'I / We* confess that have been read this outstanding piece of works and at my / us * this piece of work is acceptable from the scope and the quality for the awarded Bachelor of Mechanical Engineering (Structure & Material)'

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Potong yang tidak berkenaan

MECHANICAL PROPERTIES OF POWDER-BASED PART PRODUCED BY 3 DIMENSIONAL PRINTER MACHINE

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'This report is submitted as partial
fulfillment of the requirements for the award of
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Faculty of Mechanical Engineering
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MAY 2008

"I hereby declare that this project report is written by me and is my own effort and that no part has been plagiarized without citation"

Signature : ……..

Name of Writer : ……..

Date : …….

DEDICATION

To my parents, my supervisor and friends.

ACKNOLEDGEMENT

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ABSTRACT

Rapid Prototyping (RP) is referred to as a class of technology that can automatically build a physical model from (CAD) data. One of the rapid prototyping technologies is explored via Three Dimensional Printing (3DP) Machine developed by the Massachusetts Institute of Technology and license to Z Corporation, which is use powder-based material. The capability of Three Dimensional Printing (3DP) are speedy fabrication and low material cost. There were three types of specimen dimension, which was design, and the Compression Testing as per ASTM D695 was done to investigate the mechanical properties, which is Prism 1 (12.7x12.7x25.4) mm, Prism 2 (15x15x30) mm and dog-bone (5 specimens for each type). The 3DP machine that was used to produce the parts is ZPrinter 310 Plus and the material that the machine used is ZP130 for the powder and Zb58 for the binder. From the results that was obtained from the compression testing, dog-bone specimen obtained the highest Compressive Strength at 4.43±0.623 MPa and also the highest Modulus of Elasticity at 1.71±0.143 GPa. In comparison with prism 1 of 2.96±2.21 MPa for Compressive Strength and 1.26±0.259 GPa for Modulus of Elasticity and for prism 2 of 2.30±0.931 MPa for Compressive Strength and 1.37±0.195 GPa for Modulus of Elasticity. From the results that were analyzed, it can be concluded that the smallest cross-section area produce the highest compressive strength, this is because binder is highly concentrated and absorbed into the specimen.

ABSTRAK

Rapid Prototyping merujuk kepada suatu bidang teknologi masa kini yang mampu untuk menghasilkan model fizikal secara automatik berdasarkan data daripada lukisan terbantu computer. Cepat menghasilkan produk dan kos bahan adalah rendah merupakan kunci kepada kebaikan-kabaikan penggunaan teknologi ini. Tesis ini bertujuan untuk mengkaji sifat-sifat mekanikal terutamanya daripada aspek mampatan bagi sesuatu produk berasaskan *powder-based* yg dihasilkan melalui mesin *3DPrinte*r. Penyelidikan ini melibatkan tiga jenis specimen iaitu lima unit bagi setiap specimen. Prism 1 yang mempunyai dimensi 12.7mm x 12.7mm x 25.4 dan Prism 2 berdimensi 15mm x 15mm x30mm dan spesimen yang ketiga berbentuk dog-bone adalah merujuk kepada Ujian Mampatan ASTM D695. Mesin jenis *ZPrinter 310 Plus*, bahan asas *Zp30*, dan binder *Zb58* adalah peralatan-peralatan yang terlibat secara langsung di dalam penyelidikan ini. Berdasarkan keputusan yang diperolehi, specimen jenis dog-bone mempunyai nilai kekuatan mampatan yang tertinggi iaitu 4.43±0.623MPa modulus keanjalan dan 1.71±0.143GPa. Seterusnya, diikuti dengan Prism 1 dengan 2.96±2.21MPa nilai mampatan dan 1.26±0.259GPa untuk nilai modulus keanjalan. Untuk Prism 2, nilai kekuatan mampatan adalah 2.30±0.931MPa and 1.37±0.195GPa untuk Modulus keanjalan. Setelah kesemua keputusan yang diperolehi dianalisa, kesimpulan yang dapat dibuat adalah semakin kecil keratan rentas, akan menghasilkan nilai kekuatan mampatan yang tinggi kerana binder banyak diserap kedalam spesimen.

