International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 07 | July 2019 www.irjet.net p-ISSN: 2395-0072

Effect of Gasoline Exposure on the Mechanical Properties of PLA and ABS Material Processed by Fused Filament Fabrication (FFF)

Bagwan Muhammed Haris Mushtaq[1]

[1]*U.G Mechanical Engineering Student, Zeal College of Engineering and Research, Pune*

Abstract - *As the market for Additive Manufacturing (AM) and Rapid Prototyping (RP) is growing at an unprecedented rate, the Fused Filament Fabrication (FFF) better known by the general term 3D printing has become the most widely adopted technique. A wide array of thermoplastic materials can be used as filaments for this process, but the two materials PLA and ABS clearly standout to be the most preferred ones. The components manufactured by Fused Filament Fabrication find their application in a wide area and as the field of their application is getting broadened day after day, they might come in direct or indirect contact with gasoline. That is why it is imperative to study the effect that gasoline exposure has on their mechanical properties, in order to determine their compatibility in such applications. The aim of this study is to compare the test results of gasoline exposed standard specimens on properties like tensile strength, flexural strength, hardness, etc. with the unexposed ones and with each other.*

Key Words: **acrylonitrile butadiene styrene (ABS), fused deposition modeling (FDM), gasoline, mechanical properties, polylactic acid (PLA), rapid prototyping.**

1. INTRODUCTION

Additive Manufacturing is a method of building components by layer-by-layer addition of material, as opposed to removal of material in subtractive manufacturing which involves removal of material in a similar fashion. There are many methods of additive manufacturing like Selective Laser Sintering (SLS), Photopolymerization, Stereolithography (SLA), etc...But the most popular method among these is the Fused Filament Fabrication (FFF), or Fused Deposition Modeling (FDM), or well-known by the stylized term 3D printing. It is more widely adopted because of the development of cost effective 3D printers and their seamless integration with most CAD modeling packages. It involves heating of thermoplastic materials in form of filaments till their semi-solid phase, this is then deposited layer-by-layer on a bed till the fabricated component does not confirm to its CAD model. The first step is CAD modeling of the component, and then the conversion of this file into the standard 'STL' file format is done. This format is accepted by most commercially available 3D printers. The orientation of the part to be printed is set and then the printer starts printing the component according to the CAD model data. The parts or components fabricated by this method find their application in a very broad range of engineering applications. It may occur that a component manufactured by this method in some application is required to interact with gasoline, directly or indirectly. In that case the interaction of gasoline and the material in use need to be known beforehand. This can be studied by exposing the material to gasoline and determining the change in the mechanical properties of the material, as the manufactured components maybe be used a structural components. Among the many materials that can be used in Fused Filament Fabrication, ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid) are the most widely used materials. The aim of this research is to determine the compatibility or suitability of these materials for applications which involve their interaction with gasoline, by evaluating their mechanical properties after complete exposure to gasoline.

2. MATERIALS AND EQUIPMENT

2.1 Materials

The material specifications of PLA and ABS filament, as provided by the manufacturer, are given in the table below.

Material	Filament Diameter	Dimensional Accuracy	Tensile Strength
PLA	1.75mm	+/- 3% of diameter	51 MPa
ABS	1.75mm	+/- 3% of diameter	51.48 MPa

Table 1: Properties of material filament

2.2 Equipment

A 3D printer manufactured by Flashforge was used to print the specimens, the model name the 3D printer is 'Adventurer 3'. The specifications as provided by the manufacturer are as given in the table below.

Parameter	Value
Positioning Accuracy	Z axis 0.0025mm XY axis 0.011mm
Printing Accuracy	0.1mm
Layer Thickness	0.1-0.4mm
Building Size	150x150x150mm
Nozzle Diameter	0.4mm
Build plate temp.	Max. 100°C

