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Research Article

The mechanical behavior effect of FDM process by using PA6 and PA66 for varying its infill density on a rectilinear pattern

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ABSTRACT

Fusion deposition modeling (FDM)is an additive manufacturing technique that allows for the cost-effective, quick, and simple creation of high strength specimens with accurate dimensions. The major goal of our proposed research is to compare the mechanical properties of polyamide 6 (PA6) and polyamide 66 (PA66) in a rectilinear structure fabricatedby using FDM technique. The specimens are produced with different infill percentages for rectilinear structures such as 50%, 75%, and 100% respectively. These materials are used for testing, such as tensile strength, yield strength, percentage of elongation, clashed with the exploratory results. In the FDM process, the major influencing process effect of infill percentage reveals that rectilinear structures with 100% infill produce greater strength than rectilinear structures with 50% and 75% infill for both materials. In the future, it will be useful for engineering applications in the development of diverse parts.

***Keywords**:* PA6 and PA66-FDM – Infill percentage - Mechanical properties.

1. INTRODUCTION

Retaining additive manufacture methods for core manufacture is the standard method for reducing production waste and increasing lateral stiffness. When a small number of unique components are required to create net-shaped parts, traditional manufacturing techniques are appropriate[1].There will be numerous opportunities for future research and the advancement of three-dimensional printing in the field [2].Additive manufacturing systems are well suited to applications that require a high level of customization, design optimization, and low production volumes [3]. Based on the initial build material, the additive manufacturing process is divided into three categories: powder-based material, extrusion-based material, and resin-based material [4]Various AM process areStereo lithography, Fusion deposition modeling, Selective laser sintering, Electron beam welding, Laser engineered net shaping, Laminated object manufacturing, and polyjet process are some of the subcategories[5]. Fusion Deposition

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Modeling (FDM), a type of expulsion-based AM pioneered by Stratasys Inc in 1992, is a type of expulsion-based AM. A plastic or wax material is expelled through a spout that follows the cross-sectional layers of the part in this procedure. Although most construction materials are provided infiberform, a few setups use plastic pellets obtained from a container[6].These thermoplastic materials are earth stable, have part precision, and do not change with surrounding conditions or time. As a result, FDM parts are among the most dimensionally precise. ABS plus thermoplastic, ABS-M30, ABS-M30i, ABSi, PC-ABS, PC, PC-ISO, PPSF/PPSU, and ULTEM 9085 are the basic properties. These are some of the materials that are used in the various FDM procedures [7]. The most critical FDM parameters are built orientation, layer thickness, infill pattern, infill density, and nozzle diameteretc., [8]. Researchers induced that in the FDM process of ABS the compressive strength is higher than tensile strength and that was not affected more in production model which depends on the direction of anisotropicbehavior [9]. By using the glass blend fiber in Polyamides there is increase in tensile strength from 27.33 N/mm^2 to 58 $N/mm^2$and the elongation and the breaking elongation has decreased from 8.98%to5.26% where the ductility had reduced [10].In 3D printed structure with the Fused deposition modeling process the material has 1.20 times than injected mold structure and for few mechanical properties like mechanical properties like compressive strength, impact strength, surface roughness and corrosion rate have optimum value of 35 percentile[11]. The change in infill density determines mainly the tensile strength. The combination of a rectilinear pattern in a 100% infill shows the higher tensile strength, with a value of 36.4 MPa, with a difference of less than 1% from raw ABS material[12].The 3DP parameters like layer thickness, slicing, speed, feed are kept as constant and by varying the printorientation (X, Y, Z) with infill density (50%, 75%, 100%) was printed to check the effect of it on mechanical properties like hardness, impact strength, ultimate tensile strength, flexural strength[13].

However, previous research studies focused primarily on plaster or polymer materials or composites for a specific grade to print the sample using FDM. Furthermore, few research studies focused on the optimization of process parameters of the built product based on responses. It was discovered that the sample printed at optimal parametric conditions on FDM process by using PA6 and PA66 filament with 50%, 75%, and 100% infill percentage in rectilinear structure. These conditions have yet to be documented in the literature. In this study, a two mode of three set of experiments is carried out in order to improve the strength without compromising material properties or manufacturing time.

2. EXPERIMENTAL APPROACH

2.1Filament Material Used

Polyamide 6 (PA6), also known as nylon 6, has a density of 1.15 g/cm^3 and a property of around 200^0C. It is the most commonly used design thermoplastics, particularly in the manufacturing industry. PA6 is a semi-crystalline material prized for its strength, elasticity, durability, high tensile properties, and elongation. Its chemical resistance and low wear rate allow it to be used in the electrical field. It is commonly used in the fabrication of gear, bearings, fittings, and other automobile spare parts via extrusion, molding, or machining [14].