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CHAPTER I

INTRODUCTION

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. For 3D-Printer Machine, it actually can be simplified as a commercial RP process. 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. Layer thickness actually refers to the thickness of each part being produced by the 3D-Printer Machine.

Before any products become a product that can be use in human life, one sample or prototype required as a specimen. This is because the sample will used to allow for demonstration, evaluation or testing for the proposed product. The technology that used to make the prototype is define as Rapid Prototyping (RP) and usually come first before a specific mold tool and jigs are design. For make prototyping traditionally required skill of employee, time and cost. These three causes usually applied for cutting, bending, shaping and assembly the part that needed.

The procedure was often iterative, with a series of prototypes being built to test various options. For many applications, this process has been revolutionized by a relatively recent technology known as layer manufacturing or Solid Freeform Fabrication(SFF) which is any part from any shape, can be produced in a single process

by adding successive layers of material. Usually mold, jigs and die are also include the quickly fabrication of the tools required for mass production. Now, there are many different manufacturing process have develop using an increasing the range of material [1,].

1.1 Rapid Prototyping

Rapid Prototyping (RP) is referred to as a class of technology can automatically build a physical model from Computer-Aided Design (CAD) data. This technology make designer quickly create prototypes of their design, although just two dimension pictures [1, 2, 3, 5, 7, 9,10]. Prototype can also be used in design testing. Other than that, RP also can be use to make tooling and any production part. RP is usually best manufacturing process for small production runs and complicated object. Most producing prototype take shortly time, but the time that required depends on the size and the complexity of the object. This process rather consumes more time make the prototype but still better than conventional method such as machining. Rapid prototyping system is a technology that emerges in 1980s. During the modern concept of Rapid prototyping was conceived and developed; actually the origin of this technology is back to the 1890s [1]. This is some of the most popular and commonly used RP technique [3,10]:

i. Selective laser sintering (SLS)
ii. Fused Deposition Modeling (FDM)
iii. Stereolithography (SLA)
iv. Multi Jet Modeling (MJM)
v. Laminated Object Manufacturing (LOM)
vi. Electron Beam Melting (EBM)
vii. 3D Printing (3DP)
viii. Objet PolyJet Modeling

1.2 Three -dimensional Printer

Three-Dimensioning printing refers to a category of rapid technology which is converting a virtual 3D model to become a physical object. Typically, 3D printer is an extremely flexible system, capable of creating part of any shape using any material including ceramics, metals, polymers and composites. 3D printer also generally faster and easier to use than other additive technologies. Three-dimensional printing (3DP) developed by the Massachusetts Institute of Technology and licensed to Z Corporation of Burlington, Massachusetts. The material usually use in this system is limited to two choices: plaster or starch.

Usually the material that is recommended is the plaster based because it is more durable and gives better resolution. Starch should be used if need making investment mold. After finish printing the part, it should be infiltrated. Infiltrants that are used to wax includes cyanoacrylate (superglue) and Z Max epoxy [4].

A unique capability of three-dimensional printing is the ability to produce multicolored parts. A part's color is determined by dyes added to the liquid binder. Almost any color is possible. Each layer, in essence, is like a full-color image printed on a flat sheet of paper by an ink-jet printer

Three dimensional printing offers the advantages of speedy fabrication and low materials cost. In fact, it's probably the fastest of all RP methods. Recently color output has also become available. However, there are limitations on resolution, surface finish, part fragility and available materials. The closest competitor to this process is probably fused deposition modeling [2,10].

1.3 Aim of Works

The objective in this project is:

- To design and fabricate part from powder- based material using 3D printer.
- To investigate the mechanical properties of part produced.

The scope in this project is:

- To design a part from powder- based material used in rapid prototyping.
- To fabricate part using 3d printer machine.
- To investigate the mechanical properties of part including compression test as per ASTM D695.