Table 2: Printer Specifications

3. SPECIMEN SPECIFICATIONS

3.1 Effect of build orientation on the specimen

A substantial amount of research on the topic of variation in properties of components manufactured due to variation in the build angle or orientation can be found from many sources. A paper published by Mst Faujiya Afrose, S.H. Masood, Mostafa Nikzad, and Pio Iovenitti in the year 2014 titled “Effects of Build Orientations on Tensile Properties of PLA Material Processed by FDM” gives us a clear idea about the variation in the tensile properties of PLA material due to build orientation [1]. This paper establishes that build orientation has a significant impact on the strength of PLA, and that parts built in X-orientation (along X-axis) are much stronger than those built in Y-orientation (along Y-axis) [1]. It also concludes that parts built in [+45/-45] (diagonal) orientation, retain 60-65% strength of the raw material [1]. A conference paper authored by R. Hernandez, D. Slaughter, D. Whaley, J. Tate, and B. Asiabanpour from the proceedings of the 26th Annual International Solid Freeform Fabrication Symposium in the year 2016, has dealt with a similar study on the ABS material [2]. It states that the effect on the tensile properties of ABS due to build orientation is negligible, but significant on the flexural properties [2]. A similar study conducted by Adrián Rodríguez-Panes, Juan Claver and Ana María Camacho in the paper titled “The Influence of Manufacturing Parameters on the Mechanical Behavior of PLA and ABS Pieces Manufactured by FDM: A Comparative Analysis” supports the findings mentioned in the paper by R. Hernandez et al., it concludes that the variation in properties of ABS were negligible as compared to that of PLA [3]. These findings are of great importance to this paper, as it will be only reasonable to compare results of components that are manufacture in the same build orientation.

3.2 Specimen dimensions

The specimens under test were designed according to the ASTM standards of plastic material testing. The tensile test specimen which resembles a dog-bone follows the standards mention in the ASTM D638 Type-I [4] code. The specimen for flexural test follows the standards under the code ASTM D790 [5] for 3-point flexural test.

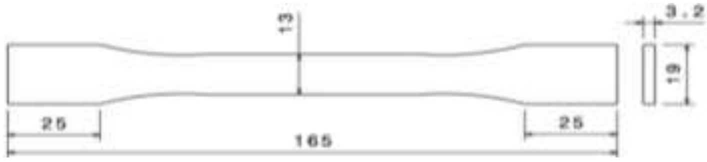

Figure 1: Tensile test specimen (All dimensions are in mm)

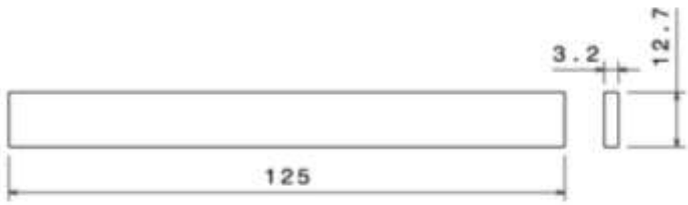

Figure 2: Flexural test specimen (All dimensions are in mm)

3.3 Build orientation

Build orientations for both the specimen were [+45/-45] flat, because of their long length as compared to the build space of the 3D printer. The axis of the specimens lies in 45 degrees from both the axes.

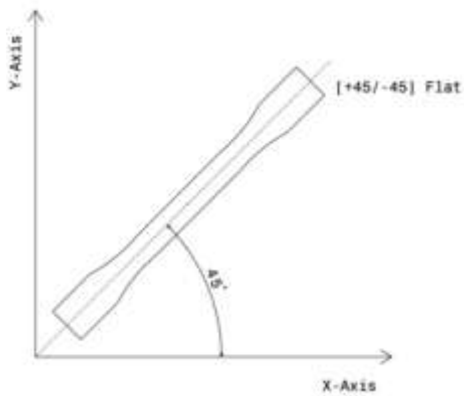

Figure 3: Build orientation of tensile specimen

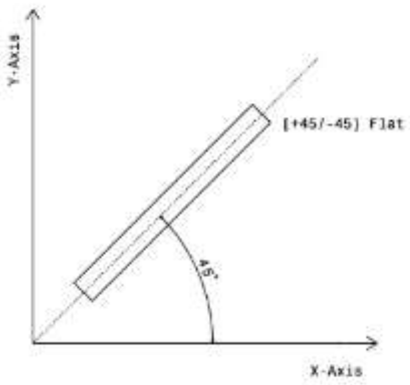

Figure 4: Build orientation of flexural specimen

4. METHODOLOGY:

As the aim of this study is to investigate the effects of gasoline exposure on the mechanical properties of the materials, proper exposure to gasoline of the specimens was necessary. It was observed that both the materials absorbed gasoline as time passed. So the specimens were kept submerged in gasoline until they were saturated. The time that they were kept under gasoline was 84 hours. Visual observation suggested that ABS had become soft like rubber, while PLA had also lost a little rigidity. After 84 hours the specimens were tested on a Universal Testing Machine (UTM) and a 3-point flexural testing machine. Their hardness was also checked post exposure to gasoline.

