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STUDYING THERMAL PROPERTIES OF PLASTIC MATERIALS OBTAINED BY THE FUSED DEPOSITION MODELING METHOD

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temperature, FDM method.

ABSTRACT

This study aimed to evaluate the thermal stability and degradation behavior of polymer materials produced using fused deposition modeling technology. The research focuses on five commonly used thermoplastics, including polylactic acid, acrylonitrile butadiene styrene, high-impact polystyrene, and polycarbonate, manufactured using different printing equipment. The objective of this study was to identify differences in thermal behavior depending on the material composition and production conditions. The investigation was carried out using thermogravimetric and calorimetric analyses, which allowed us to determine the temperature ranges of thermal decomposition, mass loss characteristics, and the nature of degradation processes. Samples of the printed polymers were subjected to controlled heating, and their thermal responses were recorded to assess their stability and decomposition patterns. The results demonstrated significant differences in the thermal behaviors of the studied materials. Polylactic acid produced on one type of equipment exhibited a single-stage degradation process typical of unmodified materials, whereas the same polymer produced using different equipment showed a two-stage decomposition, indicating structural or compositional modification. Acrylonitrile butadiene styrene and high-impact polystyrene decomposed within similar temperature ranges, although the latter demonstrated almost complete mass loss. Polycarbonate exhibited the highest thermal resistance, with decomposition occurring over a wide temperature range and leaving a noticeable residual mass. The findings of this study provide a comparative assessment of the thermal stability and degradation characteristics of commonly used printing materials. These results are significant for optimizing material selection in additive manufacturing and improving the performance and reliability of printed products under thermal exposure.

INTRODUCTION

The use of additive manufacturing (AM) in the production of three-dimensional products through 3D printing is an innovative solution. Interest in these technologies is growing worldwide, driven by the increasing market demand for more cost-efficient and less labor-inten-



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sive solutions. These inventions have found applications in a wide range of industries, including construction, shipbuilding, mechanical engineering, pharmaceuticals and medicine, oil and gas and agriculture, and astronautics. The rapid development of AM that allows for the production of products of complex shapes and sizes, is particularly rapid in such countries as the United States, Germany, Japan, and China (Glazunov & Cherepanova, 2018; Kirillova et al., 2020).

Additive manufacturing has found applications in various industries, where 3D printing technology significantly simplifies several production steps. Despite the fact that the filament market is regularly replenished with new materials, plastics and their various alloys still hold leading positions. Currently, the main challenge is selecting the right mixtures for printing materials. Scientists from various countries have studied this issue.

Study by Tychanicz-Kwiecień et al. (2025) presents the results of examining the effect of fill density on thermal conductivity. The test samples were fabricated using three materials using FDM. The highest thermal conductivity values were recorded at 50 °C. The thermal properties were also studied, with particular emphasis on the thermal conductivity of the filaments used in 3D printing over a wide range of measured temperatures. The mechanical and thermal properties of the final 3D printed components are strictly dependent on temperature and heating and cooling conditions.

Paper by Tümer and Erbil (2021) examines the chemical properties and characteristics of pure PLA, as well as its main drawbacks and advantages as a raw material for FDM 3D printing. The necessity of PLA composites for 3D printing and the requirements for them are discussed. It is also noted that the inclusion of various types of carbon-containing additives in PLA composition has led to improved properties but controlling porosity and interparticle conductivity and increasing mechanical strength remain challenging. The use of 3D-printed PLA composites in the automotive, aerospace, and space industries is expanding to reduce vehicle weight. However, the maintenance of the mechanical strength, high wear resistance, and surface smoothness of 3D-printed parts requires further development.

Paper by Vijaybabu et al. (2023) examines the current state and future trends in the use of highly thermally conductive polymer composites produced using traditional and 3D printing technologies. Polymer nanocomposites with high thermal conductivity play an important role in microelectronic applications by improving heat dissipation characteristics. It has been found that the most important parameter for producing such a nanocomposite is the formation of a conductive network using appropriate reinforcing elements.

Study by Ichakpa et al. (2023) focused on 3D printing of polyamide 6 (PA6), PA6/graphene oxide (PA6/GO), and PA6/glass fiber-reinforced (PA6/GF) composites. The effects of graphene oxide and glass fiber reinforcement on the quality of 3D-printed PA6 were studied to improve the interfacial bonding and interlayer strength under ambient, humid, and high-temperature conditions, which meet the requirements of electric vehicle battery housings. The effects of environmental conditions and process parameters on the quality of 3D-printed polymer composites were also examined. Commercial PA6 filament was modified with GO to study its thermal and mechanical properties.

Polyamide (PA6) filled with 0.1% graphene oxide (GO) and 30% glass fiber reinforcement (GF) was extruded into 3D-printed filaments using a twin-screw extruder. The filaments were used to 3D print test specimens and studied under three conditions: dry/room temperature (DA), dry/high temperature (DH), and wet/ambient temperature (WA). Each specimen was subjected to material characterization, as well as tensile and compressive mechanical testing to study its behavior.

The addition of GO and GF increased the tensile strength by 33% and 57% under DA conditions and by 10% and 103% under DH conditions, respectively.

