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Research Article

Investigation of mechanical properties and thermal conductivity coefficients of 3D printer materials

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ABSTRACT

The demand for 3D printer technology and products, one of the additive manufacturing methods, is increasing daily in the sectoral and academic fields. Many types of polymer-based filaments are used in 3D printers, pure or filled/reinforcement. Utilizing these specialized materials in places suitable for their mechanical and thermal properties will help efficiently use resources. Using 3D printers, it is possible to manufacture products that provide thermal insulation or good heat conduction in heating and cooling areas. Especially due to the energy requirements for heating and cooling, it is very important to know the thermal performance of materials to ensure and maintain energy efficiency. This study experimentally investigated the mechanical properties and heat conduction coefficients of 3D printed parts. The experiments were conducted with seven different filament materials (PLA, PLA+, PLA-CF, PLA Wood, Tough PLA, ABS+, TPU) and three layer thicknesses (0.1, 0.2, and 0.3 mm). Samples for tensile testing, hardness, and thermal conductivity coefficient measurements were produced, and measurements were performed. In the experiments, the highest tensile strength was obtained in PLA-CF with 0.3 mm layer thickness, and the lowest tensile strength was obtained in PLA Wood with 0.3 mm layer thickness. Tensile strength decreased with an increasing layer thickness in PLA, PLA Wood, ABS+, and TPU, while it increased in PLA-CF. The highest tensile strength of PLA+ was determined to be 0.2 mm and 0.1 mm layer thickness in Tough PLA. Hardness results showed minimal change in hardness values with increasing layer thickness. The thermal conductivity values of the samples varied according to the additives and layer thicknesses. The highest thermal conductivity increase was measured in PLA-CF with 11.84%, and the lowest thermal conductivity decrease was measured in Tough PLA with 9.44%.

1. Introduction

From the 1950s to 2022, global plastic production witnessed a significant surge, escalating from 1.5 million tons to a staggering 390 million tons [1]. The use of plastic cannot be abandoned due to reasons such as cost and weight advantages and easy processing [2]. Most plastic materials are petroleum-based, and those that can be recycled can be reused. However, waste management of plastics that are not biodegradable or cannot undergo recycling processes is not easy. Plastic waste poses a significant environmental problem for both water sources and natural habitats [2]. In recent years, with the growing environmental and economic concerns, the production and consumption of biodegradable materials called bioplastics, which are based on bio-based polymers and can be recycled, have been supported [3, 4]. Currently, there are various biobased materials developed, and the most popular one is polylactic acid (PLA) [5]. The use of PLA as a filament material in additive manufacturing methods (such as 3D printers) is one of the primary drivers behind its increased consumption.

Additive manufacturing is a production process in which any model designed in accordance with the production method is transformed into a physical part by being sequentially layered and fused. With additive manufacturing method, complex and multi-material parts that are difficult to produce using traditional methods can be produced. Due to its advantages, additive manufacturing is utilized in various fields such as aviation and space, automotive, architecture, and healthcare. The

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method is continuously evolving, and its applications are expanding over time.

The most widely used additive manufacturing method is 3D printing, which operates with the FDM (Fused Deposition Modeling) technology. Despite having a limited number of material options compared to traditional production techniques, 3D printers are present in almost every industry. 3D printers have played an important role in the popularity of the method as they are the choice of both industrial manufacturers and home users. With this method, it is possible to produce personalized products rapidly and at a low cost. In the simplest terms, 3D printers work according to the principle of melting thermoplastic material and layering it on a platform to build the final product [6, 7]. The consumables, known as filaments, are produced from a wide range of thermoplastics. PLA, ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene terephthalate glycol), ASA (Acrylonitrile styrene acrylate), and their derivatives are commonly used in 3D printers. The surface quality of the final products manufactured through additive manufacturing should be good. While a good surface quality is expected, the product must also be robust and durable [8]. Since the mechanical properties of the produced items, such as strength and hardness, are primarily determined by the chosen thermoplastic filaments, the selection of the appropriate material and printing parameters is crucial [9].

The low thermal conductivity of polymers can be attributed to several factors, including their low atomic densities, weak chemical bonds, and complex crystal structures, which result in intricate molecular vibrations. [10]. In addition, they are preferred as insulation materials because they have low thermal conductivity properties [11]. For this reason, the thermal conductivity properties of polymers are improved with carbon, ceramic and metallic fillers [12, 13]. The low thermal conductivity of polymers can lead to thermal fatigue. Additives, various metal powders and fibers (fiberglass, carbon fiber) are added to polymer materials to reduce thermal fatigue [11, 13]. Polymer materials also have low electrical conductivity. Most polymer materials possess electrical insulation properties. For this reason, they are used as insulating materials in the electrical and electronic industry. However, the electrical conductivity can be increased by adding conductive additives to polymer materials.

