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# ENHANCED ANISOTROPIC STRUCTURAL EVALUATION OF FUSED FILAMENT FABRICATED (3D-PRINTED) SPECIMENS FOR MECHANICAL APPLICATIONS

**Dr. G. Ramakrishna[1] P.Mutyalarao[2], U.Sriram[3],**

**V.Durgaprasad[4], Y.V.V.Bulliyya[5]**

*Associate Professor, Department of Mechanical Engineering, Godavari Institute of Engineering & Technology (Autonomous), Rajahmundry, A.P,India.[1]*

*Department of Mechanical Engineering, Godavari Institute of Engineering & Technology (Autonomous), Rajahmundry, A.P, India.[2,3,4]*

## ABSTRACT

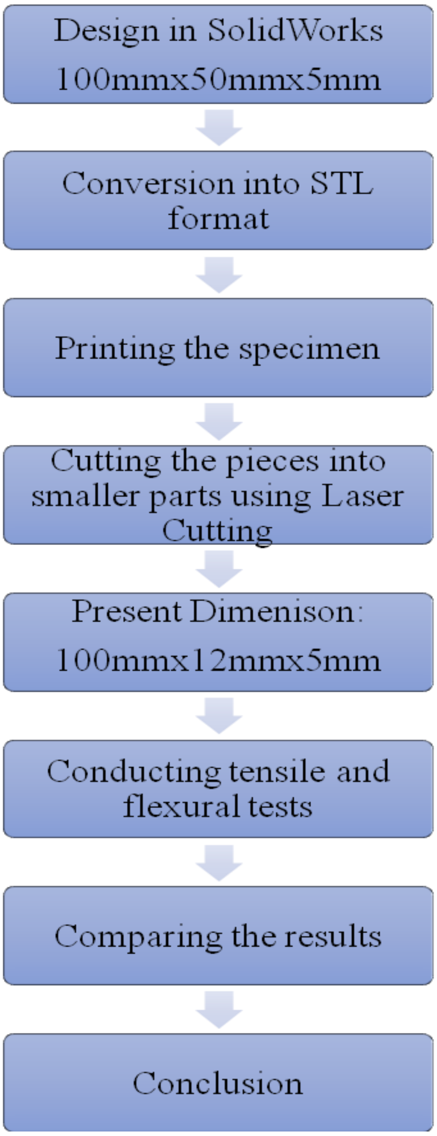
Polymer additive manufacturing has been commonplace in a variety of industries over the last decade. It's possible to make parts out of a variety of materials, like wear-resistant nylon, using the fused filament fabrication (FFF) process, which is one of the most technologically easy techniques of additive manufacturing. We are making different structures by using nylon material with a fused filament fabrication process (FFF). The aim of our project is to fabricate nylon structures with fused filament fabrication (FFF) process and carryout structural evaluation for determination of tensile, compression and bending strength.

***Keywords:*** Nylon material, Fused filament fabrication process.

## I.INTRODUCTION

It is a novel technology that enables rapid fabrication of physical models directly from three-dimensional computer-aided design (CAD) data without any conventional tooling or programming requirements. It offers greater design flexibility and allows companies to turn first and effective design ideas into successful prototypes and end products rapidly and efficiently. First additive manufacturing systems appeared in 1986 with the introduction of Stereolithography technology. In early 1990s, other technologies were commercialized including fused deposition modelling (FDM), laminated object manufacturing (LOM) and selective laser sintering (SLS). Stratasys introduced fused deposition modelling (FDM) technology in 1991, which has since become the most widely and commonly used AM process, which builds parts in a layer-by-layer manner by extruding semi-molten thermoplastic materials through a liquefier nozzle on to a platform. Recently, several entry level and open-source FDM type machines have appeared in the market, which can process a variety of thermoplastic materials. These low-cost AM machines not only serve as a means of learning and communications in education but also offer applications in design verification and functional testing of engineering parts. The 3D Printers are machines offering faster printability with acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) materials. Because of light weight, ease of fabrication of complex geometry and low cost, such thermoplastics parts processed by FDM have been applied at a significant pace in engineering and medical fields. Though the load-bearing parts in industry are common engineering applications of thermoplastics, the leading applications of FDM thermoplastics are in biomedical and tissue engineering fields such as novel scaffold architectures and knotless suture anchor. Thus, the knowledge of mechanical properties of FDM materials is significant now-a-days.

## II. METHODOLOGY




## III. MATERIALS:

1. Nylon a.k.a Polyamide is an incredibly strong, durable, and versatile 3D printing material. Flexible when thin, but with very high inter-layer adhesion, nylon lends itself well to things like living hinges and other functional parts. Nylon filament prints as a bright natural white with a translucent surface, and can absorb color added post process with most common, acid-based clothing dyes or synthetic cloth specific dyes.

