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# Experimental investigation on Mechanical properties of 3D printed PLA and ABS materials

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**ABSTRACT**
Fused deposition modelling (FDM) additive manufacturing is a technology that works horizontally and vertically in which an extrusion nozzle moves on a building platform knowing the mechanical properties of the parts manufactured by the FDM method is very important for the parts to work efficiently in places of usage. Additive manufacturing with the FDM method is widespread due to ins advantages such as easy-to-use features, low cost, flexibility in materials options, and less processing after printing. In this paper presents experimental investigation on mechanical properties of Polylactic acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) polymeric composite material using the Fused Deposition Modelling (FDM) method. The printing process parameters such as varies infill density (50% and 70%), with rectilinear pattern. In addition that to maintain constant nozzle temperature, layer height and printing speed to find the tensile, compressive, flexural properties. The results from the experiments clearly shows that the maximum tensile strength of 19.55 MPa,17.03 MPa for 50 % and 22.77 MPa 20.96 MPa for 70 % PLA and ABS respectively. Similarly maximum flexural strengths are obtained 40.13 MPa,31.34 MPa for 50 % and 41.54 MPa,33.10 MPa for 70 % PLA and ABS respectively. Finally Compressive test results showed that maximum values of 40.99 MPa,30.51 MPa for 50 % and 42.23 MPa,32.21 MPa for 70 % PLA and ABS respectively.
***Keywords:*** *ABS, PLA, Tensile, Flexural, Compressive, 3DModeling, FDM*

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## I. Introduction

Fusion Deposition Molding is a 3D printing or Additive manufacturing (AM) is a one of the manufacturing techniquesthathasenteredin bio medical applications as results of ourhuman lifesurvival.Korsay et.al[1] studied the mechanical properties of PLA and ABS material with various infill densities. The results showed that mechanical properties were improved by increasing in infill density at constant printing speed.M.Lay et.al [2] investigated tensile properties such as tensile strength young modules, elongation of PLA, ABS and nylon 6. The results obtained from mechanical testing showed improve the tensile strength, Young's modulus, elongation at break, and impact strength of 3D printing composites were enhanced by 48%, 50%, 48%, and 78%.M.Algarni et.al [3]. Analyzed on four different 3D printing materials PLA,ABS, PEEK, and PETG. The enhancement of mechanical properties results showed that based on infill density, each layer thickness of the filament by using analysis of variance (ANOVA). Xinzhou Zhang et.al [4]. Investigated mechanical properties of polylactic acid (PLA) and copper fiber reinforced PLA composite (Cu/PLA) specimen. Comparative experiments are performed on printed specimens of different angles (0°, 90°, 45°, 0°/90° and ±45°, respectively). Tensile testing, dynamic mechanical analysis (DMA), and fracture surface analysis are employed to characterize all the specimens. S. Muthu Natarajan et.al [5]. fabricated polylactic acid25 wt% and concinna (PLA/25 wt.% AC) composites by using FDM by method. By changing input parameters such as layer thickness, infill density, and printing speed based on Taguchi L9 experimental design. The results showed that improvement of tensile, flexural, and impact tests were conducted on the printed composite samples as per the ASTM standards. Adi Pandzic et.al[6]. studied the mechanical properties, such as tensile strength and elastic modulus, of PLA, Tough PLA and PC by using FDM 3D printed materials with the infill patron are analyzed and compared. Marcin Graba et.al [7].The evaluation of selected mechanical properties of PLA filaments used in the production of unmanned aerial vehicles (UAV). In addition to the assessment of the mechanical properties of the selected filament, and the effectiveness of topological optimization selected PLA filaments. Neville Tay et.al [8]. Studied about the mechanical properties of 3D printed polylactic acid (PLA) parts exposed to UV light, and moisture and kerosene bath, and compares the changes of mechanical strengths with the original samples.A Kholil et.al[9].Investigated on ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid) materials. Based on the test mechanical test results, ABS specimens with a layer thickness of 0.10 mm showed the maximum impact strength with 0.078 J/mm², while the minimum impact strength was found in PLA specimens with a layer thickness of 0.20 mm and 0.30 mm with an impact strength of 0.047 J/mm². The value of impact strength on ABS and PLA materials varies with each layer thickness change. Dragos Gabriel Zisopol et.al [10]. Studied the influence of printing parameters on the flexural strength of PLA (Polylactic Acid) and ABS (Acrylonitrile Butadiene Styrene) printed samples, by applying the Taguchi method and ANOVA (Analysis of Variance) of 3-point bending tests results. Shady Farah et.al [11]. Studied variations in mechanical properties during PLA processing i.e., thermal degradation and recyclability, biodegradation, packaging and sterilization, and aging i.e., weathering and hygrothermal.Piotr Sikora et.al [12]. Analyzed hardness values of polymeric materials such as TPU - Thermoplastic Polyurethane Elastomer, ABS - Acrylonitrile-Butadiene-Styrene copolymer, Lay wood, PET - ethylene terephthalate, PLA - Poly Lactic Acid.

