MUHAMMAD SYAZWI BIN MOHD FAUDZE BACH. OF MECHANICAL ENG. (DESIGN & INNOVATION) 2015 UTeM

INVESTIGATION OF CHARACTERISTICS AND APPLICATIONS OF 3-D PRINTER MATERIALS

MUHAMMAD SYAZWI BIN MOHD FAUDZE

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MUHAMMAD SYAZWI BIN MOHD FAUDZE

This project report is submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering
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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design and Innovation)"

Signature: ……………………………………..

Supervisor: Dr. Faiz Redza Bin Ramli

Date: ……………………………………..

DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature:	……………………………………..
Author:	Muhammad Syazwi Bin Mohd Faudze
Date:	……………………………………..

Specially dedicated to my beloved mother, Mrs. Norhayati Bte Abd. Rahman and my supportive father, Mr. Mohd Faudze Bin Sabtu

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All praise is due to Allah. We praise Him and seek His aid and forgiveness. We seek refuge in Allah from the evil which is within ourselves and from the evil in our actions. Whoever Allah guides, none can send astray; whoever Allah sends astray, none can guide. We bear witness that there is no deity other than Allah alone, and with no partner. And we bear witness that Muhammad is His slave and His Messenger.

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ABSTRACT

For the past decade, the rapid prototype market possesses a lot of changes and growth. Low end machines were responsible for the majority of the rapid prototype market growth in recent years. The purpose of the project explained in this report should be to assess, match up and evaluate a few thing about the mechanical properties for the low cost machines which are MendelMax and Kossel on the market today. A benchmarking research was performed to determine the performance for each platform by evaluating its capability to produce a complicated benchmark portion which is designed specifically for this study such as up-stand features and slots. The design was created by CATIA software which will be converted into STL file format. The results show clearly that the performance of the 3-D printer is depending on a certain criteria which are layer thickness and infill density in order to get a better profile.

ABSTRAK

Selari dengan perubahan zaman, pasaran prototaip mempunyai banyak perubahan dan pertumbuhan. Mesin berkos rendah ini bertanggungjawab sebagai pembangunan prototaip yang bertumbuh pesat pada zaman serba moden ini. Projek ini yang diterangkan di dalam laporan ini bertujuan mengakses, membanding antara satu sama lain dan menganalisa beberapa perkara berdasarkan sifat bahan mekanikal mesin berkos rendah ini seperti mesin MendelMax dan Kossel yang berada di pasaran dunia sekarang. Kajian berdasarkan penanda aras geometri telah dilakukan untuk mengenal pasti kebolehan untuk setiap geometri dengan menganalisa kebolehannya untuk menghasilkan bahagian penanda aras yg rumit yang mana rekabentuk khusus untuk kertas kerja ini seperti profil-profil yang teguh dan profil slot. Rekabentuk prototaip ini dihasilkan melalui perisian CATIA yang seterusnya akan dijadikan format STL. Keputusan menunjukkan secara jelas bahawa jurang kebolehan mesin prototaip ini ditentukan dengan beberapa faktor seperti ketebalan lapisan dan kepadatan kawasan jurang untuk menghasilkan bentuk profil yang baik.

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LIST OF ABBREVIATION

PSM	Projek Sarjana Muda
FYP	Final Year Project
RP	Rapid Prototyping
CAD	Computer Aided Drawing
FDM	Fused Deposition Modelling
SL	Stereolithography
SLS	Selective Laser Sintering
3DP	Three Dimensional Printing
ABS	Acrylonitrile Butadiene Styrene
PLA	Polylactic Acid
CMM	Coordinate Measuring Machine
STL	Standard Triangular Language
CAM	Computer Aided Manufacturing

CHAPTER 1

INTRODUCTION

Projek Sarjana Muda (PSM) or Final Year Project (FYP) is a compulsory subject that must be taken by a soon-to-be graduated student of *Universiti Teknikal Malaysia Melaka* during the final year as one of the requirement to be awarded of Bachelor degree. All students should have a project that need to be carried out during the two semesters of studies under the supervision of a selected lecturer. At the end of the semester, students are required to demonstrate their finding according to the project. This chapter will provide the project background which entitled of *Investigation of Characteristics and Applications of 3-D Printer Materials.*

1.1 BACKGROUND STUDY

Rapid Prototyping (RP) is a somewhat most recent manufacturing engineering in which the prototypes are straight made from CAD drawings. RP benchmarking is essential for reviewing the strengths and imperfections of RP technologies. By making use of benchmarking, the ability of a certain approach could be checked, measured, analysed, as well as confirmed through a standardized procedure. A handful of benchmark research appear to have been successfully done to figure out the quality of dimensional accuracy and surface quality achievable with existing RP processes. Hence, a variety of test parts have already been built for the benchmark research.

