IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Infill Density Of Pure Petg And Annealed Petg Fabricated By Using Fdm Technology

[1]Karthick N, [2] Rajesh Kumar D, [3] Chandrasekaran P

[1] Assistant Professor, Mechanical Engineering, [2] Assistant Professor, Automobile Engineering,
[3] Assistant Professor, Food Technology,
[1]Dhanalakshmi Srinivasan College of Engineering, Coimbatore, [2] SNS College of Technology, Coimbatore,
[3] Dhaanish Ahmed Institute of Technology, Coimbatore

Abstract: Polyethylene Terephthalate Glycol (PETG) has emerged as a superior material option for desktop-based fused deposition modelling (FDM) applications in the automotive and other industrial sectors. The dimensional stability, quality, functionality, and properties of the printed specimens are influenced by the process settings in the FDM technology. The impact of FDM's infill density on the mechanical characteristics of PETG-printed samples is examined in this article. Using layers of extruded filament and considerable infill density factors such as 30%, 60%, 90%, and 100%, respectively, the test samples were printed using FDM while maintaining optimal values for the remaining parameters. The total mechanical performance is determined by the infill density and annealing process. Hardness, tensile strength, impact strength, and flexural strength were all improved in Annealed PETG samples in accordance with the previous mechanical properties. It is clear that the responses provided in this study offer helpful guidelines for creating functional parts utilizing PETG and taking into account 100% infill density with annealing, which was nearly crucial for the future replacement of automotive and aerospace components.

Index Terms **-** PETG, FDM, Infill Density, Annealing.

I. Introduction

One of the newest technologies utilized in rapid prototyping techniques for component manufacture was additive manufacturing. Layer by layer addition is how a component is printed in this technique. This cutting-edge manufacturing method works well for producing intricate and crucial forms through the printing process [1][2]. Due to its low cost, simplicity, reduced waste, increased productivity, and ability to print complicated structures, fused deposition modelling was the most affordable and straightforward method of creating printed parts [3-5]. In 3D printing, filaments made of PLA, ABS, PETG, nylon, and polycarbonate are frequently utilized. Applications in the automotive, aerospace, medical, building, and electrical industries can benefit from this quick prototyping method. The creation of 3D models, slicing, support generation, 3D printing, and post-processing of produced parts are important processes in this process [6-8].

Part orientation, support material selection, and interface features are a few crucial factors to consider. PETG was one of the polymer materials utilized in engineering applications for FDM component printing [9]. The PETG was primarily used because it was more robust than other polymer filaments and was less expensive. Wall thickness, layer height applied, infill density, printing speed, infill pattern type, and orientation of the printed samples are some crucial factors to consider when slicing the model [10]. Among the several infill patterns—grid, lines, triangles, cubic, zigzag, cross-hatched, and gyroid—lines and cross-hatched offer the printed component more stability and stiffness. The next important FDM parameter will be orientation. The slicing software automatically generates supports based on the orientation that is selected. Transversal (0), diagonal (45), crosshatched (±45), and longitudinal (90) are the four main orientation angles. It was clear that specimens printed longitudinally exhibited superior flexural and tensile stress, while specimens printed transversely displayed a greater modulus of elasticity [11]. The exogenous substances utilized in the filament to improve its properties are called modifiers.

The PETG filament is combined with impact modifiers to increase the printed specimen's Izod and fatigue strength. One of the most popular post-processing methods for improving the mechanical, thermal, and tribological properties was annealing [12][13]. Annealing was found to be an effective post-processing method for restoring the 3D printed composites' decreased interlayer tensile strength. By annealing at the proper temperature, the interlayer tensile strength of 3D printed PETG composites improved by three and two times, respectively [5][14][15]. It was clear from the literature review that a great deal of research had been done on printing materials like PLA and ABS. Only a few number of studies had optimized the process parameter in PETG. No researcher had applied the post-processing technique in the FDM process on PETG filament, despite infill density being one of the most important process parameters in 3D printing that significantly affects the mechanical properties of the printed specimen. The PETG specimens in our proposed work were printed using FDM with different infill densities of 30%, 60%, 90%, and 100%, respectively. Each printed specimen was also subjected to annealing conditions. Additionally, the test specimens are removed for mechanical tests like flexural, impact, tensile, and hardness tests. Since as-printed and annealed samples are compared using the responses from the optimal infill density.