Paper by Gnidina et al. (2023) presents a study on the physical and mechanical properties of REC ABS plastic samples printed using FDM and subjected to thermal post-processing. Two post-processing methods were used in this study: treatment in NaCl powder and treatment in a closed mold with applied pressure. It was found that thermal post-processing in NaCl powder increased the strength properties of the samples by an average of 10-13% depending on the raster tilt angle. Post-processing in a mold with applied pressure increased the strength properties of the samples by an average of 25-40% compared to the control samples. The results of the study showed that the use of thermal post-processing after printing improved the strength properties and reduced the porosity of the samples. However, significant deformation of samples after post-processing is unacceptable for certain products. Therefore, based on the results of the studies conducted, further work should be carried out in the area of developing new technological methods to minimize the deformation of samples after thermal post-processing.

Paper by Kumar et al. (2026) presents the results of experimental studies on the mechanical and thermal properties of 3D printed sandwich panels using polylactic acid (PLA+), acrylonitrile butadiene styrene (ABS+), and enhanced acrylonitrile butadiene styrene (e-ABS). The results showed that PLA+ had the highest compressive strength of 23.57 MPa, flexural strength of 39.63 MPa and ultimate tensile strength (UTS) of 22.43 MPa. At the same time, ABS+ and e-ABS demonstrated lower compressive strength values of 10.30 MPa and 10.07 MPa, as well as ultimate tensile strength values of 13.15 MPa and 12.33 MPa, respectively. The obtained results provide valuable information for selecting suitable 3D printed thermoplastics for engineering applications that require a balance of strength, rigidity, and thermal stability.

Paper by Ivanov et al. (2025) provides a brief overview of the polymers (plastics) used in additive manufacturing (3D printing). The properties of the most popular plastics, namely ABS, PLA, PETG, TPU, Nylon, ASA, PC, HIPS, PVA, and PEEK, were examined. The advantages and disadvantages of these methods are highlighted. Thermal testing of the plastic products was conducted at temperatures ranging from -60 to 40 °C. No defects were observed in the products made from any of the tested plastics.

Paper by Shanmugam et al. (2024) examined the thermal properties of polymeric materials printed using FDM, covering a wide range of thermoplastic polymers and composites. By examining the effects of reinforcing elements, this study aims to provide insights into potential improvements and adjustments in the development of heat-resistant polymeric materials based on FDM printing. Controlled heat treatments, such as annealing, offer the potential to manipulate the crystalline structure of printed components to improve their thermal conductivity.

This review summarizes the thermal properties of polymer materials printed using FDM, highlighting a transformational shift toward the production of heat-resistant components. This technology has significant potential, and its widespread use in heat-resistant applications is expected.

The relevance of this study stems from the rapidly expanding development of additive 3D printing technologies and the results of studying the thermal stability of 3D-printed plastic materials over a wide temperature range.

MATERIALS AND METHODS

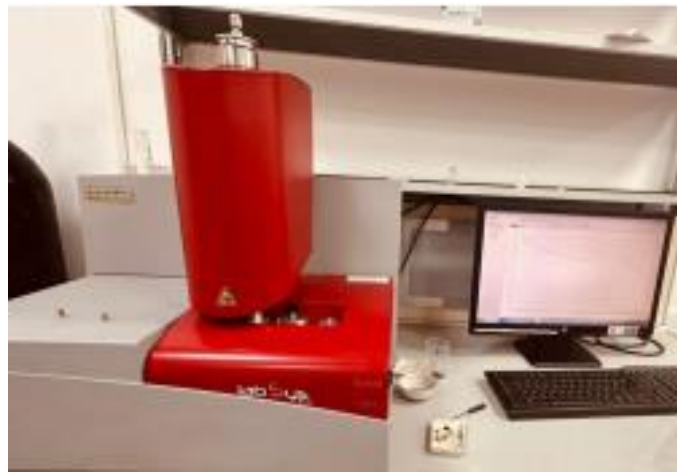
Thermal properties of the samples were studied using a Labsys Evolution TG-DTA/DSC synchronous thermal analysis instrument from the Setaram in the dynamic mode over the temperature range of 30-600 °C with heating in an Al₂O₃ crucible at 10°C/min in a nitrogen atmosphere with a flow rate of 30 ml/min. The sample weights were 10-15 mg. Figure 1 shows the Labsys Evolution TG-DTA/DSC synchronous thermal analysis instrument used in this study.



a)



b)



c)

(a) scale for measuring sample mass; (b) setup process; (c) during operation

Figure 1. Labsys Evolution TG-DTA/DSC simultaneous thermal analysis instrument

Note – compiled by the authors

Figure 2 shows the samples of the PLA 1.75 material printed using a MakerBot printer.



a)



b)



c)



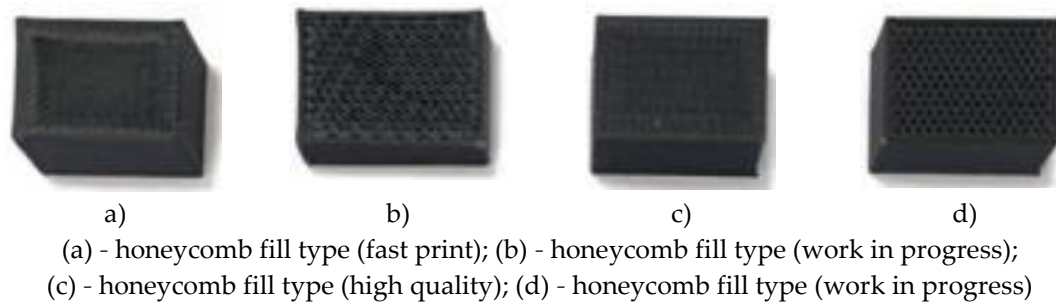
d)

(a) - diamond fill type; (b) - diamond fill type (work in progress); (c) - linear fill type;
(d) - linear fill type (work in progress)

Figure 2. PLA 1.75 print samples printed on the MakerBot printer

Note – compiled by the authors

Figure 3 shows the samples made of the PLA 1.75 material printed on the Raise3D printer.