The thermal conductivity of a material indicates its energy storage capacity and its ability to withstand extreme heat [14]. Many researchers have examined the thermal conductivity properties of 3D printer materials at different temperatures by adding different additives (nanoparticle, composite, polymer, wood, etc.) in various amounts to 3D printer materials. In most of the filaments obtained in these studies, a significant increase (up to 80%) was obtained in thermal conductivity, while some exhibited (up to 25%) decreases [15-20]. In the literature, there is a lot of of studies that examine the impact of various 3D printing parameters on the mechanical properties of filaments. These parameters include bed and nozzle temperature, printing speed, orientation angle, infill density, and more. Researchers have extensively investigated these factors to understand their influence on the final mechanical characteristics of printed objects. Nevertheless, there exists an insufficiency of investigations regarding the influence of material characteristics and printing variables on alterations in thermal conduction. Yet, thermal conductivity plays an important role in the selection of 3D printers and their filament, which have a wide range of applications. To improve the applicability of polymer materials in cooling or heating applications, it becomes imperative to comprehend the thermal conductivity characteristics of filaments and enhance them when necessary, through the incorporation of suitable fillers [21-23]. With this aim, the relationship between the mechanical and thermal conductivity properties of different filament materials used in 3D printing and the layer thicknesses has been investigated in this study. The thermal conductivity, hardness, and tensile tests were conducted on materials produced with different layer thicknesses to evaluate their material properties. In this study, unlike the literature, the mechanical properties and thermal conductivity properties of eight different filaments, which are most commonly used in 3D printing, were investigated and the changes depending on the layer thickness were revealed. This study also emphasized the importance of filament selection according to the conditions of use.

2. Material and Methods

2.1. Material

In this study, seven different thermoplastic filament materials were used, namely PLA, PLA+, carbon fiber-reinforced PLA (PLA-CF), wood-filled PLA (PLA Wood), Tough PLA, ABS+, and TPU (Thermoplastic Polyurethane). PLA is the most commonly used filament material in 3D printers. PLA, a thermoplastic derived from organic sources like corn starch and sugar cane, boasts several advantages such as being non-toxic, biodegradable, and harmless to human health. In addition to these benefits, PLA offers ease of production and excellent printing capabilities [25, 26]. The PLA-enhanced filaments used in this study are variations that enhance the mechanical properties of standard PLA. PLA+ and Tough PLA materials exhibit higher toughness and impact resistance compared to standard PLA filaments while showing less hygroscopic behavior [24]. PLA Wood filaments are composite PLA with 30% (by weight) wood content. Wood is a biodegradable material. Small pieces of wood are ground into smaller pieces to obtain fine wood flour. Fine wood particles can be used as a filler material for filaments [25]. PLA Wood filaments have higher temperature resistance, unclear layer lines and a matte wood appearance with the addition of real wood [26]. PLA-CF filament is a PLA composite filament reinforced with 15% (by weight) carbon fiber. Carbon fiber (CF) produced from natural plants and resources is lightweight, biodegradable, and biocompatible. Natural fibers can enhance the crystallization and improve the mechanical and thermal properties of PLA. PLA-CF filaments exhibit lower tensile and bending properties, dimensional stability, lightness, and ease of printing [27, 28]. ABS+ filament material is a petroleum-based thermoplastic with high strength, hardness, and toughness [29]. TPU filaments, on the other hand, are elastic filaments with high durability, toughness, wear resistance, and good chemical resistance. TPU is classified as a copolymer because of its two-phase microstructure, which comprises both hard and soft segments. This unique composition gives TPU its distinctive properties and makes it suitable for a wide range of applications [30]. The properties of the filaments used in the experiments are provided in Table 1.

2.2. Preparation of Samples

In the study, filament with a diameter of 2.85 mm (PLA, Tough PLA, ABS+) was printed using the Ultimaker S5 printer, while filament with a diameter of 1.75 mm (PLA+, PLA-CF, PLA Wood, and TPU) was printed using the Ender 3 S1 printer. The printers used in the printing process are shown in Figure 1. The produced samples had a 100% infill ratio, and the layer thicknesses were determined as 0.1 mm, 0.2 mm, and 0.3 mm. Decreasing the layer thickness improves dimensional accuracy [39] and surface roughness. However, the length of the manufacturing process varies inversely with the layer thickness. In the experiments, the layer thicknesses were determined based on the information presented in the literature. Figure 2 provides a schematic representation of the used layer thicknesses.

Table 1. Technical properties of filament materials.

Characteristic	PLA [31]	PLA+ [32]	PLA-CF [33]	PLA Wood [34]	Tough PLA [24]	ABS+ [35]	TPU 92A [36]
Diameter (mm)	2.85	1.75	1.75	1.75	2.85	2.85	1.75
Brand	Ultimaker	eSUN	Filameon	Filameon	Ultimaker	eSUN	SAVA
Color	Black	Black	Black	Light Brown	Black	Green	Light Blue
Tensile Strength	52.5	63	55	47	45.3	40	-
Elongation (Break %)	7.8	20	-	-	9.4	30	600
Density (g/cm^3)	1.24	1.23	1.23	1.13	1.22	1.06	1.20