II. Materials and Methods

2.1 Filament

Employing a filament extruder, polyethylene terephthalate (PET) is enhanced with glycol to create polyethene terephthalate glycol (PETG) filament. The properties of PETG, which include chemical resistance, impact resistance, hardness, ductility, and transparency, are enhanced by the addition of glycol to the material composition. Its healthy degree of flexibility can help keep parts from shattering under stress. The following print parameters were recommended by the PETG filament supplier are as follows; Density of the Filament: 1.27 g/cc, Extrusion temperature 2300C, Bed temperature is 75 0C and speed of the printing; 45–55 mm/s.

Fig.1 – PETG Filament

2.2 Modelling and fabrication of model

The first stage in additive manufacturing involved modeling. Our suggested work uses SolidWorks 2019 to construct the testing specimen model in accordance with the standards set by the ASTM (American Society for Testing and Materials). The hardness specimen is designed using ASTM D785, the tensile strength specimen is designed using ASTM D638; the impact strength specimen is designed using ASTM D256; and the flexural strength specimen is designed using ASTM D5943.The designed specimen was converted into. STL format for slicing the developed model and to slice the model Ultimaker Cura 4.4 software were used. Then imported. STL file and printing parameters were given as the input for printing the specimen.

Fig.2 Printed Specimens of PETG

The extrusion temperature and bed temperature for Polyethylene Terephthalate Glycol (PETG) were set at 2200C and 600C, respectively. The other printing parameters, including wall and layer thickness, were set at 1 mm and 0.1 mm for the 30%, 60%, 90%, and 100% infill density specimens. The two sets of combinational test samples were successfully fabricated. Exposed one collection of all the test samples directly taken for testing as an as-print condition and another set of all the printed samples were exposed for the annealing process.

III. Post Processing of specimens

Annealing is a post-processing technique that is used to make printed materials stronger. Therefore, the glass transfer temperature is allowed to warm up to 1200C for 60 minutes and then cool down to room temperature while the layer-by-layer manufactured samples are bound over a flat baking pan coated with teflon in a forced conventional bench oven. Finally, all pure PETG and annealing PETG samples and as-print samples arranged for testing.

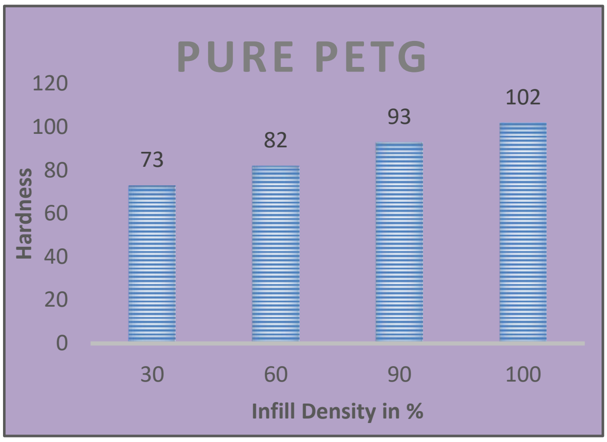
IV.Testing of specimens

As required by ASTM D785, ASTM D638, ASTM D256, and ASTM D790 standard procedure, the received standard processed specimens were subjected to testing using Rockwell hardness tester, ultimate tensile tester, impact tester, and flexural tester equipment. The tests were conducted twice, and the results were recorded for additional analysis.

V.Result and Discussion

5.1 Hardness

Annealed PETG and pure PETG with different infill density percentages of 30%, 60%, 90%, and 100% were tested for Rockwell hardness; the results, together with an error bar, are shown in Fig.3 Comparing annealed PETG at 100% infill density to other printed specimens, the greatest hardness value is 118 HRC. When the infill density was 30%, 60%, and 90%, the annealed PETG displayed values of 73, 82, and 93 HRC, respectively. Whereas pure PETG samples recorder the lower value of hardness then the annealed samples. This higher hardness rating results from the PETG filament's post-processing, which prevents the printed part's surface from being indented by the applied stress. A heavier, more substantial print results from a higher infill density. As a result, 100% infill density offers superior strength and resistance to the applied load's indentation. When compared to pure PETG, the annealed PETG shown a 28% increase in hardness at a higher infill density of 100%.



