UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A FEASIBILITY STUDY OF 3D PRINTER PARAMETERS OPTIMIZATION BY USING COW BONE POWDERS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Design) with Honours.

by

MOHD KHAIRUL ANUAR BIN MOHD SARMIN

FACULTY OF MANUFACTURING ENGINEERING

2010

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **A FEASIBILITY STUDY OF 3D PRINTER PARAMETERS OPTIMIZATION BY USING COW BONE POWDERS**

SESI PENGAJIAN: 2010/11 Semester 2

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APPROVAL

This thesis is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The member of the supervisory committee is as follow:

………………………………………………

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ABSTRACT

Now days, the usage of the latest technology such as rapid prototyping machine have been use in order to create prototype. One of the categories in rapid prototyping is 3D printing. This 3D prototyping are use in developing prototype in a systematic, fast and easies method. The materials that have been used in this prototyping development are powder and binding. The basic material cost is expensive in the market. Based on this reason, this study are made to find new alternative to change the powder with using hydroxyapatite (HA) material whish came from the cow bone. This cow bone will be crushed into powder size using a couple of machine. Then, it will be used in the 3D printer machine as the relay to the actual powder for research. Couple of parameter will be fixed to analyze the surface roughness and dimensional accuracy of the prototype which came from the crush powder and for example using the build orientation, layer thickness and the speed. The couple of binder will be used to analyze the most suitable binder for this powder. After the prototypes have been fabricated, it will be test by using surface roughness machine to analyze the surfaces. The application of coordinate measuring machine will be used in this study to measure the accurate of the dimension and also the suitable parameter. Data collection will be used to determine which one of the prototypes has good surface roughness and dimensional accuracy.

ABSTRAK

Pada masa kini, penggunaan teknologi terkini seperti mesin *rapid prototyping* banyak diaplikasikan dalam kaedah untuk menghasilkan prototaip. Diantara salah satu cabang bagi mesin *rapid prototyping* ialah mesin *three dimensional printing*. Mesin *three dimensional printing* digunakan untuk menghasilkan prototaip dengan kaedah yang lebih sistematik, pantas dan mudah. Bahan asas yang digunakan bagi menghasilkan prototaip terdiri daripada *powder* dan juga *binding*. Bahan asas yang digunakan tersebut mempunyai harga yang agak tinggi di pasaran. Atas sebab yang berikut, kajian ini dibuat untuk mencari satu alternatif lain bagi menggantikan *powder* asal dengan menggunakan bahan hydroxyapatite (HA) yang dihasilkan daripada tulang lembu. Bagi menghasil *powder* daripada tulang lembu tersebut, beberapa jenis mesin digunakan untuk menghacurkanya daripada bentuk asalnya menjadi serbuk halus. Ia kemudiannya diaplikasikan dalam penggunaan mesin *three dimensional printer* sebagai bahan gantian kepada *powder* asal untuk kajian. Beberapa parameter ditetapkan bagi mengkaji struktur kekasaran permukaan dan juga ketepatan dimensi pada prototaip yang akan dihasilkan menggunakan serbuk halus tersebut diantaranya ialah orentasi, ketebalan lapisan dan juga kelajuan. Disamping itu juga, tiga jenis binder akan digunakan bagi mengkaji kesesuaian binder yang seharusnya digunakan bersesuaian dengan serbuk tersebut. Apabila prototaip selesai dihasilkan, ia kemudiannya diuji dengan menggunakan mesin *surface roughness* bagi menguji kekasaran permukaan. Penggunaan mesin coordinate measuring machine juga diaplikasikan dalam kajian ini bagi menentukan ukurkan ketetapan dimensi yang dapat dihasilkan dengan menggunakan serbuk tersebut dan juga garis parameter yang bersesuaian dengannya. Daripada data yang diambil pada hasil kajian tersebut, ia kemudiannya digunakan bagi menentukan jenis prototaip yang manakah yang mempunyai kekasaran permukaan yang halus dan juga ketepatan dimensi yang jitu.

DEDICATION

To my lovely family and fellow friends that accompanying me along the difficult pathway in my university life, thanks for your help and support.

ACKNOWLEDGEMENT

I would like to take this opportunities to express my sincere thank to all people that helping me to succeed this project. Firstly, I would like to thank to my project supervisor, Mrs. Rahimah Binti Hj. Abdul Hamid. Without her guidance, I would not be succeeding to accomplish my project. Once again thanks for her guidance, advice, and help in this project.

