

Preparation and Characterization of Poly Lactic Acid (PLA) & Acrylonitrile Butadiene Styrene (ABS) Using Different 3D Printing Angles

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ABSTRACT: The conventional manufacturing process involves removing material to get desired shape which is called as subtractive manufacturing. Whereas Three-dimensional (printing is an additive manufacturing method in which a 3D item is formed by laying down successive layers of material. 3D printers are machines that produce representations of objects either planned with a CAD program or scanned with a 3D scanner. Acrylonitrile butadiene styrene (ABS) 'is a common thermoplastic polymer. It is amorphous and therefore has no true melting point. ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The most important mechanical properties of ABS are impact resistance and toughness. Polylactic Acid (PLA) plastic is a thermoplastic polymer that softens when heated and hardens when cooled. It is made from renewable resources, such as corn starch and sugarcane. PLA plastic is commonly used as filament in 3D printing to create 3D printed parts.

The work presented in this paper, is a comprehensive effort undertaken to study the tensile strength and wear strength compression strength and shear strength of thermoplastics like ABS, PLA obtained from the same 3D printing technology for different printing angles. PLA and ABS material were prepared by 3D printing technology. The specimens were prepared according to ASTM standards.

KEYWORDS: ABS, PLA, ASTM standards, tensile test, wear test, 3D printing technology.

I. INTRODUCTION

3d-printers have become affordable for the dedicated home user. In fact, there are many high quality 3d-printers for under\$3000 – complete with dual extruders and a heated build surface. Many of these consumer level 3d-printers are being sold As printers that print using the material Poly Lactic Acid (PLA) as opposed to the more traditional, but more difficult to print with, Acrylonitrile Butadiene Styrene (ABS) material. PLA is stronger than ABS, but more brittle. PLA has a lower coefficient of thermal expansion, which reduces the effects of warping, not adhering to the printed surface, and large parts cracking as they are printed. PLA also does not have the same health risks as ABS when printing in improperly ventilated spaces . The most glaring disadvantage of PLA is the lower deflection temperature under load (50 to 140°C), which will cause printed parts to deform when exposed to warm environments.

With all of this in mind, it is easy to understand why many 3d-printer manufacturers are producing and supporting 3d-printerthat print exclusively using PLA. Many people are now, and many more people will soon be printing in PLA in their own homes with personal 3d printers. Maker Bot alone has sold more than 15,000 3d-printers in the last5 years . Material properties and characteristics of ABS have been well studied, including many studies that test print orientations . Most of these studies were performed on the“ professional” model machines. Consumer machines print quality has been largely untested for ABS, and literature describing material property characteristics of 3d-printed PLA could not be found. This study aims to begin to understand the behavior of 3d-printed PLA from a consumer level 3d-printer.Specimen were printed to study tensile strength, flexural strength, and fatigue, along with the filament also being tensile tested. By default, if the Maker Ware software, used by the Maker Bot line of 3d-printers, is told to print a specimen/object at 100% infill, the slicing software will print in alternating raster orientations, layer by layer. A custom

printing profile was written to print the specimen entirely in a single raster orientation for each specimen to examine printing orientation as it relates to material anisotropy.

Several types of mechanical property testing were conducted on PLA filament and specimens that were 3d-printed using PLA. All specimen were printed on a consumer level 3d-printer, the Maker Bot Replicator 2x. Custom printing profiles were used to control the slicing/printing software which allowed printing in a single specified raster orientations for the entire Specimen.

Each specimen was printed individually at the center of the printing bed in order to produce all specimen as similarly as possible. For all specimen, two "shells" were used on the perimeter of the specimen and the inside of the specimen was printed with 100% infill at specified raster orientations. The PLA material was extruded at 230°C at a speed of 100mm/sec with the heated bed surface at 65°C. All specimen were printed with the same generic brand of PLA filament from two 1-kg spools purchased together. Figure 1 shows the raster orientations tested and their definitions.

