Design and Mechanical Strength Testing of a 3D Printed Phone Holder

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***Abstract*— In this paper, we will cover the entire process of making a 3D phone holder, how we came up with the idea for making it, slicing process in Orca Slicer, printing on Shenzen Creality 3D Technology, the features that this printer has and what materials it can print from. Following the printing process, mechanical strength testing of the model was conducted under controlled pressure and temperature conditions. The model was printed using PETG material in two different orientations, namely horizontal and vertical printing, in order to evaluate the influence of print orientation on the mechanical performance of the final product.**

Keywords—3D design, 3D printing, Materials, Temperature, Pressure, PETG

I. INTRODUCTION

3D printing or additive manufacturing is a process of making a three-dimensional solid object of virtually any shape from a digital model. [1]. Today, 3D printer technologies are used in almost every field and their use in different fields is becoming widespread day by day. Some of these areas are used in areas such as automotive, aerospace, industrial manufacturing, military applications, architecture and construction, food, textile and education. With the effective use of 3D printer technology in educational areas, experiences can be experienced in many different fields. [2].

The technology used in the 3D printer machine depends on the procedure, material, and the performance and nature of the final product. There are three types of methods that are most widely used, including Fused Filament Fabrication (FFF), Stereolithography (SLA) and Selective Laser Sintering (SLS) [3]. The main difference that distinguishes these three technologies is in the raw materials used before the printing process. FFF is the most commonly used method, the material used is a plastic known as a filament which is heated by the nozzle to make the desired layers. SLA uses liquid resin as the initial base while SLS starts with powder composite, which is melted to form a model. SLS uses powder compacted with lasers to make layers in the 3D printing process. There are two types of materials commonly used with this method, including plastic powder and metallic composite. [3].

Typically, the most common materials used for 3D printing are different types of polymers such as polylactic acid (PLA), polyethylene terephthalate glycol (PETG), acrylonitrile butadiene styrene (ABS), acrylonitrile styrene acrylate (ASA), polyamide (PA), and others, due to their excellent processing and forming potential at low temperatures (usually in the range between 200-300 °C). [4].

For the needs of our project, PETG material was used, given its physical and mechanical characteristics, which provide good impact resistance, flexibility, thermal and chemical stability, as well as good adhesion between layers during 3D printing. These properties make PETG suitable for the production of functional and durable parts, with precise shape and high surface quality.

In this paper, we present the design and manufacturing process of a smartphone holder produced using 3D printing technology. The holder is intended to help maintain an appropriate and consistent distance between the user's eyes and the smartphone, improving comfort and usability during everyday use. Although PETG has been investigated for various functional 3D-printed applications, limited attention has been given to smartphone holders manufactured from this material and their mechanical behavior. Therefore, this study experimentally evaluates the mechanical performance and thermal stability of a PETG smartphone holder under compression loading and elevated temperature conditions. The results provide valuable insights into the suitability of PETG for functional smartphone holders and contribute to the optimization of their design and manufacturing process.

II. CREATING 3D MODEL

3D printing starts by making a virtual design of the object you want to create. The virtual design is used as a template of the physical object to be created. This virtual design can be made using a 3D modelling program such as CAD (Computer Aided Design) to create a design from scratch. The model is then sliced into hundreds or thousands of horizontal layers in preparation for printing. This prepared file is thus uploaded in the 3D printer, which will see the printer creating the object layer by layer. [1]. Phone holder is known as a phone accessory that has become a necessity in the age of technology. Like all other phone accessories, the phone holder is produced to make our lives easier (Fig. 1). [5].

Fig.. 1. Phone holder.

The biggest advantage of this accessory is that it allows you to use your phone comfortably in your hands-free position. In this way, watching movies and series on your phone and searching the internet becomes easier and more enjoyable. You put your phone on the stand and continue to do other work while you do. It is a wide range of accessories. For example, It is not possible to hold the phone in your hands while washing dishes, eating or preparing food, before going to sleep, while driving and working on the computer. [5].