1.4 Problem Statement

This research is dedicated to the study of particularly for compression behavior of part which produces using 3D-Printer Machine. From the literature review, many researches reported about the specimen dimension, technical specification of machine but very few resources have reported about mechanical properties of powder-based part produced from the 3D Printer.

1.5 Planning and Execution

Table 1 below depicts the research activity that is carried out throughout the project. The first four months is dedicated to the literature review and design of the experiment (DOE) that cover the research methodology.

Table 1.0: Gantt Chart for the Research Activity in this Project.

Research Activity/Time	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
PSM 1													
Problem Statement													
Literature Review													
Rapid Prototyping													
3D Printer													
Raw Material used													
Mechanical Properties													
Methodology													
Experimental review													
Research Design													
DOE													
RP Process													
Mechanical Testing													
Design of Test Specimen													
Report Writing													
Submission Report													
PSM 2													
Literature Review													
RP/3D Printer													
Raw Material													
Mechanical Properties													
Methodology													
Produce Specimen													
Procedure of Mechanical Testing													
Mechanical testing													
Compression Test													
Result & Findings													
Report Writing													
Submission report													

CHAPTER II

LITERATURE REVIEW

2.1 Rapid Prototyping

Rapid Prototyping (RP) refers to a group of technologies that can fabricate physical, three dimensional part of arbitrary shape directly from Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) by fully automated, fast and highly flexible process [2, 5, 7, 8, 9, 10]. According to the Wohler Report (2004), Rapid Prototyping refers to fabricate a physical model of a design using digital driven, additive processes. RP also produce model very quickly from 3D CAD data, CT and MRI scans, and data from 3D digitizing system. This means, Rapid Prototyping method can save the processing time and also save cost producing the prototype than using conventional technique for fabricating physical model which can be more expensive and also time consuming which may take a few days or even weeks [2, 5].

Rapid Prototyping was emerged in 1980's, where the high technology was conceived, developed and promote in 1980's. 1890's is the date of the origin technology. For the early history for rapid prototyping, it's also known a layered manufacturing.

This is because of the concept for building something using layer by layer at least two technical areas: topography and photosculpture. In that time, the method used

to produce tool or even prototype and usually the product that have produce in small quantities [2].

This technology allow designer quickly create prototypes of their design, although just two dimension pictures. Designer will makes the prefect visual aids for show their ideas to their co-workers and also to customers. Prototype usually numerous use such as, it can be use in design testing. Other than that, RP also can be use to make tooling and any production part. RP is usually best manufacturing process for small production runs and complicated object. Most producing prototype take shortly time, but the time that required depends on the size and the complexity of the object.

RP system has it own advantages such as; prototype that required can build even though the prototype has a complex shape. It also builds the prototype without setting the arrangement of the machine. Besides that, RP also build the prototype using multiple materials by available technique. Other than that, RP has reduced time to market. Cut trial cost and improved the quality of the product.

RP have become an important part of the product development process. By using RP has time taken can be reduced, cut cost and improve the quality of the product. This means, RP allowed user do and fabricate the design and prototype to verify before they involve in the expensive tooling and fabrication of mass production. Below are several type of application in education and industry [2].

i. Application in Product Development

In this new era of global for providing product and service, RP technology become one of the medium that make the process become easier. This is because all the company involve in product development and manufacturing will face with the competition to bring the product to market faster, cheaper and also with high quality functioning. In this problem, RP is the best solution for the problem that help all companies by reduce the cycle of product development and also during making the

design for making improvement of the product. The most application can be dividing into three major categories:

a) Prototype Design Evaluation
b) Prototype for Function Verification
c) Prototype for Manufacturing Process Validation

ii. Application in Reverse Engineering

Reverse Engineering is science by taking the physical model and produce it surface geometry in 3D data file on CAD file. RE is the faster way to get 3D data into any computer system. The example for this application is situation includes hand made prototypes, craft work, dental application and reproduction of old engineering object.

