INVESTIGATION OF REHEAT POST-PROCESSING USING FUSED FILAMENT FABRICATION (FFF) METHOD

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

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DECLARATION

I hereby declare that this thesis is submitted to University Malaysia Sabah in partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering. The work presented and studied in this report is entirely my own except for quotations, summaries, and theory otherwise stated by reference.

29th June 2022

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Thank You,

Jay nelson

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29TH JULY 2022

ABSTRACT

Production in additive manufacturing (AM) must meet customer demand and satisfaction. Thus, producing the highest quality product is needed to implement, and one way to improve the quality of the product is by implementing post-processing. One of the post-processing that is not usually used is reheating, and this paper discusses the effect of reheat post-processing on the 3D model. The first thing that can be done is to model the heating plate on the engineering software and perform a thermal analysis to see the suitable distance between the heating plate and the 3D model and exposure time before the specimen goes to a melting state. For information, the specimen material used is polylactic acid (PLA). The installation of the heating plate on the 3D printer will be done after the thermal analysis is carried out. The specimen will be printed and reheated and will be tested to see the surface roughness of the specimen that has been reheated and analyzed accordingly. From the thermal analysis conducted, for thin specimens, the suitable distance between heating plate and specimen is 3 cm and below, where the exposure time should be less than 300 s. The specimen will become smoother after testing with a surface roughness machine and a surface image, but based on the findings, after a certain temperature, the specimen will bend, so we can say that it is not suitable for thin layer specimens or models. The best exposure time for this project is 300 s, with a distance of 1.3cm between the heating plate and the specimen. The surface image testing is done to observe the layer line or bead when the distance between the heating plate and specimen is at 1.7cm.

ABSTRAK

Pengeluaran dalam 'Additive Manufacturing(AM)' mesti memenuhi permintaan dan kepuasan pelanggan. Oleh itu, penghasilan produk yang berkualiti tinggi diperlukan untuk melaksanakan, dan salah satu cara untuk meningkatkan kualiti produk adalah dengan melaksanakan pasca pemprosesan. Salah satu pasca pemprosesan yang biasanya tidak digunakan ialah pemanasan semula, dan kertas kerja ini membincangkan kesan pemanasan semula pasca pemprosesan ke atas model 3D. Perkara pertama yang boleh dilakukan ialah memodelkan plat pemanas pada perisian kejuruteraan dan melakukan analisis haba untuk melihat jarak yang sesuai antara plat pemanas dan model 3D dan masa pendedahan sebelum spesimen pergi ke keadaan lebur. Untuk makluman, bahan spesimen yang digunakan ialah polylactic acid (PLA). Pemasangan plat pemanas pada pencetak 3D akan dilakukan selepas analisis haba dijalankan. Spesimen akan dicetak dan dipanaskan semula dan akan diuji untuk melihat kekasaran permukaan spesimen yang telah dipanaskan semula dan dianalisis dengan sewajarnya. Daripada analisis haba yang dijalankan, untuk spesimen nipis, jarak yang sesuai antara plat pemanas dan spesimen ialah 3 cm dan ke bawah, di mana masa pendedahan hendaklah kurang daripada 300 s. Spesimen akan menjadi lebih licin selepas ujian dengan mesin kekasaran permukaan dan imej permukaan, tetapi berdasarkan penemuan, selepas suhu tertentu, spesimen akan bengkok, jadi kita boleh mengatakan bahawa ia tidak sesuai untuk spesimen lapisan nipis atau model. Masa pendedahan terbaik untuk projek ini ialah 300 s, dengan jarak 1.3 cm antara plat pemanas dan spesimen. Pengujian imej permukaan dilakukan untuk memerhati garis lapisan atau manik apabila jarak antara plat pemanas dan spesimen adalah pada 1.7 cm.

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CHAPTER 1

INTRODUCTION

1.0 Overview

An introduction is a part where the reader will gain a better understanding of the purpose of making this project. This chapter consists of the background of the research study, problem statement, objective of this project, scope of work, proposed a methodology for this work, and lastly the thesis organization