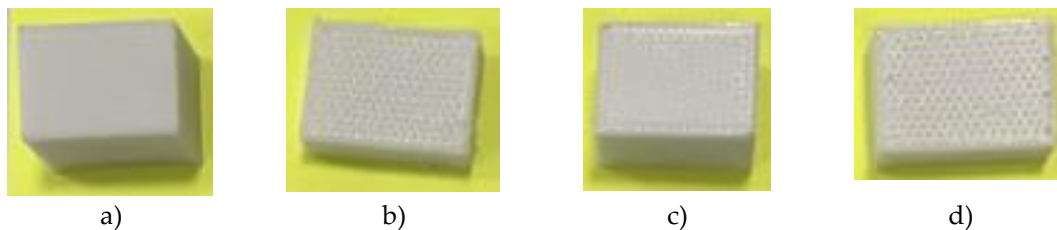


(a) - honeycomb fill type (fast print); (b) - honeycomb fill type (work in progress);
(c) - honeycomb fill type (high quality); (d) - honeycomb fill type (work in progress)

Figure 3. PLA 1.75 print samples printed on the Raise3D printer

Note – compiled by the authors

Figure 4 shows the samples of the PC 1.75 material printed on the Raise3D printer.



(a) - honeycomb fill type (fast print); (b) - honeycomb fill type (work in progress);
(c) - honeycomb fill type (high quality); (d) - honeycomb fill type (work in progress)

Figure 4. Samples of the PC 1.75 material printed on the Raise3D printer

Note – compiled by the authors

Figure 5 shows the samples of the HIPS 1.75 material printed on the Raise3D printer.



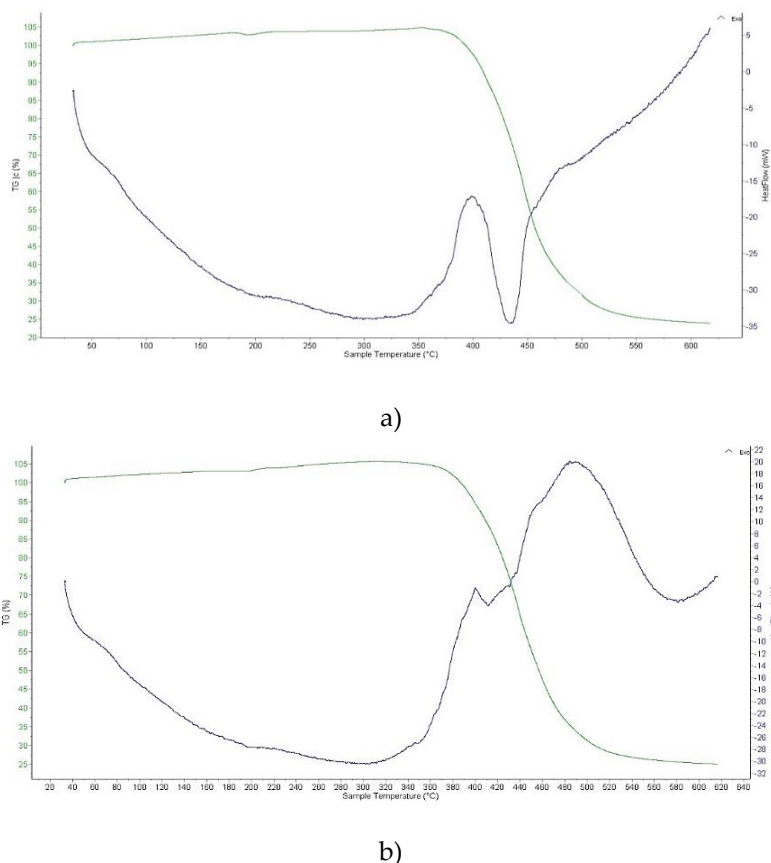
(a) - honeycomb fill type (fast print); (b) - honeycomb fill type (work in progress);
(c) - honeycomb fill type (high quality); (d) - honeycomb fill type, high quality
(work in progress)

Figure 5. Samples of the HIPS 1.75 material printed on the Raise3D printer

Note – compiled by the authors

The study involved thermogravimetric (TGA) and calorimetric analyses (CMA) of five polymer samples used for FDM printing: PLA printed on the MakerBot printer, as well as PLA, ABS, HIPS, and PC produced on Raise3D equipment. The obtained data allowed us to characterize the thermal stability of the materials, determine their degradation patterns, and identify differences between various polymer and filament types.

Figure 6 shows a graph of the thermal behavior of the PC material printed on the Raise3D printer at various temperatures.



