INVESTIGATION OF DIMENSIONAL ACCURACY OF ADDITIVE MANUFACTURED SAMPLE

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I declare that this project entitled "Investigation of Dimensional Accuracy of Additive Manufactured Sample" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	…………………………………………..
Name	:	Mohamad Afiq Bin Sharum
Date	:	25th February 2023

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.) I hereby declare that I have read this report and in my opinion this thesis is sufficient in the terms of scope and quality.

Signature : ……………………………………………....

Supervisor Name : Associate Prof. Ir. Ts. Dr. Shajahan bin Maidin

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ABSTRAK

Percetakan 3D adalah suatu process dimana bahan akan dibekukan dan dicantumkan bagi membentuk objek 3 dimensi yang kompleks melalui kawalan daripada komputer. Pencetakan 3D ini digunakan dalam penghasilan prototaip dan pembuatan tambahan. Teknik yang sering kali digunakan untuk pencentakan 3D adalah teknik Pemodelan Pemendapan Berfungsi (FDM). Ketahanan bahan yang digunakan dalam FDM, kestabilan sifat mekanik mereka dalam jangka masa yang tertentu, dan juga kualiti yang baik merupakan antara kelebihan menggunakan FDM. Walaubagaimanapun, terdapat beberapa kekurangan FDM seperti penampakan garisan di antara lapisan dan juga pembentukan lebihan bahan percetakan di atas permukaan produk. Kekangan ini akan menjejaskan ketepatan demensi daripada model yang dihasilkan oleh pencetak 3D. Kajian ini telah dijalankan bagi mengenal pasti kesan-kesan dan hasil penggunaan filamen besi terhadap ketepatan dimensi produk yang dihasilkan menggunakan pencetak 3D.Perisian yang digunakan bagi membuat model kajian ini adalah dengan menggunakan CATIA dan pencetak Ultimaker 3D printer. Filamen besi, PLA Teguh dan ABS yang akan digunakan dalam kajian ini akan diuji meggunakan Coordinate Measuring Machine (CMM). Antara geometri yang telah diuji dengan CMM adalah, ketebalan, sudut jejari, sudut, diameter lubang and juga kerataan. Hasil kajian emnunjukkan bahawa tiada filamen yang mencapai 100 peratus keputusan akurasi geometri yang perlu dicapai. Kajian telah mendapati bahawa beberapa faktor telah dikenalpasti yang menjadi penyebab kepada kekurangan akurasi geometri seperti pengecilan dan kolpeks geometri ayng digunakan di dalam eksperimen. Keputusan daripada CMM. Ketetapanoptimum yang dikenalpasti boleh digunakan bagi menghasilakan produk pencetakan 3D yang mempunyai ketepatan dimensi yang lebih baik.

ABSTRACT

3D printing is a process of which material is solidified and joined to form a complex three-dimensional object under the control of a computer. 3D printing is used in both rapid prototyping and additive manufacturing. The most common technique used for 3D printing is the Fused Deposition Modeling (FDM). The durability of the materials FDM used, the stability of their mechanical properties over time, and the quality of the parts are some of the advantages of using FDM. However, it also has several limitations for instance the appearance of seam line between layer and the formation of excess material residue on the parts surface. These limitations will affect the dimensional accuracy of the parts produced by the 3D printer. The test models were made using CATIA software and printed using the 3D printers. The metal filaments that will be used for this project is Stainless Steel, ABS and Tough PLA; the test models were tested using the Coordinate Measuring Machine (CMM). The thickness, corner radius, angle, perpendicularity, hole diameter and flatness are some of the geometries to be tested with the CMM. The result shows that none of the filaments are able to obtain 100% result accuracy although Stainless Steel managed to reach the closest value to the expected data. These data are then studied to identify the problems which have led to several factors such as shrinkage and geometry complexities. The optimum parameters for printed FDM sample can be used in order to achieve better dimensional accuracy for future production.

DEDICATION

This project is dedicated to

My beloved parents

Dearest Sibling

Honorable supervisor and lecturers

Supportive friends

ACKNOWLEDGEMENT

In the name of Allah, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without any predicament. I would also like to express my highest gratitude to everyone who has supported me throughout the process of completing my Final Year Project. I am very thankful for their advice throughout the process of completing this project.