There are several possibilities for obtaining the 3D model or digital model that is wanted to print. In particular, there are three possibilities: To model the piece using a CAD software, to obtain the geometry by Reverse Engineering and 3D scanners, downloading the model from repositories. No matter how the digital model is obtained, what it is important is to get a robust 3D model, thought for 3D printing. That is to say that any designed and modelled piece, or scanned piece, or downloaded from the internet, could not be adequate for being 3D printed. This means that some issues such as internal gaps, the precision to achieve, the detail level, the size of the piece, etc. should be taken into account. [6].

A. *Characteristics of the Model*

When you work designing and printing 3D models, a wide range of formats or types of files are available. Some of them are thought for designing or scanning, but others are associated to 3D printing, such as: STL, OBJ, PLY or FBX, among others. Depending on the modeled piece, on the software, on the 3D printer features, etc., one or another format must be used. When the piece is designed and modelled, a format conversion to the “.stl" file is needed [6].

For the purposes of this research, an already prepared 3D model of a phone holder was used obtained from the Thingiverse repository (GoAftens, 2017), which was downloaded in STL format and imported into the software (Fig. 2). After importing it into the software, we analyzed the geometric and functional characteristics of the model, which is designed for stable and practical everyday use.

The model has a functional and optimized design, with the following dimensions: 83.57 mm (width), 67.00 mm (depth), and 84.99 mm (height) (Fig. 3). Its structure consists of a stable base and an inclined surface for supporting the phone, which allows comfortable viewing of the screen. Additionally, the design features smooth and rounded edges, improving both the aesthetic appearance and user safety, making it suitable for children as well.

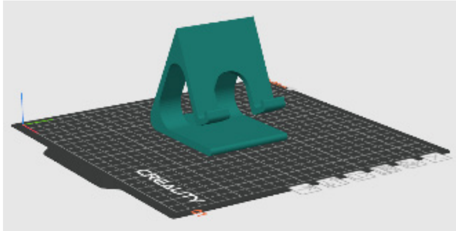


Fig. 2 Phone holder.

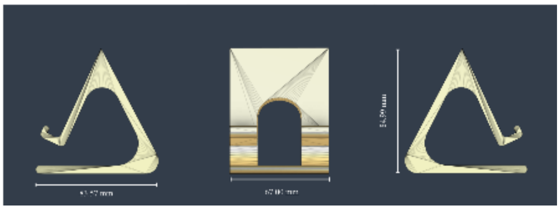


Fig. 3 Dimensions of the phone holder.

B. *Software for 3D Modeling*

Autodesk Fusion 360 is an all-encompassing 3D computer-aided design (CAD), computer-aided engineering (CAE), and computer-aided manufacturing (CAM) application. It is frequently used for product development and prototyping by engineers, designers, and manufacturers (Rahman et al., 2020; Sholeh et al., 2018). Fusion 360 provides various practical tools and capabilities that facilitate product redesign. The software offers a robust set of tools and features to facilitate the product redesign process. It streamlines the entire design-to-manufacturing workflow, enabling designers and engineers to create, modify, simulate, and visualize their redesigned products efficiently [7].

III. Printing Process

The workflow for turning an idea into a 3D print can be summed up as model (or capture), fixup, slice, and print. At each step, there are multiple software solutions to choose from [8].

Before printing a 3D model from .STL file, it must be processed by a piece of software called a "slicer" which converts the 3D model into a series of thin layers and produces a G-code file from .STL file containing instructions to a printer. There are several open-source slicer programs exist, including Slic3r, KISSlicer, and Cura. The 3D printer follows the G-code instructions to put down successive layers of liquid, powder, or sheet material to build a model from a series of cross-sections of a model. These layers, which correspond to the virtual cross sections from the CAD model, are joined or fused to create the final shape of a model. The main advantage of this technique is its ability to create almost any shape or geometric model. Construction of a model with existing methods can take anywhere from several hours to days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to very few hours, it varies widely depending on the type of machine used and the size and number of models being produced [9].