1.1 Research Background

Nowadays, 3D printing has become one of the most used technologies since it can transform digital solid modeling into real-world without a conventional subtractive manufacturing process such as tuning, milling, drilling, and more (Krishnanand & Taufik, 2021). 3D printing can transform industries and improve the manufacturing process. The use of 3D printing technology will speed up production while also lowering expenses. At the same time, consumer demand will have a greater impact on manufacturing. Consumers have a bigger say in the final product and can ask for it to be made to their exact specifications. Meanwhile, 3D printing technology facilities will be positioned closer to the consumer, allowing for a more flexible and responsive manufacturing process as well as better quality control. Furthermore, the demand for global shipping is considerably reduced when 3D printing technology is used because manufacturing sites are closer to the ultimate destination, all distribution can be done with fleet tracking technology, which saves energy and time. Finally, the adoption of 3D printing technology may alter the company's logistics. Companies' logistics departments can handle the entire process and provide a more comprehensive and end-to-end service (Shahrubudin et al., 2019a). The figure below show the basic process of 3D Printer to create 3D object

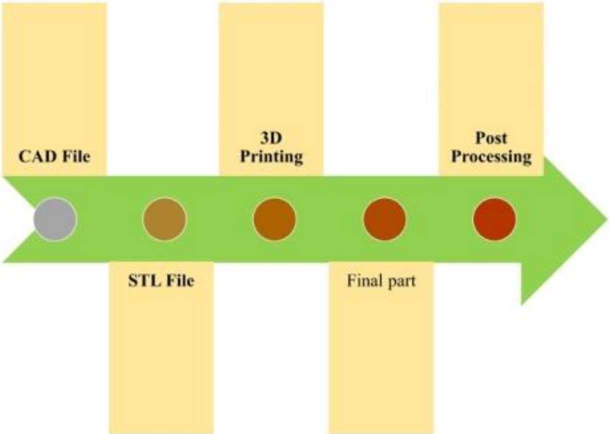

Figure 1.1: The basic process of 3D printers to create 3D object

Source: (Jandyal et al., 2022)

There are lots of types of 3d printing that have nowadays such as selective laser melting (SLM), stereo lithography apparatus and laminated object manufacturing (LOM) and fused filament fabrication (FFF) and the most used type of 3D printing is the fused filament fabrication method is fused filament fabrication (FFF) method. This method is widely used since it can fabricate a lot of complicated components whereas the other method is only suitable for simple components since it cannot fabricate more detail than the fused filament fabrication method (Dickson et al., 2020). Other advantages of using FFF 3D printing technology. For starters, because of the clean, safe, and non-toxic operating environment, it can be utilized in an office or at home. Second, because no expensive equipment, such as a laser, is required, most FFF printers are quite inexpensive. Finally, the raw ingredients are filamentous solids that are simple to work with and replace. Finally, after decades of development, FFF 3D printing components have sufficient stiffness, strength, and geometric precision (Shahrubudin et al., 2019b).

Post-processing in 3D printing can be known as the finishing process to enhance the solid 3D model quality, especially the quality in terms of its surface roughness. It is important for improving mechanical, chemical, and aesthetic qualities, as well as fulfilling tight tolerances, producing close-to-injection-molded finishes, and increasing durability ((Dizon et al., 2021). It allows for the delivery of a product with the most value and impacts possible since it provides aesthetic effects while increasing mechanical, geometric, and other high-value features. It improves the surface attributes of prints beyond the initial print, for example, by controlling wetting behaviors, gloss, scratch resistance, and other characteristics. These critical surface qualities enable post-processing to vastly expand the number of applications and use-cases across a wide range of sectors(Albright B., 2018). According to Albright B. (2018), Post-Processing of 3D printing depends on the type of 3D Printing and type of material. various post-processing processes used on 3D-printed polymer components while taking into account elements such as printing technology, materials, and print settings Stereolithography (SLA), for example, employs post-processing techniques such as basic support removal, washing, wet sanding, and mineral oil finish, as opposed to the standard finish, dyeing, and metal coating employed by selective layer sintering (SLS), and the fused filament fabrication (FFF) technology, which employs support removal, sanding, and gap filling

This project will focus more on the design and development to investigate the effect of reheat post-processing by using the fused filament fabrication method. After this project is developed, the evaluation will be made on this post-processing to see its efficiency in improving the quality of 3D solid modeling.

1.2 Problem Statement

Because polymers are insulators, large temperature gradients occur during this layer formation. As a result, the various cooling rates create residual stresses within the polymer part. Warpage and delamination occur as a result of these large internal stresses, which have a significant impact on the overall quality of the printed component. Previous studies examined the effects of varying print settings, e.g., FFF bead width, extrusion rate, and build layer thickness, and how they affect the surface quality, the phase transition, the issue of filament buckling at the nozzle entry, and the internal residual stresses caused by internal part temperature gradients. However, there has been little effort in measuring and simulating the deposition process and the effect of the print settings and resulting void formation between beads and layers on the cooling and reheating behavior. Therefore, this work establishes a basic model to simulate the FFF process as well as measure reheating effect.