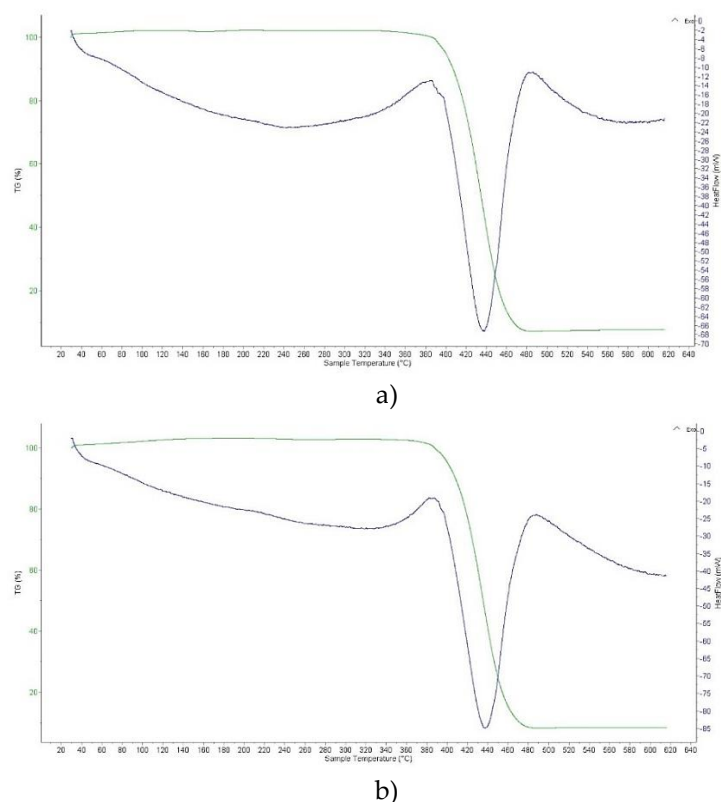
(a) - PC 1.75 high-quality honeycomb; (b) - PC 1.75 fast-print honeycomb
Figure 6. Thermal behavior graph of the PC material printed on the Raise3D printer at various temperatures

Note – compiled by the authors

Figure 6a shows that the sample analysis revealed the thermal behavior characteristics of polycarbonate: the main decomposition stage occurred over a wide range of 360–600 °C, accompanied by a total mass loss of approximately 75%, indicating the high thermal stability and stability of the aromatic polycarbonate chain. The DSC curve clearly shows a pronounced endothermic peak at ≈ 430 °C, which corresponds to the intense destruction of the polycarbonate matrix and the onset of primary polymer degradation (see Figure 6a). The polycarbonate decomposition mechanism begins with the thermally induced cleavage of carbonate bonds ($-\text{O}-\text{CO}-\text{O}-$), accompanied by the formation of phenoxyl radicals and subsequent depolycondensation of the macromolecule. The next stage is characterized by β -cleavage and dehydration reactions, which lead to the formation of phenolic products and isophores, and at higher temperatures, to aromatic recondensation and the formation of a carbon residue.

The sample in Figure 6b demonstrates the thermal degradation typical of polycarbonate, which occurs in the range of 350–600 °C with a total mass loss of approximately 75%, indicating the material thermal stability regardless of the printing mode. The DSC curve shows a small endothermic peak at ≈ 410 °C, which reflects the onset of polycarbonate chain degradation and the lower energy intensity of the process compared to that of the high-quality sample (see Figure 6b). Taken together, the TGA/DSC data confirm that, despite slight differences in morphology, the thermal behavior of PC remains stable under both printing modes.

Figure 7 shows a graph of the thermal behavior of the HIPS material printed on the Raise3D printer at various temperatures.

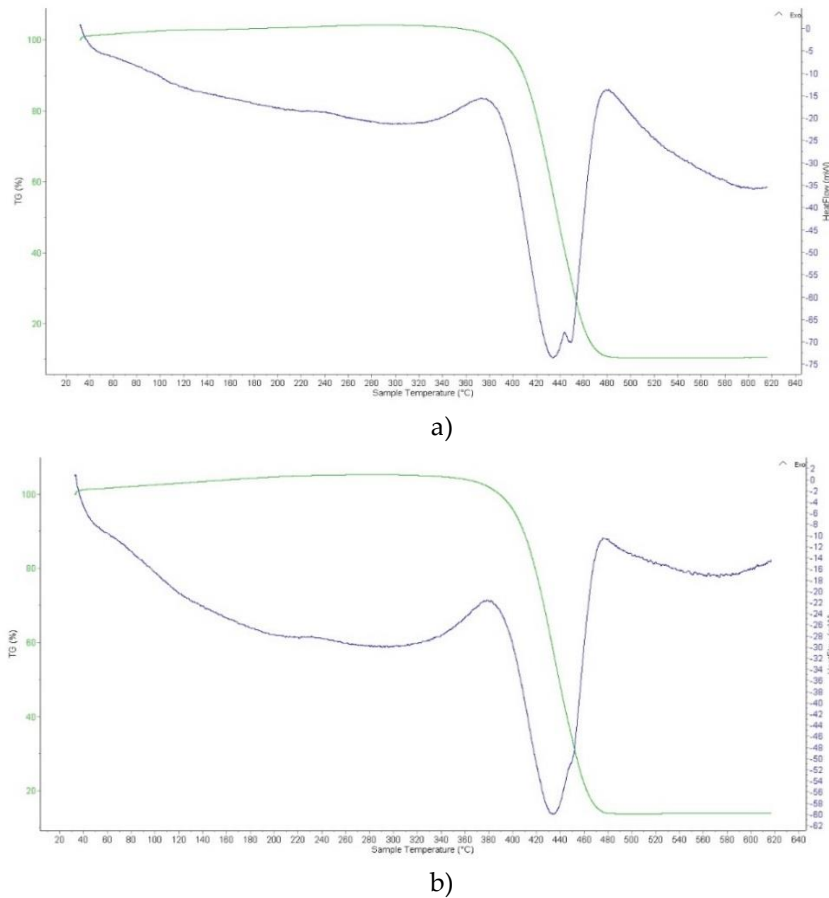


(a) - HIPS 1.75 high-quality honeycomb; (b) - HIPS 1.75 fast-print honeycomb
Figure 7. Thermal behavior graph of the HIPS material printed on the Raise3D printer at various temperatures