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LIST OF ABBREVIATIONS

FDM	-	Fused Deposition Modeling
AM	-	Additive Manufacturing
CMM	-	Coordinate Measuring Machine
CAD	-	Computer Aided Design
ABS	-	Acrylonitrile Butadiene Styrene
PLA	-	Polylactic Acid
STL	-	Standard Triangle Language
SLA	-	Stereolithography
RM	-	Rapid Manufacturing
SLB	-	Selective Laser Beam
EBM	-	Electron Beam Melting
PBF	-	Metal Powder Bed Fusion
STL	-	Stereolithography
SLS	-	Selective Laser Sintering
DMLS	-	Direct Metal Laser Sintering
PC	-	Polycarbonate
HIPS	-	High Impact Polystyrene
PVA	-	Polyvinyl Alcohol

CHAPTER 1

INTRODUCTION

1.1 Project Background

Additive manufacturing (AM) is a unique kind of manufacturing process that involves connecting materials to create products from three-dimensional (3D) model data, generally layer by layer. It offers several benefits over traditional manufacturing procedures. AM, often known as 3D printing, is a cost-effective and time-saving method for creating low-volume, customised goods with complex geometries and sophisticated material characteristics and functionality (Huang et al., 2020). In contrast to subtractive manufacturing processes, additive manufacturing (AM) is the process of connecting materials to produce items using Computer Aided Design (CAD) model data, generally layer by layer. 3D printing, additive fabrication, and freeform fabrication are all terms used to describe AM. While these new approaches are still in their infancy, they are expected to have a significant influence on production. They can provide new design freedom to the industry, reduce energy consumption, and reduce time to market.

AM printing is undergoing a remarkable transformation, which is resulting in an exponential increase in its application. Its use grew because to its exact and repeatable design capabilities in a variety of materials. It was originally used to manufacture moulds or prototypes. This made prototyping prototypes in a variety of sizes, styles, materials, and colours much faster. The public now has access to 3D printing, and a basic fused deposition modelling (FDM) printer may be purchased at a shopping mall. Due of its simplicity, FDM technology is far less expensive than other AM approaches (Cano-Vicent et al., 2021). Fused Deposition Modelling (FDM) is a cheaper 3D printing technique mainly developed for the additively manufacturing of polymer materials. During the manufacturing process, filamentous polymer is first melted in the printing nozzle at a temperature lightly higher than the melting point of the printing polymer, then deposited onto the printer hotbed layer by layer under the control of computer, and finally fused with the bottom adjacent layers.

The dimensional accuracy of AM parts is extremely important especially in the context of manufacturing assemblies or parts that needs to precisely fit together. The studies to identify the common factors that can affect this accuracy such as raster angle, printing speed, layer thickness, and even the build orientation will be crucial in identifying the dimensional accuracy for this project. The accuracy of printed a part depends heavily on the design. Variations in cooling and curing result in internal stresses that can lead to warping or shrinkage. AM is not suited for flat surfaces or long thin unsupported features. Accuracy will also decrease as part sizes become larger while the smaller and intricate parts on this project require higher dimensional accuracy. Metals, polymers, composites, and other powders may now be used to "print" a variety of functional components, including complicated structures that can't be made any other way, using additive technology FDM has been widely employed in AM techniques that generate working prototypes in various metal printings. Steel and its alloys are the most often utilised metals in AM because of its availability, low cost, and biocompatibility as bone and dental implants. Nickel, aluminium, copper, magnesium, cobalt-chrome, and tungsten are the least often used metals, followed by titanium and its alloys. To improve mechanical qualities, crack-free metal matrix composites (MMC) with a density of 99.9% can be combined with tungsten carbide-cobalt (WC-Co), ceramic, or nonferrous reinforcements.

The aim of this project is to investigate the dimensional accuracy of printed 3D samples which will thus be achieved through extensive research throughout the PSM 1 and practical approach of printing and dimensional accuracy analysis during PSM 2. Specifically, in this project, Stainless Steel will be used as the main filament during the printing process. Additionally, the project will be utilizing FDM machine Ultimaker in order to print out the test samples throughout the project. The machine will be able to identify the optimum parameters in order to print the samples with ideal parameters which will then be proven by using Coordinate Measuring Machine (CMM) to identify the dimensional accuracy. The dataset that is obtained from this project will be analysed and used for further research.