A. Printing Materials

3D printer filament is the primary material used to create three-dimensional objects. These filaments are polymers that are melted and extruded through a printer nozzle to build a model layer by layer. Choosing the right filament is critical to the success of any 3D-printed part, as different materials offer different mechanical and physical properties.

The most common types of filaments in the field of 3D printing are PLA, ABS, and PETG. Along with these materials, engineered filaments such as PEEK, PEI, and PC are used in industrial applications due to their thermal stability, chemical resistance, and exceptional strength. [10].

In terms of materials, poly(ethylene terephthalate)-glycol (PETG) is one of the most used materials in 3D printing technology due to the chemical alkali resistance, transparency, gloss, low haze and good printability, among other benefits. PETG combines some of the best features of PLA and ABS, offering good flexibility, strength, and chemical resistance. Furthermore, with the correct print settings, it is possible to obtain excellent layer adhesion and very low shrinkage properties. At the same time, it is extremely strong, which allows one to print objects that can function at high temperatures or in food-safe applications and possess exceptional impact performance [10, 11].

Some disadvantages in 3D printing PETG include: (1) shrinkage and deformation while the printed specimen cools down, (2) difficulties have been encountered in achieving a constant melt flow producing a distinct texture of 3D-printed parts, (3) PETG requires a high temperature above 230C for its FDM processing printability [12].

B. Slicing Software

Slicing software processes triangulated surface meshes, typically in STL or 3MF format, and generates G-code that directs the printer's movements and extrusion behavior. This process includes mesh repair, model orientation, planar segmentation, and the calculation of toolpaths for perimeters, infill structures, and supports. The resulting G-code comprises motion instructions such as G0 and G1, which define positions along the X, Y, and Z axes and regulate material extrusion via the E parameter, while the travel speed is defined by the F parameter. These commands are executed layer by layer, producing a physical object that closely conforms to the encoded instructions [5].

To transform 3D digital files consumers must undergo a slicing process that converts the files into G-code files using slicer software. It is very important to have the right slicing software because, with the appropriate setting, the best quality print is possible. The slicing software that converts digital 3D models based on the settings to the 3D printer and to create a part. The slicer calculates how much material it will need and how long it will take to do it [13, 14].

C. Printing Process

The finalized 3D model was printed on Creality Ender-3 V2 Neo. The Creality Ender-3 V2 Neo printer uses FDM technology for 3D printing. Fused Deposition Modeling (FDM) is a common way to 3D print plastic parts on a desktop.

Fig. 4. 3D Printing Machine Creality Ender-3 V2 Neo.

TABLE I. IMPORTANT TECHNICAL SPECIFICATIONS OF PRINTER

Print Technology	(FFF), (FDM)
Filament Diametar	1.75 mm
Build Volume	22.0 x 22 x 25.0 cm (1 Extruder)
Build Plate Temperature	212°F / 100°C
Layer Resolution	5 to 35 micron / 0.05 to 0.35 mm
Print Speed	120 mm/s
Nozzle Diameter	0.4 mm
Nozzle Temperature	500°F / 260°C
Materials	ABS, PETG, PLA
Supported 3D File Types	.amf, .obj, .stl
Price	~250–300 €

An FDM printer works by extruding a plastic filament layer by layer onto the build platform. It's a quick and cheap way to make physical models. The printing parameters were set in Orca Slicer. The models were printed with a honeycomb pattern, five shell walls, and five top and bottom layers, with a layer height of 0.2 mm. Carefully setting the printing speeds helped improve the quality of the prints. The first layer was printed at 15 mm/s to make sure it stuck to the bed properly, and the wall printing speed was set to 40 mm/s. A support angle of 30° was used with a breakaway support configuration. The nozzle temperature was set to 230°C and the bed temperature to 80°C to make sure the material stuck well and the layers bonded. The model was printed in two different orientations, namely horizontal and vertical printing, in order to evaluate the influence of print orientation on the mechanical performance of the final product. During the printing process, all specimens were regularly observed to ensure proper print quality and to identify any visible defects. After printing, the specimens were visually inspected once again, and no visible printing defects were observed.

