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OBSERVATION OF MACRO SURFACE AND GEAR MASS OF 3D PRINTING MACHINE USING PLA FILAMENT

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ABSTRACT

3D Printing Machine is a machine that works with the basic principle of CNC, namely the movement of the machine in making the workpiece which is regulated by the G code in 3 coordinate axes x, y, and z. Based on how it works, 3d printing machines are classified into 7, namely, Vat photopolymerization, Material Extrusion, Powder-Bed Fusion, Sheet Lamination, Binder Jetting, Material Jetting, Directed Energy Deposition. The results of the research on 3d Printing Material extrusion this time using PLA material with a machining diameter of 1.75mm, nozzle distance with bed 0.1mm, nozzle diameter 0.4mm, layer height 0.12mm, nozzle temperature 200^{0}C, bed temperature 60^{0}C, printing speed 80mm/s. The experimental results found problems such as clogging, the filament does not stick to the bed, the filament has a different freezing point, thus affecting the geometry of the workpiece to be printed. For the mass of all printed workpieces after measuring the mass with no significant changes, it is ensured that the problem originates from variables related to the printing of each layer in the form of printing speed, bed temperature, nozzle temperature, and system temperature.

Keywords: *3D Printing Machine; Macro Surface; Gear Mass; CNC; PLA Filament.*

1. INTRODUCTION

Since the early 2000s, the term CNC (Computer Numerical Controler) machining has been broadened to include a new generation of fast-acting prototyping that has the potential to make personal production scale ready-made. "Personal scale manufacturing tools enable makers who do not have special training in carpentry, metalworking, or embroidery to create a product of a certain geometry, they have a unique craftsman style object". In general, the process of making parts starts from making 2-dimensional and 3-dimensional drawings, then performing a stress-strain analysis, after it is determined that it is safe, the next step is cutting (Slicer) to provide the G code used in CNC machines. Cutting software (Slicer) currently only exists for plastic printing purposes and is not optimal enough for printing food or other types of materials other than plastic [6]. Fuse Deposite Material type 3D printing technology can print workpieces integrally [7]. Giving the G code is very easy from the form of 2 or 3-dimensional image parts converted using software into STL (Stereolithography) or NC (Numerical Controler) files. Then the program is given on the machine and is ready to work to print the workpiece we want earlier [1]. The product of the XY FDM core type 3D printer has good quality because it has a precise size with a 2-

dimensional design drawn for a rigid shape and not the shape of the machine element [3]. 3D printer machines present the opportunity to provide a platform that allows for the rapid manufacture of a wide variety of thermoplastic prototypes [4]. Additive Manufacturing methods to date are Powder Bed Fusion and Directed Energy Deposition [5]. The technology is therefore not set to replace conventional manufacturing as many previously suggested, but provides additional scope for increasing production [9].

Additive manufacturing (AM) is a rapidly evolving technology that integrates into manufacturing processes as well as our daily lives. Its emergence into the commercial world has been labeled by various names, such as three-dimensional (3D) printing, rapid prototyping (RP), layered manufacturing (LM), or solid-free form fabrication (SFF). Conceptually, AM is an approach where 3D designs can be built directly from computer-aided design (CAD) files [12]. In this fabrication based on freeform layers, multiple layers are constructed in the X-Y axis direction which is interconnected, and to produce the Z-axis direction or 3rd dimension. Once the part is built, it can be used for concept models, tested for functional prototypes, or used in practice. Every day consumers should realize that AM can be a way to connect with producers on a new level. AM is more than just a process that can be used to create new items or personalized prototypes.

With the new developments in AM, we live in age at the height of the fast manufacturing industry, which is taking over the process of mass-producing products and making them economically viable, designing and manufacturing new ones on time. As a result, manufacturing processes sectors around the world will adapt to this development by incorporating new styles of interaction between customers and producers [14].