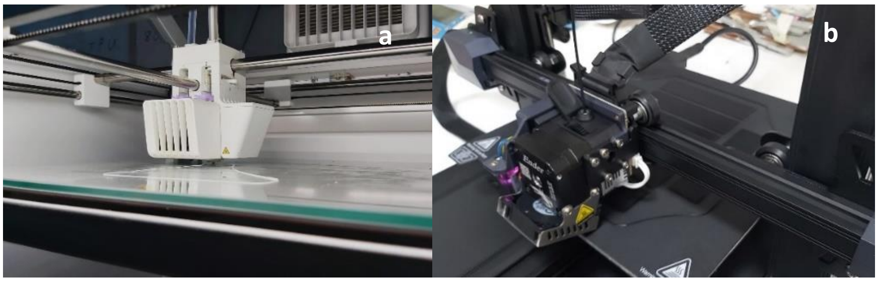

Figure 1. 3D printers (a) Ultimaker S5 and (b) Ender 3S1

Table 2. Printing materials.

Material	PLA	PLA+	PLA-CF	PLA Wood	Tough PLA	ABS+	TPU 92A
Infill Density (%)	100	100	100	100	100	100	100
Printing Temperature (°C)	200	210	215	220	210	250	235
Build Plate Temperature (°C)	60	60	65	65	60	110	55
Print Speed (mm/sec)	60	60	45	50	45	50	30

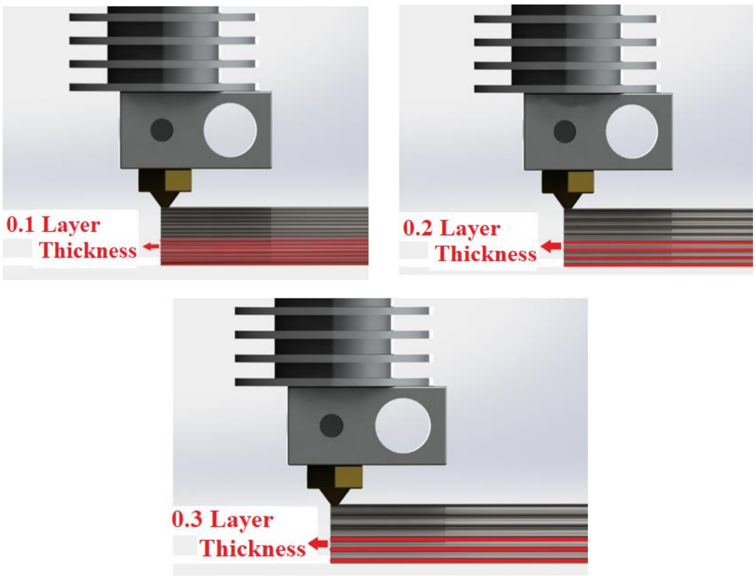

Figure 2. Change of layer thickness applied in 3D printer

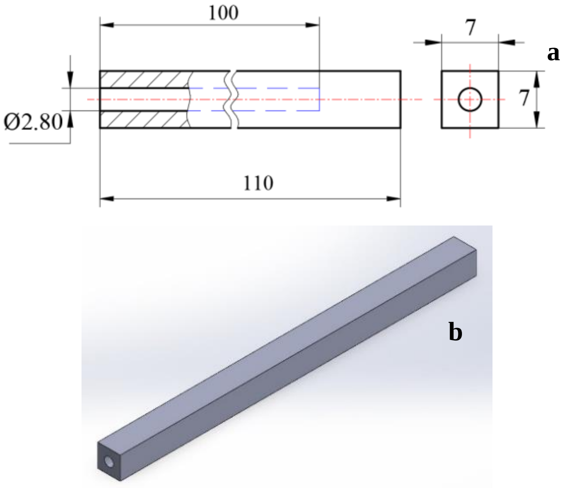

Figure 3. Thermal conductivity measurement samples a) Technical drawing (mm) b) Solid model

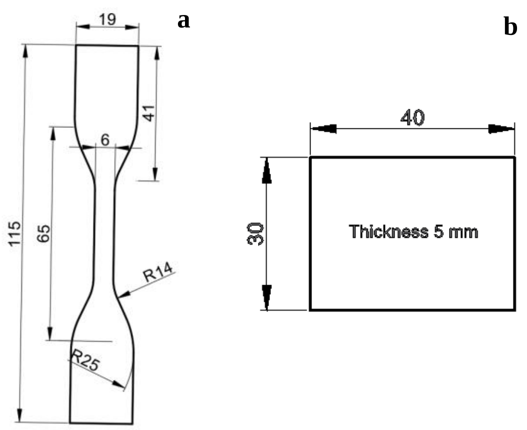

Figure 4. Sample dimensions (mm) for tensile specimen (a) and hardness measurement (b)

The three-dimensional models of the samples used for thermal conductivity measurement were created using the Fusion 360 modeling program. The subsequent step involved the slicing process, which was conducted using the Cura 5.2.1 program. Finally, the production process was completed using the FDM (Fused Deposition Modeling) method.