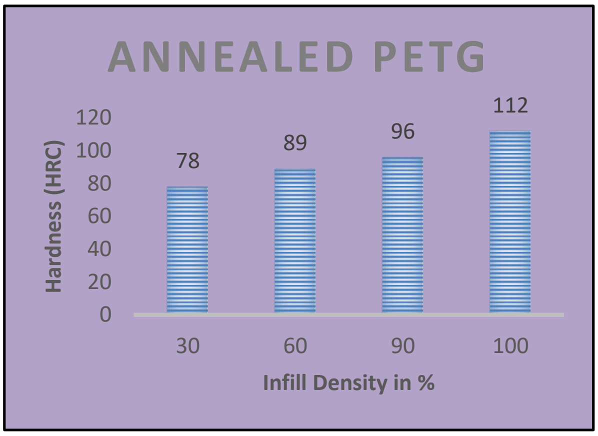


Fig.3 Hardness Values of Pure PETG vs Annealed PETG

5.2 Tensile strength

An Instron tensile machine with an extra extensometer was used to evaluate the ultimate tensile strength of pure and annealed PETG with different infill density percentages of 30%, 60%, 90%, and 100%. The results, together with an error bar, are shown in Fig.4. The tensile strength of annealed PETG at various infill density reflected the value as 42.5, 47, 52.5 and 56.8 MPa at each infill densities. The maximum tensile strength of 56.8 MPa was recorded in annealed PETG at 100% infill density.

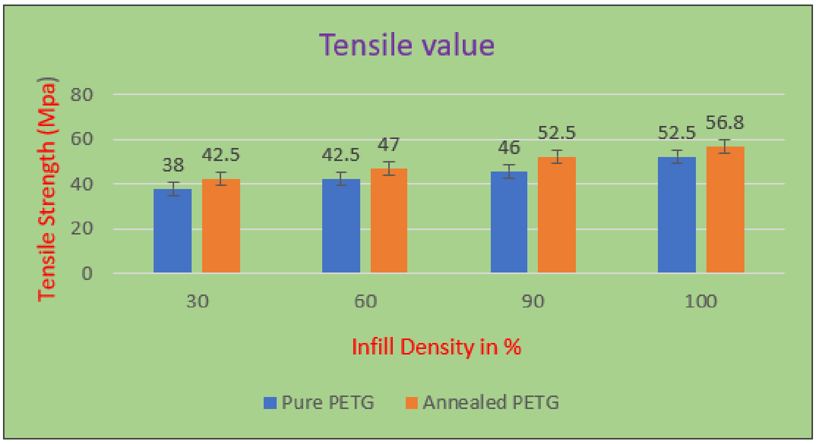


Fig.4 Tensile Values of Pure PETG vs Annealed PETG

5.3 Impact Strength

Employing a pendulum-type Izod impact apparatus, the impact strength of pure and annealed PETG with different infill percentages (30%, 60%, 90%, and 100%) was evaluated. Pure PETG had impact strengths of 72, 76, 82, and 97 J/m2, while annealed PETG had impact strengths of 92, 102, 116, and 126 J/m2 at different infill densities. The PETG filament's annealing process was the cause of this increased impact energy. When compared to pure PETG, annealed PETG at 100% infill density demonstrated a 28% increase in impact strength.

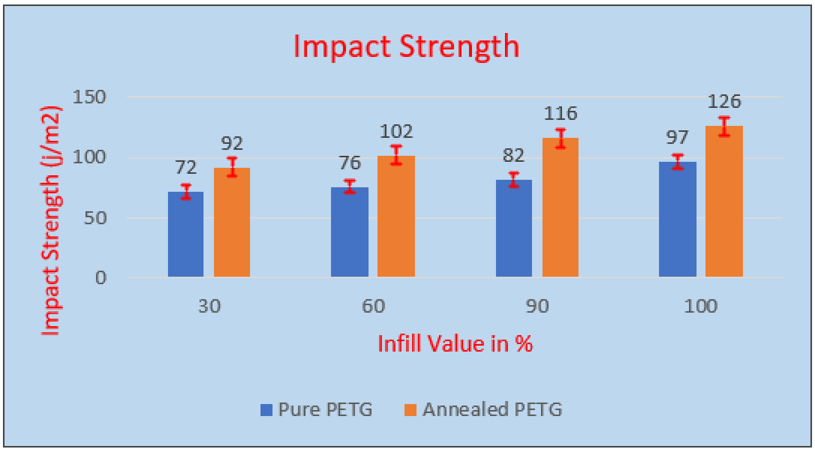


Fig.5 Impact Values of Pure PETG vs Annealed PETG

5.4 Flexural Strength

Flexural testing equipment was used to examine printed specimens of pure PETG and annealed PETG with different infill percentages (30%, 60%, 90%, and 100%).As compared to other infill densities, the flexural strength of Annealed PETG at 100% infill density demonstrated greater strength. The flexural strengths of annealed PETG samples are 53, 62, 69, and 74 MPa. The improvement in flexural strength may be due to noticeable of ductility nature because of annealing process of pure filament.

