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RESEARCH ARTICLE

EXPERIMENTAL DETERMINATION OF MECHANICAL PROPERTIES OF ABS MATERIAL COMPONENTS MADE BY RP MANUFACTURING TECHNIQUE

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ABSTRACT

In the recent years utilization of polymeric materials increased due to their good mechanical properties and easy manufacturing. Starting from automotive industry up to food industry polymeric materials are used for obtaining components by molding or by machining. Taking into account the wide range of applications, it is important to know the mechanical behavior of the materials in different loading conditions. Rapid Prototyping Techniques (RPT) are widely used to produce objects with good dimensional accuracy, surface roughness and material strength by adding the material layer by layer. Though there are many types of RP techniques used to produce a product, in this work Fused Deposition Modeling (FDM) technique is selected as one of the manufacturing system. ABS polymer material is used as raw material for the parts produced by FDM process. Therefore, this work mainly focused on various mechanical properties of parts made of ABS and manufactured by FDM process. The ABS specimens are prepared as per ASTM standards. These specimens are tested for tensile test and bending test and results are tabulated. Finally the stresses are calculated with the variation of elongation at various applied loads.

INTRODUCTION

Rapid Prototyping (RP) is defined as a group of techniques used to decrease time needed for implementation of a new product. Layer by layer building technique is used. Model is prepared using three -dimensional computer aided design (CAD) data. The other names for this process are solid freeform fabrication and layered manufacturing. Since the introduction of the first commercial rapid prototyping (RP) machine widely known as Stereo lithography in 1986, a wide range of RP machines have been commercialized, and now many more newer techniques continue to be developed in various parts of the world. In addition to prototypes, RP techniques can also be used to make tooling (referred to as rapid tooling) and even production-quality parts (rapid manufacturing). For low production runs and complicated objects, rapid prototyping is often the best manufacturing process available. RP techniques that are currently commercially available, including Stereo lithography (SLA), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), Fused Deposition Modeling (FDM), and 3D printing (3DP).

A polymer is a large molecule composed of many repeated subunits, known as monomers. In many polymers, only one monomer is used. In some others, two or three different monomers may be combined. Because of their broad range of properties, there are both naturally occurring and synthetic polymers are in use. Polymers like proteins, starches, cellulose, and latex are naturally occurring polymers. Synthetic polymers are produced commercially on a very large scale and have a wide range of properties and uses. The materials commonly called plastics are all synthetic polymers. Acrylonitrile butadiene styrene (ABS) (chemical formula $(C_8H_8)_x\cdot(C_4H_6)_y\cdot(C_3H_3N)_z$) is a common thermoplastic polymer. Its glass transition temperature is approximately 105 °C (221 °F) ABS is amorphous and therefore has no true melting point. A typical ABS contains 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene but these proportions may vary in a relatively wide range. The result is a long chain of polybutadiene cross linked with shorter chains of polystyrene-co acrylonitrile. The nitrile groups, being polar, attract each other and join the chains together, making ABS stronger than each of its constituent components. The ABS properties essentially depend on the properties of each component: acrylonitrile enhances hardness and chemical resistance, butadiene acts as plasticiser to increase impact strength and styrene improves thermal and processing properties. Thus, high hardness and impact strength, high chemical and thermal resistance, negligible creep as well as easy processing are the most significant advantages of ABS while relatively low fatigue strength is a disadvantage. ABS Plastics were discovered during World War 2 and was used as the alternative to rubber. Features of ABS are high heat resistance, good

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impact resistance, high flow, good dimensional stability, flame retardance.

M. Żenkiewicz [1] [Żenkiewicz et al., 2009] in his experimental study found that tensile strength of the specimen varies with the multiple injection mouldings. The magnitude of variation in tensile strength is varied from one injection moulding to the next injection moulding. The glass transition temperatures of butadiene and acrylonitrile-styrene fractions don,t vary with the number of injection mouldings.

