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Experimental Investigation of Various 3D Printing Materials for Making Travel Bag Wheels

Chirag Sanghani[1,*], Vishal Rana[2]

Abstract

3D printing is one of the emerging areas of manufacturing. Fused deposition modelling (FDM) is widely used 3D printing technique in various fields like jewellery, fashion, art and sculpture, medical, etc. In this paper, different polymer materials like ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), carbon fibre, PETG (Polyethylene Terephthalate), HIPS (High Impact Polystyrene), etc. were analysed for compressive strength by preparing standard specimens according to ASTM standard D695 to check their feasibility in making travel bag wheels. No. of specimens were prepared from material having highest compressive strength by 3D printing with varying process parameters. It was found that 3D printed wheel made from PLA+ material can replace currently used nylon wheel in market.

Keywords: 3D printing, FDM, ASTM D695, Compressive test, Travel bag wheel

INTRODUCTION

3D printing is also known by other terms like additive manufacturing, free form fabrication, layered manufacturing, etc. It is a process of preparing a part of any shape from computerized data of 3D model. In this process, material is added layer by layer to form a required shape of part under computer control. In 1984, Charles Hull founder of company 3D Systems Corp., has developed first 3D printing technique known as stereolithography. Since invention of 3D printing technology, lots of researches have been carried out in the direction of converting this technology into production grade. The effect of various parameters on tensile and flexural strength of ABS + hydrous magnesium silicate composite was investigated by Jaya Christiyan et al [1]. and it was found that lower value of printing speed and layer thickness gives maximum tensile and flexural strength. Vishwas and Basavaraj [2]. concluded that the orientation angle and the shell thickness are the most influential process parameters for mechanical properties of ABS. From the fracture analysis of ABS specimens, Rankouhi et al [3]. observed that smaller airgap to material ratio is the main responsible factor for higher strength. Letcher and Waytashek [4]. found mechanical properties in PLA filament similar to printed specimen which depicts feasibility of recycling of failed 3D printed parts and converting into reusable filament. Zolfagharian et al. [5] examined fracture behaviour of nylon specimen prepared by fused deposition modelling and multi-jet fusion using equivalent material concept and J-integral failure principle. The effects of various 3D printing parameters on mechanical properties of poly-ether-ether-ketone (PEEK) parts were analysed and compared with injection molded parts by Li and Lou [6]. Gonabadi et al [7]. employed digital image correlation (DIC) to analyse fracture of PLA specimens prepared by fused filament fabrication (FFF) during tensile and shear testing. For best working setup in FDM based 3D printer, Tafaoli-Masoule et al [8]. carried out experimental investigation of various printing parameters for tensile strength of polyether ether ketone (PEEK) specimens. A comparative analysis

*Author for Correspondence
Chirag Sanghani
E-mail: crs19.tdec@gmail.com

[1]Senior. Lecturer, Department of Mechanical Engineering, Tapi Diploma Engineering College, Surat, Gujarat India
[2]Lecturer, Department of Mechanical Engineering, Tapi Diploma Engineering College, Surat, Gujarat India

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of ABS, PLA and PETG materials for tensile, thermo-mechanical, and adhesive wear properties was carried out by Yilmaz [9]. He observed ABS as the most stable material and PLA as the most sensitive material in terms of variation in tensile strength with temperature. Kabir et al. [10] investigated potential of extrusion based 3D printing technology for fabrication of complex geometries by comparing ring-spinning travelers fabricated by 3D printing and Injection-Molding. It was found that 3D printing technology offers many favourable aspects like flexibility in reinforcement patterns and materials for fabrication of fiber-reinforced composite parts. Sonaye et al. [11] studied the influence of essential parameters of 3D printing on cranial implants' material and mechanical properties and determined an optimum set of parameters to make cranial implants with suitable impact strength. Finite element analysis (FEA) was used by Wang et al. [12] to improve 3D printing technology for fabrication of PEEK parts. Based on experimental and analytical results, they suggested optimum parameters which can result in improvement in the density, reduction in internal defects, strengthening of binding layers and reduction in surface roughness. In this work, a feasibility of using 3D printed wheel in travel bag has been evaluated by performing no. of experiments on various polymer materials.