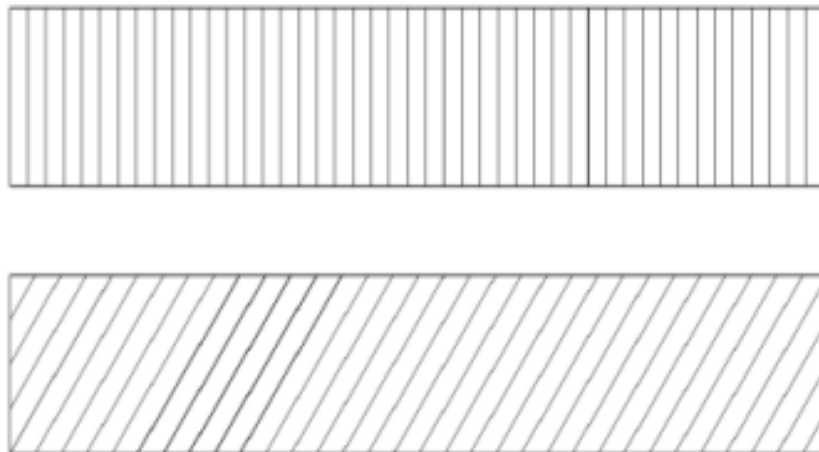


Figure 1: Specimens for 90 and 45 raster angle

II. PROBLEM DEFINITION

Oral health ailments are rampant among the masses as 95 per cent of adults suffer from gum diseases. 50 percent in the country do not use tooth brush. Nearly 77 percent have not visited the dentist in the past one year. 70 percent of children under the age of 15 have dental caries. Nearly 53 percent Indians suffer from common tooth problems such as bleeding gums, bad breath, sensitive teeth & decays teeth.

To overcome all the above said problems, in our study we are doing comparative study of PLA and ABS materials are selected and carried out 3D printing for different raster angles. Mechanical characterization like, tensile, wear and chemical tests are carried out which are very essential properties required in materials used in dental applications.

III. METHODOLOGY

- Selection of suitable material.
- Procurement material in the filament form.
- Preparation of CAD models using CAT-IA or Unigraphics according to ASTM standards.
- Printing of the material in the true filament form according to ASTM standards using FDM 3D printing technology.
- Characterization of specimens.
 - Tensile Test using UTM
 - Wear test using pin on disc method
 - Compression test
 - Chemical Test

Objectives:

- 1) Preparation of materials by using 3D printing for different raster angles according to ASTM standards.
- 2) Characterization of printed materials for tensile and wear strength and validating the results using FEM.

Mechanical Characterizations

1) Tensile Test:

a) Tensile Test Results for ABS Material

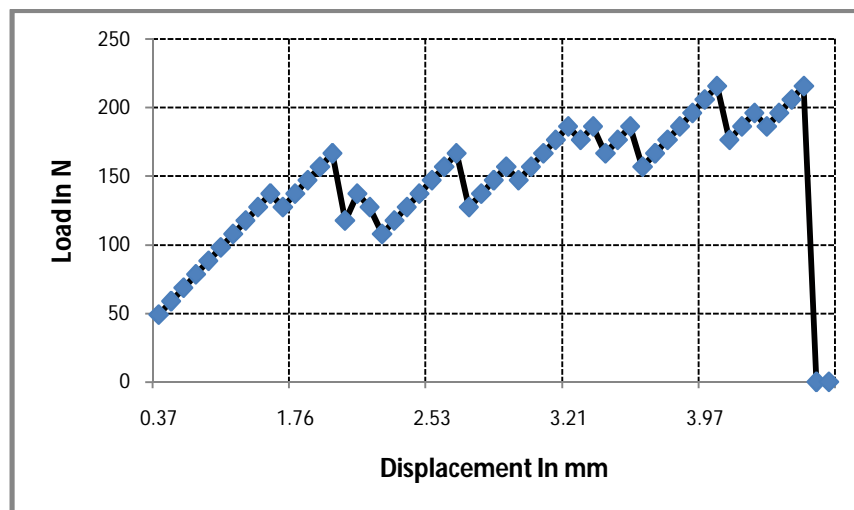


Figure.2: Load v/s Displacement curve for ABS 45° raster angle

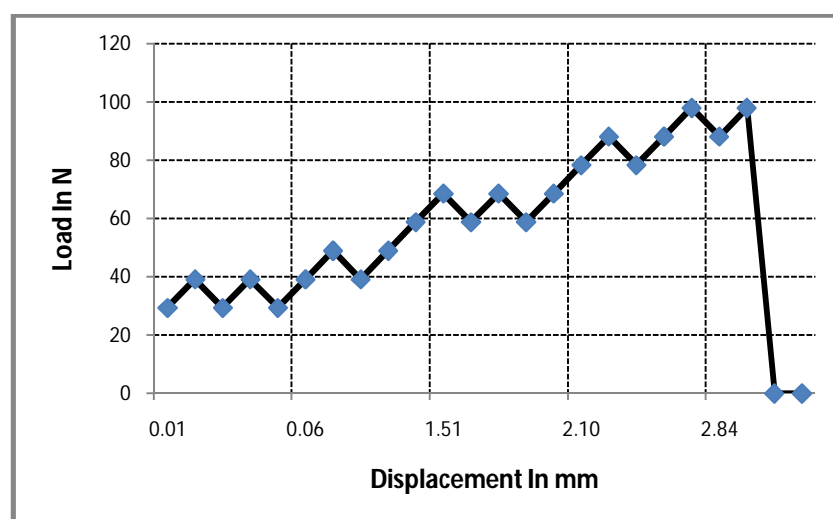


Figure.3: Load v/s Displacement curve for ABS 90° raster angle

Finite Element Analysis of ABS Materials

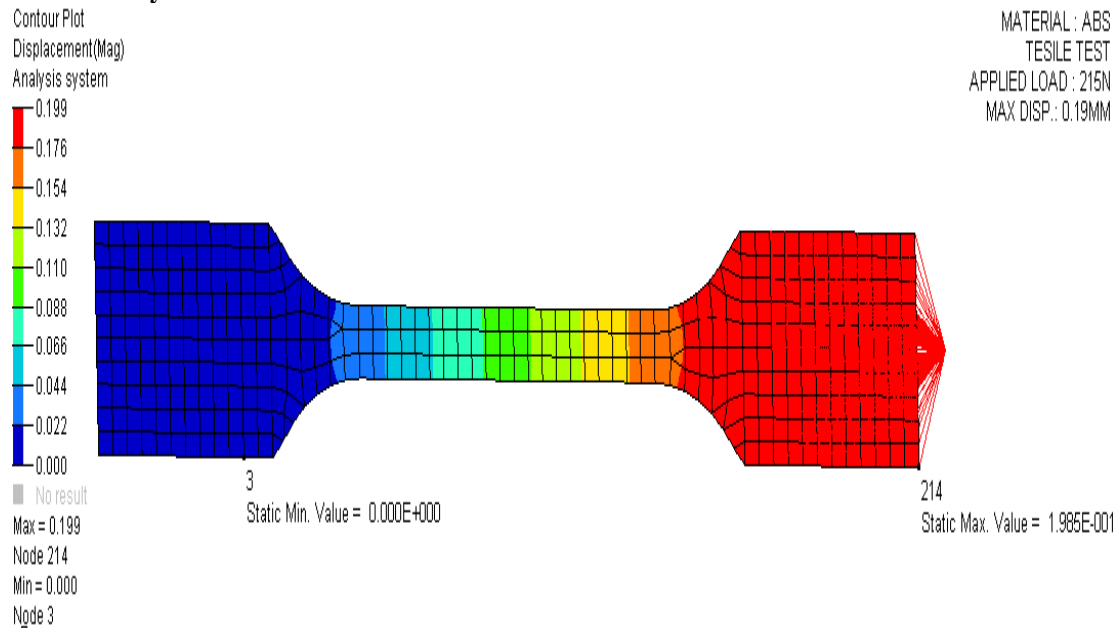


Figure.4: FEA result for ABS Material

b) Tensile Test Results for PLA Material

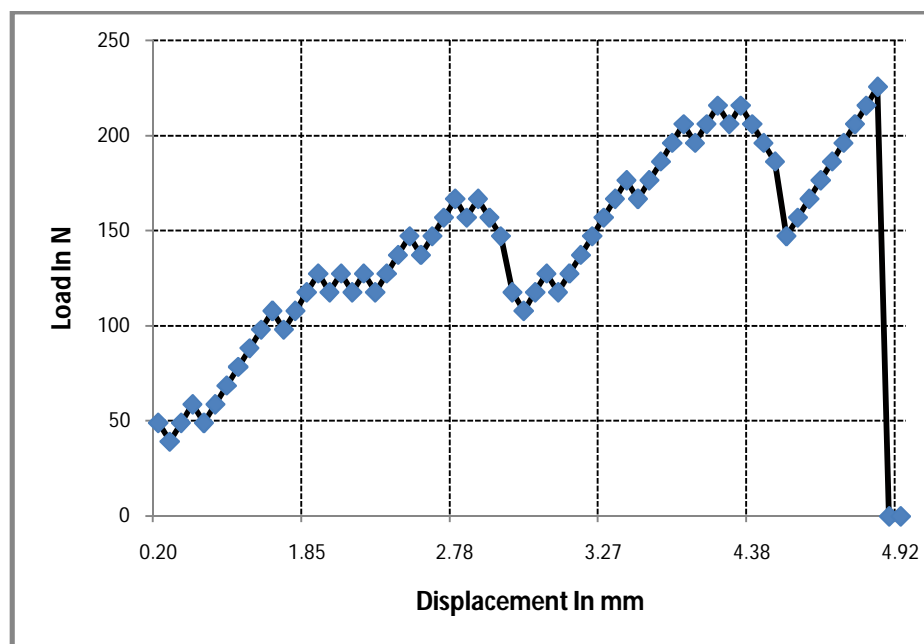


Figure.5: Load v/s Displacement curve for PLA-90° raster angle

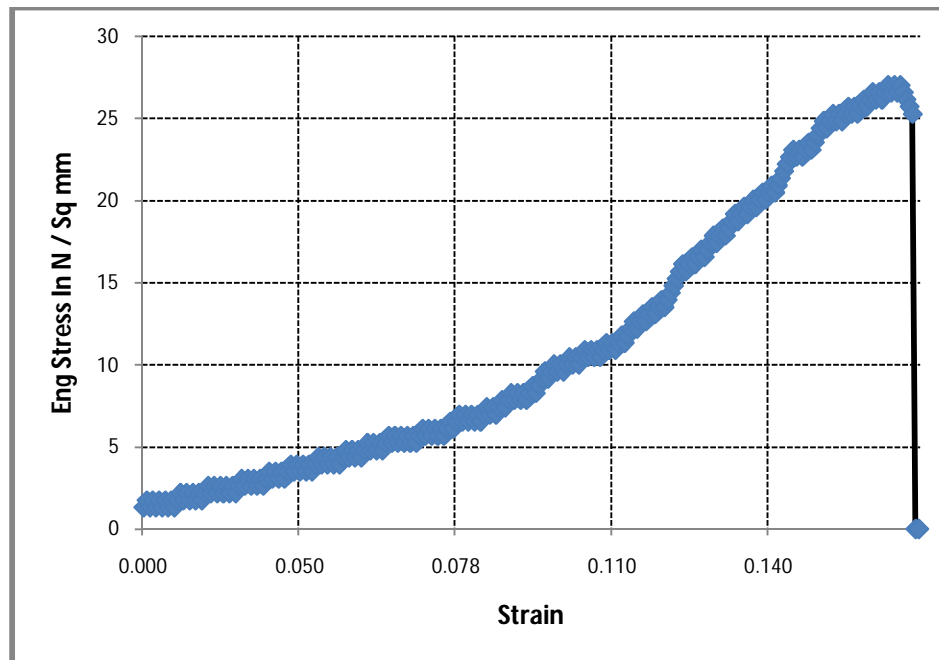
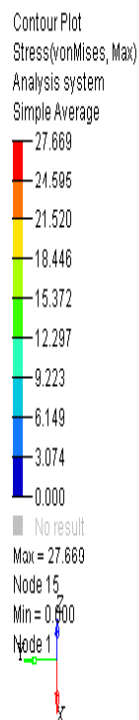


Figure.6: Stress v/s Strain curve for PLA-45° raster angle



Model info: E:\SIDDHARTH\pla_nas\pla_tensile_rect\pla tensile rect shape.op2
Result: E:\SIDDHARTH\pla_nas\pla_tensile_rect\pla tensile rect shape.op2
SUBCASE 1 = NL : 100.00 % of Load
Frame 1 : Angle 0.000000

Figure.5: FEA result for PLA Material

Comparison of tensile test results PLA and ABS materials

Table 1: Comparison of Tensile test results for ABS and PLA

Material	Raster angle	Break load(N)	Ultimate tensile loads(N)
ABS	90°	98.1	98.1
	45°	215.8	215.8
PLA	90°	225.6	225.6
	45°	568.8	608

2) Wear Test Results: Using Pin on Disc Method

Material	Max. Load Applied in Kg's	Initial Weight (Grams)	Final weight (Grams)	Weight Loss in (Grams)
ABS	2.4	1.77	1.70	0.07
PLA	2.4	1.98	1.92	0.06

Table 2: Wear test results for ABS and PLA

IV. CONCLUSION

ABS and PLA printed specimen mechanical properties were tested. For tensile testing, it was observed that the 45° raster orientation specimens were the strongest when compared to 90° raster angle. The ultimate tensile load taken by the PLA is 568.8N for 45° raster angle which is three times greater than ABS material.

From wear test it has been observed that for both the materials under same load of 2.4 kg's the rate of wear is approximate the same that is 0.07 and 0.06 grams as shown in the table 2.

So we can conclude that PLA is has very good tensile load bearing capacity when compared to ABS. From the wear strength point of view there is no much difference in rate of wear.

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