AM enables people to contribute to the design process from virtually any location at all and will break down local engineering barriers and emerge on a global scale. Just as the internet has given us the ability to share and access information from any location, digital design and CAD have given people the ability to create, modify, and improve designs from anywhere. With AM, the design can be fabricated and tested from almost any location with very little lead time. AM machining capabilities have become sophisticated, to the point where thinking about design and modeling in CAD is the limit instead of product manufacturability [11].

As the new generation grows with CAD Technology and the capabilities and availability of AM machines grow, the process of designing a product will mature as it is created by a select group of engineers to be manufactured by consumers and companies together, with the final product being produced anywhere in the world at the right time.

Many parameters can be adjusted in most of the FDM machines to achieve accurate prints. Build speed, extrusion speed, and nozzle temperature control the consistency of the filament extrusion and are set by the operator (some machines use automatic presets based on the type of material being printed) [2]. At a basic level, the nozzle diameter and the coating height determine the resolution of the FDM molded part. While all parameters define the dimensional accuracy of a part, smaller nozzle diameter and lower coating height are generally seen as a solution for parts where a smoother surface is required and a higher level of detail is required. The use of 3d printers with the FDM system is very possible for making cork patterns because they have good shape and accuracy [8].

The available build volume should be considered when printing using FDM. On average, desktop printers are typically 200x200x200mm. Larger industrial machines can offer a build chamber of 1000x1000x1000mm. For very large parts, disassembling a design into components that can be assembled after printing is often the best solution [10].

Warping of FDM parts occurs due to differential cooling. Different parts of the mold cool at different rates, they contract and shrink. This pull in the surrounding area (Figure 1) creates internal stresses that can cause bending or distortion. The heated bed, as well as good adhesion, plays an important role in holding the FDM apart, limiting the possibility of bending or distortion.

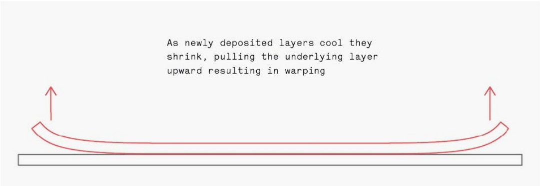

Figure 1. Warping [14]

The adhesion or bonding of the coating is an important part of FDM printing. When the filament is extruded, it needs to bond and harden with the previously molded layer to form a solid, cohesive part. To achieve this, the filament is pressed into the previous layer. The hot extruded material reheats and re-melts the previous mold layer. The downward force and partial re-melting of the underlying material allow the bonding of the new layer to the previously printed layer. This also means that the FDM filament is deposited in an oval rather than circular shape (Figure 2). Since the printed layers are oval, the joints between each layer are small valleys (Figure 3). This creates concentration stress at which cracks can form when subjected to load and leads to the inherent anisotropic behavior and a rougher surface finish of the molded part, as well as a layered appearance (Figure 4).

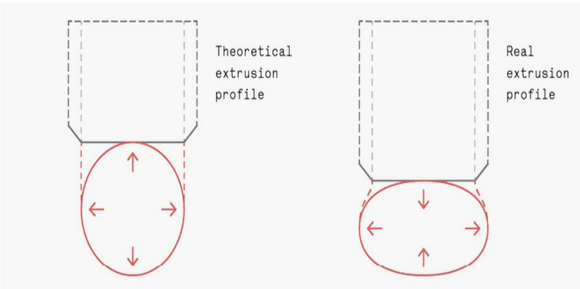

Figure 2. Extrusion Filament [14]

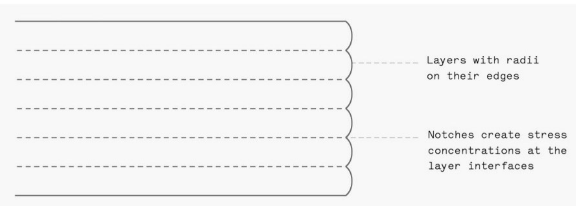

Figure 3. Layering [14]