MATERIALS

Different types of 3D printing materials are available in the market. According to requirement of travel bag wheel, seven materials like Polylactic acid (PLA), Acrylonitrile butadiene styrene (ABS), Carbon fibre, Polyethylene terephthalate glycol (PETG), High Impact Polystyrene (HIPS), PLA+ and ABS+ were selected. A compressive strength is important property for travel bag wheels and the ASTM D695 standard is used for compression testing of plastic materials [13]. A block or cylindrical shaped specimen is used for compression test according to ASTM D695 [14]. In this analysis, cylindrical shape was chosen to prepare all the specimens. The dimensions of the test specimen to be fabricated according to ASTM D695 standard for compressive test are Ø12.7 x 25.4 mm as shown in Figure. 1.

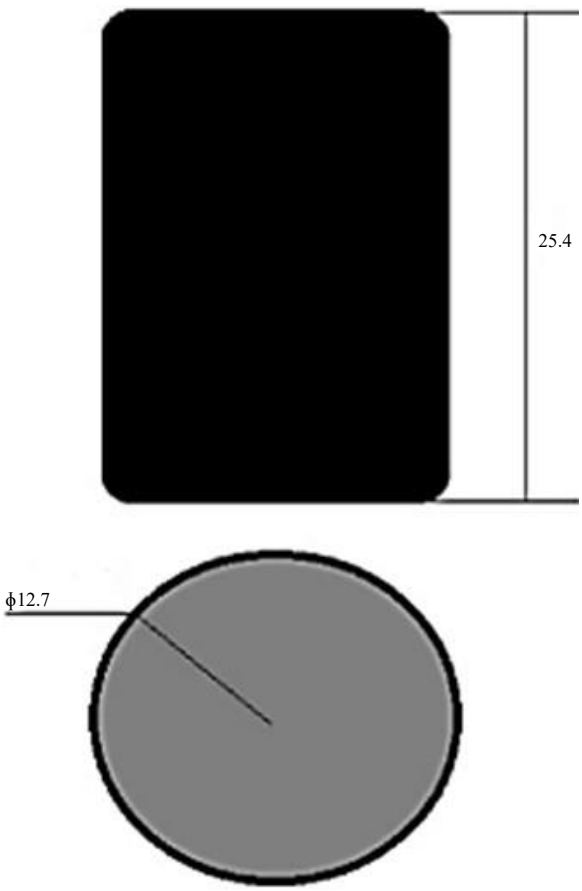

Figure 1. Dimensions of compression test specimen [14].

PREPARATION OF SPECIMEN

All the specimens were prepared as per ASTM D695 standard from PLA, ABS, Carbon fibre, PETG, HIPS, PLA+ and ABS+ using FDM based 3D printer having build volume 600mm x 600mm x 600mm. In this process, a filament of polymer material is forced through a heated nozzle fitted in a print head, which melts and deposits it in thin layer form on the platform. The print head deposits the filament onto the previous layer and then it hardens with the help of cooling fans mounted on the print head. These layers fuse with each other to create a three-dimensional part. During 3D printing, some parameters were kept constant and some were varied. The selected process parameters during 3D printing are shown in Table 1. The test specimens prepared by 3D printing are shown in Figure. 2.

Table 1. Process parameters for 3D printing.

Parameters	ABS/ABS+	PLA/PLA+	PETG	Carbon fiber	HIPS
Bed temp. (°C)	60	80	70	80	70
Extrusion temp. (°C)	235	210	230	250	230
Layer thickness (mm)	0.2				
Infill density (%)	100				
Nozzle size (mm)	0.4				
Print speed (mm/s)	80				

Figure 2. Test Specimens prepared by 3D printing (a) ABS (b) PLA (c) Carbon fiber (d) PETG (e) HIPS (f) ABS+ (g) PLA+

COMPRESSION TESTING

As the travel bag wheels are subjected to compression loading, compressive strength is critical property for wheel material. Hence, it is necessary to investigate compressive strength of all the selected materials. For checking compressive strength of all the specimens, a compression testing machine was used as shown in Figure. 3 with specifications shown in Table 2.

Figure 3. Compression testing machine.

Table 2. Specifications of compression testing machine

Parameters	Value
Capacity	500 kN
Platen size	160 mm
Ram diameter	120 mm
Ram Travel	50 mm
Vertical daylight	230 mm
Horizontal daylight	230 mm
Weight (approx)	292 kg
Least count	0.001 kN

The result of compression testing is shown in the Figure 4 in form of bar chart. From the results, it was found that PLA+ has highest compressive strength 10.8 kN while PETG has lowest compressive strength 3.2 kN.