## II. Materials and Methods

### 2.1 PLA

PLA (poly lactic acid) is a new type of biodegradable material made from starch raw materials extracted from renewable plant resources. Due to its good processability and biodegradability, PLA 3D printer filament has become one of the most commonly used 3d printing materials

### 2.2 Acrylonitrile Butadiene Styrene (ABS)

The acrylonitrile in ABS plastic provides chemical and thermal stability, while the butadiene adds toughness and strength. The styrene gives the finished polymer a nice, glossy finish. ABS has a low melting point, which enables its easy use in the injection molding process and 3D printing.

### 2.3 Fused Deposition Modelling (FDM)

From Fig 2.1shows the FDM machine's working principle is to heat the filament on the nozzle to reach a semiliquid state and then extruding it on a plate or layer that was previously printed.

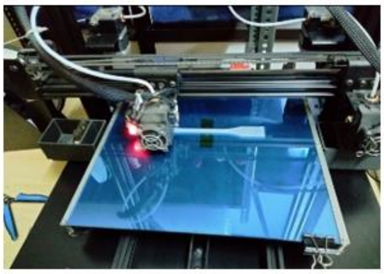

**Figure 2.1Materials printing in FDM**

### 2.4TensileTest

Tensiletestwasconductedinatestmachine(AGS-X,Shimadzu Co., Kyoto, Japan)with a 10 kNforce transducercapacity as shown in Figure 2.2Tensile test employed two grips(one fixed grip and one movable grip) to hold the specimens, thespecific testing parameters for the tensile test were carried out ata pull rate of 1 mm/s.


**Fig2.2ImagesofallcomponentsofTensilestrengthtest;a)PLAspecimensb)ABSspecimensc)experimentalsetup**

**2.5Flexural Test**

Flexural testwasconductedinatestmachine(AGS-X,Shimadzu Co., Kyoto, Japan)with a 10 kNforce transducercapacity as shown in Figure 2.3Flexural test employed three grips(two ends fixed middle load applied to the specimens, thespecific testing parameters for the flexural test were carried out ata pull rate of 1 mm/s.

