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INFLUENCE OF ANNEALING ON WARPING ANGLE ON POLYLACTIC ACID IN FUSED DEPOSITION MODELING 3D PRINTER

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ABSTRACT

The industrial world has been developing at an increasingly rapid pace. The use of additive manufacturing technology is increasingly being used by various companies around the world. Fused deposition modeling (FDM) is a type of 3D printing that falls under the category of material extrusion. It is also known as fused filament fabrication (FFF). Fused deposition modeling (FDM) is the most cost-effective additive manufacturing technique. Polylactic acid (PLA) is a type of plastic that is made from renewable resources such as corn starch, tapioca roots, chips or starch, or sugarcane. It is biodegradable and bioactive and can be used for a variety of applications such as packaging materials, disposable tableware, medical implants, and 3D printing. PLA is also used in the food industry as a food packaging material. The goal of this study is to analyze the warping angle of polylactic acid when it received annealing treatment. In this study, the commercial eSUN PLA with a diameter of 1.75 mm was used. This study used experimental method with predetermined conditions such as ISO 527-2 printed specimens, annealing temperature at 50ºC and 70ºC. The test result shows that annealing at 50ºC have the highest degree of side view 1.88º, and 1.32º on average. The top view have 2.21º and 1.19º on average. Afterwards, the study shows that annealing at 70ºC have the highest degree of side view 6.19º, and 3.96 on average. The top view have 3.84º, and 2.33º on average.

Keywords warping angle; polylactic acid; 3d printing; annealing; fused deposition modeling
Paper type Research paper

INTRODUCTION

Over time, the industrial world has been developing at an increasingly rapid pace. The manufacturing industry is one of the most advanced industries, particularly in its use of technology. One of these technologies is additive manufacturing. The use of additive manufacturing technology is increasingly being used by various companies around the world.

Additive manufacturing is a process of creating an object by building it one layer at a time. It is the opposite of subtractive manufacturing, in which an object is created by cutting away at a solid block of material until the final product is complete. Additive manufacturing is also known as 3D printing and is used in various industries such as aerospace, automotive, medical, and consumer products[1][2]. The International Commission ASTM International Committee F42 defines additive manufacturing as the process of connecting materials when making objects directly from 3D computer models, usually layer by layer, which is in contrast to the subtractive mode of production[3].There are seven main types of additive manufacturing technologies[4][5][6]. These are: Material Extrusion, Vat Polymerization, Powder Bed Fusion (PBF), Sheet Lamination, Directed Energy Deposition (DED), Binder Jetting, Material Jetting. Each of these types of additive manufacturing processes works differently and has its own uses, advantages, and differences among them.

Fused deposition modeling (FDM) is a type of 3D printing that falls under the category of material extrusion. It is also known as fused filament fabrication (FFF). Fused deposition modeling (FDM) is the most cost-effective additive manufacturing technique[7]. Fused deposition modeling (FDM) has been used in the automobile industry for testing models, lightweight tools and final functional components. The benefits of FDM include its cost-effectiveness as it is the most cost-effective method of manufacturing bespoke thermoplastic components and prototypes. Due to the lower cost of FDM printers and wide availability, the lead times are minimal and cheaper than other additive manufacturing processes. There is a wide range of thermoplastic materials available for prototyping and certain non-commercial practical. Scalability is one of the most favorable advantages of FDM. It can scale to any dimensions effortlessly. The only restriction in the dimension of construct extract is the motion of the individual frame- create the frame rails extended and the construct extract can be designed immensely.

Fused deposition modeling (FDM) uses filament as printing material. Thera are many filaments available in the market such as polylactic acid, acrylonitrile butadiene styrene (ABS), polyethylene terephthalate glycol (PETG) and et cetera. Filaments used in 3D printing are thermoplastics. They are plastics that melt rather than burn when heated, can be shaped and molded, and solidify when cooled. The filament is heated to its melting point and then extruded through a metal nozzle as the extruder assembly moves, tracing a path programmed into a 3D object file to create, layer by layer, the printed object[8].

Polylactic acid (PLA) is a type of plastic that is made from renewable resources such as corn starch, tapioca roots, chips or starch, or sugarcane. It is biodegradable and bioactive and can be used for a variety of applications such as packaging materials, disposable tableware, medical implants, and 3D printing. PLA is also used in the food industry as a food packaging material[9][10][11].Polylactic acid (PLA) is one of the most widely used plastic filament materials in 3D printing. It has a low melting point, high strength, low thermal expansion, good layer adhesion, and high heat resistance when annealed. These properties make it an ideal material for 3D printing.

Figure 1. PLA filament

It is not yet clear about the influence of annealing on the warping angle of polylactic acid. This study is important because annealing has a positive influence on the tensile strength of a material[12][13][14][15]. Therefore, this study was conducted to ascertain the influence of annealing on the warping angle of polylactic acid material.