Polyamide 66 (PA66) is another material and it has a melting point of270°C. Its mechanical properties, such as hardness, tensile strength, and density 1.01 g/cm^3.It has a good resistance to shock and electrical insulator. The material can be used for manufacturing fibers for textiles and carpets and molded parts., etc. [15].

2.2Modeling of Polyamide Test Specimen

This segment is responsible for the design of inspection specimens for tensile strength parts. Printed specimens for dumbbell shape are designed in accordance with ASTM standards, with dimensions of 165 mm length, 19 mm outer width, 13 mm inner width, and 0.6 mm thickness, as shown in fig 2. The specimen's CAD model is created in SOLID WORKS (2017) and exported as a Standard Template Library (STL) file, which is then imported into the FDM software to create date files. The Desktop 3D Printer was used to fabricate test specimens for each experiment, and the filament feedstock used is PA6 and PA66. During the experimental run, the infill percentage for the rectilinear structure for printing the specimens varies between 50%, 75%, and 100% for both materials PA6 and PA66.

2.3Printing of Specimen by using FDM

This paper focuses on the effect of process parameters on sample mechanical properties. The infill percentages are varied as experimental factors to investigate the effect of these parameters on the mechanical properties of parts. Among the many FDM process parameters available, such as layer thickness, orientation, extrusion speed, bed temperature, extrusion temperature, raster gap, rasterwidth, and so on, The optimum parameters were found from the literature review followed by pilot experiments were conducted and obtained major influencing parameters are as follows; extrusion temperature 180°C, extrusion speed 30mm/sec, layer thickness 0.1mm, bed temperature 50°C, printing temperature 230°C, infill speed 40mm/sec. These parameters were kept constant during experimentation. Furthermore, the infill percentage for the rectilinear structure varies from 50% ,75% and 100% for both PA6 and PA66 materials for conducting experiments successfully.

Fig 1.FDM experimental setup

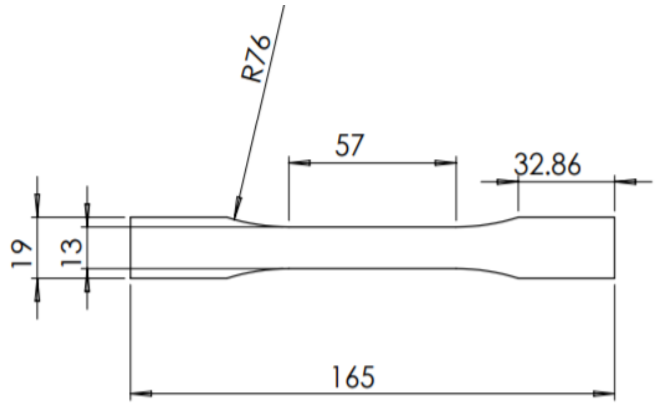

Fig2.CAD model of tensile specimen

2.4 Testing for tensile strength

The universal testing machine was utilize to determine the ultimate tensile strength of the specimens.Three indistinguishable test specimens are worked for each case, which brought about an aggregate of test specimensfor PA6 and PA66.The universal testing machine was used to measure the ultimate load with crosshead speed of 2 mm/s and the room temperature as 28^{o}C. Then the tensile strength,yield strength and percentage of elongation of the test specimens'responses was noted.

Fig 3.Various infill density like 50%, 75% and 100%

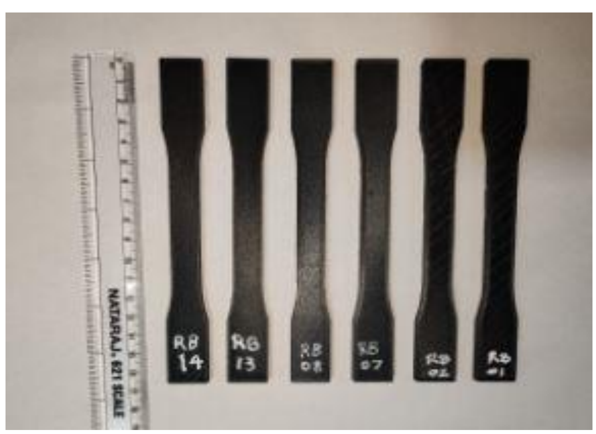

Fig 4. FDM Printed samples

3. RESULTS AND DISCUSSION

3.1 Ultimate Tensile Strength

From the experiment it was seen that, for 50% infill rectilinear PA6 ultimate tensile strength was 63.32MPa which varies 20.8% from the ultimate tensile strength 43.9MPa ofPA6 wire. The strength of 75% rectilinear infill PA6 was 68.73MPa which varies 8.54% from the 50% infill rectilinear PA6 sample and the strength of 100% infill structure attains 71.92MPa which was 4.6% more than 75% infill rectilinear PA6 sample.