Note – compiled by the authors

Figure 7a shows that the Raise3D HIPS 1.75 sample, which was printed with high quality and had a honeycomb structure, exhibited intense single-phase degradation in the range of 390–480 °C with a mass loss of approximately 95% during TGA, which reflects the characteristic decomposition mechanism of high-impact polystyrene. Thermal-oxidative degradation begins with the cleavage of the butadiene rubber phase, initiating depolymerization and the opening of styrene block chains. The process then proceeds to the stage of active β -scission degradation, accompanied by the formation of styrene, oligomers, and volatile aromatic products. The DSC curve displays a broad endothermic peak at approximately 440 °C associated with the energy-consuming cleavage of aromatic bonds and destruction of the modifying rubber network. The TG/DSC curve in Figure 7b demonstrates intense thermal degradation in the range of 380–485 °C, accompanied by a mass loss of approximately 92%. The first stage is the destruction of the butadiene rubber phase: as the temperature increases, the double bonds in the elastomer segments cleave, initiating the formation of radicals and triggering the subsequent depolymerization of the styrene block. Degradation then proceeds to the β -cleavage stage along the polystyrene backbone, accompanied by the release of styrene, its dimers, and other aromatic volatile products. The DSC curve displays a broad endothermic peak at ≈ 440 °C, which reflects the combined energy consumption of the destruction of both the rubber inclusions and the aromatic styrene matrix. The broad nature of the endo peak is due to the overlap of several sequential mechanisms: the cleavage of the modifying rubber segments, depolymerization of the polystyrene chains, and fragmentation of the residual aromatic structures. The data obtained indicate a two-component degradation process typical of HIPS, where the butadiene phase initiates the process and the styrene phase determines the bulk of the thermolysis.

Figure 8 shows a graph of the thermal behavior of the ABS material printed on the Raise3D printer at various temperatures.



(a) - ABS 1.75 fast honeycomb printing; (b) - ABS 1.75 high-quality honeycomb
Figure 8. Thermal behavior graph of the ABS material printed on the Raise3D printer at various temperatures