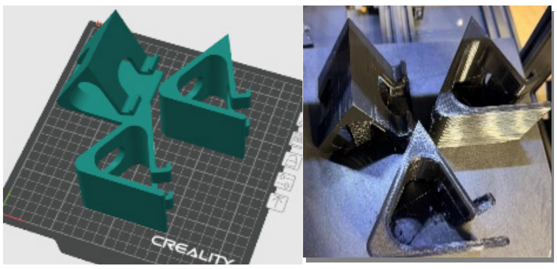


Fig. 5. Setting up the object and final product.

Based on the process characteristics of point-by-point melting and layer-by-layer manufacturing, the AM technology can quickly produce three-dimensional complex structural parts. The AM technology has many advantages such as fast free molding, short manufacturing cycle, and low production costs of small-batch parts. The AM technology only needs raw materials and equipment to produce parts without the need for complex tooling or molds, effectively saving the processing and assembly time [15].

D. 3D Model

The model is allowed to undergo post-processing, which includes cleaning, curing, and removing support structures, following printing. The completion of this phase is prerequisite to a precise and seamless final outcome. Finishing/post-processing plays a significant role in improving both mechanical/ chemical and aesthetic properties, meeting tight tolerances, providing near injection molded finishes, and achieving added durability. The need for post-processing depends on the printing technology, materials used, and print settings. the fused deposition modeling (FDM) technology commonly uses post-processing techniques such as support removal, sanding, and gap filling. In the end, a comparison with the original Standard Tessellation Language (STL) files is made to assess the printed model's correctness.[12][16]. No post-processing was performed prior to mechanical testing. When printing is finished, the excess material is removed with pliers, sandpaper, scalpel, etc.

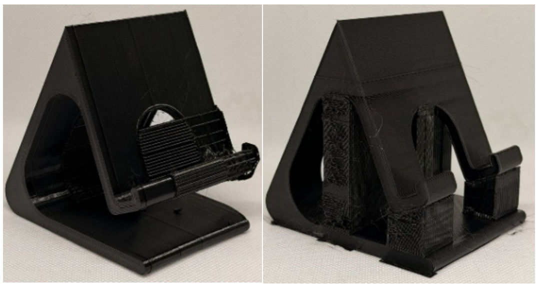
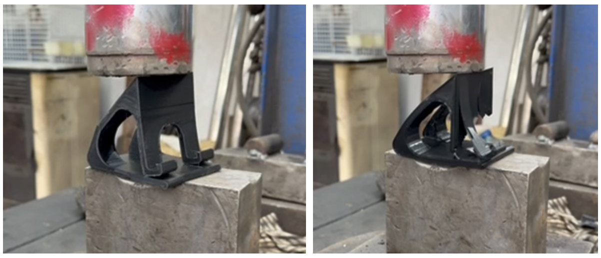


Fig. 6. The products before removing the supports.

Fig. 7. The final products.

IV. Results and Analysis

After completing the process of producing a device called a smartphone holder, designed to control the distance between the smartphone and the user’s eyes [3], the mechanical strength of the model was tested under controlled pressure and temperature conditions. Using a hydraulic press, both phone holder models (one printed vertically and the other horizontally) were tested to determine the pressure at which they would break. Another test was conducted to determine the melting point of the model, using handheld butane blowtorch and non-contact infrared thermometer. The obtained results are presented in the table below [Table 2,3]. The total time required to print all three models was approximately 27 hours.



a) b)

Fig. 8. Mechanical strength testing of the smartphone holder under a hydraulic press: (a) horizontally printed specimen; (b) vertically printed specimen.