Harish Kumar [2], [2014] Concluded that Replacement of Conventional materials with newer one for the practical application has reduced the pressure on the non-renewable resources. Plastics through non-biodegradable can be recycled to minimize the ill effects of non-decomposable nature of these polymers. The plastic materials are chosen so that it can fulfill the physical and mechanical properties of the existing wheel in sprocket. The model of the plastic gear wheel is developed using Pro-E, pre-processed using HYPER MESH and finally analyzed using ANSYS software. For the manufacture of the plastic gear wheel a mold is designed such that the component can be manufactured on a low capacity machine. Injection molding is selected to increase the productivity. This replacement is a step towards reducing cost and the weight of the sprocket there by proving the flexibilities and functionalities of plastics. The replacement of plastic gear wheel and two wheeler sprocket is visualized using RP's FDM technique.This technique produces the component at lower cost with shorter time.

Niteen P Brahmbhatt [3], [Niteen P Brahmbhatt, 2015; Anoop Kumar Sood [4] et al., 2009] Presented the analysis of optimization of manufacturing parts by FDM techiquie. FDM is the most widely used rapid prototyping technology. The effect of each process parameter such as Layer Thickness, Orientation, Raster Angle, Raster Width and Air Gap on the Dimensions, Surfaces Roughness and Mechanical Properties are analyzed. Hardness increases with a decrease in layer thickness. In x and y-axis at 0° built up orientation, FDM parts have good flexural strength and tensile strength. Negative gap, smaller raster width, zero part orientation, and increased raster angle improve tensile strength.

Flip Gorski [5], experimental in this publication [Filip Górski, 2015] revealed that, with change in orientation microscopic material behaviors under load will also change in addition to change in values of strength indices.

EXPERIMENTATION

Materials

Acrylonitrile-butadiene-styrene (ABS), type of the melt flow rate (MFR) equal to 1.62 g/10 min (5 kg, 200°C) and density equal to 1.05 g/cm3 was used as the study material.

Fused Deposition Modeling (FDM) process

One of the most frequently used RP technique in now a days for the industrial purpose is the Fused deposition modeling (FDM) which is a rapid prototyping process in which a 3D part is fabricated directly from CAD model by integrating the technology computer aided design (CAD). The first step in this process is to generate a 3D model using CAD software. Then the part file is converted into STL file. The STL file is then converted into SLC file by slicing them into thin cross sections at a desired resolution. The sliced model is then changed into Stratasys modeling language (SML) file, which contains actual instructions code for the FDM machine tip to follow the specified tool path. Then the various parameters like raster width, built style and raster pattern are set and then the SML file is sent to the FDM machine. Fig. 1 shows the schematic diagram of the FDM process.

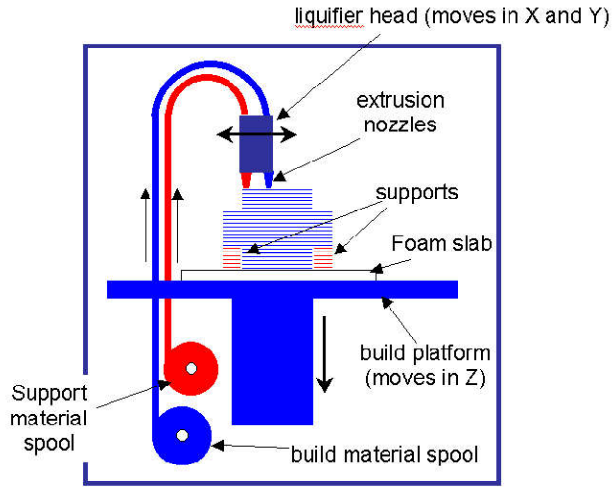


Fig. 1. Fused deposition modeling process principle

In the FDM machine, the liquefier head plays a major role, which is the key to the success of fused deposition modeling technology. The material in the filament form is pulled or pushed with the help of drive wheels which is attached to the electric motors and then enters into the heating chamber. The material flows through the liquefier tube and is deposited through an extrusion tip. The tip is extremely threaded and screwed up into the heating chamber exit. They reduce the diameter of the extruded filament to allow for better detailed modeling. The extruded plastic bonds with the previously deposited layer and hardens immediately. The chamber, in which the entire system is held, is kept at a temperature just below the melting point of the plastic used, which aids the bonding process. Finally the part is removed from the chamber and no post processing is required in FDM. The FDM vantage machine has number of parameters, which affect the part strength and mechanical properties. The key parameters considered in this study are built style, raster width, and raster angle.

