

Tensile test & FEM Analysis of ABS material using FDM Technique

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ABSTRACT: Fused deposition modelling is one of the additive manufacturing techniques that produce parts from plastic materials such as Acrylonitrile Butadiene Styrene (ABS), nylon and polycarbonate by depositing semi molten plastic filament through heated nozzle onto the build platform through as per CAD data. The main objective of the paper is to study the optimum part building orientation of ABS material processed by FDM technique. In FDM one of the critical factors is the selection of the build orientation which affects quality of strength of the component, in the light of the above objective of the present study is to build orientation of mechanical properties of the component. The test specimens were prepared according to ASTM standard with different built up orientations 0°, 45° and 90°. From FEM analysis it has been observed that in 45° build orientation angle as more tensile stress compared to 0° & 90°.

KEYWORDS: Fused deposition modelling, Acrylonitrile Butadiene Styrene (ABS), ASTM standards, FEM analysis.

I. INTRODUCTION

In recent years, opening up local markets for world-wide competition has led to a fundamental change in a new product development (NPD). In order to stay competitive, manufacturers should be able to attain and sustain themselves as “world class manufacturers”. The manufacturers should be capable in delivering products in fulfilling the total satisfaction of customers, products in higher quality, short delivery time, at reasonable costs, environmental concern and fulfil all the safety requirements.

In many fields, there is great uncertainty as to whether a new design will actually do what is desired. New designs often have unexpected problems. A prototype is often used as part of the product design process to allow engineers and designers the ability to explore design alternatives, test theory and confirm performance prior to starting production of a new product. Engineers use their experience to tailor the prototype according to the specific unknowns still present in the intended design.

Michael Montero et al [1], seeks to characterize the properties of ABS parts fabricated by the FDM 1650. Using the Design of Experiment (DOE) approach, the process parameters of FDM, such as raster orientation, air gap, bead width, colour, and model temperature were examined. Tensile strengths of crisscross specimens, [45°/-45°], cross specimens, [0°/90°], and directionally fabricated tensile specimens ([0°] and [90°]) were measured. For the FDM parts made with a -0.003” air gap, the typical tensile strength ranged between 65 percent and 72 percent of the strength of injection moulded ABS P400. From the experiments, several build rules for designing FDM parts were obtained. N. Vidakis et al [2], studied the effect of tensile test speed on the tensile strength of fused deposition modelling (FDM) parts built with Acrylonitrile-butadiene-styrene (ABS) and ABS plus material. Khan et al [3], concluded that layer thickness, raster angle and air gap are found to significantly affect elastic properties of FDM ABS prototype. K.G. Jaya Christiyani, et al [4]. In this paper, mechanical properties of the ABS material were evaluated. The influence of raster orientation of 0°, 45°, 60°, and 90°, and layer thicknesses of 0.254 mm and 0.331 mm were studied in detail. Tusharkumar B, et al [5]. This paper presents tensile behaviour of ABS polymer. Tensile deformation behaviour of (ABS) was experimentally investigated, following a practice guideline by ASTM.

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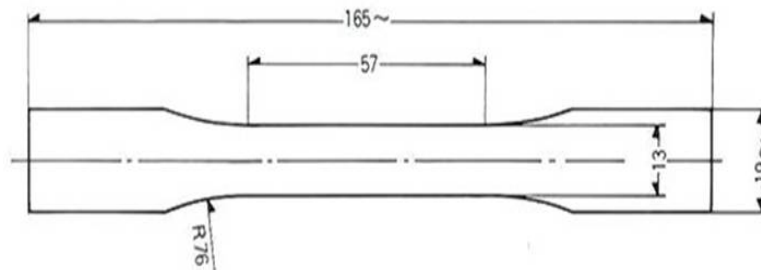
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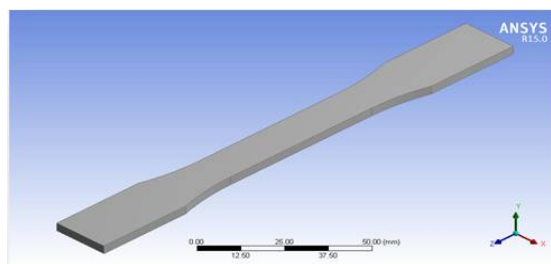
II. MODELLING OF TEST SPECIMEN IN CAD SOFTWARE