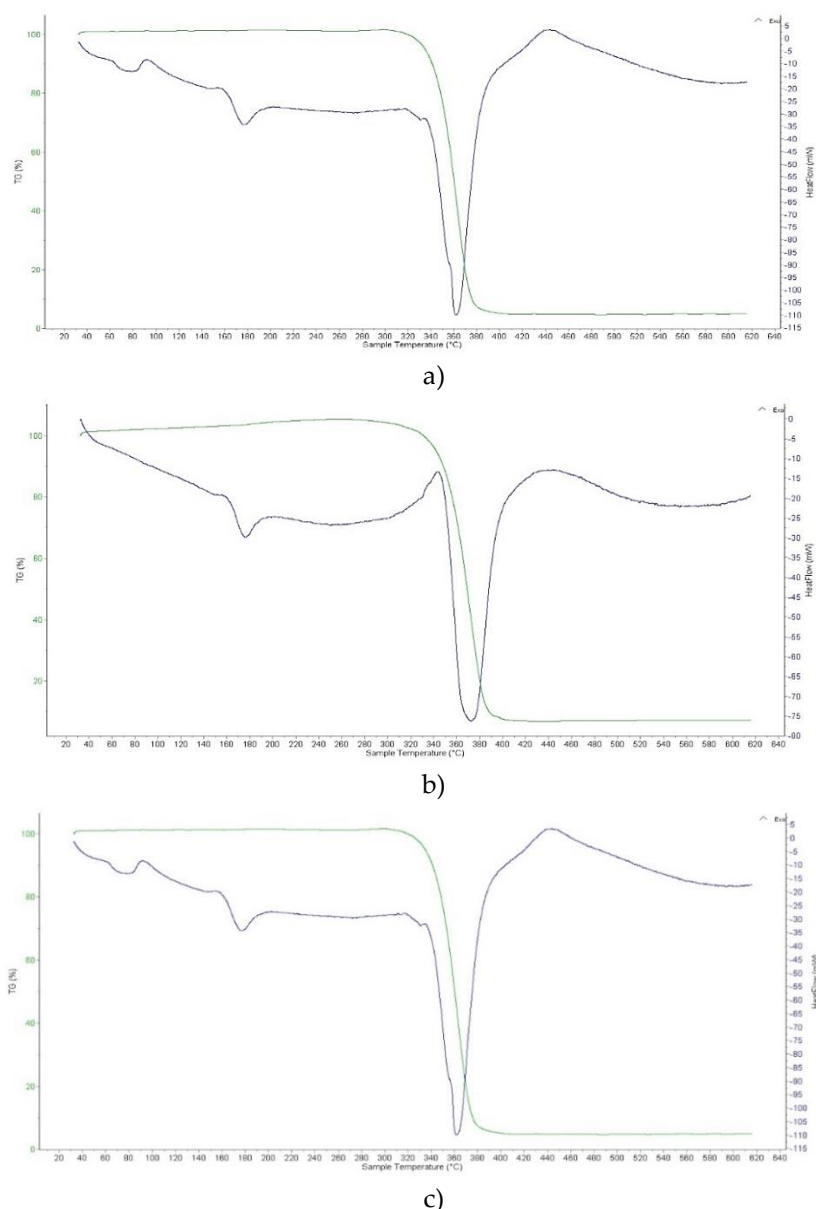
Note – compiled by the authors

An ABS sample printed on the Raise3D printer with 1.75 mm filament and fast print mode exhibited a two-stage degradation pattern in thermogravimetric analysis (TGA), with a noticeable range of mass loss between 370 and 490 °C (see Figure 8a). The TGA curve shows a gradual onset of degradation at approximately 370 °C, followed by a sharp increase in the rate of mass loss that reaches a peak at approximately 430 °C. The graph displays two partially overlapping endothermic peaks, the main one at 445 °C, indicating the sequential destruction of the macromolecular structure and partial decomposition of various polymer fractions. The overall shape of the curve is characteristic of amorphous ABS, with random chain scission predominating, while the second endothermic peak indicates concomitant processes of dehydration or fragmentation of side groups, which provide a smooth decline in the curve until degradation is complete at approximately 490 °C. The observed behavior reflects both the thermal stability of the polymer during rapid heating and the presence of small structural inhomogeneities typical of samples produced by layer-by-layer 3D printing.

A high-quality ABS sample printed on the Raise3D printer with a 1.75 mm filament exhibited a single-stage degradation in the TGA curve in the range of 370–480 °C with a pronounced endothermic peak at approximately 435 °C (see Figure 8b). The curve indicates a

gradual onset of degradation at $\sim 370^\circ\text{C}$, which is caused by the thermal cleavage of the side and main polymer chains, followed by a sharp increase in the rate of mass loss up to the peak at 435°C , which corresponds to the intense destruction of the macromolecular structure. After the peak, degradation slows, reflecting the gradual separation of chain fragments and the formation of volatile products. The end of the process at approximately 480°C indicates the almost complete destruction of heat-resistant fractions. The decomposition mechanism is mainly associated with the random cleavage of ABS chains involving side acrylonitrile and styrene groups, which is reflected in the shape of the TGA curve and the nature of the endothermic peak.

Figure 9 shows a graph of the thermal behavior of the PLA printed using the Makerbot printer at different temperatures.



(a) - PLA 1.75 Diamond fill (fast); (b) - PLA 1.75 Diamond fill; (c) - PLA 1.75 Linear
Figure 9. Thermal behavior graph of the PLA material printed on the Makerbot printer at different temperatures

Note – compiled by the authors

A PLA sample printed on the MakerBot printer with 1.75 mm filament and Diamond fill in Fast Print mode exhibited thermal behavior in the TGA curve in the range of 310–400 °C (see Figure 9a). An early glass transition was observed at ~80 °C, which reflected the polymer transition to a more mobile amorphous state. The onset of melting was observed at approximately 170 °C, indicating the presence of crystalline PLA fractions. The main thermal decomposition occurred in the range of 310–400 °C, with an endothermic peak at 360 °C that corresponded to the intense cleavage of the polymer backbone and the release of volatile products. The TGA curve reflects the typical PLA degradation mechanism through random and depolymerization-induced macromolecular cleavage, with degradation gradually completing at ~400 °C, with nearly 98% of the mass lost, indicating the high purity and homogeneity of the polymer material.

A PLA sample printed on the MakerBot printer with 1.75 mm filament and Diamond fill exhibited thermal degradation in the TGA curve in the range of 320–410 °C (see Figure 9b). The onset of melting was recorded at approximately 170 °C, which corresponds to the crystalline polymer fractions, while the main endo peak at 370 °C reflects the intense destruction of PLA macromolecules. The curve suggests a degradation mechanism involving random and depolymerization-induced chain decomposition with the formation of volatile products, while the end of the process at approximately 410 °C indicates the complete destruction of thermally stable fractions. This behavior is characteristic of homogeneous PLA with high purity and a well-formed crystalline structure, which is typical of samples produced by layer-by-layer 3D printing.