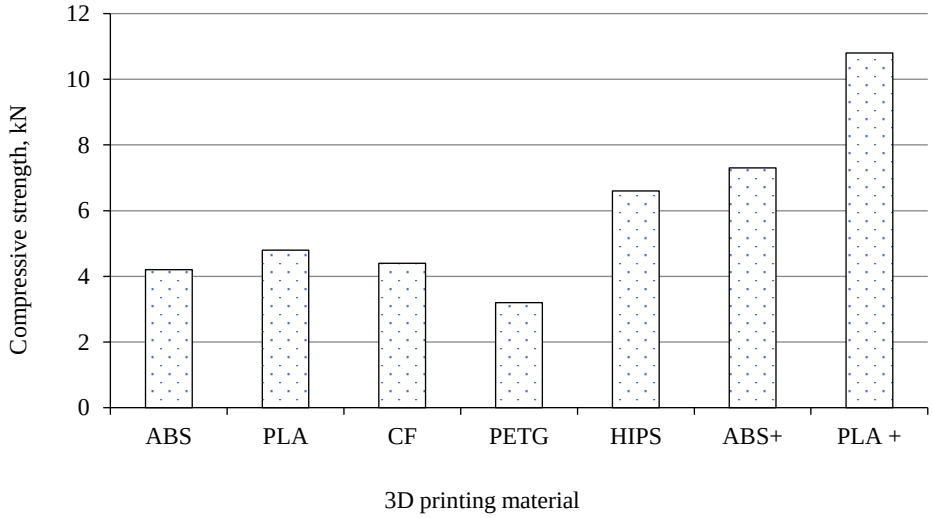

Figure 4. Compressive strength of 3D printing material

To explore the effect of printing pattern and layer thickness on compression strength of PLA+ material, experimental investigation was carried out. In this investigation, three different printing patterns such as rectilinear, concentric and grid as well as three different layer thickness such as 100µ, 200µ and 300µ were taken under consideration. Total 9 specimens were prepared by keeping all parameters used in previous 3D printing of PLA+ specimens as constant and varying printing pattern and layer thickness. After preparing these specimens, all were tested on the compression testing machine and the result is shown in Table 3.

Table 3. Result of parametric effect on compressive strength.

Printing pattern	Layer thickness (µ)	Compressivestrength (kN)
Rectilinear	100µ	10.9
	200µ	10.2
	300µ	9.1
Concentric	100µ	10.4
	200µ	7.8
	300µ	8.0
Grid	100µ	9.8
	200µ	8.7
	300µ	8.6

After testing all the specimens prepared by varying process parameters, results depicted that the combination of rectilinear pattern and 100µ layer thickness gives highest compressive strength of 10.9 kN while the combination of concentric pattern and 200µ layer thickness gives lowest compressive strength of 7.8 kN.

TESTING OF TRAVEL BAG WHEEL

The main aim of this work is to find 3D printing material having higher compressive strength for wheel of travel bag as compared to nylon, currently used material for wheel. So, a wheel was printed from PLA+ material with optimum parameters as per the design of existing wheel. Then, existing nylon wheel and 3D printed PLA+ wheel both were tested for compressive strength and the result is shown in Table 4. Both the wheels before and after testing are shown in Figure 5. The result shows clearly that the PLA+ wheel is better than the existing nylon wheel.

Table 4. Compression test result of both the wheels.

Wheel material	Initial load	Maximum capacity
Nylon	1.8KN	6.8KN
PLA+	4.2KN	15KN

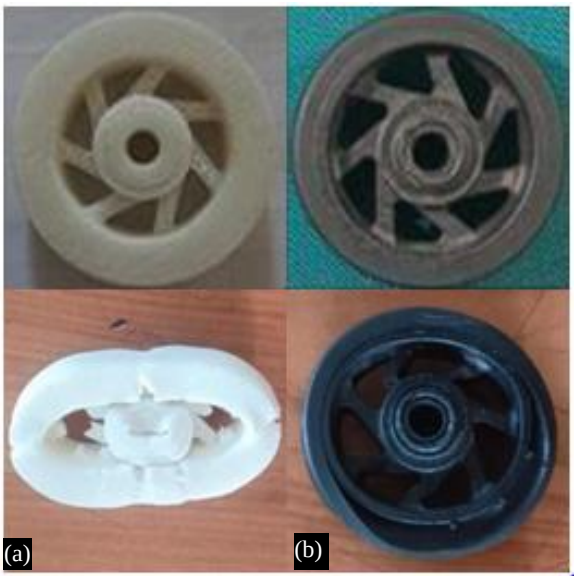

Figure 5. Wheels before & after compression test: (a) PLA+, (b) Nylon.