The parameters required to produce parts using 3D printers are given in Table 2. The technical drawing and solid model of the samples prepared for thermal conductivity measurement are provided in Figure 3. The samples were printed without supports, with 100% infill, and in the horizontal printing orientation (printing direction along the thickness/horizontal growth direction).

2.3. Tensile test and hardness measurements

Tensile samples (Figure 4 a) were printed with 0.1 mm, 0.2 mm, and 0.3 mm layer thicknesses at 100% infill ratios in order to determine the mechanical properties of PLA, PLA+, PLA-CF, PLA Wood, Tough PLA, ABS+, and TPU according to ASTM D638-10 [40] standards. Tensile tests were conducted at room temperature using a WDW-5 model universal testing machine with a 5 kN capacity at a crosshead speed of 1 mm/min. The Durometer (Shore) hardness measurement method was used for hardness measurements of the plastic materials. Durometer hardness measurements, which evaluate the material's resistance to indentation, are widely used in evaluating the mechanical properties of polymers [41]. ASTM D2240-15 standard was followed by using LOYKA D-type shore hardness durometer to perform the hardness tests.

Hardness measurement samples were prepared in different layer thicknesses of 5x30x40 mm for each filament material (Figure 4 b). Measurements were repeated at five different points for each sample and the averages were taken. Additionally, the surfaces of the printed parts were examined using a digital microscope, and the damage types were evaluated by taking the images of the rupture surfaces after the tensile test.

2.4. Thermal conductivity coefficient measurement

The coefficient of thermal conductivity is the rate of heat transfer from a unit area through a unit thickness of a material at a unit temperature. A high thermal conductivity value indicates that the material conducts heat well. Materials with low thermal conductivity are called insulators. The thermal conductivity of solid materials is measured using the Decagon/KD2 Pro [42] device with a TR-1 sensor (2.4 mm diameter x 100 mm length) operating based on the transient hot wire method. The KD2 Pro thermal conductivity measurement device and TR-1 sensor are shown in Figure 5. The operating temperature range of the TR-1 sensor used for determining the thermal conductivity value of filament materials is -50 to +150 °C, a measurement time is 5 minutes per sample, and a measurement range is between 0.10 to 4.00 W/mK [43]. The thermal conductivity measurements of PLA, PLA+, PLA-CF, PLA Wood, Tough PLA, ABS+, and TPU filaments used in different layer thicknesses (0.1, 0.2 and 0.3 mm) were repeated at least 5 times for each sample. The average thermal conductivity and temperature values are provided in Table 3. It was observed that the measured thermal conductivity values measured from the experimental samples with different layer thicknesses varied between 0.082 and 0.113 W/mK.

Figure 5. Thermal conductivity measurement device

Table 3. Thermal conductivity and Temperature Values Measured from Samples.

Material	Layer Thickness (mm)	Thermal Conductivity (W/mK)	Temp. (°C)
PLA	0.1	0.096	23.12
	0.2	0.098	25.27
	0.3	0.099	24.69
PLA +	0.1	0.094	23.12
	0.2	0.096	25.57
	0.3	0.096	25.20
PLA-CF	0.1	0.095	22.96
	0.2	0.102	24.84
	0.3	0.106	26.12
PLA Wood	0.1	0.091	21.24
	0.2	0.094	22.21
	0.3	0.101	25.77
Tough-PLA	0.1	0.090	23.22
	0.2	0.090	23.67
	0.3	0.082	23.42
ABS +	0.1	0.085	24.24
	0.2	0.091	24.98
	0.3	0.087	24.81
TPU	0.1	0.104	24.65
	0.2	0.108	25.64
	0.3	0.113	24.80

3. Result and Discussion

There are many variables that affect the strength in the design and production process of parts manufactured using the EYM method. Some of these variables are called 3D printer printing parameters, including printing temperature, printing speed, layer thickness, infill pattern, part orientation angle, and infill ratio [44]. Additionally, it is known that the addition of fillers to filaments significantly affects the strength, toughness, and elongation. Therefore, in the literature, different mechanical properties can be observed for the same material due to the use of different variables in printing [45].

3.1. Tensile test and evaluation of hardness values

In ± this study, the highest tensile strength (56.26 ± 2.6 MPa) was obtained in PLA-CF with 0.3 layer thickness, and the lowest tensile strength (26.31 ± 1.3 MPa) was obtained in PLA Wood with 0.3 mm layer thickness. It can be observed that the strength value decreases with an increase in layer thickness for PLA, PLA Wood, ABS+, and TPU (Figure 6). This result is consistent with the literature [28, 46, 47]. The highest tensile strength (49.31 ± 2.95 MPa) was obtained in PLA+ with a layer thickness of 0.2 mm. Similarly, Tymrak et al. achieved the highest tensile values at a layer thickness of 0.2 mm and a production angle of 45/-45 in their study on ABS and PLA filament materials using three different layer thicknesses (0.2,1, 0.2 and 0.3 mm) and two different production angles [48]. While the highest tensile strength (55.11 3.8 MPa) for Tough PLA was obtained at a layer thickness of 0.1 mm, it was observed that the strength decreased at 0.2 mm layer thickness and increased slightly at 0.3 mm layer thickness. According to this result, it can be understood that the parts to be produced with Tough PLA and a layer thickness of 0.1 mm will have higher strength. It has been determined that the mechanical properties will change with the addition of filler material into the filament. It is seen that the tensile strength of PLA-CF increases with the increase of the layer thickness. On the other hand, in PLA Wood, although the increase in layer thickness decreases the tensile strength, the tensile strength has decreased significantly when compared to PLA. The low strength observed in PLA Wood can be attributed to high porosity, adhesion defects between layers, and irregularities in the print diameter due to the wood additive [49].