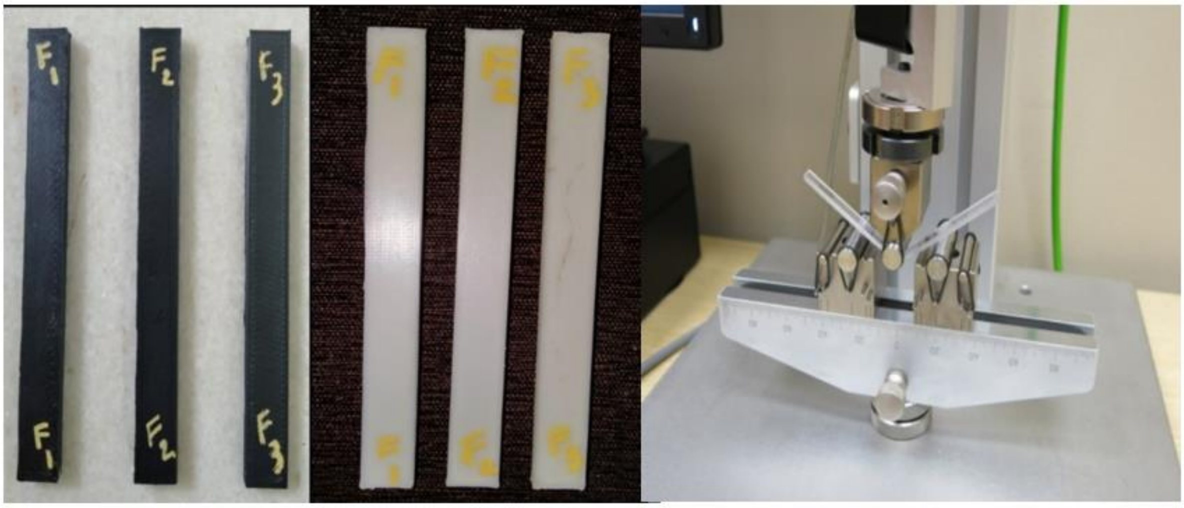

**Fig2.3ImagesofallcomponentsofFlexural test**
**a)PLAspecimensb)ABSspecimensc)experimentalsetup**

**2.6Compression Test**

compressive testwasconductedinatestmachine(AGS-X,Shimadzu Co., Kyoto, Japan)with a 10 kNforce transducercapacity as shown in Figure 2.3Flexural test employed three grips(two ends fixed middle load applied to the specimens, thespecific testing parameters for the flexural test were carried out ata pull rate of 1 mm/s.

**Figure2.4Imagesofallcomponentsofcompressivetest;**
**PLAspecimensb)ABSspecimensc)experimentalsetup**

## III. Result and Discussions

**3.1Tensile strength**

The tensile strength test results obtained from the experimental testing as shown in Fig 3.1.It is seen that PLA 50% and 70% material samples have higher strength values than ABS samples. This is due to thefact that the bond provided between the layers in the samplemanufacturing process is better for PLA material samples thanABS samples. In Figure 3.2, it is seen that the tensile strength and tensile modules ofboth PLA and ABS material samples increased partially as the fillrate 50% to 70% ofthe samplesincreased.