iii. Application in Casting and Pattern Making

This application is important for casting and pattern making. Casting allows fabricate complex shape but for the simple shape machining can be used.

iv. Application in Rapid Tooling

According to the rapid solution web, Rapid tooling is using a rapid prototype, either indirectly or directly, as a tooling pattern for creating a mold. Rapid tooling techniques enable you to have molds with the correct material at a substantially reduced cost in a fraction of the time it takes to produce parts from production tooling processes. The greater the complexity of the part, is the greater the benefits of cost and time.

v. Application in Medical

Application in medical is one of the most successful applications for rapid manufacturing. For the example this application is used to the production of customized hearing aids. This is because every ear is

different, and the size of the parts makes it possible to fabricate the products in large, economical batches with existing equipment.

vi. Application in Rapid Manufacturing

a. In Rapid manufacturing, there are still having a lot of challenges for the limitation of speed, material and accuracy. But by using the rapid prototyping technology most of the companies show the successfully[2,3,7,9]

According to Rochus, et.al (2007) their article was reported rapid prototyping and manufacturing are known to be destructive technologies. Everyday industry used of this method has increase rapidly. The principal of this technology of manufacturing parts is layer by layer starting from liquid, paste or powder. After the material is deposited, the selecting surface is treated according to a process define by the chosen technique in order to solidify a cross section of the final component. This process are applied for prototyping, small series, injection moulds manufacturing, mock-ups and also used in several engineering sectors. In their article also state the general description for the rapid prototyping technique such as, Stereolithography (SLA), Selective Laser Sintering (SLS) and Jet Based Technology. The start with a 3D CAD model, then the model need to convert to the stereolithography (STL) format. Only this format can be read by the machine. This is because the format will change dividing the model into layer form. By dividing the object into the layer form, the machine will printed the object layer by layer according to the STL format. This process is continuously until the layer becomes an object.

It is reported from in their article, rapid prototyping is a innovative technology develop rapidly and very useful for industry. The aim of this technology is to produce prototype relatively quickly. Most the RP system is now commercially available. There are three type of system that can be classified according to the material used which is powder based, resin based and sheet based. For powder based, the RP process includes the Selective Laser Sintering (SLS) and 3D Printing process. Resin based process such

as Stereolithography (SLA) and the laminated sheet based process included the Laminated Object Manufacturing (LOM) process. Generally all the principal of process are similar but the things that make the technique different are the materials that use to make prototyping. In this paper also mention the advantage of this technology such a reducing time and cost. This is because, all the process will make the prototype in the short time than the traditionally method. And also can produce more prototypes in one time. Besides that, this technology make the cost reduce by making the prototype in exactly as the real one. But, this technology has the limitation such as the quality and accuracy. But not all the system of RP has this problem [Choi,et al (2003)].

According to Durham. (2003) Rapid Prototyping is very useful in industry. This is because RP is a powerful tool to reducing time to market and it also improving quality and reducing cost. He also said the challenge is during selecting the suitable process that need to use. During making decision for what process that need to choose, the important thing that needs to consider is combination with the intended material. This is because; selecting a process without considering the material will yield the questionable result. In his article also state the RP process that usually used in industry which is, Stereolithography (SLA), Selective Laser Sintering (SLS) and also PolyJet. In this article also mention comparison the process as the material available for each. Stereolithography (SLA) process is used material in liquid resin. The process is using ultraviolet laser to solidify the material. Although the SLA is limited in its range of applicable material, it is suitable for conceptual visualization. Selective Laser Sintering (SLS), the material is from powder material. The SLS process create the object by heating the powder using heat from a carbon dioxide laser fuses (sinter). The advantage for this process is more widely using in industry and also suitable for function analysis.

Hatsopoulos, (2000) wrote that Rapid Prototyping introduces a method that is called “3D Printing”. Before this, the model making take too much time and the cost is high. Also the technique is always limited for use. But it is less expensive and faster when using 3D printing method. From this, this technology give the designer better access to model, which is provide the freedom to make many more of model. This