The filaments used in the experiments were selected from among the materials that are highly demanded in the 3D printing industry and user forums. Due to the difficulty of accessing some filament materials from the same manufacturer and manufacturers producing in the diameters they determine, the printing processes of the samples were carried out using two different printers. Therefore, it was accepted at the beginning of the study that there might be some differences due to the use of different printers and brands.

The rupture surface images of the samples printed in the horizontal growth direction after the tensile test are given in Figure 7. The fracture behaviour of PLA+, PLA-CF, PLA Wood, Tough PLA and TPU was in zigzag pattern. This is due to the internal structure where the layer lines create either parallel and 45° angles or 45° and -45° angles with the applied tensile load. The flat and sharp form of rupture of PLA and ABS+ tensile samples suggests that the tensile load follows the angle of the lines forming the structure of the samples [50].

After the tensile test, it was observed that the PLA-CF samples had thin, wire-like extensions at the fracture ends. These extensions are believed to be the carbon fiber additives present in the filament. In contrast, although PLA Wood is an additive-based filament, a similar situation did not occur at the fracture end. Unlike the carbon fiber in PLA-CF, the wood additives in PLA Wood filament have thin and small powder-like dimensions. The unit strain of the tensile specimens were found to be 2.73% ± 0.13 for PLA, 7.23% ±0.36 for PLA+, 4.67% ±0.23 for PLA-CF, 1.8% ±0.1 for PLA Wood, 3.27% ±0.16 for Tough PLA, and 3% 0.15 for ABS+. While the unit strain values for these samples ranged from 1.8% to 7.23%, the TPU rod showed significantly greater elongation due to the flexibility of the material, with a value of 567.5% ±11.35.

When examining the hardness results, it can be observed that there is minimal change in hardness with increasing layer thickness (Figure 8). The highest hardness values were obtained in PLA-CF (due to the carbon fiber additive), while the lowest hardness values were found in TPU. The hardness of TPU materials can vary depending on their chemical composition. The second lowest hardness value was measured in PLA Wood parts. The low hardness value of PLA Wood can be attributed to its high porosity and uneven gaps between layers caused by the presence of wood particles. In the case of ABS+, it can be seen that the hardness value is not significantly affected by the layer thickness. This is believed to be due to the high printing temperature of ABS+, which allows for better interlayer fusion and adhesion (Figure 9).

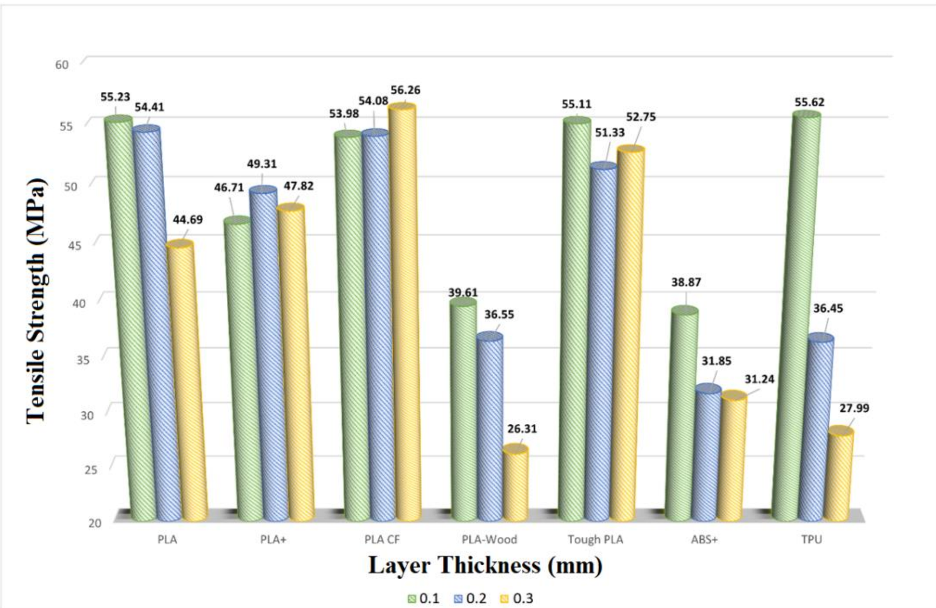

Figure 6. Change of tensile strength with layer thickness

Figure 7. Image of the sample with a 0.1 mm layer thickness after tensile testing