Secondly, I would like to thank to Manufacturing Engineering Laboratory of Universiti Teknikal Malaysia Melaka (UTeM) for providing me the equipments and machines. Moreover, I would like to thank to Mr. Fairus for giving me lot convenience in using the equipments in the Laboratory. Besides, I would like to thank to laboratory of Universiti Tun Hussein Onn Malaysia (UTHM) for providing equipments to accomplish my project.

Furthermore, special thanks to all my friends. They had giving me advice, ideas, comments and sharing their time to completed my project.

Lastly, unforgettable I would like to thank to my parents and family that always give me encourage and supports to me. I was very appreciating the supports they give to me with heartfelt.

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LIST OF ABBREVIATIONS

CAD	-	Computer Aided Design
HA	-	Hydroxyapatite
RA	-	Roughness Average
RP	-	Rapid Prototyping
SLA	-	Center Line Average
SLS	-	Selective Laser Sintering
STL	-	Stereolithography
TCP	-	Tricalcium Phosphate Phases
3DP	-	Three Dimensional Printing

CHAPTER 1

INTRODUCTION

This chapter describes the introduction of the project and briefly explained the problem statements and objective in the study. This chapter also includes the scope and the importance of the study.

1.1 Background

This study will focus on the parameter optimization in 3D printer prototype machine by using cow bone as a basis material. The scientific term called Hydroxyapatite (HA, Ca_{10} (PO_4) 6 (OH) $_2$) has been widely described as a bioactive and osteoconductive ceramic, which makes it a potential material for bone tissue engineering applications. (Marí-Buyé, N. *et al*.2007)

In this study, the 3D Printing is envisioned as a suitable method to build three dimensional prototypes, directly by using the hydroxyapatite powder and apply a suitable design extracted from CAD programs. 3D printing requires a 3D dataset for the fabrication process. Since 3D printing generates physical models layerwise, the 3D dataset has to be converted into 2D data by a special slice algorithm. Afterwards, the 3D printer uses these 2D data to create a physical model known as prototype, which is a 1:1 copy of the computer model. The quality of the surface roughness and dimension accuracy will be evaluated by using surface roughness test and coordinate measuring Machine (CMM).

1.2 Problem Statement

While using the 3D printing machine, many aspects should be considered to archive a good result in order to aim the goals such as to get the suitable binder for the powder. Cracking and brittle condition is often situation that was happen because of the failure combination by binder and powder. In addition, the existing material have drawback from costing which means those material expensive in market place. According to that issue, this study tries to explore new alternative in 3D printer material to replace the existing material by cow bone powder. Cow bone powder is one of nature sources that easy to obtain and cost to get it also cheap. Besides, by using natural material which are one of the step where encourage the green environment.

1.3 Objective

This study embarks on the following objectives:

i. To study the feasibility of the 3D printer machine (3D Printer 310 Manual Plus) in producing prototypes when using cowbone powders as raw material with three different proposed Z- binders (ZB56, ZB60, ZB51).
ii. To apply different 3D Printer parameter settings (build orientation, layer thickness and speed) when building up prototypes.
iii. To study on the prototypes quality [surface roughness (R_a) and dimensional accuracy (mm)] with the different settings of 3D printer parameters (Build orientation, Layer thickness and speed).

1.4 Scopes of Study

The focus of this study is to investigate on the surface quality of 3D Printer prototypes in terms of surface roughness (R_a) and dimensional accuracy (mm) when cow bone powders are utilized instead of the common 3D Printer powders. Different parameter settings will be used in fabricating the prototypes and the effect of these settings to our final prototypes in terms of its quality will be investigated and discussed. In addition, three different Z-binders are proposed to be used while fabricating the prototypes which are ZB56, ZB60 and ZB51. Normally there is a guideline chart provided by the Z-Corp Corporation, which is the provider of our 3D Printer machine which shows which binders are recommended for some powders. Due to the new proposed material in this study, three different binders will be used and the success of fabricating the prototypes with these binders will be discussed.

1.5 Expected Results

From this study, it is expected to:

i. Investigate whether 3D printer machine (3D Printer 310 Manual Plus) can utilize other than its own powder material to fabricate parts.
ii. Find out if there are any significant effects of different parameter settings on the final quality of 3D Printer prototypes [surface roughness (R_a) and dimensional accuracy (mm)].

CHAPTER 2

LITERATURE REVIEW

This chapter describes the material and process to generate the bone powder prototype and the parameters influenced to the surface roughness and dimensional accuracy test by referred from the previous journal. Besides, the method that used for design the experiment was also explained in this chapter.