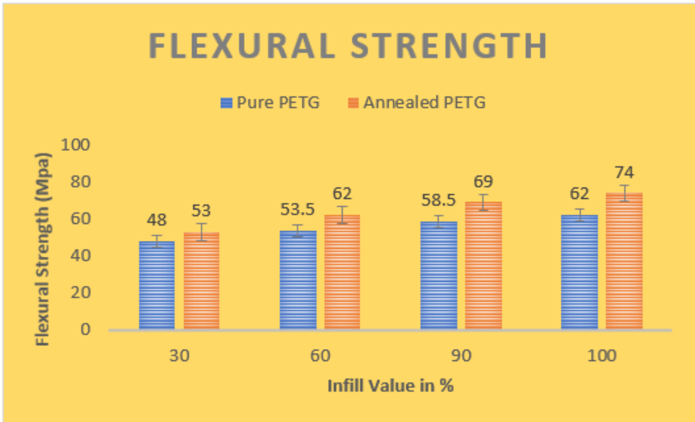


Fig.6 Flexural Values of Pure PETG vs Annealed PETG

5.5 Comparison of Pure vs Annealed PETG

Mechanical properties of filament have been improved due to annealing process which was carried out after printing the specimen. Annealed PETG at 100% infill density shows around 16 to 18% increase in mechanical properties when compared with As-printed PETG at 100% infill density.

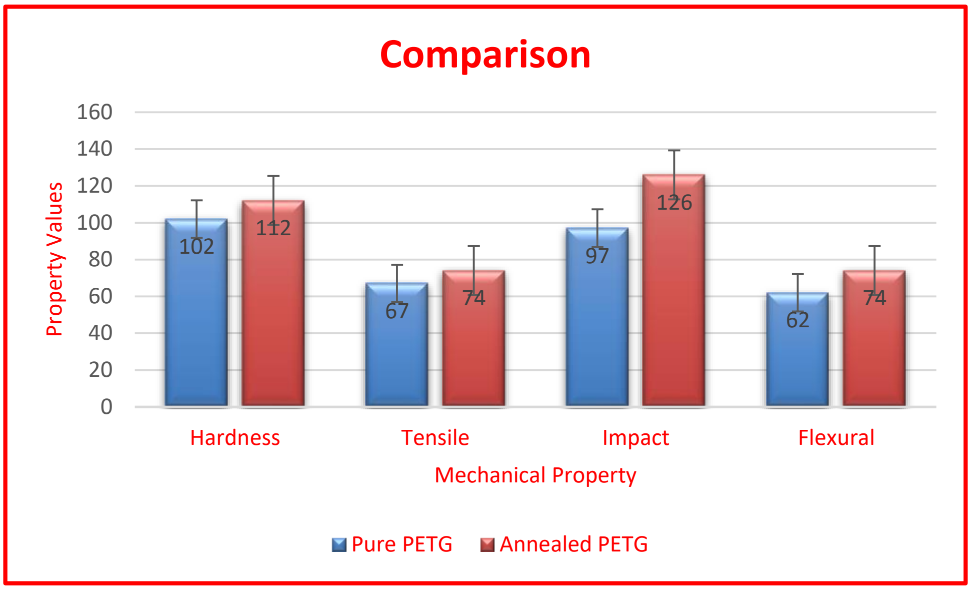


Fig.7 Mechanical Propety Comparison of Pure vs Annealed PETG

6.Conclusion

The following result were drawn from the experimentation carried out over the printed and post processed PETG various infill densities of 30%, 60%, 90% and 100% through FDM technique.