Figure 4. Layers [14]

FDM parts may require a support structure to print successfully. Support is required for features that protrude and are shallower than 45 degrees relative to the ground plane as illustrated in Figure 1.5. The new coating cannot be deposited into thin air, a sturdy scaffold is required to create it. If there is no undercoat for printing, it requires support. This allows the feature to be printed if it is not possible to stand alone. The backing material is a low volume, lattice structure that is removed after molding. While it is possible to print overhangs that are less than 45 degrees (due to the inherent stickiness of the molten filament), the surface quality angle begins to decline. For fast printing to fit and shape proofing required, the overhang limit can be extended to an angle lower than 45 degrees. For accurate printouts with a smooth surface finish, it is recommended to maintain the 45 degrees limit. The negative side of the supports has a detrimental effect on the surfaces in contact, resulting in a rougher surface finish. Post-processing is usually required if a smooth surface is desired. This is a factor to consider when orienting parts of the building process. In general, it is best to minimize the amount of contact the supporting structure makes with the flat surface [13].

FDM parts are generally not solid printed. To save material and reduce manufacturing time, a part is molded with a low-density structure known as a filler (Figure 1.6). The infill percentage is a parameter that can be varied based on the implementation of a section. For high strength, parts can be molded 80% solid. If the model is used only for form and fit testing, the fill percentage can be lowered to as low as 10%, enabling parts to be manufactured faster and at a lower cost. 20% is a common fill percentage for FDM printing.

The fill geometry also affects the performance of the part of the FDM. Common fill geometries include triangles, rectangles, and honeycombs. Some slicing programs allow the density and geometry of the filler to be varied across the die.

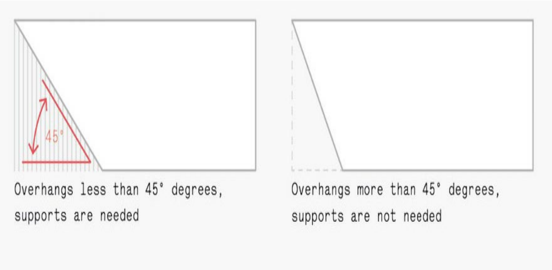

Figure 5. Support [14]

Figure 6. Infill [14]

2. METHODS

2.1 Research Methodology

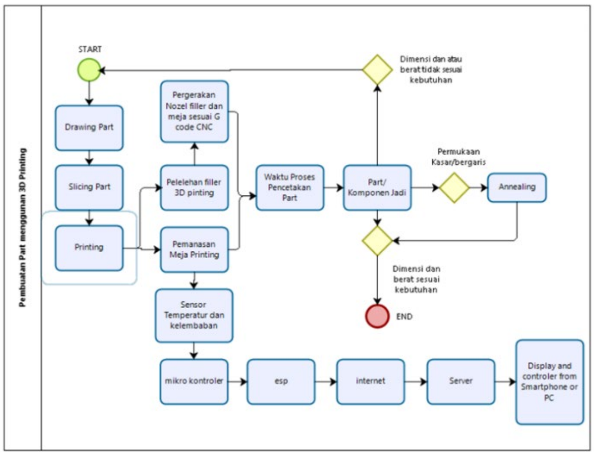

Figure 7. Schematic of The Research Process

The research method starts with a 2-dimensional drawing of the gear cross-section, then extrudes and modifies the radius and chamfer. Furthermore, the 3D image file is opened using "Cura" as a slicer to provide settings related to printing variables such as temperature bed, nozzles, layer height, printer speed, and filament infill. From the Slicer, you will find the results of the printing process. After the part/workpiece is printed, the next step is to make macro observations and weigh the mass, then process the data and determine the results of the research (Figure 7).