Taking PA66 with 50% infill rectilinear whose strength was 46.63MPa which varies 28% from the maximum ultimate tensilestrength 32MPaof the wire. While PA66 with 75% infill rectilinear has strength of 50.02MPa which was7.26% more than 50% infillrectilinear specimen and 100% infill structured PA66 whose strength was 54.29MPa and gains 8.53% maximum strength than 75% infill rectilinear PA66 specimen.

From the result, it was observed that infill percentage and structure of the specimen improves the ultimate tensile strength of printed samples. It was due to the increase in resistant area. When infill percentage was high amount of material used was high which improves resistant area which in turn improves the ultimate tensile strength of the printed sample. High ultimate tensile strength of the 100%rectilinearinfill structure shows uniform distribution of load on each nodes of the structures.

From the figure 5, the ultimate tensile strength of PA6and PA66 gradually increased in all the levels. On further comparing with PA66, around 23-33% improvement in ultimate tensile strength values of PA6 printed specimen. Alsoit was found that 100% infill rectilinear structure shows higher ultimate tensile strength values in both PA6 and PA66. While considering 100% infill rectilinear structure of PA6 was higher than PA66 of 100% infill rectilinear structure.

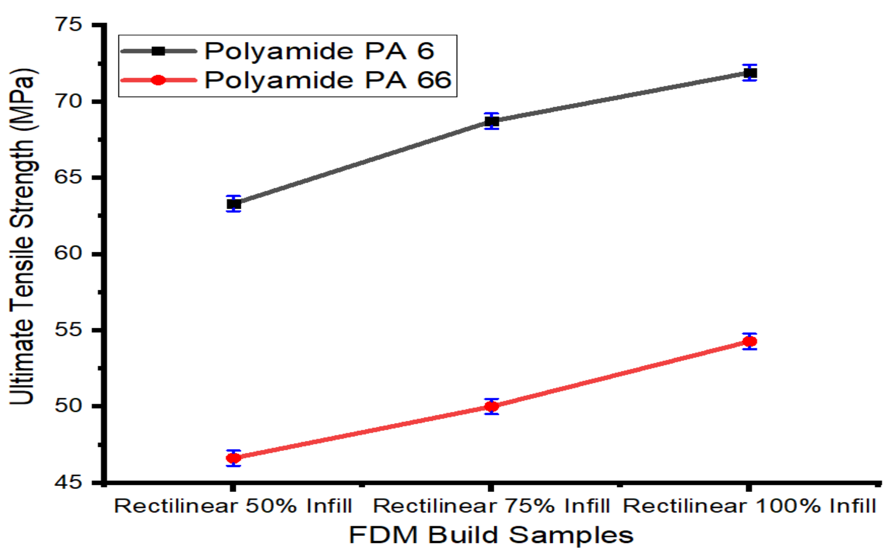

Fig 5.Ultimate tensile strength

3.2 Yield Strength

From the investigation it was seen that, for half infill rectilinear PA6 yield strength is 51.78MPa which increases 13.5% from yield strength of PA6 wire. Infill rectilinear PA6 of 75% has yield strength of 53.13MPa which differs 2.6% from the half infill rectilinearPA6 printed sample and comparing 100% infill rectilinear structure of PA6 with75% infillrectilinearPA6, the yield strength is enhanced by 10% i.e., yield strength of PA6of 100% infill rectilinear structure is 58.42MPa.

Considering PA66 with half infill rectilinear whose yield strength is 36.93MPa which improved by 15.2% from the yield strength of the wire. PA66 with 75% infill rectilinear has yield strength of 38.87MPa which was 5.25% more than 50% infill rectilinear sample and 100% infill rectilinear PA66 with yield strength of 46.30MPa which adds yield strength 19% than 75% infill rectilinear PA66 samples.

From the end result, it was noted that influence of infill percentage and structure increases the yield strength of printed samples. Increase in yield strength was due to the resistance offered by the infill area. Higher the infill percentage results in higher the resistant area which improves the yield strength of the printed specimen. Uniform distribution of load on each nodes of the structures leads to high yield strength of the 100% infill rectilinear structure.

From the figure 6,the yield strength of PA6and PA66steadily increased in all the levels. On further comparing with PA66, around 21.3-24.3% improvement in yield strength values ofPA6 printed specimen. Also seen that 100% infill rectilinear structure shows higher yield strength values in case ofboth PA6 and PA66. While considering 100% infill rectilinear structure of PA6 has higher yield strength than PA66.