Other than this, the costing of the material design need to be considered for this project so it might be easy for academic purposes to demonstrate the FFF 3D printer. Last but not least, material selection to carry out the experiment is very important need to be made to carry out the reheat post-processing. Suitable material and component on the heating plate need to be made for the purpose of this project.

1.3 Objective

There are a few objectives that need to be obtained from this project as listed below.

1. To model the reheat post-processing using the Fused Filament Fabrication (FFF) method with finite element analysis (FEA)
2. To select and install the heating plate for reheat post-processing implemented on 3D printer
3. To investigate and analyze the effect of reheat post-processing on the 3D solid model.

1.4 Scope of Work

This project will be started by finding the related journal regarding the reheat post-processing using the FFF method and reviewing the past research paper. This step is very important to create a literature review about the project and to make sure the project keeps on the right track

This project is basically on how to improve the FFF 3D Printer so the roughness on the layer surfaces will be improved better. The first step that can be done is by designing the deposition process by creating a 3D model on the engineering software to ensure the accuracy of the model. The modeling also needs to consider the type of material used especially for the heating plate because the evaluation or performance of this project will determine the distance and exposure time required of the heating plate to supply the heat on the specimen. After that, the installation of a heating plate on the 3D printer was made by using equipment cutting and connecter the alloy metal. After the installation of heating plate has been made for the post-processing part, the investigation will be made to ensure whether the reheat post-processing is effective to improve the quality of the 3D solid modeling especially in terms of its surface roughness.

Finally, the material selection for heating plate is very important to ensure the costing and the product value cooperates with the given project. the costing of this project should be able to achieve even for academic purposes

1.5 Methodology

The methodology of this project consists of 4 stages that aim to investigate and fabricate the FFF 3D printer to improve the surface roughness. The 4 main stages of the proposed methodology consist of literature review, modeling, modification of reheat post-processing, and specimen performance evaluation. A flow chart is presented below to summarize the flow of the methodology.

i. Literature review

Past research papers related to reheating post-processing and topic related to fused filament fabrication (FFF) 3D Printing will become a reference and guide to start the project. The past project or research paper will be reviewed and studied to ensure the project is on track. Other than that, the past paper also will give more understanding on how reheating post-processing can be done, how to model virtually design the reheat post-processing part using finite element analysis (FEA) and how to investigate the performance of the 3D solid modeling whether the project able to achieve the objective. Last but not least, the methodology of the project paper mostly will be referred to the past research paper that has been made.

ii. Modeling

The heating plate will be modelled on 3D printer virtually using engineering software such as Solidwork to get a suitable distance between heating plate and specimen and exposure time using Finite Element Analysis (FEA). The modeling itself will follow the standard measurement of 3D printer since the heating plate will be included on the 3D Printer for the reheat post-processing able to works together with a 3D printer and perform to do the analysis.

iii. Installation of Heating Plate for reheat post-processing

installation of heating plate needs to be done so the reheat post-processing able to carried out. An important thing that needs to be considered is the material costing for heating plate so that this project is achievable even for low cost investment and academic purposes. Other than that, the material temperature needs to be considered so the heating plate able to supply heat until the specimen reach its softening temperature.

iv. 3D solid modeling Performance analysis

The data and the result of the experiment will be put inside the analysis by referring to the research paper. Other than that, the performance or reheating post-processing will be discussed such as the effect by referring to the past research paper to make an accurate analysis. The effect of distance between specimen and heating plate and exposure time will be discussed to see the effect on the specimen. The result will be tested and analyze using surface roughness measurements and surface image to see better and accurate result for the experiment.