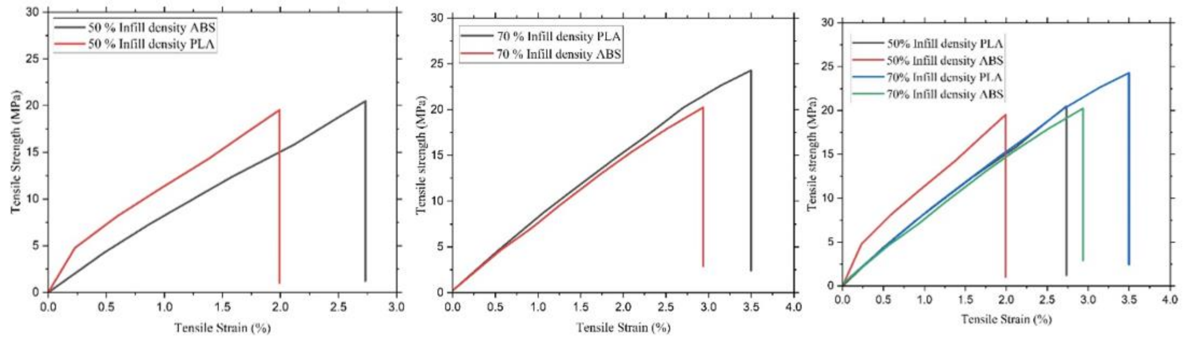


**Fig 3.1 Tensile stress Vs Tensile strine for 50% and 70% PLA and ABS**

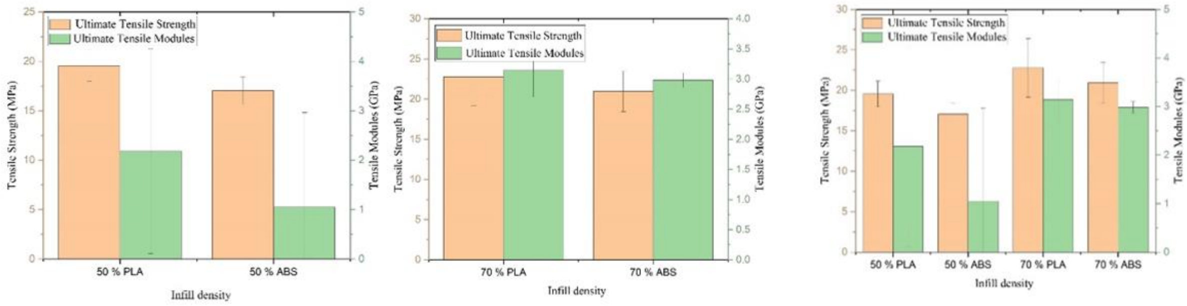


**Fig 3.2 Tensile stress Vs Tensile modules for 50% and 70 % infill density PLA and ABS**

**3.2Flexural strength**

The 3-point bending test results obtained from experimental flexural testing as shown i Figure 3.3 shows the flexural stress – flexural strain diagrams of 50% and 70% infill density PLA and ABS manufactured from different parameters.It is seen that PLA-containing samples have higher bending strength values than ABSsamples. This is due to differences in the molecular structure ofthese materials and differences in the number of branches andfunctional groups of polymers. PLA has a $CH_3$and $O_2$groupsubstitutesinmaterials.