1.2 PROBLEM STATEMENT

FDM process is still in early phase of commercialization and thus, it have the potential for further research and studies. Apparently, there is no further studies on investigation of mechanical properties for low cost 3D Printer in intention to differentiate the quality of finishing product of various geometric features based on standard benchmarking models produced. Therefore, it is vital to revamp a further studies on a benchmark geometry in order to enhance the technical proficiency such as the accuracy and repeatability of FDM operation and the comparison of the geometries.

1.3 OBJECTIVES

The objectives of the project are:

1. To investigate the vital parameters required for 3D printer by the quality of finishing product for low cost 3-D printers.
2. To differentiate the quality of finishing product of various geometric features based on standard benchmarking models produced from low cost 3-D printers.
3. To investigate the condition of produced part in terms of geometric dimensional accuracy, capacity to fabricate specific geometry, repeatability, and surface roughness.

1.4 SCOPES

1. Design a standard test part based on standard benchmarking models.
2. Investigate the finishing quality of produced part.
3. Varying different plastic material which are ABS and PLA.
4. Varying different low cost 3-D printers which are MendelMax and mini Kossel.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a thorough review will be made based on the previous research regarding on the investigation of characteristics of the 3-D printer material. This chapter will facilitate the readers to understand the Rapid Prototyping (RP) technologies and on how the geometric benchmark proposed will effect to the performance evaluation of rapid prototyping processes.

2.1 RAPID PROTOTYPING

RP is a common concept for several modern technology that allow materials to be produced without requiring any traditional tooling. A lot of manufacturing processes are subtractive, for the reason which they customize the geometry of plenty materials by eliminating components of the material until the final appearance is attained. Traditional milling as well as turning are pretty decent examples of subtractive techniques. By comparison, RP approaches are additive techniques. RP components are built-up eventually in layers until the final geometry is acquired. The manner wherein the layers are manufactured, in spite of this, as well as the materials by which parts could be created significantly between the distinct RP processes (Fletcher, 2003).

A variety of RP techniques have already been engineered and are commercially on the market which includes Stereolithography (SL), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM) and Three Dimensional Printing (3DP). Each and every RP approach produces parts in a variety of materials and through the use of various operating process such as photopolymerisation by SL, sintering by SLS, extrusion by FDM and jetting by 3DP (Hopkinson et al., 2012).

2.2 FUSED DEPOSITION MODELLING (FDM)

FDM is regarded as the RP modern technology which utilizes an additive manufacure concept. Every single commercially attainable FDM model carries unique variations of process criteria for a variety of applications. A few of the wanted parts need to have remarkable surface finish together with good tolerance. The most popular criteria needing installation are the raster angle, tool path, slice thickness, build orientation, and deposition speed (Rizal et al., 2010).

FDM is also an RP method wherein a plastic is extruded via a nozzle that can trace the part's cross sectional geometry layer by layer. The FDM device usually requires two materials which are build material and support material. During this method, an automated robot is monitored the extruder head motions in two basic principle orientations over a table. The table could be lifted or dropped whenever you like. Extruder head keeps with a direction which is operated by the software and creates a thin layer of build or support material. After first layer the table is dropped and following layers are produced. Every single brand new layer creates seal with the previous layer. The support material is accustomed to develop the support structures which are instantaneously created for overhanging geometries and are afterwards taken away by splitting them away (Marcincinova, 2012).

2.3 ACRYLONITRILE BUTADIENE STYRENE (ABS) MATERIAL

According to Stratasys (2011) ABS is the most frequently used thermoplastics, has recently become the strong foundation for FDM for quite some time. Assessed by yearly usage, it is really the most in-demand material in FDM equipments as it is so broadly applied. The ABS materials are an outstanding selection for models or prototypes in which the thermoplastics for FDM machines will give better tensile and impact strength.