- Mechanical tests including hardness, tensile, impact, and flexural strength were performed on the 3D printed and annealed PETG specimens, and the results were compared.
- It was clear from each test result that a 3D printed and annealed specimen with 100% infill density had superior mechanical qualities because a specimen with a higher infill density is heavier and more substantial due to its increased strength and high load carrying capacity, which also shows resistance to the applied load's indentation.
- When compared to pure PETG specimens at 100% infill density, annealed PETG specimens exhibited increases in hardness, tensile, impact, and flexural strength of 22%, 26%, 28%, and 22%, respectively.
- In automotive and aerospace applications, post-processed annealed PETG with 100% infill density will be the perfect material to replace temporary functional parts or permanent metal with medium loads.

References:

[1] M. Vaezi, H. Seitz, S. Yang, A review on 3D micro-additive manufacturing technologies, Int. J. Adv. Manuf. Technol. 67 (5-8) (2013) 1721–1754, https:// doi.org/10.1007/s00170-012-4605-2.

[2] W.D. Zhou, J.S. Chen, 3D printing of carbon fiber reinforced plastics and their applications, MSF 913 (2018)

[3] A.J.M. Puigoriol, S.M. Alex, G. Antonio, G. Gómez-Gras, M. Pérez, Flexural fatigue properties of polycarbonate fused-deposition modelling specimens, Mater. Des. 155 (2018) 414–421, https://doi.org/10.1016/j.matdes.2018.06.018.

[4] G. Jun, X. Rui, Tian, Chuanshuai, Optimizing physical aging in poly (ethylene terephthalate)-glycol (PETG), J. Non-Cryst.

[5] Karthick, N.; Soundararajan, R.; Arul, R.; Prasanth, J.A. Evolution of Tribological Performance of Polypropylene with Carbon Fibre Composites Fabricated Through FDM Technology by Varying Infill Density. *J. Inst. Eng. Ser. D* **2024**, *105*, 961–968

[6] Jiang, Y.; Liu, L.; Yan, J.; Wu, Z. Room-to-low temperature thermo-mechanical behavior and corresponding constitutive model of liquid oxygen compatible epoxy composites. Compos. Sci. Technol. 2024, 245, 110357.

[7] Nathaphan, S.; Trutassanawin, W. Effects of process parameters on compressive property of FDM with ABS. Rapid Prototyp. J. 2021, 27, 905–917.

[8] Zhao, Y.; Zhao, K.; Li, Y.; Chen, F. Mechanical characterization of biocompatible PEEK by FDM. J. Manuf. Process. 2020, 56, 28–42.

[9] Muammel Hanon, Robert Marczis, L. Zsidai, Anisotropy evaluation of different raster directions, spatial orientations, and fill percentage of 3D printed PETG tensile test specimens, Key Eng. Mater. 821 (2019) 167–173, https://doi.org/ 10.4028/www.scientific.net/KEM.821.167.

[10] R, Soundararajan, K, Sathish, Gopal, Shanthosh, C, Pradeep. The Effect of Print Orientation and Infill Density for 3D Printing on Mechanical and Tribological Properties. (2020). 10.4271/2020-28-0411

[11] Matthew Woern Reich, Aubrey Tanikella, Nagendra Pearce, Joshua., Mechanical properties and applications of recycled polycarbonate particle material extrusion-based additive manufacturing, Materials 12 (2019) 1642, https://doi.org/10.3390/ma12101642.

[12] Soundararajan R, Sathish K, Gopal, Shanthosh, Palanivelu, Ramprakash. Enhancing the Tribological Properties PETG and CFPETG Composites Fabricated by FDM via Various Infill Density and Annealing, (2020), 10.4271/ 2020-28-0429

[13] R. Soundararajan, N. Jayasuriya, R.G. Girish Vishnu, B. Guru Prassad, C. Pradeep, Appraisal of mechanical and tribological properties on PA6-TiO2 composites through fused deposition modelling, Mater. Today. Proc. 18 (2019) 2394–2402, https://doi.org/10.1016/j.matpr.2019.07.084.

[14] I. Ferreira, D. Vale, M. Machado, J. Lino, Additive manufacturing of polyethylene terephthalate glycol /carbon fiber composites: an experimental study from filament to printed parts, Proc. IMechE 233 (9) (2019) 1866–1878, https://doi.org/10.1177/1464420718795197.

[15] E.J. Moskala, Fatigue resistance of impact-modified thermoplastic copolyesters, J. Mater. Sci. 31 (2) (1996) 507–511, https://doi.org/10.1007/ BF01139171