2.1 Rapid Prototyping

In this study, the basic method of using the rapid prototyping machine (3D printer generally) must be understood before staring the experiment. The rapid prototyping is a class of technologies that can automatically construct physical models from CAD data. These three dimensional printers allow designers to quickly create tangible prototypes of their designs, rather than just two-dimensional pictures. Such models have numerous uses. They make excellent visual aids for communicating ideas with co-workers or customers. In addition, prototypes can be used for design testing (Nikam, 2005).

2.1.1 Overview of Rapid Prototyping

Designers have always utilized prototypes. Rapid Prototyping allows them to be made faster and less expensively. In addition to prototypes, RP techniques can also be used to make tooling and even production-quality parts. For small production runs and complicated objects, rapid prototyping is often the best manufacturing process available.

This may seem slow, but it is much faster than the weeks or months required to make a prototype by traditional means such as machining. These dramatic time-savings allow manufacturers to bring products to market faster and more cheaply. The latter term is particularly descriptive of the manufacturing process used by all commercial techniques (Nikam, 2005).

In the rapid prototyping processes, the part is fabricated by deposition of layers contoured in a (x -y) plane two dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z-coordinate. Therefore, the prototypes are very exact on the x-y plane but have stair-stepping effect in z-direction. If model is deposited with very fine layers such as smaller z-stepping, model looks like original. RP can be classified into two fundamental process steps namely generation of mathematical layer information and generation of physical layer model (Chua *et al*.2000).

2.1.2 Three Dimensional Printing (3DP)

Three Dimensional Printing (3DP) technologies was developed at the Massachusetts Institute of Technology and licensed to several corporations. The process is similar to the Selective Laser Sintering (SLS) process, but instead of using a laser to sinter the material, an ink-jet printing head deposits a liquid adhesive that binds the material. Material options, which include ceramic powders, are somewhat limited but are inexpensive relative to other additive processes. 3D Printing offers the advantage of fast build speeds, typically two to four layers per minute. However, the accuracy, surface finish, and part strength are not quite as good as some other additive processes. 3D Printing is typically used for the rapid prototyping of conceptual models (limited functional testing is possible) (M. Firdaus, 2009).

The 3D printing process begins with the powder supply being raised by a piston and a leveling roller distributing a thin layer of powder to the top of the build chamber. A multi-channel ink-jet print head then deposits a liquid adhesive to targeted regions of the powder bed. These regions of powder are bonded together by the adhesive and form one layer of the part. The remaining free standing powder supports the part during the build. After a layer is built, the build platform is lowered and a new layer of powder added, leveled, and the printing repeated. After the part is completed, the loose supporting powder can be brushed away and the part removed. 3D printed parts are typically infiltrated with a sealant to improve strength and surface finish (M. Firdaus, 2009).

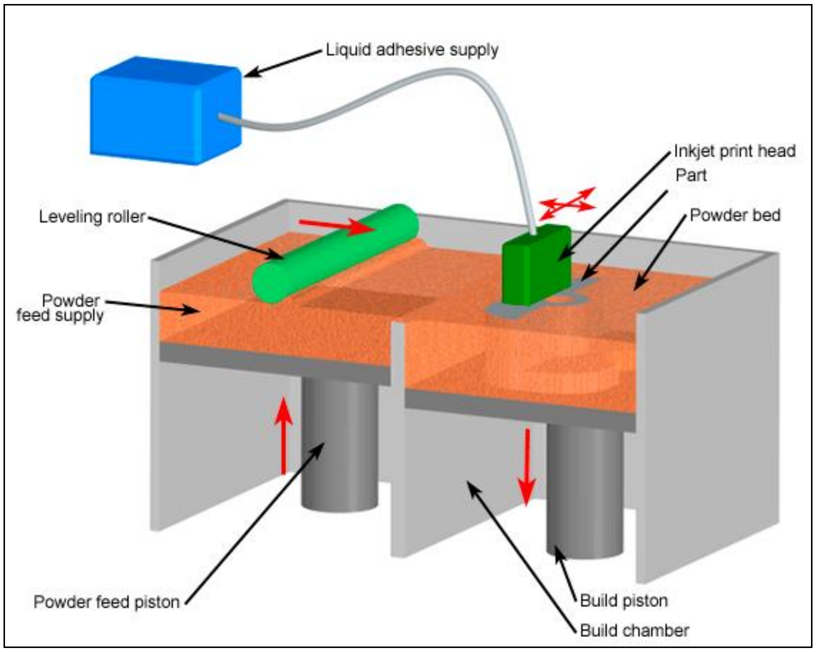

Figure 2.1: Three dimensional printing machine system.