CONCLUSION

To use wheels having higher compressive strength than existing one in travel bag, the feasibility analysis of various 3D printing materials like PLA, ABS, Carbon fibre, PETG, HIPS, PLA+ and ABS+ was carried out. PLA+ material had shown highest compressive strength during experimental investigation. Then, parametric analysis was conducted to find optimal process parameters for highest compressive strength. This analysis depicted rectilinear pattern and 100µ layer thickness as the optimal parameters. Using these parameters, a travel bag wheel was printed as per the actual design and tested with nylon wheel for compressive strength. The PLA+ wheel showed excellent strength than nylon wheel. Hence, it is recommended that PLA+ material can be used for making travel bag wheels.

REFERENCES

1. Jaya Christiyan KG, Chandrasekhar U, Venkateswarlu K A study on the influence of process parameters on the Mechanical Properties of 3D printed ABS composite. IOP Conf Series: Mater Sci Eng. 2016; 114: 012109.
2. Vishwas M, Basavaraj CK Studies on Optimizing Process Parameters of Fused Deposition Modelling Technology for ABS. Mater Today Proc. 2017; 4, 10994–11003p.

3. Rankouhi B, Javadpour S, Delfanian F, et al. Failure Analysis and Mechanical Characterization of 3D Printed ABS With Respect to Layer Thickness and Orientation. J Fail Anal Prev. 2016; 16: 467–81p.
4. Letcher T, Waytashek M, Material property testing of 3D-printed specimen in PLA on an entry-level 3Dprinter. Proceedings of the ASME 2014 International Mechanical Engineering Congress & Exposition (IMECE2014). Montreal, Quebec, Canada. 2014 November 14-20.
5. Zolfagharian A, Khosravani MR, Kaynak A Fracture Resistance Analysis of 3D-Printed Polymers. Polym. 2020; 12:302p.
6. Li Y, Lou Y Tensile and Bending Strength Improvements in PEEK Parts Using Fused Deposition Modelling 3D Printing Considering Multi-Factor Coupling. Polym. 2020; 12:2497p.
7. Gonabadi H, Yadav A, Bull SJ The effect of processing parameters on the mechanical characteristics of PLA produced by a 3D FFF printer. Int J Adv Manuf Technol. 2020; 111:695–709p.
8. Tafaoli-Masoule M, Shakeri M, Zahedi SA, Vaezi M Experimental investigation of process parameters in polyether ether ketone 3D printing. Proc Inst Mech Eng, Part E: J Pro Mech Eng. 2024; 238(1): 267-79p.
9. Yilmaz S Comparative Investigation of Mechanical, Thermo-Mechanical and Tribological Properties of Commonly Used 3D Printing Materials. Eur J Sci Tech. 2021; 32: 827-31p.
10. Kabir SMF, Mathur K, Seyam A-FM Comparing Performance of 3D-Printed and Injection-Molded Fiber-Reinforced Composite Parts in Ring-Spinning Traveler Application. Techno. 2021; 9(4): 75.
11. Sonaye SY, Mack JP, Tan KT, et al. A comprehensive analysis of high-temperature material extrusion 3D printing parameters on fracture patterns and strength of polyetheretherketone cranial implants. Prog Addit Manuf. 2024. https://doi.org/10.1007/ s40964-024-00688-9.
12. Wang P, Zou B, Xiao H, et al. Effects of printing parameters of fused deposition modeling on mechanical properties, surface quality, and microstructure of PEEK. J Mater Process Technol. 2019; 271: 62-74p.
13. ASTM Standard D695, 2023, Standard test methods for Compressive Properties of plastics. ASTM International, West Conshohocken, PA, 2023.
14. Raj SS, Michailovich KA, Subramanian K, et al. Philosophy of Selecting ASTM Standards for Mechanical Characterization of Polymers and Polymer Composites. Mater Plast. 2021; 58(3): 247-56p.