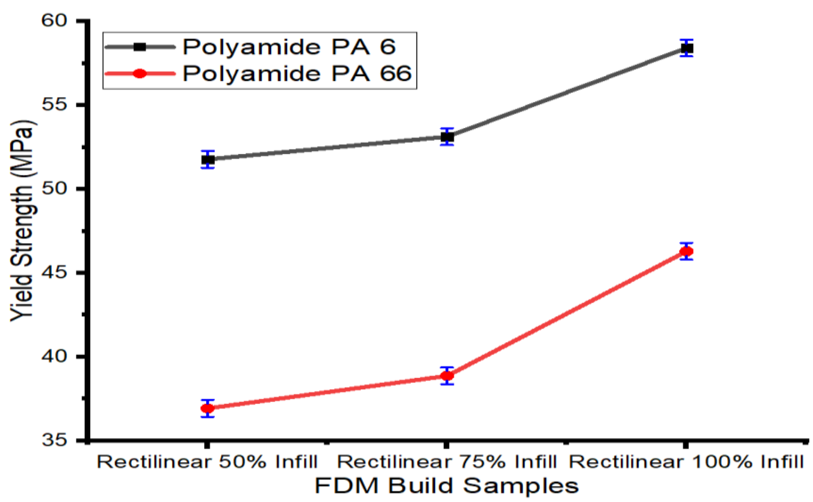

Fig 6.Yield strength

3.3 Percentage of elongation

From the experiment, percentage of elongation of 50% infill rectilinear PA6 is 10.2% and that of 75% infill rectilinear PA6 was 7.3%. Percentage difference between above rectilinear infill was 28.1. For 100% infill rectilinear PA6 has value of 6.8%, elongation was decreased by 6.7% compared to 75% infillrectilinear PA6.

Considering 50% infillrectilinear PA66 elongation was10.19% which wasmore when compared to 75% infillrectilinearPA66whose value was 8.8%.Elongation had varied about was about 20.4% and 100% infill rectilinear PA66shows elongation of 7.1% which varies 19.1% from75%infillrectilinear PA66.

From the figure 7, itwas shown that half infill rectilinear structure gives finest elongation property. Contrastively100% infill rectilinear structure shows elongation nearer to half infill rectilinear structure. While coming up with elongation property of PA6 and PA66,elongation of PA66 is more.

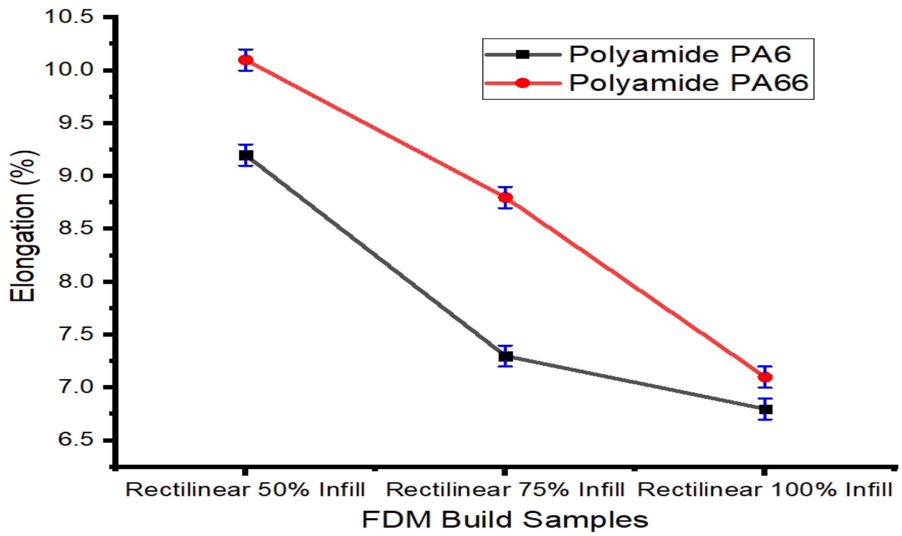

Fig 7. Percentage of elongation

4. CONCLUSION

The following conclusions was drawn from the experimental work of PA6 and PA66 by varying infill percentage and structures.

1) PA6 and PA66 with 50%,75%and 100% infill rectilinear structure are printed by FDM.

2) The ultimate tensile strength of PA6 and PA66, 75 % infill rectilinear structures improved to 68.73MPa and 50.02MPa, respectively. When compared to ultimate tensile strength of 75 percent infill rectilinear structures, ultimate tensile strength of 100 percent infill rectilinear PA6 and PA66 reaches maximum values of 71.92MPaand 54.29MPa. For both PA6 and PA66 materials, the rectilinear structure was 50%, 75%, and 100%.

3) When compared to the PA66 100 percent rectilinear infill structure in the FDM process, the PA6 100 percent rectilinear infill structure was stronger in all aspects.

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