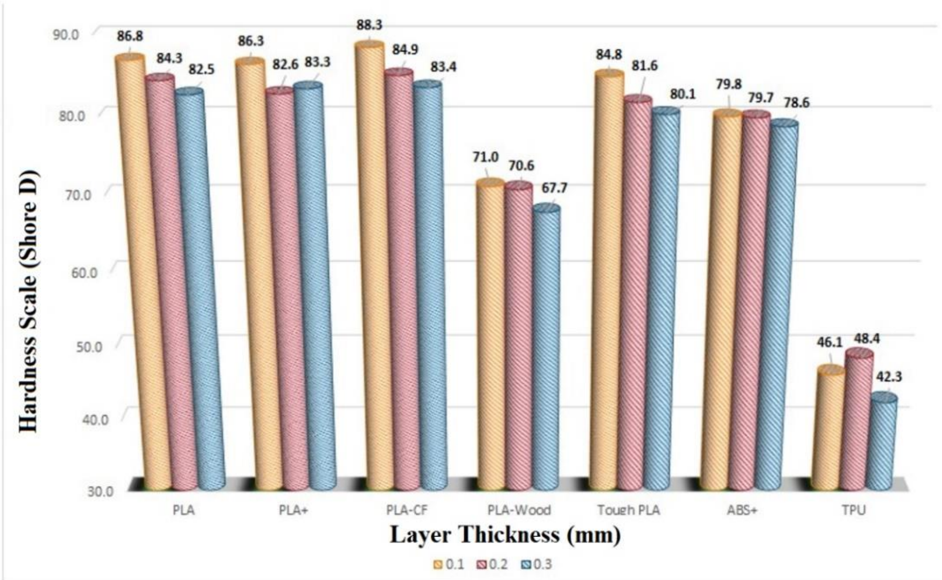

Figure 8. Change of hardness values depending on layer thickness

3.2. Evaluation of optical microscope images

The surface images of PLA, PLA+, PLA-CF, PLA Wood, Tough PLA, ABS+, and TPU materials with 0.1, 0.2 and 0.3 mm layer thicknesses are given in Figure 9 and Figure 10. The layer thicknesses and the number of layers are clearly visible in PLA, PLA+, Tough PLA, and TPU. In these materials, 12, 6 and 4 layers were placed in the same unit area for 0.1, 0.2 and 0.3 mm layer thicknesses, respectively (Figure 9). In ABS+, it can be observed that the transitions between layers become less visible, and the layers merge better.

In PLA-CF and PLA Wood, on the other hand, the presence of carbon fiber and wood additives within the filament leads to a discontinuity in the layers. Therefore, surface images were taken again using a digital microscope (Figure 10). When the surface images are examined, it is seen that the additive materials change the appearance of PLA. It has been determined that the carbon fiber additive does not significantly affect the printing process, and a linear and smooth printing is obtained during the 3D printing process. In PLA Wood, on the other hand, during the 3D printing process, dimensional differences and burning marks resulting from the wood additives are seen. Therefore, it can be said that the fusion between the layers is insufficient compared to PLA. Surface views of PLA-CF and PLA Wood samples are given in Figure 10.