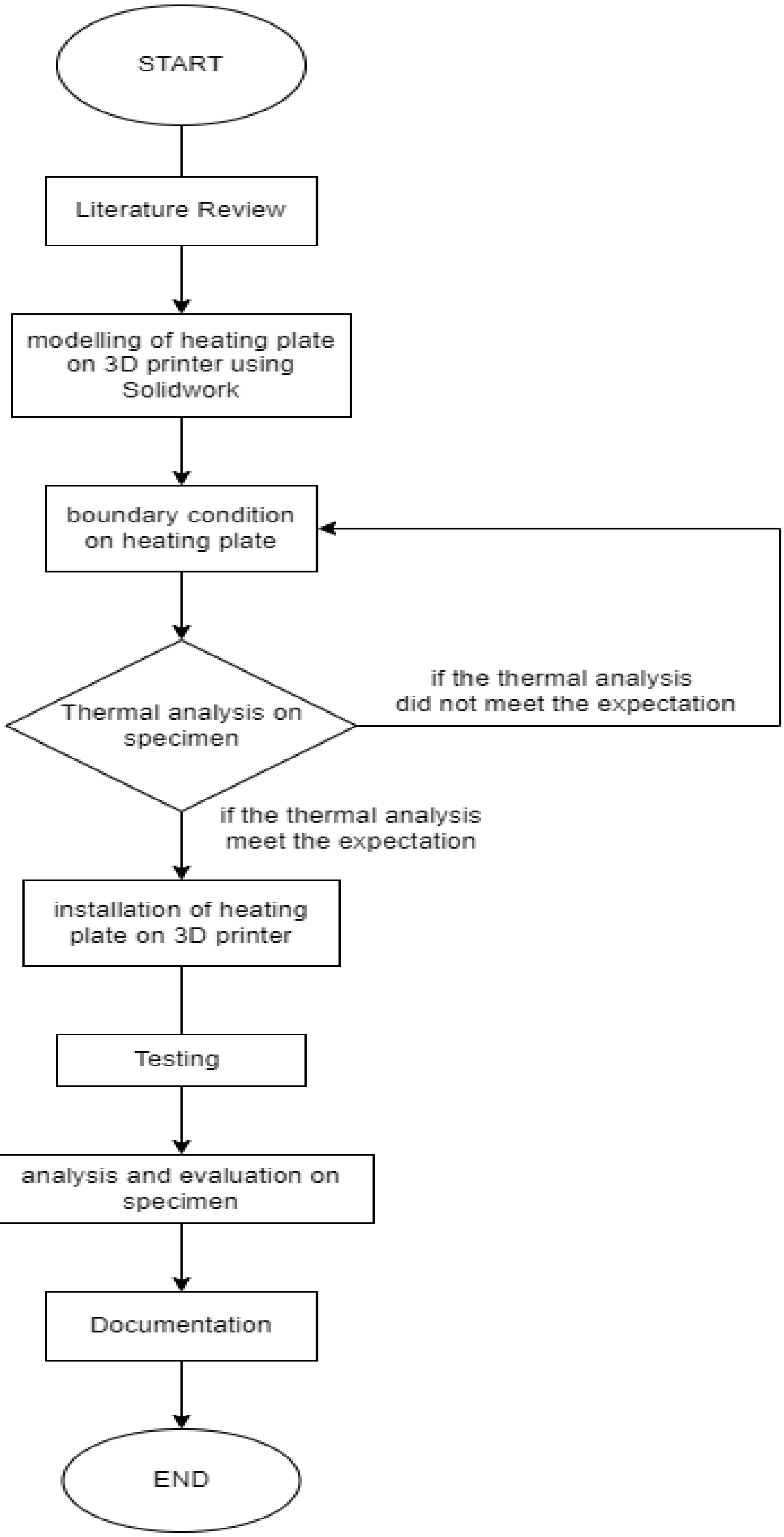

Figure 1.2: Project Flowchart

1.6 Project Outcomes

From this project, the project should meet the desired objective that has been listed and be able to achieve it successfully. Starting from the design itself, there should meet certain considerations, especially the distance between the heating plate and specimen since we want the heating plate able to supply heat to the specimen and how much time for the specimen is exposed to heat before it go to a melting state. Both parameters need to be considered using the FEA method. After that, the heating plate will be able to be installed with the 3D printer for reheat post-processing able to carried out. Lastly, the performance of the reheat post-processing will be evaluated based on the effect of the reheat on the specimen and will be verified using the testing for the surface roughness.

1.7 Project Contributions

This project will contribute a lot to improving the quality of 3D solid modeling that will be produced. This also helps additive manufacturing to improve their quality product to be better which will help a lot of people, not only in the manufacturing industry but in the 3D printing industry also. People also will gain more knowledge on how post-processing will give an impact on 3D models produced by 3D printers where directly this project also can be as an educational purpose for students, or any party interested in 3D modeling to improve their quality products.