ABS resins are thermoplastic resins made up of about three types of monomers which are firstly acrylonitrile, secondly butadiene, and the third one is styrene. The combination of those element as shown in Fig. 2.1 made as resins with the balance of hardness as well as softness by enhancing the brittleness, which can be the glaring issue polystyrenes, with inclusion of a rubber component while keeping hardness as well as fluidity, which have been the benefits of polystyrenes (Margolis, 2005)

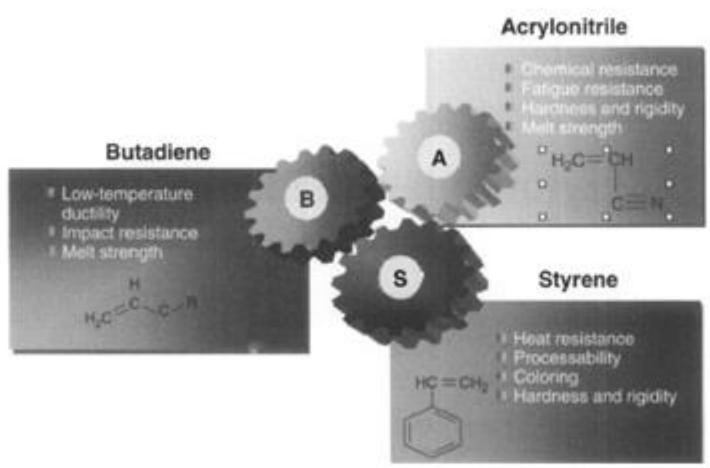

Fig. 2.1 The Compound Structure of ABS

(Source: Margolis, 2005)

2.4 SLICING METHOD

To summarize, a thinner slice layer generates perfect surface texture however it is going to boost up the creation of the model period. A lot of analysts have discovered that the layer thickness considerably affects the surface finish.

In accordance to Azanizawati (2003) better surface finish has been produced with low layer thickness. Ahn et al. (2009) revealed that layer thickness is regarded as the most convincing parameter for the surface texture of layer production. The publisher explained that the rates of surface roughness rely on various angles of the printing parts.

Anitha et al. (2001) practiced Taguchi approach to figure out the consequence of layer thickness, road width as well as deposition speed each at three levels on the surface roughness of part developed by using FDM method. The results show that layer thickness is regarded as the most convincing process parameter causing surface roughness along with road width as well as deposition speed.

Khan et al. (2006) discovered the impact of slice layer and also the support structures thickness on the surface roughness of product produced by FDM approach. Measurement of roughness was carried out on the either side of the specimen in perpendicular to the path of build up layer. The publishers claimed that lower positioning of slice thickness provides greater surface quality. Furthermore the part surface that is next to the top layer of the support provides smoother composition when compared with the other surfaces.

2.5 REVIEW OF PREVIOUS BENCHMARK GEOMETRIES

A geometric benchmark part is a produced and constructed for the productivity evaluation of rapid prototyping processes. The benchmark part integrates important shapes and top features of well-known benchmark parts. This also comprises brand new geometric features, for instance freeform parts, particular mechanical features which are rapidly required on of RP processes. The part is appropriate for manufacturing on an average RP machines. In this paper, the application of the benchmark part is exhibited by making use of slightly typical RP processes. The capability of the benchmark part to discover possible geometric features and accuracy. In this session, the related benchmark parts will be briefly discussed.

Table 2.1 Summing up of documented benchmark parts

Properties	Kruth (1991)	Lart (1992)	Gargiulo, 3D systems (1992)	Ippolito (1994)	Juster and Childs (1994)	Mike Shellabear (1999)
Size	Small	Medium	Large	Large	Large	Small
Dimensions	100 x 50 mm	-	240 x 240 mm	240 x 240 mm	250 x 250 mm	71 x 75 mm
Features incorporated	Simple: cylindrical shell, inclined cylinders, pegs and overhangs	Complex: rich in fine- and medium sized features	Simple: features are planar	Simple: Used the 3d systems benchmark part	Comprehensive: Features to test linear accuracy and feature repeatability	Simple: Planar surfaces, which include various angles
Complexity of measurement	Simple: but not standardized	Difficult: Features not accessible to CMM	Simple	Simple	Simple	Easy but not standardised

(Source: Wong et al., 2004)