1.2 Problem Statement

One of the first AM methods is rapid prototyping. It enables the development of printed parts as well as models. The ability to generate practically any form that would be difficult to machine is one of the key benefits of this approach for product development. It saves time and money, eliminates human contact, and so shortens the product development cycle. (Wong & Hernandez, 2012). Whenever (FDM is utilised to create small intricate structures and features with extensive overhangs, FDM tends to produce unwanted faults in terms of dimensional errors (Tronvoll et al., 2018). Helical threads are often used for assembling components with fine details and significant overhangs, such as sub-millimetre scale details with 60-degree overhangs. The main performance of the additive manufacturing method determines which process parameters should be used. To assure product quality, improve dimensional accuracy, minimise unacceptable waste and substantial scraps, increase efficiency, and reduce production time and costs, production engineers must determine ideal process conditions.

Because numerous contradicting aspects impact component quality and material attributes to establish ideal parameters, the FDM process is complicated. The quality of the component and the mechanical qualities of the generated part are determined by the suitable selection of process parameters(Patel et al., 2022). In addition to the fast improvements in 3D Printing technology, this procedure has enabled the development of several unique items. However, things made using additive manufacturing may have surface roughness and dimensional accuracy concerns. Manufacturing thin-walled items, particularly those used in aviation, aerospace, and biomedicine, need a higher level of dimensional precision (Babu & Gb, 2022). Not only are build times with metal 3D printing glacially slow as compared to machining, but the pieces aren't always completed when processed, and they're not always perfectly precise. Powder bed fusion, also known as direct metal laser sintering, electron beam melting, or selective laser melting, with average tolerances of +/- 0.005 inches and a surface finish comparable to an investment casting. This results in machining is almost usually necessary to clean up any critical surfaces, bore holes, cut threads and more.

1.3 Objectives

The aim of this project is to investigate the dimensional accuracy of various open source FDM 3D printed samples.

1. To create CAD drawing of the test model using CATIA V5 drawing software.
2. To print various type of material samples sample using FDM.
3. To study the dimensional accuracy of the various samples printed using CMM.

1.4 Scopes of Project

The sole focus of this project is to identify the accuracy dimension and the factors that may affect the results of different samples on 3D printed samples using FDM. The samples may vary from wide ranges of shapes to measure the effectiveness of FDM as a whole. Different geometrical shapes will be highlighted throughout the project in order to measure the dimensional accuracy and project its result parallel to the different settings and settings on the machine and surrounding environment. The main software that will be used to run this project will be CATIA as the software caters to the aspects of this project. The measurements for the samples that will be printed is 1.5 cm x 1.5 cm x 1.5 cm. The metals that will be used in the printer's filament will be different each time in order to get the best readings in terms of accuracy. To obtain information on its output, the FDM prototype is physically and mechanically tested. Quality management or validation can be destructive or non-destructive in nature (NDT). Relying on the required confidence and uniqueness of the items, NDT tests may be performed on an allocated element or all components obtained. The main factors that will be considered in the research will be microstructure, hardness, tensile strength relative density and shrinkage.

1.5 Report Organization

This report consists of five main chapters and several sub-chapters namely introduction, literature review, methodology, result and discussion and finally the conclusion and recommendation. For the first chapter, it will briefly explain regarding the background, objectives, scopes, and also the importance of study which will provide readers with a better overview of the whole report.

The second chapter will focus more on the literature review on previous related research on this subject. This includes the definition and types of AM, the advantages and disadvantages of each examples of FDM. This chapter will also elaborate more on FDM and also the application of FDM.

Chapter three's main concern is about the methodology. The methodology focuses on the method or steps used in order to carry out this research. It will show how this experiment will be conducted, the experiment setup, testing technique and how to analyze of each of the data obtained from each sample. On the other hand, chapter four will display the results along with the necessary comparison including a comprehensive discussion. Chapter five will conclude the overall findings of this research and provide some suggestions for future studies

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss some of the related knowledge on the additive manufacturing as well as the Dimensional accuracy of additive manufactured sample. Some process parameters of 3D printing are also discussed in this chapter.