METHOD

The goal of this study is to analyze the warping angle of PLA. In this study, the commercial eSUN PLA filament with a diameter of 1.75 mm was used.

This study used experimental method with predetermined conditions:

1. This research used eSUN polylactic acid (PLA).
2. ISO 527-2 printed specimens[16].
3. The annealing temperatures are 50ºC and 70ºC

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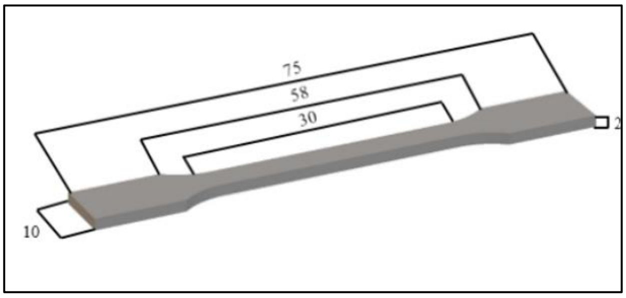

Figure 2. ISO 527-2 specimen

TABLE I. PRINTING PARAMETERS

	Annealing Temperature (ºC)	Nozzle Temperature (ºC)	Layer Thickness (mm)	Printing Speed (mm/s)
1	50ºC	200ºC	0.2	40
2	70ºC	200ºC	0.2	40

Experimental method are as follows:

1. Designing 3D design of specimen according to ISO 527-2 standard using FreeCAD software. The 3D design was STL files.
2. Using Cura software to slice the STL files into the gcode files.
3. Printing ten specimens. Each annealing temperature had five specimens. The specimens were printed by 3D printer machine Kingroon KP3.
4. Each specimen warping degree were then measured.

Figure 3. The testing specimens

Figure 4. Kingroon KP3

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DISCUSSION

The specimens were printed by 3D printer. There are five specimens for 50ºC annealing temperature and 70ºC annealing temperature, for a total of 10 specimens. Every specimens were undertaking annealing treatment for 1 hour. Then a specimen would be cool down on a room temperature for about 3 hours. Afterwards, every specimens were measured. The results are shown in Table II.

TABLE II. WARPING ANGLE ANNEALING 50ºC

Angle	Specimen					
	1	2	3	4	5	average
Side	1.41	1.49	0.41	1.41	1.88	1.32
Top	0.54	2.21	1.48	0.43	1.28	1.19

TABLE III. WARPING ANGLE ANNEALING 70ºC

Angle	Specimen					
	1	2	3	4	5	average
Side	2.36	4.18	3.47	3.62	6.19	3.96
Top	1.86	3.17	2.18	0.59	3.84	2.33

Annealed PLA parts have tendency of warping.The fusion process of fused deposition modeling was primarily driven by thermal energy.The way the layers were fused together can lead to the development of a new type of flaw. Figure 5 and Figure 6 shows that warping angle raising along the increase in temperature.

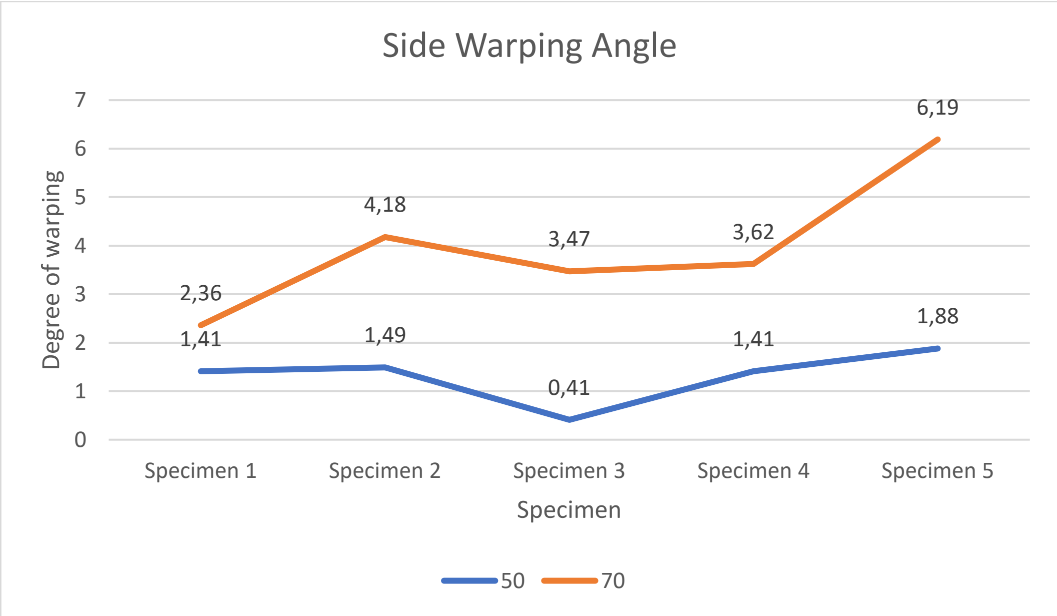

Figure 5. Warping angle

The behavior of the warping show that annealing temperature affecting the mechanical properties of polylactic acid (PLA), altering the material harder and less ductile. The test result shows that annealing at 50ºC have the highest degree of side view 1.88º, and 1.32º on average. The top view have2.21 º and 1.19 on average.