5. RESULTS AND COMPARISON

The test result for tensile test, flexural test, and hardness test after submersion in gasoline for 84 hours are given in the table below.

Table 3: Test results

Test	Unit	PLA	ABS
Tensile Strength	MPa	9.01	0.21
Flexural Strength	MPa	16.56	0.33
Hardness	Shore A	92-93	24-25

*These results relate to the specimens designed according to ASTM standards and with infill - 100%, Speed-50 mm/s, Raster angle - 90° and layer height-0.2mm

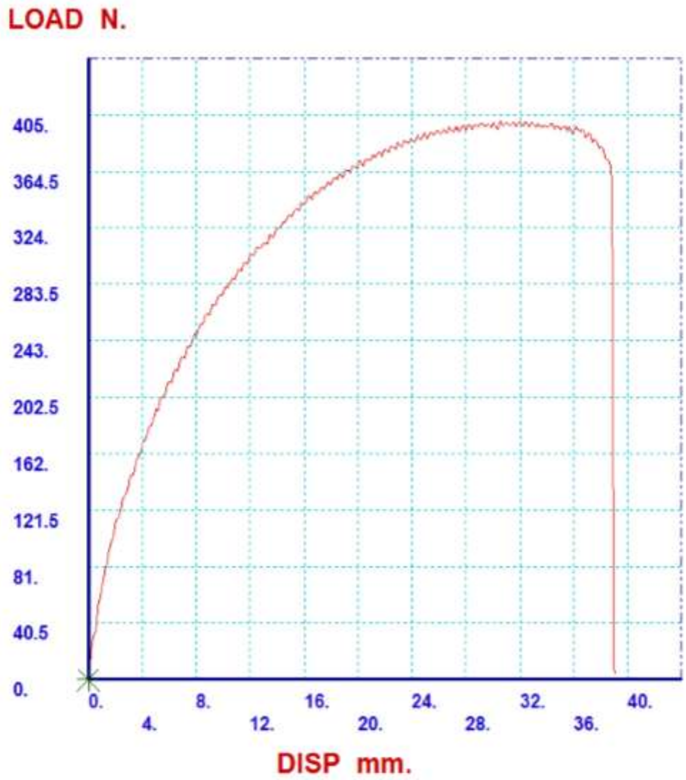

Figure (a): Graph of Load vs. Displacement for PLA

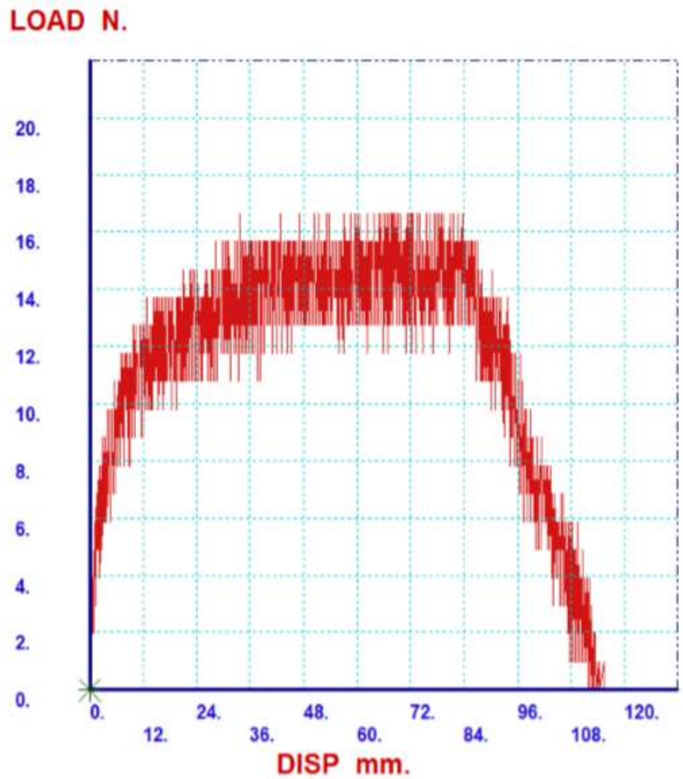

Figure (b): Graph of Load vs. Displacement for ABS

Comparison of the test results of gasoline exposed specimens with the un-exposed ones will give us an idea of how much the results vary. For this comparison test data from published papers needs to be taken. As previously stated that the properties of material vary due to build orientation [1, 2, 3], the data relevant to the build orientation that has been used for the above tests must be used that is of [+45/-45] flat build orientation, their parameters such as infill percentage and layer height need to be considered as well.