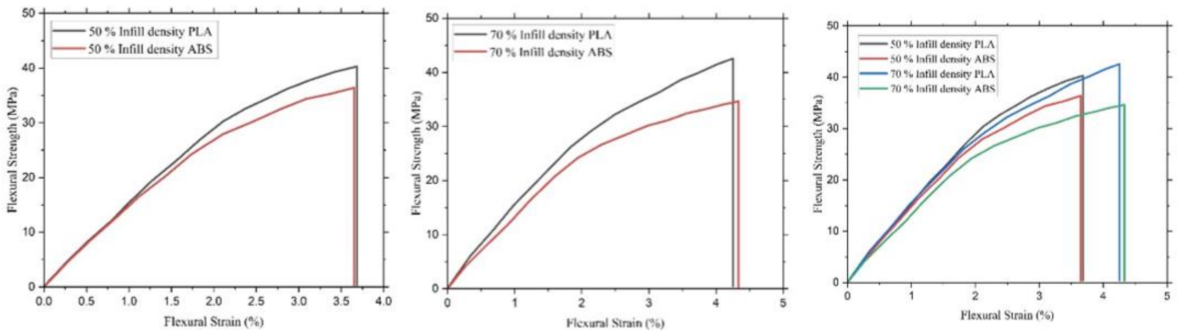


**Fig 3.3 Flexural stress Vs Flexural strine for 50% and 70% PLA and ABS**

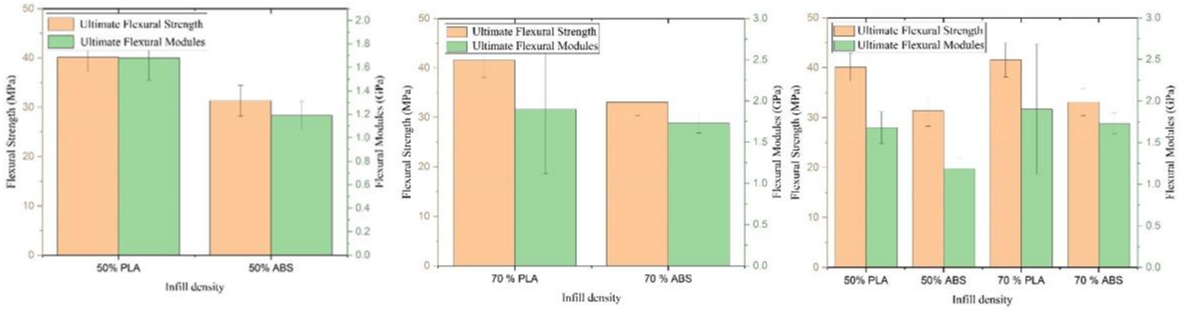


**Fig 3.4Flexural stress Vs Flexural modules for 50% and 70 % infill density PLA and ABS**

### 3.3 Compressive test

Compressiontestresultsobtainedfromthecompressive testing machine as shown in Fig 3.5 Withtheexaminingthecompressive stress – compressive strain ofvalues. ItisseenthatPLA material samples have higher compressive strength values thanABS samples. This is due to the differences in the molecularstructure of these materials and differences in the number ofbranches and functional groups of polymers. PLA has a $CH_3$ and$O_2$groupsubstitutesinmaterials.Thisaffectsthechainentanglementin PLAandincreasestheglasstransitiontemperature. In addition, as the fill rate increased in PLA and ABSsamples,itwasobservedthatthesampleswerestackedandshortened in the longitudinal section without spreading in thecross section as a result of the compression test. In Figure 3.6, asthefillrateofthesamplesdecreased,thecompressive strengthofboth PLA and ABS material increased partially. However, theductility of ABS material shows the rigidity of ABS material andcanalsobeexpressed asitsresistanceto elasticstretching.