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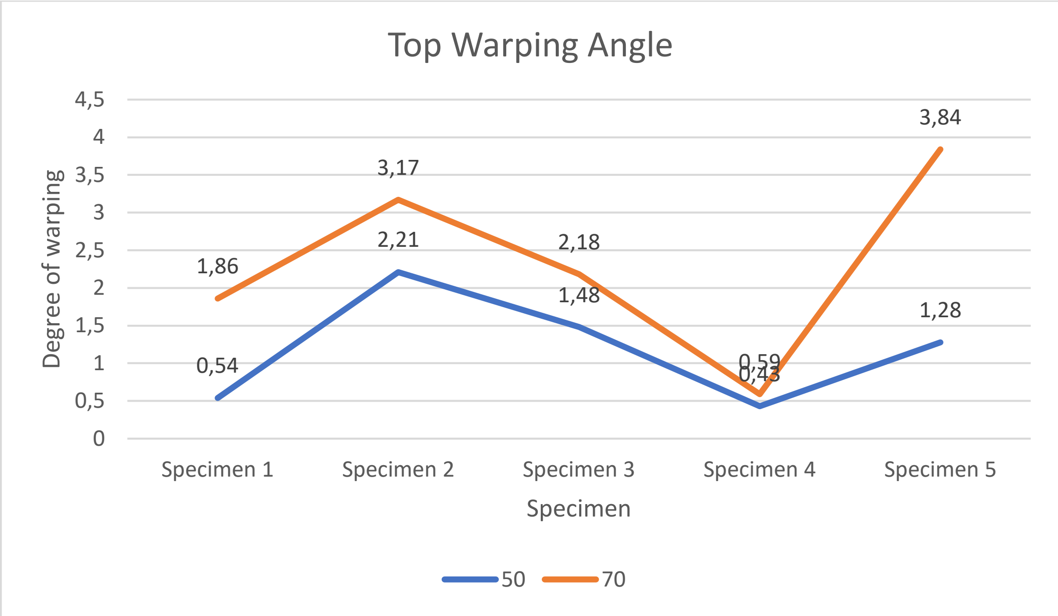

Figure 6. Top Warping angle

Afterwards, the study in Figure 5 and Figure 6 shows that annealing at 70ºC have the highest degree of side view 6.19º, and 3.96 on average. The top view have 3.84º, and 2.33º on average. When a thermoplastic polymer is heated, it becomes more flexible and can be easily molded or shaped. This is because the heat energy causes the intermolecular forces between the polymer chains to weaken. When these forces weaken, the polymer chains are able to slide past each other more easily, which makes the material more flexible.

When PLA is heated, the intermolecular bonds between the polymer chains weaken. This allows the chains to move more freely and start to align themselves in a regular, crystalline pattern. This process is called crystallization. The crystallization of PLA can be divided into two processes: nucleation and growth. Both processes depend on the thermal energy within the material. First, the polymer chains must come together to form a nucleus. Once a nucleus is formed, it can grow into a larger crystal. Both of these processes require thermal energy[17][18].

The rate of crystallization depends on the temperature of the material[19][20]. At higher temperatures, the polymer chains have more energy and are more likely to come together to form a nucleus. Once a nucleus is formed, it can grow more quickly at higher temperatures. Some studies have found that packing FDM parts in salt powder[21][22] can help to prevent deformation during thermal post-processing. This is because salt has a high specific heat capacity, which means that it can absorb a lot of heat without significantly increasing its own temperature.

Lluch[23] investigated the use of a ceramic powder mold to prevent deformation of PLA parts during an annealing post-process at 135 degrees Celsius. The results of Lluch's experiment suggest that using a ceramic powder mold can be an effective way to prevent deformation of PLA parts during annealing. This could be a valuable technique for improving the quality and performance of PLA parts. The dimensional change in a polymer is affected by three key factors: the initial alignment of the microstructure, the rate of cooling, and the way heat energy is distributed throughout the material.

Conclusion

From the results of testing and data analysis that has been conducted, it showed that annealing temperature can influence the warping angle of polylactic acid (PLA). The higher the temperature, tbe greater the warping angle. The test result shows that annealing at 50ºC have the highest degree of side view 1.88º, and 1.32º on average. The top view has2.21º and 1.19º on average. Afterwards, the study shows that annealing at 70ºC have the highest degree of side view 6.19º, and 3.96 on average. The top view has 3.84º, and 2.33º on average. The deformation of polylactic acid occurred because of thermal post-processing specifically annealing in this study.

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