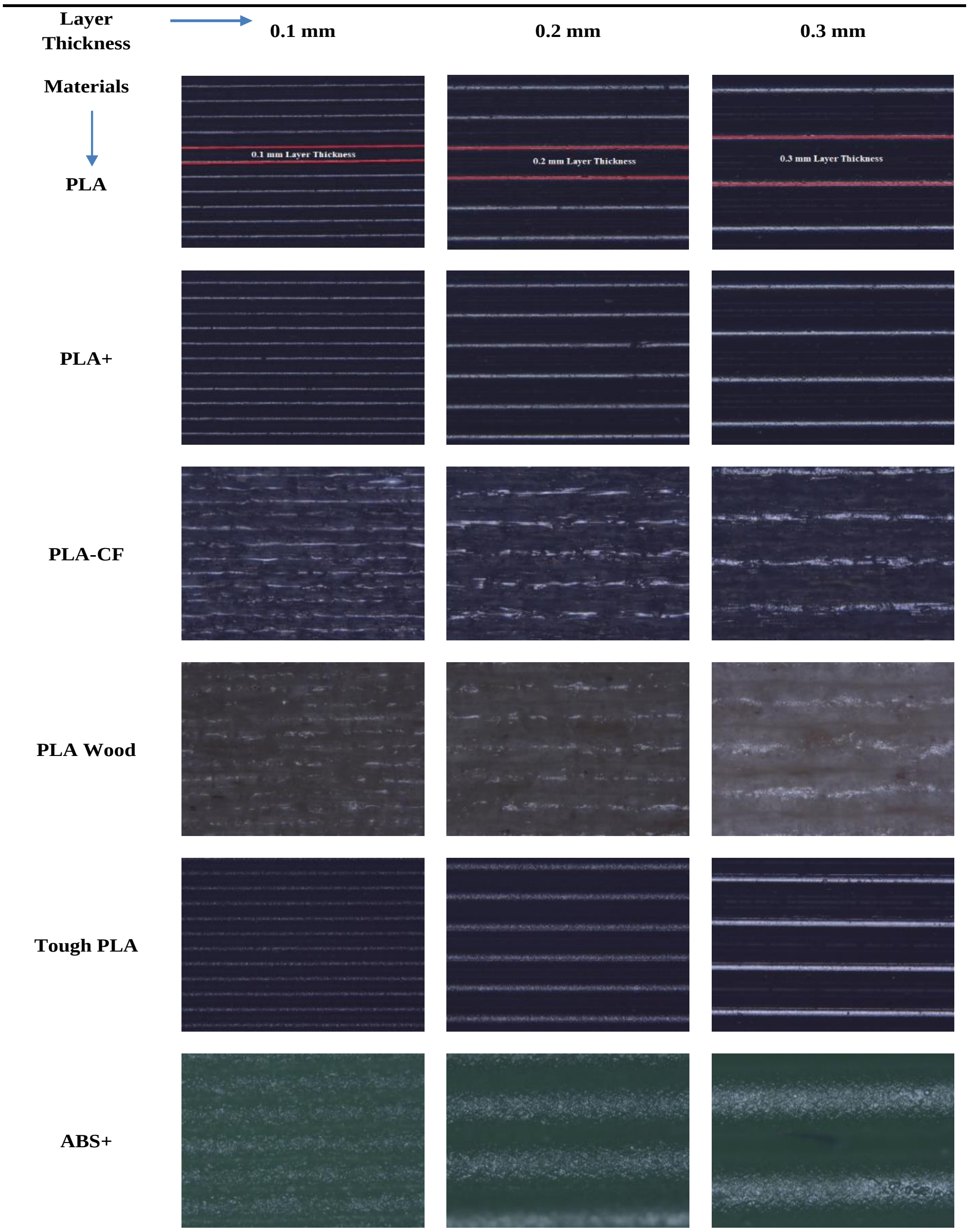

Figure 9. Surface images with an optical microscope (50x)

3.3. Evaluation of thermal conductivity coefficient measurement

The thermal conductivity values of the parts produced in 3D printers from PLA, PLA+, PLA-CF, PLA Wood, Tough PLA, ABS+ and TPU filaments with different layer thicknesses (0.1, 0.2 and 0.3 mm) were measured. The variation between the measured thermal conductivity values and the layer thicknesses is given in Figure 11. It was observed that the thermal conductivity of TPU, PLA-CF, and PLA Wood increased with the increasing layer thickness. In contrast, Tough PLA showed no significant change in thermal conductivity when layer thickness was changed from 0.1 mm to 0.2 mm. However, a noticeable decrease in thermal conductivity was observed with a layer thickness of 0.3 mm. ABS+, PLA+, and PLA materials, on the other hand, exhibited little change in thermal conductivity with increasing thickness. PLA-CF, PLA Wood, TPU, and Tough PLA filaments showed a maximum increase of 11.84%, 11.33%, and 8.65% in thermal conductivity, respectively, with increasing layer thickness, while Tough PLA showed a decrease of 9.44%. It was observed that the thermal conductivity properties were improved due to the additives added to PLA-CF and PLA Wood filaments, and the two-phase structure of TPU. The thermal conductivity properties of PLA-CF and PLA Wood improved due to the additives in the filaments, while the thermal conductivity of TPU improved due to its two-phase structure.

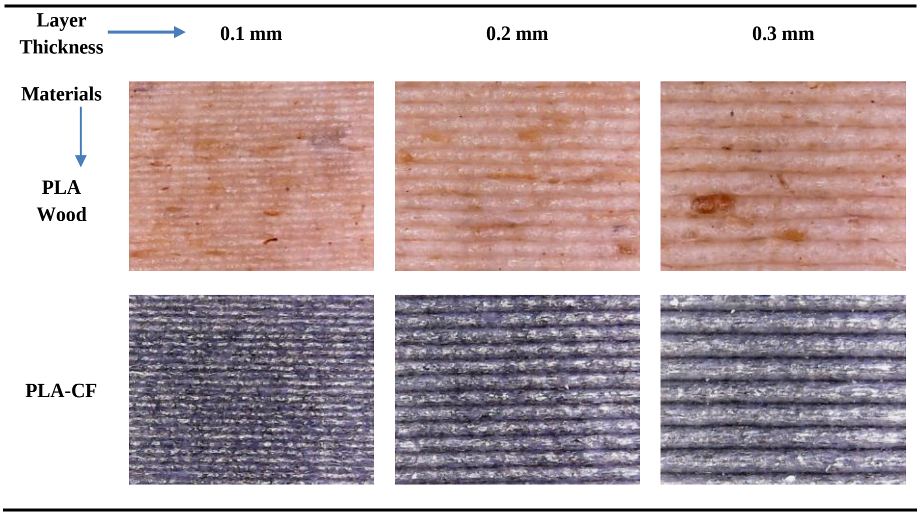

Figure 10. Surface images of PLA-CF and PLA Wood with a digital microscope (100x)