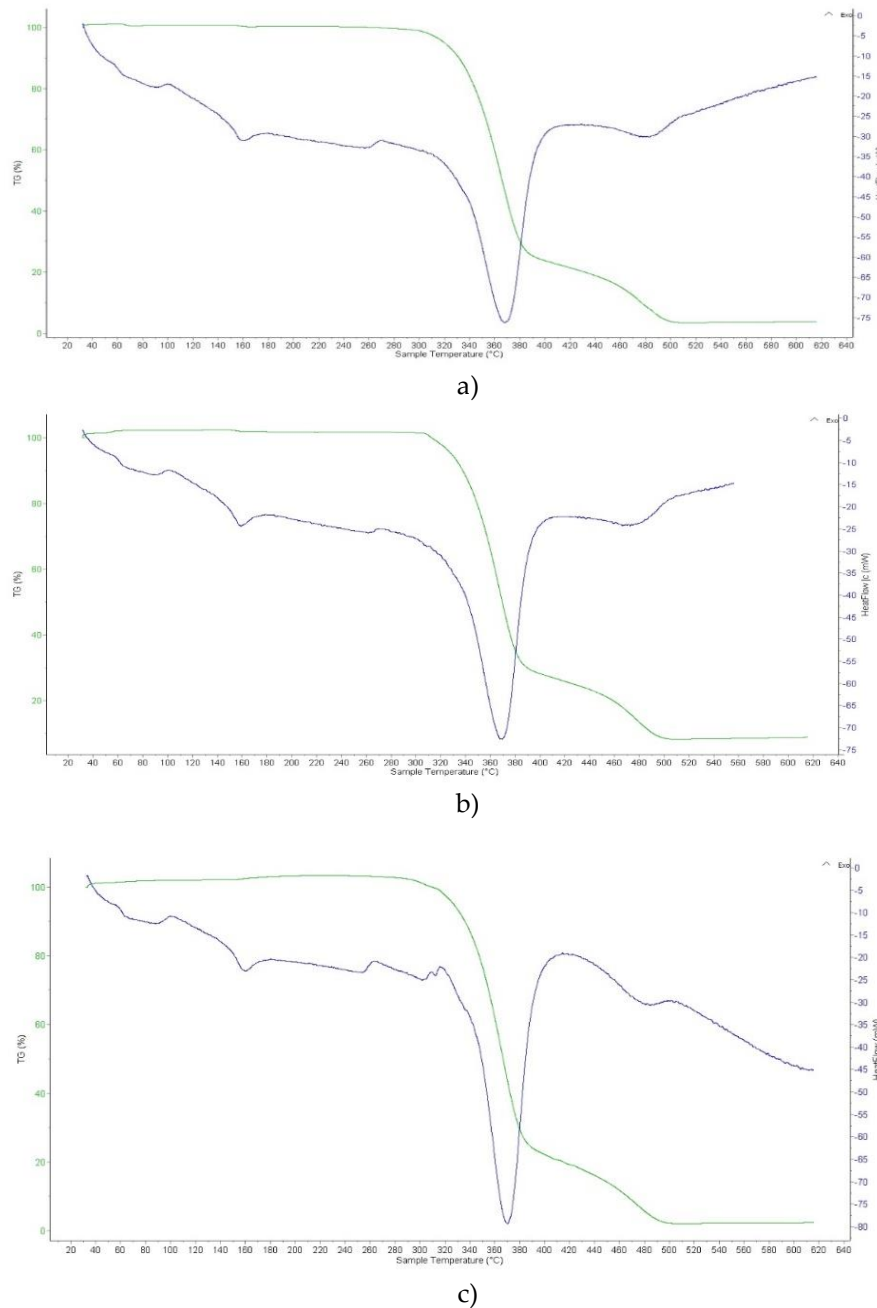
A linear PLA sample printed on the MakerBot printer with 1.75 mm filament exhibited thermal behavior in the TGA curve in the range of 320–400 °C (see Figure 9c). Early on, at approximately 80 °C, a glass transition was observed that reflected the transition of the amorphous regions of the polymer to a mobile state, and melting was recorded at 175 °C, which corresponds to the crystalline fractions of PLA. The main endo peak at 360 °C (presumably meant to be 160 °C, as PLA decomposition below 320 °C is unlikely) reflects the intense breakdown of polymer macromolecules and the formation of the volatile products. The TGA curve shows that the degradation process occurs primarily through random and depolymerization chain decomposition, with approximately 97% of the mass lost, indicating the high purity and homogeneity of the material, which is characteristic of linear PLA printed using layer-by-layer 3D printing.

Figure 10 shows a graph of the thermal behavior of the PLA material printed on the Raise 3D printer at various temperatures.

Figure 10a shows a PLA sample printed on the Raise 3D printer with 1.75 mm filament in fast print mode with the mesh-like fill. The TGA curve demonstrates a two-stage degradation: the first stage occurs in the range of 300–380 °C with the mass loss of approximately 77%, and the second stage occurs at 380–500 °C with an additional 20% loss. The curve displays several thermal transitions: glass transition at ~90 °C, melting of crystalline regions at 160 °C, and re-glass transition at 260 °C that reflects relaxation of the residual crystalline structure. The primary degradation mechanism is related to the cleavage of the polymer backbone and the sequential formation of volatile products, while the two-stage mass loss indicates the presence of different PLA fractions with different thermal stability. This behavior is typical for fast printed samples with the mesh-like fill, which contain both amorphous and partially crystalline regions affecting the shape of the TGA curve and the distribution of endothermic peaks.

Figure 10 shows that a high-quality PLA sample printed on the Raise 3D printer with 1.75 mm filament and a honeycomb fill exhibits a two-stage decomposition in the TGA curve: the first stage in the range of 320–385 °C, the second one at 385–500 °C. The mass loss distribution follows the pattern observed in the previous rapidly printed sample. The curve displays thermal transitions: glass transition at ~90 °C, melting of crystalline regions at 160 °C, and re-glass transition at 260 °C that reflects the presence of both amorphous and crystalline polymer

fractions. The primary degradation mechanism of PLA involves macromolecular cleavage and release of volatile products. The two-stage mass loss indicates different thermal stability of the fractions within the sample. This thermogram is characteristic of high-quality PLA, where the well-formed structure and homogeneity of the material ensure a smooth onset of degradation and clear delineation of the degradation stages with maintaining stability up to ~500 °C.