2.1 Definition of AM process

Additive manufacturing processes take the information from a computer-aided design (CAD) file that is later converted to a stereolithography (STL) file. In this process, the drawing made in the CAD software is approximated by triangles and sliced containing the information of each layer that is going to be printed. There is a discussion of the relevant additive manufacturing processes and their applications. The aerospace industry employs them because of the possibility of manufacturing lighter structures to reduce weight. Additive manufacturing is transforming the practice of medicine and making work easier for architects (Wong & Hernandez, 2012).

Metal Additive manufacturing techniques is employed to manufacture the complex geometries product from 3D CAD model data. The metal powders are applied as successive layers of materials until it becomes a final product. Process parameters of the additive manufacturing include layer thickness, scan speed, hatch spacing, size of the powder particles and orientation of the layer. This AM technique is being used in various industries like biomedical and aircraft industries as this AM technique possess benefits like minimum of waste and flexibility in the design of complex shape. 3D printing of new/novel metals is being developed and need to investigate the impact process factors of 3D printed novel metals. Additive manufacturing adequately changed old manufacturing technique and it has gained great potential to fabricate the metal parts with good integrity and AM seems to be a powerful tool to minimize the complexity and able to make tailor-made products (Nurhudan et al., 2021).

As its name indicates, AM comprehends all processes that adds material during a part manufacturing, making it difficult to enumerate all of them. In this work, only the processes related to material layer addition - Layer Manufacturing (LM) are considered and are following described. The reason for this is that all LM processes considers few basic steps (Hyndhavi et al., 2018).

1. Material is fused, sintered or bound over a support surface depending on the process type. The material can be already laying in the surface (powder or liquid) or can be projected over it (powder, binder, extrusion), mainly by a beam fashion way and then hatched over the surface following an external contour defined by part’s horizontal slice, or layer, geometry.
2. After the first layer is ready, the support surface is lowered by a device at a distance equal to the layer thickness and the material deposition follows the same procedure of the preceding layer, including the support surface lowering.
3. When the last layer is ready, the process is finished and the part is removed from machine compartment.
4. Depending on the process and other requirements, a post processing is performed before part delivery.

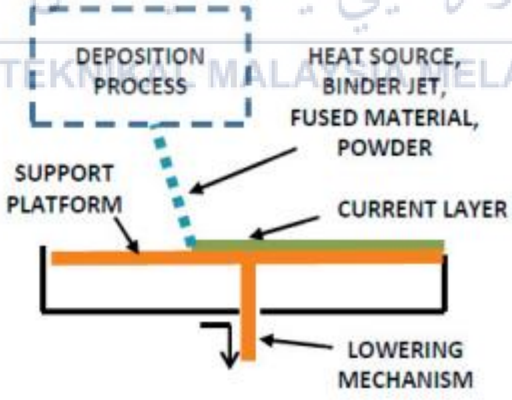

Figure 2.1: AM Deposition process (Hyndhavi et al., 2018)

2.2 General AM Process

The process of converting a virtual CAD model into a real product or prototype is known as AM. The functioning premise of AM has seven main phases. The processes can be referred in Figure 2.2

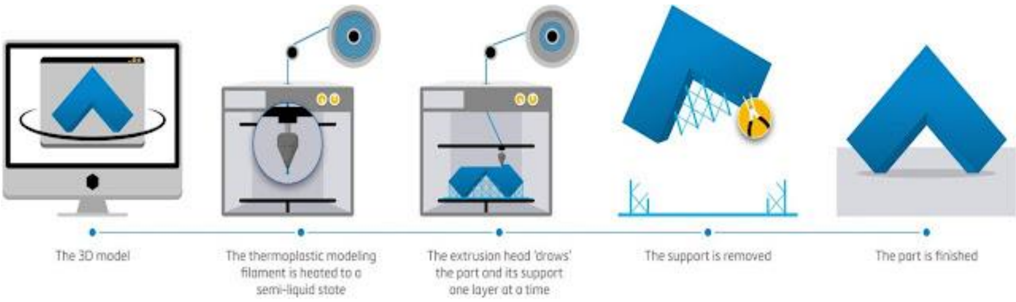

Figure 2.2: Steps in AM processes
(Source: https://additivemanufacturingindia.blogspot.com/2018/04/additive-manufacturing-overview.html)

STEP 1: CAD model design model generation

The initial stage in every product design is to imagine the product's purpose and look. Models are conceptualised using 3D digital CAD software throughout the AM process. Solidworks, AutoCAD, CATIA, and other CAD applications are examples. However, in this project, CATIA will be used as the CAD programme. An example of the CAD design in CATIA can be referred in the Figure 2.3.