TABLE II. Results obtained from pressure testing

Orientation	Pressure (bar)	Deformation Level	Critical Failure Location
Horizontally	1 bar	Higher	Base and central support
Vertically	0.5 bar	Lower	Front support

The horizontally printed specimen withstood a pressure of 1 bar, whereas the vertically printed specimen failed at 0.5 bar. This means that the horizontally printed model was able to withstand twice the pressure of the vertically printed model. These results confirm that print orientation has an important influence on the strength of the printed part.

a) b)

c)

Fig. 9. Temperature testing using a handheld butane blowtorch and a non-contact infrared thermometer. (a) onset of melting; (b) significant melting; (c) structural deformation.

The results obtained from the experimental testing are presented in Figure 10, highlighting the changes in the model under the applied pressure and temperature conditions.

TABLE III. RESULTS OBTAINED FROM TEMPERATURE TESTING

Temperature (°C)	Thermal State	Mechanical Response	Observation
210 °C	Onset of softening	Initial reduction in stiffness	Slight surface deformation
250 °C	Partial melting	Significant reduction in mechanical strength	Pronounced deformation
300 °C	Thermal degradation	Complete loss of structural integrity	Severe deformation and loss of shape

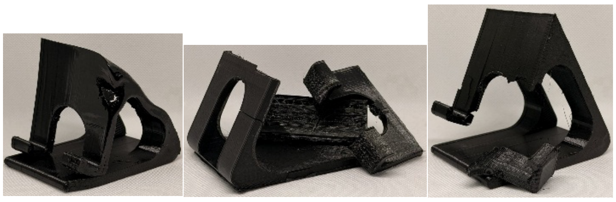


Figure 10. Smartphone holder models after experimental testing.

V. CONCLUSIONS

Fused Deposition Modeling (FDM) is one of the most widely used additive manufacturing technologies due to its relatively low cost and accessibility. The mechanical performance of FDM-printed components is strongly influenced by both the filament material and the printing parameters employed during fabrication. Parameters such as infill ratio, layer height, printing speed, infill pattern, and print orientation significantly affect the mechanical properties of printed parts [17–19].

The results of this study confirm the importance of print orientation, demonstrating a clear effect on the mechanical strength of the smartphone holder manufactured from PETG material. Horizontally printed specimens withstood a higher failure pressure (1 bar) than vertically printed specimens (0.5 bar), indicating superior load-bearing capacity and structural stability. This observation is consistent with previous research showing that filament alignment relative to the applied load can significantly influence the mechanical behavior of FDM-printed components [20]. In addition, thermal testing showed that PETG gradually loses its mechanical properties with increasing temperature. Softening began at approximately 210°C, significant deformation occurred at 250°C, and complete thermal degradation was observed at 300°C.

These findings highlight the importance of selecting an appropriate print orientation and considering thermal limitations to improve the strength, reliability, and performance of functional PETG components manufactured using FDM technology.

REFERENCES

[1] T. P. Mpofu, C. Mawere, and M. Mukosera, "The impact and application of 3D printing technology," International Journal of Science and Research (IJSR), vol. 3, no. 6, June 2014.

[2] E. Şimşir, İ. Yavuz, A. F. Yuran and N. Yazar "Car phone holder design and manufacturing with three-dimensional (3D) printer technology," Conference Proceedings of the International Symposium on Automotive Science and Technology (ISASTECH 2021), vol. 2, Ankara, Sept. 8–10, 2021.

[3] A. Dewi, H. Rante, A. Basuki, F. Pasila, and M. Lund, "3D printing process of making a smartphone holder," E3S Web of Conferences, vol. 188, p. 00003, 2020, DOI:10.1051/e3sconf/202018800003

[4] N. Petrov, M. Ormanova, and I. Zhelezarov, "3D printing of polymers: methods and current progress," in International Scientific Conference UNITECH 2025, Gabrovo, Bulgaria, 2025.