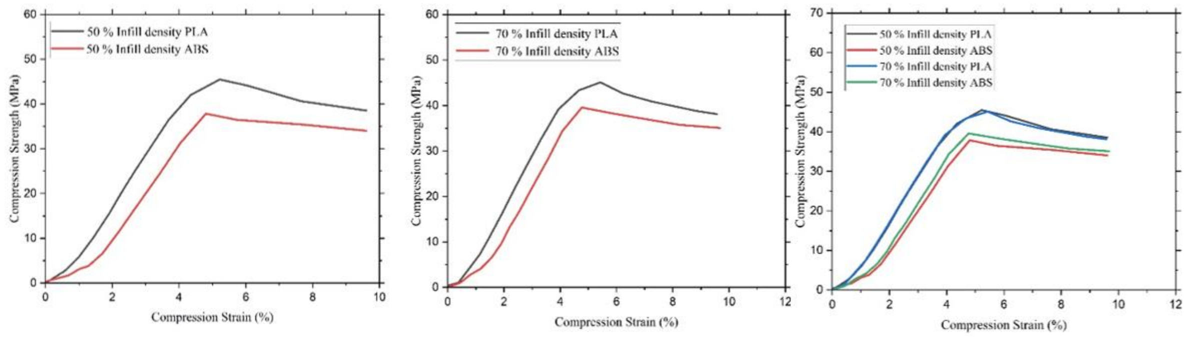


**Fig 3.5 Compressive stress Vs Compressive strine for 50% and 70% PLA and ABS**

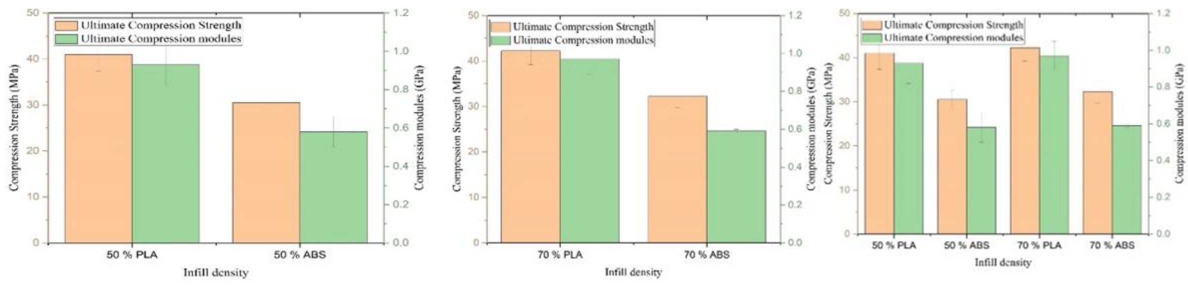


**Fig 3.6 Compressive stress Vs Compressive modules for 50% and 70 % infill density PLA and ABS**

## IV. Conclusion

In this project studied experimental investigation on mechanical properties of PLA and ABS specimens produced with 50% and 70% infill density through a FDM additive manufacturing technique. The direct effects of parameters such as layer thickness, nozzle temperature and bed temperature are taken as constant. The mechanical properties such as tensile, flexural and compressive of PLA and ABSmaterials are also compared. According to the findings obtainedfromtheexperimentalresults,ithasbeenobservedthatthe increase in the infill density 50% and 70% improves the mechanical properties.

- The tensile test specimen made of PLA with 50% infill density obtained maximum tensile strength, young's modulus, and tensile strain are 19.55 MPa, 1.08 GPa and 8.28% respectively. Similarly, PLA with 70% infill density specimen have the maximum tensile strength, young's modulus, and tensile strain are 22.77 MPA, 3.14 GPa and 9.20% respectively.
- The tensile test specimen made of ABS with 50% infill density obtained maximum tensile strength, young's modulus, and tensile strain are 17.03 MPa, 2.07 GPa and 8.49 % respectively. Similarly, ABS with 70% infill density specimen have the maximum tensile strength, young's modulus, and tensile strain are 20.96 MPA, 0.12 GPa and 0.20% respectively.
- The flexural test specimen made of PLA with 50% infill density obtained maximum flexural strength, flexural modulus, and flexural strain are 40.13 MPa, 1.68 GPa and 4.11 % respectively. Similarly, PLA with 70% infill density specimen have the maximum flexural strength, flexural modulus, and flexural strain are 41.54 MPA, 1.73 GPa and 4.76 % respectively.
- The flexural test specimen made of ABS with 50% infill density obtained maximum flexural strength, flexural modulus, and flexural strain are 31.34 MPa, 1.19 GPa and 8.82 % respectively. Similarly, ABS with 70% infill density specimen have the maximum flexural strength, flexural modulus, and flexural strain are 33.10 MPA, 1.90 GPa and 9.04 % respectively.
- The compressive test specimen made of PLA with 50% infill density obtained maximum compressive strength, compressive modulus, and compressive strain are 40.99 MPa, 0.93 GPa and 6.27 % respectively. Similarly, PLA with 70% infill density specimen have the maximum compressive strength, compressive modulus, and compressive strain are 42.23 MPA, 0.97 GPa and 6.34 % respectively.
- The compressive test specimen made of ABS with 50% infill density obtained maximum compressive strength, compressive modulus, and compressive strain are 30.51 MPa, 0.58 GPa and 25.73 % respectively. Similarly, ABS with 70% infill density specimen have the maximum compressive strength, compressive modulus, and compressive strain are 32.21 MPA, 0.59 GPa and 25.98 % respectively.
- The tensile, flexural and compressive properties increase belong to test specimens made ofPLA material with infill density increases from 50% to 70% as compared to ABS materials.
- The lowest mechanical properties obtained in test specimen made of ABS material with infill density increases 50% to 70% has compared to PLA material because of the ABS material does not carry the loads until reaches the maximum failure. In addition, that interface regions between the matrix and ABS are very weaker section.

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