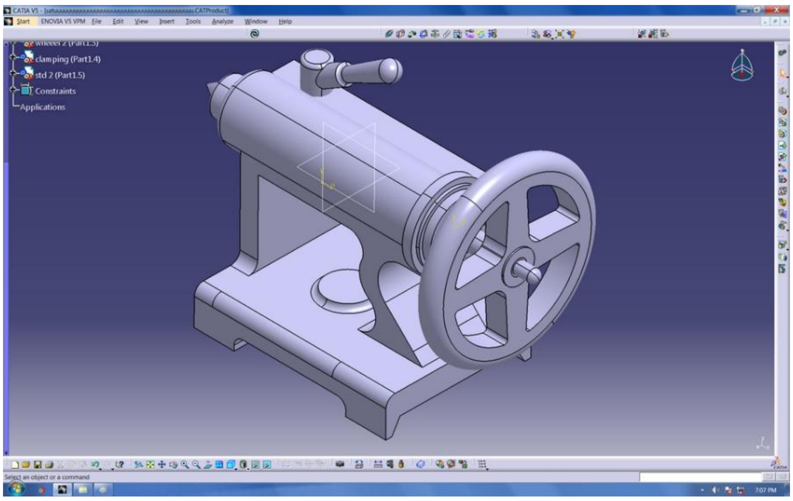

Figure 2.3: Example of CAD drawing
(Source: https://grabcad.com/library/lathe-tail-stock-5)

STEP 2: Converting CAD model into STL file

Almost every AM technology uses the STL file format. The STL format uses triangles to mimic the surface of a solid object. These properties enable AM pre-processing tools to determine the spatial positions of the model's surfaces. Figure 2.4 shows an example of STL file being used for CAD purposes.

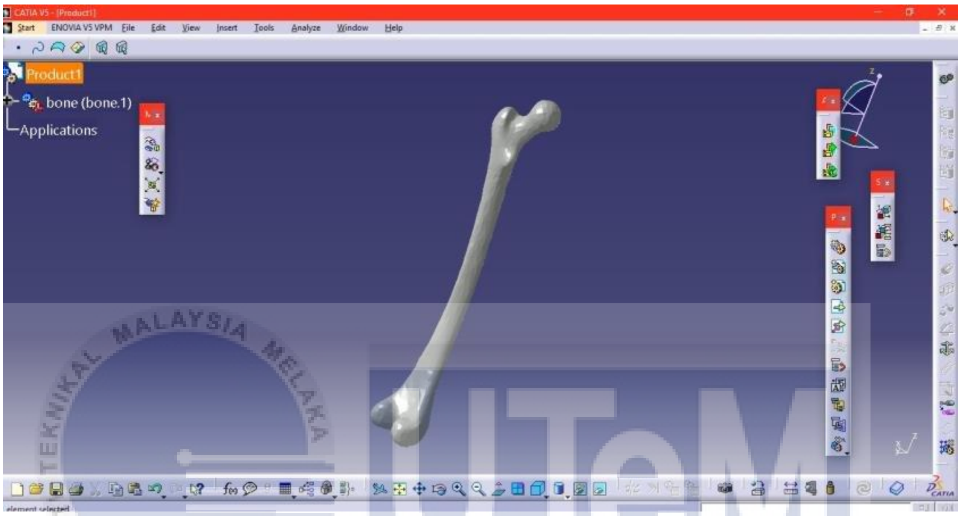

Figure 2.4: STL model of a bone

(Source : https://www.researchgate.net/figure/Conversions-of-the-stl-file-into-ANSYS-format-in-CATIA-V5_fig3_339776311)

STEP 3: STL slicing

The information that were carried out in sliced forms by the STL file will be identified by the AM machine and the product will be formed layer by layer

STEP 4: Machine Set-up

Machine preparation is required prior to beginning any printing. Before starting printing, the desired settings such as layer thickness, surface roughness, bed temperature, and printing orientation must be established.