[5] M. Işın and O. Gül, "Design and static analysis of a phone holder with powerbank unit," in Proc. 1st Int. Conf. on Pioneer and Innovative Studies (ICPIS), Konya, Turkey, Jun. 2023

[6] Erasmus 3D Printing Vet Center. 3d printing technical guide [online] from https://www.e3dplusvet.eu/wp-content/docs/O1A1-EN.pdf (2017). [Accesed on 25th June 2019].

[7] T. A. Setiawan, A. I. Juniani, D. A. Purnomo, N. Rinanto, and H. N. Faruq, "How to utilize Autodesk Fusion 360 that reinforces product redesign simulation?" JISO: Journal of Industrial and Systems Optimization, vol. 6, no. 1, pp. 48–54, Jun. 2023.

[8] A. K. France, Make: 3D Printing: The Essential Guide to 3D Printers. Maker Media, 2013.

[9] V. G. Gokhare, D. N. Raut, and D. K. Shinde, "A review paper on 3D-printing aspects and various processes used in the 3D-printing," International Journal of Engineering Research & Technology (IJERT), vol. 6, no. 6, Jun. 2017.

[10] V. Bakardzhiev, S. Sabev, and K. Chukalov, "Studying influence of 3D printing parameters of PETG to improve hardness and maximum tensile strength," Engineering Proceedings, vol. 104, no. 1, p. 39, 2025, DOI: 10.3390/engproc2025104039

[11] S. Valvez et al., "Compressive behaviour of 3D-printed PETG composites," Aerospace, vol. 9, no. 3, p. 124, 2022, DOI: 10.3390/aerospace9030124

[12] J. R. C. Dizon, C. C. L. Gache, H. M. S. Cascolan, L. T. Cancino, and R. C. Advincula, "Post-processing of 3D-printed polymers," Technologies, vol. 9, no. 3, p. 61, 2021, DOI: 10.3390/technologies9030061

[13] B. S. Shim and J.-U. Hou, "Improving estimation of layer thickness and identification of slicer for 3D printing forensics," Sensors, 2023.

[14] M. Šljivic et al., "Comparing the accuracy of 3D slicer software in printed end-use parts," IOP Conference Series: Materials Science and Engineering, vol. 659, p. 012082, 2019.

[15] X. Peng, L. Kong, J. Y. H. Fu, and H. Wang, "A review of post-processing technologies in additive manufacturing," Journal of Manufacturing and Materials Processing, vol. 5, no. 2, p. 38, 2021, DOI: 10.3390/jmmp5020038.

[16] R. Bisht, A. Verma, and R. Kumar, "3D printing in medical applications," in Advanced Research in Medical Science and Technology, vol. 7, ch. 6, p. 109.

[17] P. Szczygieł and K. Radoń-Kobus, "Influence of printing orientation on tensile strength and surface characterization of a steel-powder-reinforced thermoplastic composite manufactured by FDM technology," *Materials*, vol. 18, no. 24, p. 5656, 2025.

[18] M. A. Nashruhi, K. I. Ismail, and T. C. Yap, "The effect of printing orientation on the mechanical properties of FDM 3D printed parts," in Lecture Notes in Mechanical Engineering, Springer, 2017.

[19] M. Albaşkara and I. Yıldız, "A comparative study on the tensile properties of PLA, PETG, and ABS in FDM 3D printing: effects of infill geometry and build orientation," International Journal of 3D Printing Technologies and Digital Industry, vol. 9, no. 3, pp. 688-697, 2025

[20] B.M. Tymrak, M. Kreiger, J. M. Pearce, "Mechanical properties of components fabricated with open-source 3-d printers under realistic environmental conditions," Materials & Design, vol. 58, pp. 242-246, 2014.