2.1.3 Overview the Z-Printer 310 Plus Machine

The Z-Printer 310 Plus printing technology is generate by using 3D source data, which often takes the form of computer-aided design (CAD) models. Mechanical CAD software packages, the first applications to create 3D data, have quickly become the standard for nearly all product development processes. Due to the widespread adoption of 3D-based design technologies, most industries today already create 3D design data and are capable of producing physical models with Z-Printer 310 Plus machine. The software that drives Z Corp.'s 3D printers accepts all major 3D file formats, including .stl, .wrl, .ply, and .sfx files, which leading 3D software packages can export. After exporting a solid file from a 3D modeling package, the next step is open the file in ZPrint™, the desktop interface for Z-Printer 310 Plus. The primary function of ZPrint™ is to cut the solid object into digital cross sections or layers. In addition to sectioning the model, ZPrint™ also can utilize to address other production options, such as viewing, orienting, scaling, coloring, and labeling multiple parts. The ZPrint™ software sends 2D images of the cross sections to the 3D Printer via a standard network, just as other software sends images or documents to a standard 2D printer. Setup takes approximately 10 minutes (Z Corporation, 2005).

2.1.3.1 The Z-Printer 310 Plus Machine Operation

The Z-Printer 310 Plus use standard inkjet printing technology to create parts layer-by-layer by depositing a liquid binder onto thin layers of powder. Instead of feeding paper under the print heads like a 2D printer, a 3D printer moves the print heads over a bed of powder upon which it prints the cross-sectional data sent from the ZPrint software. The Z Corporation system requires powder to be distributed accurately and evenly across the build platform. The 3D Printers accomplish this task by using a feed piston and platform, which rises incrementally for each layer. A roller mechanism spreads powder fed from the feed piston onto the build platform, intentionally spreading approximately 30 percent of extra powder per layer to ensure a full layer of densely packed powder on the build platform (see Figure 2.2). The excess powder falls down an overflow chute, into a container for reuse in the next build. Once the layer of powder is spread, the inkjet print heads print the cross-sectional area for the first, or bottom slice of the part onto the smooth layer of powder, binding the powder together (see Figure 2.3). A piston then lowers the build platform and a new layer of powder are spread on top (see Figure 2.4). The print heads apply the data for the next cross section onto the new layer, which binds itself to the previous layer. The ZPrint repeats this process for all of the layers of the part. The 3D printing process creates an exact physical model of the geometry represented by 3D data. Process time depends on the height of the part or parts being built. Typically, Z-Printer 310 Plus builds at a vertical rate of 25mm – 50mm (1" – 2") per hour. When the 3D printing process completes, loose powder surrounds and supports the part in the build chamber. The part can remove from the build chamber after the materials have had time to set, and return unprinted, loose powder back to the feed platform for reuse. Then, forced air will use to blow the excess powder off the printed part, a short process which takes less than 10 minutes. The Z Corporation technology does not require the use of solid or attached supports during the printing process, and all unused material is reusable.

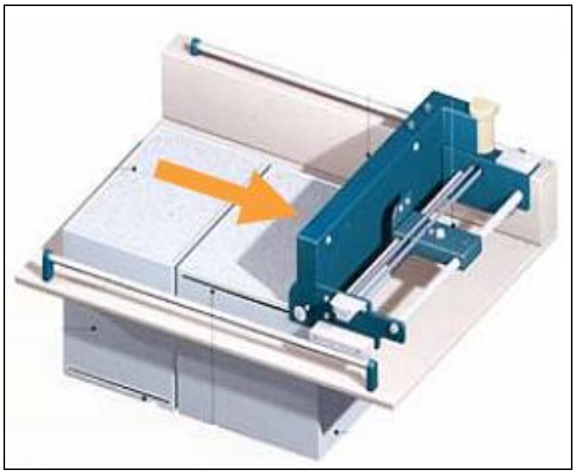

Figure 2.2: Spread a layer of powder

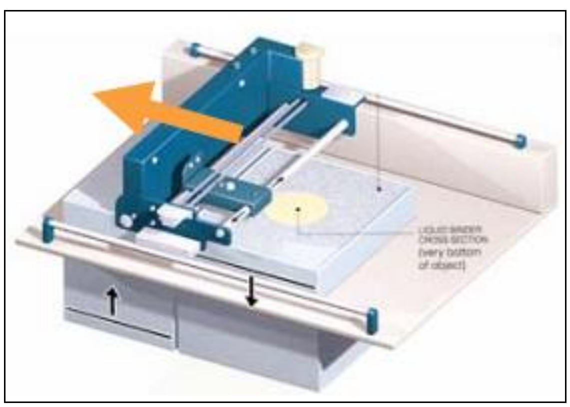

Figure 2.3: Print cross section