2. Polylactic AcidorPLA filament is by far the most popular material used in FDM 3D printing. It comes in many shades and styles, making it ideal for a wide range of applications. Whether you're looking for vibrant colors or unique blends, PLA filament is an easy to use and aesthetically pleasing material.

| | Nylon | PLA |
|---|---|---|
| Molecular Formula | $(C_{12}H_{22}N_2O_2)_n$ | $(C_3H_4O_2)n$ |
| Melting Point | $215^OC$ | $175^OC$ |
| Density | $1.14\ g/cm^3$ | $1.23$ to $1.25\ g/cm^3$ |
| Elongation at Break | 15-45% | 3.8% |
| Extrusion Temperature | $240\text{-}250^0C$ | $190\text{-}220^0C$ |
| Transparency | Opaque | Translucent |

Table 1: Materials

### IV. CAD

The CAD model was prepared in SolidWorks 2013 version. The dimension of the specimen is 100mmx50mmx5mm. First a rectangle was made in the X-Y axis and then it was extruded along the Z axis. After the preparation the model was then converted into .stl format. This format is suitable for 3-D printing process.

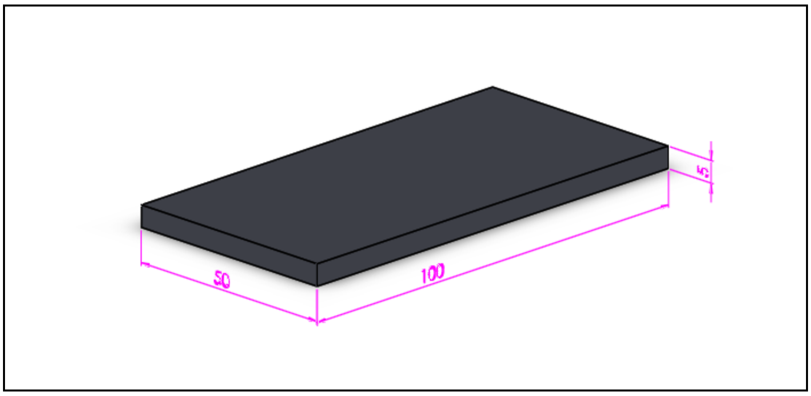



Fig 1: Specimen designed as per required dimensions using Solid works.

The model was then cut into three pieces using the process of laser cutting. This was done to ease the testing process and to observe the anisotropic properties of the material.

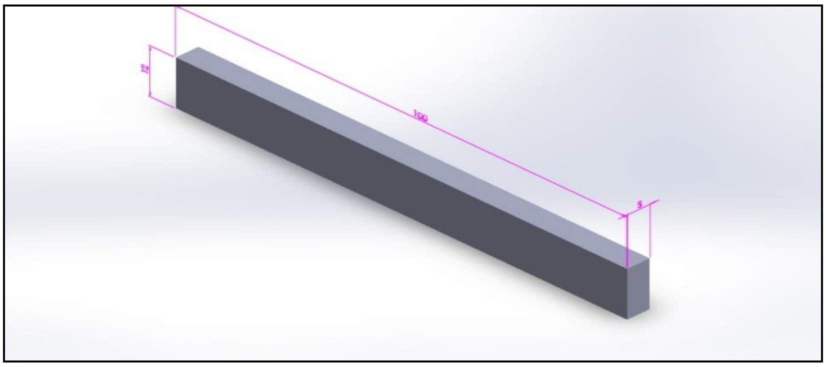


Fig 2: Specimen to be cut as per required dimensions.

### V. CONTROLLER AND SOFTWARE:

The Universal Testing Machine (UTM) 5906 is supplied with a digital 8800 controller that provides full system control including features such as automatic loop tuning, amplitude control, specimen project, 19-bit resolution across the full range of transducers, and adaptive control technology. It also allows access to Wave Matrix dynamic testing software, Blue hill Software for static tests, and other applications specific software, such as the Low Cycle Fatigue Mechanics suite.

### VI. EXPERIMENTATION

#### TENSILE TEST:

The tensile tests are conducted on UNIVERSAL TESTING MACINE (UTM) 5906 as per ASTM D3039-07 standards test method for tensile properties of composite specimens. This test method determines the in plane tensile properties 3D printed material particulate filler. The dimension of the sample is 150 mm x 12 mm x 6 mm with a fixed gauge length of 100 mm. Tests are conducted for the samples at normal room temperature (27ºC) and quasi-static strain-rate of 10E-4/s. At least three specimens for each composite are tested to get the mean value of the tensile strength. UNIVERSAL TESTING MACINE (UTM) 5906 with tensile test setup and the test.

|  |  |
|---|---|
| Tensile test on sample 1 | Tensile test on sample 2 |

Fig 3: Tensile Test

**BENDING TEST:**

Three point bending test usually provides values for flexural test, flexural strain, modulus of elasticity in bending and the flexural stress strain reproof the material. The method of testing involves usually a specified text fixture on a universal testing machine. Details of the test preparations, conditioning and conduct affect the test results. The sample is placed on two supporting pins at a certain distance apart. The flexural strength of a composite is the maximum tensile stress that it can withstand during bending before reaching the breaking point. The three point bend test is conducted on 3D printed filling samples, using a testing machine UNIVERSAL TESTING MACINE (UTM) 5906 as per ASTM D790-10 standard test method. The dimension of each specimen is 60 mm ×12 mm × 6 mm with a span of 50mmlength and a constant cross head-speed of 1.5 mm/min is maintained. The arrangement for the test and the test specimen  For both flexural strength and ILSS, the test is repeated three times for each composite type and the mean value is reported. The flexural strength of the composite specimen is determined using the following equation:

Flexural strength = (3PL)/(2bt^2)

where L is the span length of the sample (mm); P is maximum load (N); b the width of specimen (mm); t the thickness of specimen (mm).The data recorded during the three point bend test is used to evaluate the Inter laminar shear strength (ILSS). The ILSS values are calculated as follows:

ILSS= (3P)/ (4bt).