1.8 Project Commercialization

This project's goal is to evaluate and analyze the performance of 3D solid modeling where the quality of the solid modeling especially the surface roughness will be evaluated. This project especially can be commercialized in so many applications since 3D printing is broadly used for its tooling aids, visual and functional. The one application that can be used is in aerospace since in aerospace the value proposition of 3D printing brings to functional prototypes, tooling, and lightweight component.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter consists of a past research paper related to this project where this past year's research mostly related to how the reheat post-processing happens on FFF 3D Printer. Before beginning on the post-processing of the 3D printer, we need to know how 3D Printing works system and its type of 3D Printing to gain a better understanding of how to conduct a good methodology. After that, all types of post-processing of 3D printers will be listed and discussed in this chapter to give an idea of how post-processing works. Lastly, thermal, temperature, and reheat processing will be discussed further since this project post-processing is about reheating post-processing. Thus, further investigation will be made on this part where the expectation of this project can be made.

2.1 Background and Overview of 3D Printer

To gain a better understanding of this project paper, we need to know how the 3D Printer started and how it works. The first known examples of 3D printing may be found in Japan in the early 1980s. Hideo Kodama was looking for a technique to design a quick prototyping system in 1981. He devised a layer-by-layer manufacturing method based on a photosensitive resin that was polymerized by UV radiation. Despite the fact that Kodama was unable to meet the technology's patent requirement, he is often acknowledged as the initial developer of this production technique, which is a precursor to the present SLA machine (Horvath, 2014).

In the 90s, many companies and startups began popping up and experimenting with the different additive manufacturing technologies. In 2006, the first commercially available SLS printer was released, changing the game in terms of creating on-demand manufacturing of industrial parts. CAD tools also became more available at this time, allowing people to develop 3D models on their computers. This is one of the most important tools in the early stages of creating a 3D print. During this time, the machines were very different from those that we use now. They were difficult to use, expensive, and many of the final prints required a lot of post-processing. But innovations were happening every day and discoveries, methods, and practices were being refined and invented.

The world's largest operable 3D-printed building was finished recently. Hearing aids and other healthcare applications are now routinely 3D printed, and many industries and sectors have integrated the technology into their daily operations (Whitaker, 2014).

A common 3D printer functions similarly to an inkjet printer controlled by a computer. In a method known as fused filament fabrication (FFF), it builds up a 3D model one layer at a time, from the bottom up, by repeatedly printing over the same area (Krishnanand & Taufik, 2021). The printer builds a model over the course of several hours by converting a 3D CAD drawing into a series of two-dimensional, cross-sectional layers—effectively independent 2D prints that sit one on top of the other without the use of paper. Instead of employing ink, which would never build up too much volume, the printer employs adhesive or ultraviolet radiation to fuse layers of molten plastic or powder together (and to the existing structure). (Huang & Lin, 2017)

Noted that since FFF has more advantages especially since it can print complicated 3D models, thus this topic will only discuss more on the fused filament fabrication (FFF) 3D Printing.

2.2 Post-processing of 3D Printing

FDM 3D printing is best suited for low-cost prototypes with a rapid turnaround time. Because layer lines are common on FDM prints, post-processing is necessary if a smooth finish is desired. Some post-processing techniques can strengthen prints, reducing the anisotropic behavior of FDM parts (Dizon et al., 2021).

2.2.1 Support Ejection

The initial stage of post-processing for any 3D printing technology that requires support to precisely generate pieces is often support removal. Dental picks and needle-nose pliers can be used to remove support material from the print with minimum effort, and dental picks and needle-nose pliers can be used to clean support material in hard-to-reach spots (such holes or hollows). The visual impact of support material on the final print can be considerably reduced with well-placed support structures and suitable print orientation (Piedra-Cascón et al., 2021). The advantage of this post-processing is that it will not affect the geometry of 3D modeling and it takes less time to do the post-processing (Park et al., 2022a). Whereas the disadvantage of this post-processing is no layer lines, striations, or imperfections on the print surface are removed and the precision and appearance of the print are harmed when support structures leave behind excess material or blemishes (Trincat et al., 2022).

2.2.2 Sanding

After the supports have been removed or dissolved, the part can be sanded to remove any visible imperfections, such as blobs or support marks. The grit of sandpaper, to begin with, is determined by the layer height and print quality (Sivarupan et al., 2021). The advantage of this post-processing is enhanced surface roughness and makes extra post-processing (such as painting, polishing, smoothing, and applying an epoxy coating) a breeze. While the disadvantage of this post-processing is for complicated surfaces and prints with small details, this is a difficult task. Secondly, if sanding is done too vigorously and too much material is removed, it can affect the print's overall accuracy (Liu et al., 2022).