Main Process Parameters

- Orientation:
  Part builds orientation or orientation referrers to the inclination of part in a build platform with respect to X, Y, Z axis. Where X and Y-axis are considered parallel to build platform and Z-axis is along the direction of part build.
- Layer thickness:
  It is a thickness of layer deposited by nozzle and depends upon the type of nozzle used, it is taken as 0.2mm
- Contour width:
  The width of contour deposited by nozzle 0.4mm
- Raster Angle:

It is a direction of raster relative to the x-axis of build table is 45^0

- Air Gap:
  It is the gap between two adjacent raster on same layer is 0.5mm

Design of Specimen

Rapid prototyping is a process that automatically creates a physical model from a 3D CAD data in a short period of time. The model is build layer by layer. In general, the rapid Prototyping involves following steps:

- Creation of CAD models of all components
- Conversion of CAD models to STL format
- Slicing of STL file into thin cross-sectional layers
- Layer by layer construction of the models
- Cleaning and finishing of the RP models

The RP model is created by various modeling CAD software packages such as AUTO CAD, solid edge, solid works, CATIA etc. Then, convert the CAD file into STL format here the CAD file has to be stored in the STL format. This format represents a three-dimensional surface as an assembly of planar triangles "like the facets of a cut jewel''. The file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Since, STL file uses planar elements, it cannot represent curved surface exactly. Increasing the number of triangles improve the approximation so designer must balance accuracy with manageability to produce a useful STL file .Since the STL format is universal, this is identical for all of the RP build techniques. In the Fused Deposition Modeling" INSIGHT" software is used to slice the STL files. Each RP machine manufacturer supplies their own proprietary slice software. In this software, STL model is sliced into a number of layers from 0.01mm to 0.7mm thick, depending on the build technique.

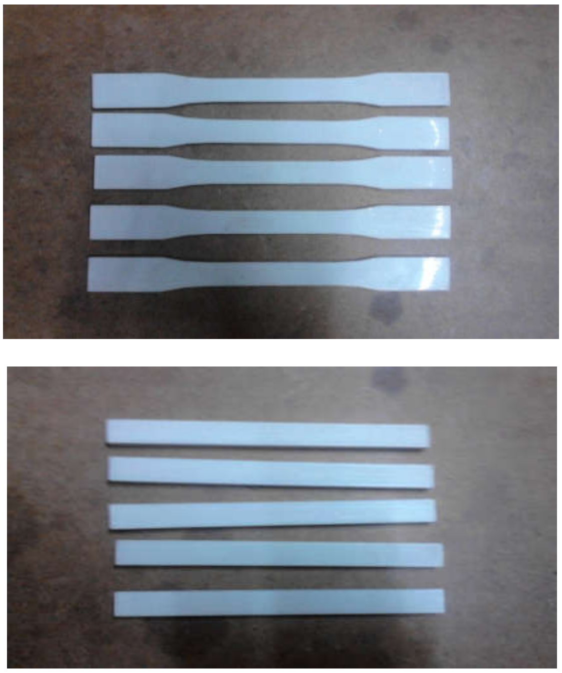


Figure 2. Tensile and flexural specimen prepared in Rapid Manufacturing

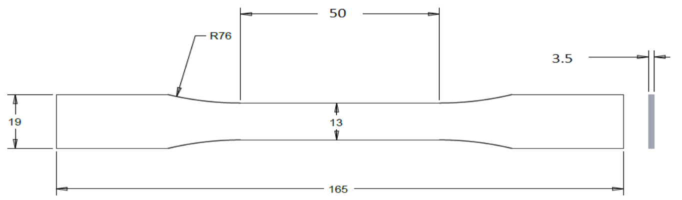


Figure 3. Tensile specimen according to ASTM standands prepared in CAD Software

Figure 4. Flexural specimen according to ASTM standards prepared in CAD Software All Dimensions are in MM

The program may also generate auxiliary structures to support the model during the build. The "INSIGHT" software calculates the time taken to build the parts and amount of building material and the support material needed for building the model. In this study Fused Deposition Modeling (FDM) is used to fabricate the step bar master patterns. A plastic filament (ABS) is unwound form coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off. As the nozzle is moved over the table in the required geometry, it deposits a thin extruded plastic to form each layer. The entire system is contained within a chamber which is held at a temperature just below the melting point of the plastic The final step is post processing .This step involves removal of the prototype from machine and detaching the supports, also it requires minor cleaning and surface treatment.