- We will get those stress-strain graphs and other information in the monitor.
- Save that result information in CD-drive.
- Before starting the experiment, we need required values like poison’s ratio and dimensions in the software.

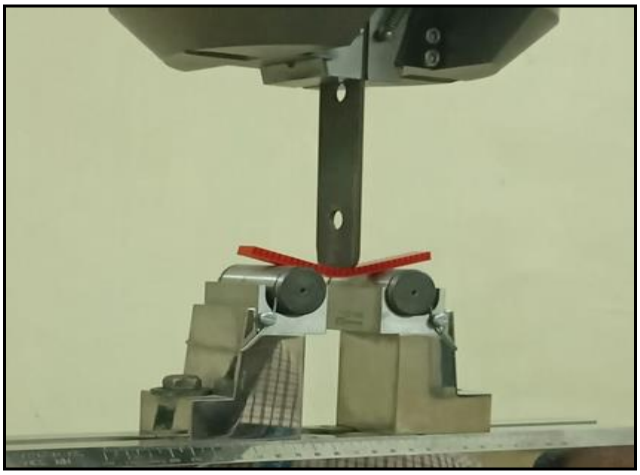


Fig 4: Bending test on the specimen

| | |
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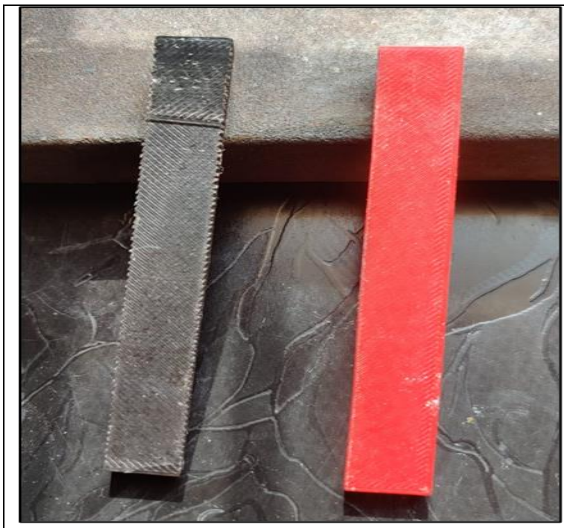
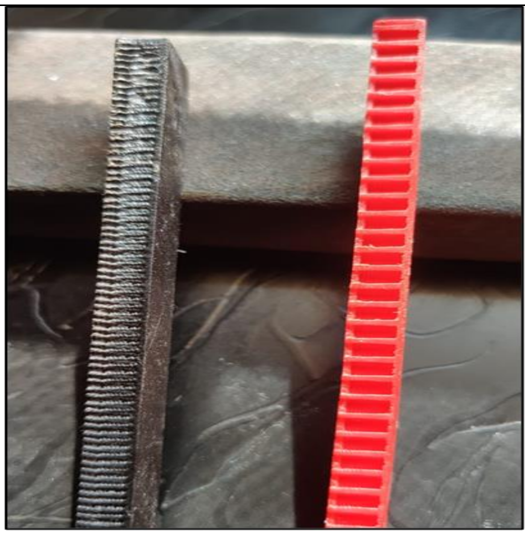
|  |  |
| Nylon and PLA | Infill view of the Nylon and PLA |

Fig 5: 3D Printing of specimens

## VIII. RESULTS

By comparing the graphs of all the materials which have been tested for flexural strengths which is as, we can see that within the same material, the values are different even when taken from different sides. It is also observed that the middle portion has lower values than those that of corners. This may be because of the fact that the corners are covered from the three sides whereas the centre portion is only covered from top and bottom.

Drastic change in the properties was observed in the case of PLA and nylon where the difference of +22 MPa and -23 MPa can be observed.

## IX. CONCLUSION

While comparing polymers, be it naturally manufactured or 3-D printed ones specific strength or strength-weight ratio is one of the most important factors that has to be compared. This is because when we compare any composite or polymer with a metal, we cannot compare them solely on the basis of its strength as metal obviously has higher strength value than the composites. So, we have to compare them on specific strength basis, where we can say that for a particular weight, the composite offers more strength or for a same weight the composite material has more strength than that of metal.

Here in this project, we have compared the specific strength of one 3-D printed polymer with another 3-D printed polymer. We have found that PLA has highest specific strength compared to all other polymers. This is because of its composite nature. While comparing flexural properties we found anisotropy in the material as we were getting different results for same composition. We came to a conclusion that the difference in build orientation might have affected the properties of the polymer. Also other major reason may be that since the material was exposed to laser light during the cutting process, its properties might have changed.

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