab and mother; Hamimah binti Ali, thank you for their supports and encouragement all the way in my life. To all my friends, thank you for their helped and cooperation during completing the thesis. Also, to Aznida binti Mohd Zaki…=)

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AFNOR	-	Association Francaise de Normalisation (France Standard Association)
ANSI	-	American National Standard Institute
ASTM	-	American Society of Testing & Material
CAD	-	Computer Aided Design
cm	-	Centimeter
DIN	-	Deutsches Institut fur Normung (German Institute of Standardization)
FDM	-	Fused Deposition Modeling
FKP	-	Fakulti Kejuruteraan Pembuatan
in	-	Inch
mm	-	Millimeter
NCDS	-	Nano composite deposition system
PSM	-	Projek Sarjana Muda
RP	-	Rapid Prototyping
SFF	-	Solid Freeform Fabrication
SGC	-	Solid Ground Curing
SLA	-	Stereolitography
SLS	-	Selective Laser Sintering
UTM	-	Universal Tenting Machine
3 DP	-	Three Dimensional Printer

W	-	Width of narrow section
L	-	Length of narrow section
WO	-	Width overall
LO	-	Length overall
G	-	Gage length
D	-	Distance between grip
R	-	Radius of fillet

CHAPTER 1

INTRODUCTION

1.1 Background

Rapid prototyping (RP) is an automatic construction of physical objects using solid freeform fabrication. The first techniques for rapid prototyping became available in the late 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 arts exhibitions [1].

Regarding to this investigation, the machine use in producing the prototypes would be 3D-printer machine. The models of this 3D-printer machine known as Zprinter 310 Plus, manufactured by Z Corporation (based in Massachusetts Institute of Technology). This 3D-printer consists of an inkjet printing systems; where layer of powder are selectively bonded by 'laying' a water-based adhesive from inkjet print head. The print head actually is capable to print the shape for each cross-section of the prototype as determined by a CAD file. [2, 6]

Material used which been supplied by manufacturer is called zp130 powder-based, specially made for Zprinter 310 Plus printer [6].

1.2 Problem Statement :

Rapid Prototyping (RP) is a technology that provides the ability to build or fabricate prototypes for initial design of a product. There are various materials can be used in producing the prototypes needed, which depends on the RP machine itself. In this research, material used to produce the specimen is zp130 powder. The material selection also affect the physical and mechanical properties of part produced. However this research is dedicated to study the affect of layer thickness on part produce by 3D-printer machine. Various process parameters can be found in 3D-printer which affects the character of RP parts; including build direction, layer thickness, temperature and so on [1,2,6]. Layer thickness actually refers to the thickness of layered for each part produced by the 3D-Printer Machine.

According to previous study conducted, the main objective is to investigate the mechanical behaviour of parts made by RP, and also the measurement of material properties. Here, the research is about to make comparison on mechanical properties of parts made by RP; consist of FDM, 3D-printer and nano-composite deposition system (NCDS). Build of direction is the main parameter which had been tuned in order to investigate the affect and differences among those three types of RP method [3]. Another study is about to improved the RP part accuracy through parameter tuning. It is focusing on SLA machining processes; and the optimization result obtained from this research can be applied to any other RP machines using the similar method [4].

Limitations of previous studies are; the only parameter that has been studied for 3D-printer is build of direction, and to come out with compressive strength data only. This research aims at conducting an experimental study in RP part strength through parameter tuning of 3D-printer processes. Here, it is about to investigate the effect of layer thickness on tensile, compression and hardness strength of part which produce using the 3D-printer machine. This research covers the measurement of mechanical properties of part produce by 3D-printer; where the parameter involved will be the layer thickness.

By varying the layer thickness; which is one of process parameter found in 3D-printer, each part produce will be tested on specific method to determine the mechanical structure of the part. From here, technical data on how the layer thickness affected the parts produce by 3D-printer machine can be provided. Thus, the tensile, compression and hardness strength of part produce by 3D-printer also can be predicted at the end of this research.

1.3 **Objectives of the Project**

There are three main objectives for this research:

a) To measure the tensile, hardness and compression strength of part produce by 3D-printer machine.
b) To analyze the effect the of layer thickness on the tensile, hardness and compression strength of part produced using 3D-printer.
c) To compare the effect of layer thickness on the tensile, hardness and compression strength of the part produced using 3D printing method.

1.4 **Scope of the Project**

a) Identify the properties of the material used in producing parts using three dimensional printing.

b) Prepare the specimen in two layer thickness;
    i) 0.1000 mm of layer thickness
    ii) 0.0875 mm of layer thickness

c) Produced five specimen for each layer thickness by using rapid prototyping 3D-printer includes three type of testing;

   i) Tensile test
   ii) Compression Strength
   iii) Hardness (Rockwell)

d) Analyze the effect of the build direction on tensile strength of part produced using three dimensional printing

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of RP Technology

Rapid prototyping is the automatic construction of physical objects using *solid free form* fabrication. The first techniques for rapid prototyping became available in the late 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. It has the ability to build or fabricate prototypes for initial design of a product, using various materials in producing the prototypes needed which depends on the RP machine itself [1,2].