3. RESULTS AND DISCUSSION

The FDM machine-made as shown in Figure 8 has the advantage of a room temperature monitoring system that is integrated with the server. The results of the printing of the gear components or specimens are quite good as shown in Figure 9, while the visible part of the surface is shown in Figure 10 even though the diameter of the hole in the shaft of the gear hole changes the print dimensions. In addition, when printing, it failed to print as shown in Figure 11, which is called multiple-layer shift, namely the filament is not attached to the previous layer. The finding from the next observation is the warping of Figure 12, which is an asymmetry of the plane caused by several things including the temperature being too hot so that the temperature transfer to reach the frozen filament is too long. Furthermore, the findings in the form of prints such as hair (Hairy Prints) Figure 13 is a form of melted filament that experiences dislocation orientation in the circular geometry direction due to the non-adherence of the filament to the layer. Figure 14 is a type of over and under extrusion defect, this is due to the continuous feeding process from the nozzles, thus providing a contour line according to the movement of the layers in the slicer. One of the defects experienced when an FDM-type machine is in the form of repeated movements from the initial position to the end in the stacked layer is shown in Figure 15 with a line phenomenon on the z-axis that distinguishes between several layers which are called Z-wobble. Then when a power outage occurs the FDM machine will stop working and return to work when the operator performs the printing process again, in this condition, it will produce a single layer shift-type defect which can be seen in Figure 16, there is a line in the XY-axis plane which makes a weakness from the FDM type so that it requires to add a Power Supply Unit in the continuous printing process. At the end of our macro observations, it turns out that we found a workpiece defect in the form of delamination as shown in Figure 17, some layers appear to be detached from the gear geometry. This is due to the low adhesion between layers.