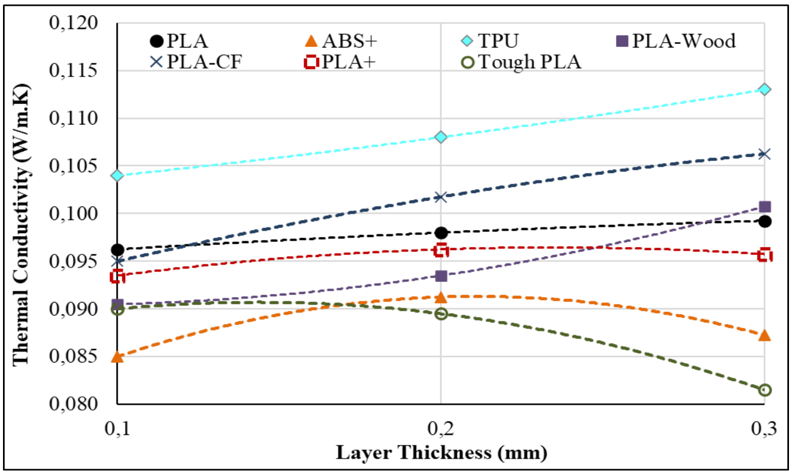

Figure 11. Change of thermal conductivity depending on layer thickness.

In PLA-CF and PLA Wood, the thermal conductivity decreased in parts with a layer thickness of 0.1 mm due to the higher number of layers per unit. The reason for this is that as the number of layers increases, the number of gaps and irregularities between the layers increases. PLA-CF, PLA Wood and TPU materials can be used in cooling and heating systems because of their good heat transfer capacity compared to other test materials. It has been observed that the layer thickness of these filament materials directly affects the thermal conductivity property. Therefore, layer thickness and selection of appropriate filament materials play an important role for 3D printed materials to be used in heating and cooling systems. Materials produced from other filament types (PLA, PLA+, Tough PLA, ABS+) can be considered as insulation materials.

4. Conclusion

The rapid development of technology has affected both user demands and production techniques. 3D printers have emerged as innovative technologies and tools that can meet the needs of many different sectors, ranging from the furniture industry to food production. This technology has been expanding its market share in the manufacturing field day by day due to the increasing variety of filament materials, which are the raw input, and the growing number of products produced with them. Therefore, it is necessary to have knowledge about the mechanical and thermal properties of the parts produced with 3D printers.

In this study, the effects of different layer thicknesses and filament materials on the mechanical and thermal conductivity properties of printed parts were examined. The results obtained are summarized below:

- The highest tensile strength of 56.25 MPa was obtained in PLA-CF with a layer thickness of 0.3 mm. The lowest tensile strength of 26.31 MPa was obtained in PLA Wood with a layer thickness of 0.3 mm. It was observed that the tensile strengths obtained in the PLA types with additives varied depending on the strength of the additive material. In PLA, PLA Wood, ABS+, and TPU, the tensile strength decreased as the layer thickness increased. In PLA-CF, on the other hand, the tensile strength increased with an increase in layer thickness.

- In PLA+ and Tough PLA, it was observed that the tensile strength did not show a clear change depending on the layer thickness.
- When the hardness results are examined, it is seen that the hardness values change very little depending on the layer thickness and the hardness value is inversely proportional to the increase in layer thicknesses. Among the six different filament materials used in the experiments, the highest hardness values were observed in the 0.1 mm layer thickness, with the exception of TPU material, which showed the highest hardness value at 0.2 mm layer thickness.
- When the surfaces of the 3D parts were examined, it was seen that the layers bonded well, especially at low layer thicknesses, due to the use of high nozzle and bed temperature to produce ABS+ samples. In PLA Wood, it was determined that high porosity and interlayer adhesion defects increased with the increase of layer thickness. On the other hand, in PLA, PLA+, Tough PLA and TPU, the layers were stacked smoothly, with a distinct and gapless structure.
- When the measured thermal conductivity values are examined, it is seen that the additive materials and layer thicknesses in the filament are significant factors. Except for Tough PLA material, as the layer thickness increased, the thermal conductivity values increased. PLA Wood, TPU and PLA-CF showed better energy storage capacity and heat resistance at lower layer thicknesses.
- It can be said that PLA-CF, PLA Wood and TPU materials, which have an increase in thermal conductivity value as the layer thickness increases, have good thermal conductivity. It can be said that other materials with constant or decreasing thermal conductivity as the layer thickness increases can be preferred as insulating materials

Declaration

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The authors also declared that this article is original, was prepared in accordance with international publication and research ethics, and ethical committee permission or any special permission is not required.

Author Contributions

Conceptualization, O.K. and N.A.; methodology, O.K. and B.E.; investigation, F.P. and N.A.; data curation, N.A. and F.P; writing—original draft preparation, F.P., O.K., N.A. and B.E.; writing— review and editing, F.P., O.K., N.A. and B.E. All authors have read and agreed to the published version of the manuscript.

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