Basically, RP would takes virtual designs from computer aided design (CAD) or animation modeling software, transforms them into thin horizontal cross sections, still virtual, and then creates each cross section in physical space, one after the next until the model is finished. With additive fabrication, the machine reads in data from a CAD drawing and lays down successive layers of liquid, powder, or sheet material, and in this way builds up the model from a series of cross sections. These layers, which correspond to the virtual cross section from the CAD model, are joined together or fused automatically to create the final shape. The primary advantage to additive fabrication is its ability to create almost any shape or geometric feature. The standard data interface between CAD software and the machines is the STL file format. An STL file approximates the shape of a part or assembly using triangular facets. Tiny facets produce a higher quality surface.

2.2 <u>Solid Freeform Fabrication</u>

This statement refers to a technique which used to manufacture solid objects by the sequential delivery of energy and materials to specific point in space to produce that solid. It also can be known as rapid prototyping, layered manufacturing, additive fabrication and so on. There are several technique used to perform this SFF, which can be referred as below:

2.2.1 Selective Laser Sintering (SLS)

The technique uses a laser beam to selectively fuse powdered materials, such as nylon, elastomer, and metal, into a solid object. Parts are built upon a platform which sits just below the surface in a bin of the heat-fusable powder. A laser traces the pattern of the first layer, sintering it together. The platform is lowered by the height of the next layer and powder is reapplied. This process continues until the part is complete. Excess powder in each layer helps to support the part during the build [3]. Figure below will give briefly explanation about SLS.

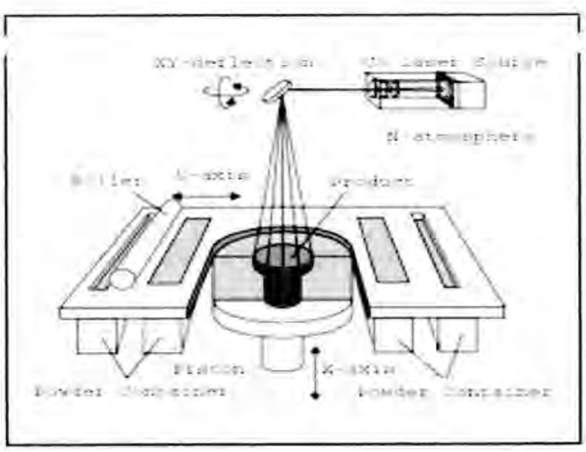

Figure 2.1 : Selective laser sintering machine diagram

2.2.2 Laminated Object Manufacturing

Sheet of paper or plastic film are attached to previous layer by sprayed glue, heating or embedded adhesive. Then desired outline of the layer will be cut out by laser or knife. Commonly, the finished product look similar and act like wood [3]. Diagram below can give briefly explanation on how this machine works.

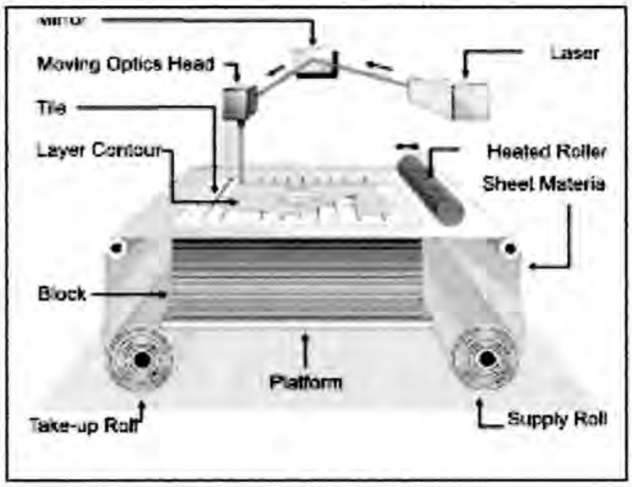

Figure 2.2 : Laminate object manufacturing machine diagram

2.2.3 Fused Deposition Modeling (FDM)

This technique consist of process where extrudes hot plastic through nozzle to perform a prototype needed. Firstly, filaments of heated thermoplastic are extruded from a tip that moves in the x-y plane. The controlled extrusion head then deposits very thin beads of material onto the build platform to form the first layer. The platform is maintained at a lower temperature, so that the thermoplastic quickly hardens. After the platform lowers, the extrusion head deposits a second layer upon the first. Supports are built along the way, fastened to the part either with a second, weaker material or with a perforated junction [3].