PLA

The value of tensile strength from the result table of paper authored by Mst Faujiya Afrose et al. for [+45/-45] flat specimen is 33.63 MPa [1]. Therefore there is a loss of 24.62 MPa; percentage decrease of 73% is observed.

The value of flexural strength from the result table of paper authored by J.M. Chacon, M.A. Caminerob, and E. Garc´ıa-Plazab for flat specimen is 46.0 MPa [6]. Therefore there is a loss of 29.44 MPa; percentage decrease of 64% is observed.

ABS

The average value of tensile strength from the result table of paper authored by R. Hernandez et al. for [+45/-45] flat specimen is 9.46 MPa [2]. Therefore there is a loss of 9.25 MPa; percentage decrease of 97% is observed.

The average value of flexural strength from the result table of paper authored by R. Hernandez et al. for [+45/-45] flat specimen is 99.6 MPa [2]. Therefore there is a loss of 99.27 MPa; percentage decrease of 99.6% is observed.

Table 4: Comparison of loss of strength

Material	Loss of Tensile Strength in MPa	Loss of Flexural Strength in MPa
PLA	24.62 (73)	29.44(64)
ABS	9.25(97)	99.27(99.6)

*Figures in parenthesis indicate percentage loss of strength as compared to unexposed specimens.

Hardness test figures indicate that ABS has become very soft as it score only 23-24 on Shore A scale, while PLA has retained its hardness with a 92-93 score on the Shore A scale.

6. CONCLUSION

It is clear from the results that exposure to gasoline has its effect on both the materials, but a more adverse effect can be observed on ABS material. PLA has lost 73% and 64% of its tensile and flexural strength respectively, but ABS has lost 97% and 99.6% of its tensile and flexural strength respectively. It can be said that ABS has completely lost its strength and can be said to have 'failed'. It has also become soft, while PLA has retained its hardness. It is concluded that ABS is seriously incompatible in applications involving direct or indirect contact with gasoline.

REFERENCES

[1] Mst Faujiya Afrose, S.H. Masood, Mostafa Nikzad, and Pio Iovenitti (2014), Advanced Materials Research, Effects of Build Orientations on Tensile Properties of PLA Material Processed by FDM, Vols 1044-1045 (2014) pp 31-34

[2] R. Hernandez, D. Slaughter, D. Whaley, J. Tate, and B. Asiabanpour (2016), ANALYZING THE TENSILE, COMPRESSIVE, AND FLEXURAL PROPERTIES OF 3D PRINTED ABS P430 PLASTIC BASED ON PRINTING ORIENTATION USING FUSED DEPOSITION MODELING, Solid Freeform Fabrication 2016: Proceedings of the 26th Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference

[3] Adrián Rodríguez-Panes, Juan Claver and Ana María Camacho (2018), Materials 2018, 11, 1333, The Influence of Manufacturing Parameters on the Mechanical Behavior of PLA and ABS Pieces Manufactured by FDM: A Comparative Analysis

[4] ASTM D638-14. (2014). Standard Test Method for Tensile Properties of Plastics. West Conshohocken, PA, United States: ASTM International

[5] ASTM D790-10. (2010). Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. West Conshohocken, PA, United States: ASTM International

[6] J.M. Chac´on, M.A. Caminero, E. Garc´ıa-Plaza, P.J. N´u˜nez, Additive manufacturing of PLA structures using fused deposition modelling: effect of process parameters on mechanical properties and their optimal selection, (2017), doi: 10.1016/j.matdes.2017.03.065).

BIOGRAPHY

Bagwan Muhammed Haris Mushtaq
Diploma Mechanical Engineer And B.E Mechanical Engineering Student At Zeal College Of Engineering And Research, Pune.