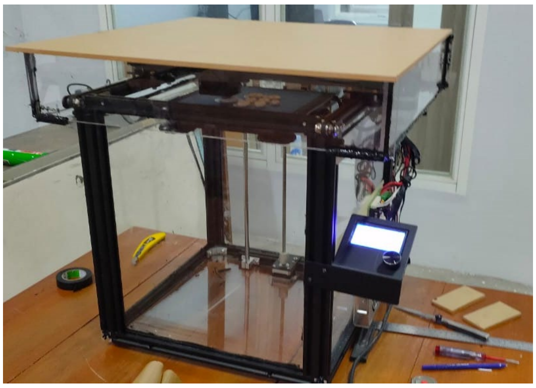

Figure 8. 3D Printing Machine

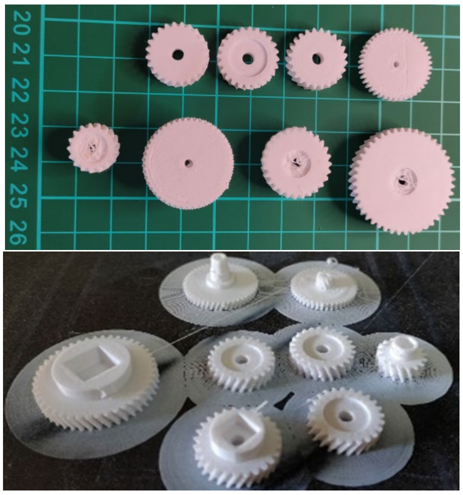

Figure 9. Printout

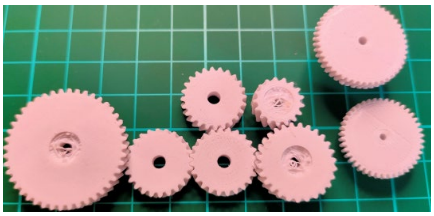

Figure 10. Specimen

Figure 11. Multiple Layer Shift

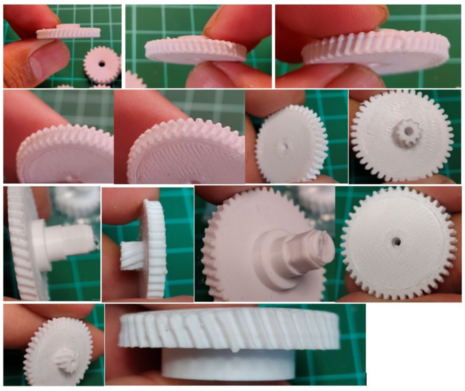

Figure 12. Warping

Figure 13. Hairy Prints

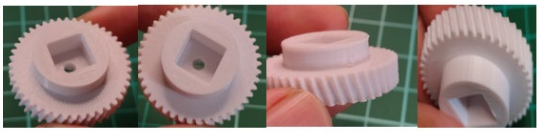

Figure 14. Z-wooble

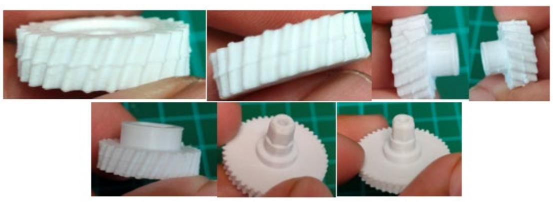

Figure 15. Single Layer shif

Figure 16. over and under extrusion

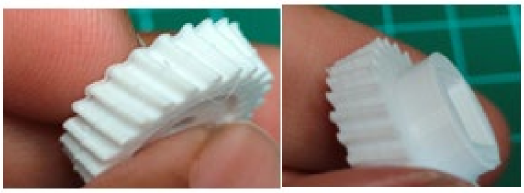

Figure 17. Delamination

Figure 18. Mass Specimen 1

Figure 19. Mass Specimen 2

Figure 20. Mass Specimen 3

Figure 21. Mass Specimen 4

Figure 22. Mass Specimen 5

Figure 23. Mass Specimen 6

Figure 24. Mass Specimen 7

Of the 7 specimens shown in Figures 18 to 24 with 3 repetitions, we weighed the mass (Figure 25). Specimen 2 has a mass difference of 0.1 grams, while for the whole specimen other than 2 there is no difference in mass so that it can be ascertained that the mass in the geometry does not change and it is ensured that the geometry of the workpiece only experiences dislocations in the layer according to some defects in the workpiece. it's been discussed before.

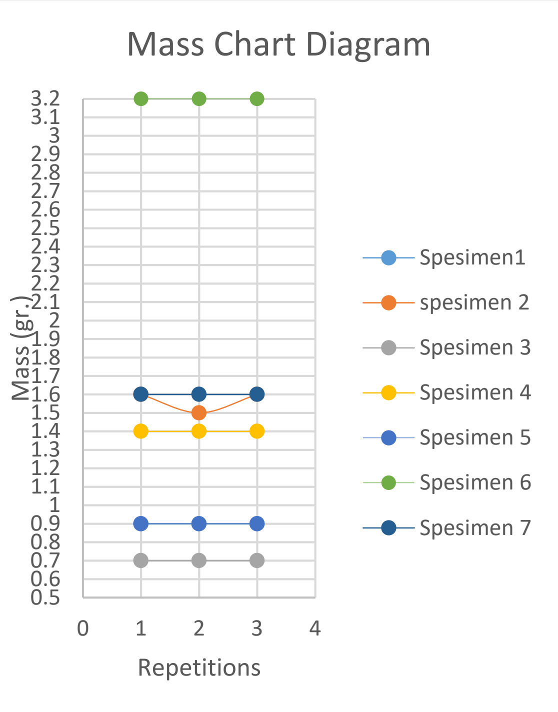

Figure 25. Mass Vs Specimens

4. CONCLUSION

From macro observations and mass measurements that have been carried out, it can be concluded that some defects of the 3d printing workpiece include:
1. Multi-layer Shift
2. Warping
3. Hairy Prints
4. Over/under extrusion
5. Z wobble
6. Single-layer shift
7. Delamination

While the mass measurement proves that the calculation of the use of filaments by the slicer does not change significantly, what occurs during the printing process is the disorientation of the various filament locations.

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