(a) - PLA 1.75 fast mesh print; (b) - PLA 1.75 high-quality honeycomb; (c) - PLA 1.75 fast honeycomb print

Figure 10. Thermal behavior graph of the PLA material printed on the Raise3D printer at different temperatures

Note – compiled by the authors

In Figure 10, the TGA curve shows a two-stage decomposition with a gradual onset at approximately 320 °C and a transition to more intense degradation up to ~385 °C, after which a second stage of decomposition is observed, continuing up to 500 °C with a gradual loss of the remaining mass. Thermal transitions are visible on the curve: an initial glass transition at ~90 °C, melting of the crystalline regions at 160 °C, and a re-glass transition at 260 °C, indicating a combination of amorphous and crystalline regions of the polymer. The degradation mechanism involves cleavage of the PLA backbone and the formation of volatile products, while the two-stage mass loss reflects the presence of fractions with different thermal stability. This thermogram is typical of samples with rapid layer-by-layer formation, where the polymer structure is slightly less ordered than that of high-quality PLA, which is manifested in a smoother distribution of endothermic peaks and an extended degradation range. Overall, the comparative analysis shows that MakerBot PLA exhibits classic PLA characteristics, while Raise3D PLA exhibits modified thermochemical behavior demonstrated by two-stage degradation and a broader range of thermal effects.

ABS and HIPS decompose in similar temperature ranges, but HIPS exhibits almost complete mass loss. PC is the most heat-resistant material that is resistant to high temperatures and forms a significant carbon residue. The obtained results allow for an objective comparison of thermal stability of the materials, determining their limits of use, and considering the effect of the filament composition and printing conditions on the thermal behavior of the resulting parts.

RESULTS AND DISCUSSION

Thermal properties of the samples were analyzed using a Labsys Evolution TG-DTA/DSC synchronous thermal analyzer from the Setaram in dynamic mode over the temperature range of 30–600 °C, heating in an Al₂O₃ crucible at 10 °C/min under the nitrogen atmosphere with the flow rate of 30 ml/min. The sample weights were 10–15 mg.

The study included thermogravimetric and calorimetric analysis of five polymer samples used for FDM printing: PLA printed on a MakerBot printer, as well as PLA, ABS, HIPS, and PC, all manufactured on Raise3D equipment. The data obtained allowed characterizing thermal stability of the materials, determining their degradation patterns, and identifying differences between various types of polymers and filaments.

PLA printed on a MakerBot printer exhibited single-stage degradation, typical of polylactide. Degradation began at approximately 300 °C and was complete by 410 °C, with the total mass loss of approximately 95%. The DSC curve showed characteristic endothermic effects: glass transition at approximately 90 °C, melting at 180 °C, and an intense endothermic peak at 365 °C corresponding to the active thermal degradation zone. The behavior of this material matches the classic thermochemical characteristics of PLA.

PLA, the Raise3D printing material, exhibited a fundamentally different thermal behavior, distinguishing it from its unmodified counterpart. Degradation had a pronounced two-stage nature: the first phase occurred between 300–390 °C with the 75% mass loss, and the second phase occurred between 390–510 °C with an additional 20% loss. The DSC curve showed more transitions and energy effects, including a glass transition at 90 °C, a structural rearrangement at 260 °C, and three distinct endothermic peaks at 150, 370, and 490 °C. This multiphase nature indicates the presence of stabilizers or the other modifying additives, which is typical for some of Raise3D specialized PLA filaments.

ABS printed on Raise3D decomposed in the 380–480 °C range with the mass loss of approximately 90%. The observed endothermic peak at 435 °C reflects the energy-consuming degradation of the acrylonitrile-butadiene-styrene copolymer blocks. The residual mass was approximately 10%, consistent with known ABS thermal degradation mechanisms, which include the formation of a small amount of carbonized residue.

HIPS exhibited a similar temperature window for degradation to ABS but degraded almost completely, losing up to 97% of its mass in the 370–480 °C range. The endothermic peak at 440 °C corresponds to intense degradation of the polystyrene chain and the destruction of the modifying butadiene fragments. The minimal residue of approximately 3% confirms the low content of inorganic impurities and the low susceptibility of this material to carbonization.

Polycarbonate (PC) exhibited the highest thermal stability of all the samples studied. Decomposition began at approximately 360 °C and continued up to 620 °C, with the total mass loss of only approximately 75%. A significant portion of the material was converted into carbon residue (approximately 25%), due to the aromatic nature of the PC macromolecules. The DSC curve showed a large endothermic peak at approximately 430 °C that corresponded to the cleavage of carbonate bonds and aromatic structures.

Table 1 provides a comparison of the obtained results.

Table 1. Comparison of the results obtained

Material	Decomposition range, °C	Mass loss, %	Residue, %	Endothermic peaks	Features
PLA MakerBot	300–410	~95	~5	~180, ~365	Single-stage degradation, typical PLA behavior
PLA Raise3D	300–510 (2 stages)	~95	~5	150, 370, 490	Modified PLA, pronounced two-stage behavior
ABS	380–480	~90	~10	~435	Multi-stage degradation, typical of a copolymer
HIPS	370–480	~97	~3	~440	Almost complete degradation, low carbonization
PC	360–620	~75	~25	~430	High heat resistance, significant carbon residue
<i>Note – compiled by the authors</i>					

CONCLUSIONS

A comparative analysis of the obtained results revealed that MakerBot PLA exhibits classic PLA characteristics, while Raise3D PLA exhibits modified thermochemical behavior that is demonstrated by two-stage degradation and a broader range of thermal effects. The study shows that ABS and HIPS decompose in similar temperature ranges, but HIPS exhibits almost complete mass loss. PC is the most heat-resistant material to high temperatures and forms a significant carbon residue. The obtained results allow for an objective comparison of thermal stability of the materials, determining their limits of use, and considering the effect of the filament composition and printing conditions on the thermal behavior of the resulting parts.

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