Testing

The experimental study consists of static tensile Test and flexural test on specimen. All tests were performed at room temperature. The tensile testing specimen is prepared according to ASTM D638 and the flexural testing specimen is prepared according to ASTM D79M.

RESULTS

Results of all the strength tests are presented in Tables 1, 2 (tensile, bending respectively).

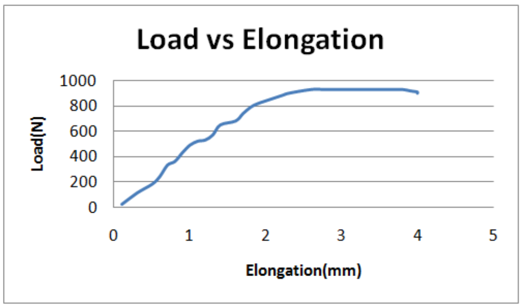
Table 1. Tensile Test

S.No	Load(N)	Elongation(mm)	Stress(N/mm^2)
1	920	2.9	20.43
2	930	3.8	20.21
3	950	3.3	20.87

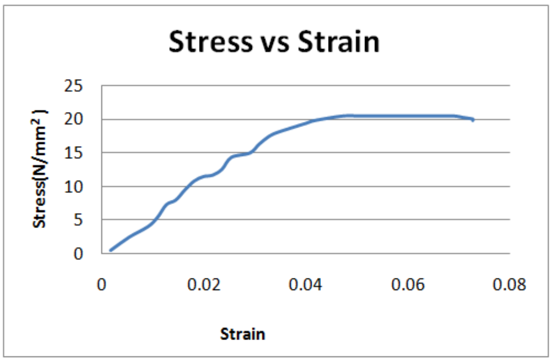
The two main groups of characteristics are presented: strength interpreted as the maximal stress recorded in a sample and strain presented as elongation at the maximal force. The data is also presented in graphic representation and bar charts to compare them at easily. The test results of the FDM are tabulated and the average ultimate tensile strength is 20.50N/mm^2.

The bending test data of ABS sample shown in Table (2). The flexural strengths are greater than the tensile strengths.

Load vs Elongation curve for a peak load of 920N (Sample 1)



Graph 1. The Load Elongation curves of the Tensile test of sample 1

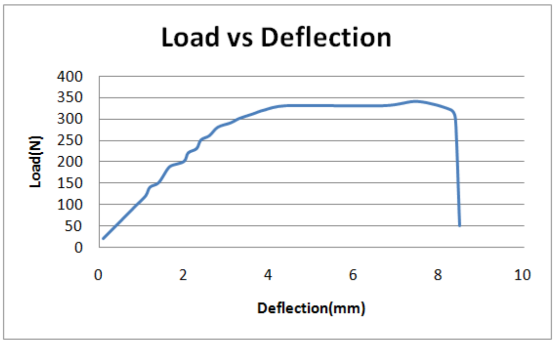


Graph 2. The stress strain curves of the Tensile test of sample1

Table 2. Flexural Test

S.No	Load(N)	Deflection(mm)	Stress(N/mm^2)
1	340	7.5	81.6
2	210	7.3	50.4
3	190	5.5	45.6

Load vs Deflection curve for a peak laod of 340N (Sample 1)



Graph 3. The Load Deflection curves of the Flexural samples

Conclusion

The samples are made of ABS using the Additive FDM technology. The two response viz; tensile strength and flexural strength of test specimens are studied. The results of the present studies are helpful for engineers who plan to use additive manufacturing by the FDM method for manufacturing parts subjected to varying loads. As it is important to know whether the component is able to sustain more load or not, the tensile strength and the flexural strength of the component are measured.

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