The preliminary step was to design the test specimens which were to be built on additive manufacturing technologies like Fused Deposition Modelling (FDM) technology. Since the test specimen which was built on FDM process were subjected to mechanical property testing like tensile testing, compressive testing and hardness testing, the specimens have to be designed as per the ASTM standards i.e., a standard dog bone shape specimen for tensile testing and a standard block shape specimen for compressive testing as well as for hardness testing of the specimens, these specimens were made as 2D sketches in Solid Edge V18 as shown in below figure.



Sketch of ASTM standard tensile test specimen

The test specimen has a gripping head or a holding head so that the test specimen can be easily fixed on the work holding jaws of the UTM on both the ends. This gripping head as a length of 32.86mm and a breadth of 19mm. The test specimen has a gauge length of 57mm and a gauge breadth of 13mm where actually the properties of the polymers can be found subjected to the respective test as shown in figure.



Tensile Test Specimen

III. MECHANICAL PROPERTIES OF ABS MATERIAL

Test	Mechanical property	Material
		ABS
Tension Test	Tensile Strength (ASTM 638)	57MPa
	Tensile Elongation	4%

IV. TENSILE TEST USING UTM

A computerized universal testing machine UTM-20 is used. Tensile test specimen is modelled according to ASTM D638 standard compression test specimen obeying ASTM D695 standard. ASTM D638 Type I standard is chosen to carry out the test.

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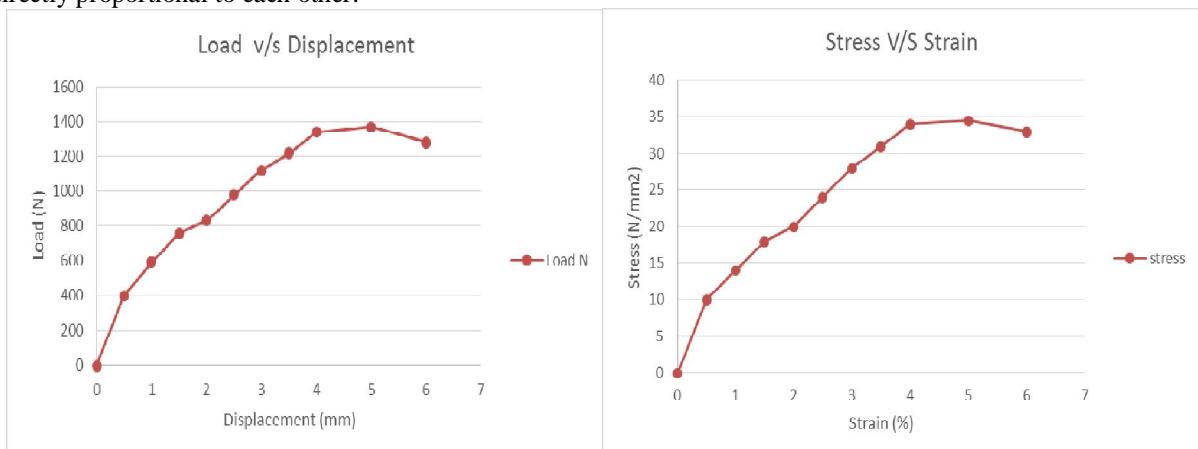
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Universal Testing Machine used UTM-20

TENSILE TESTING OF ABS MATERIALS:

Most of the AM/RP materials are polymers, the parts built on RP processes cannot be subjected into tensile test under a high capacity UTM. So, here to conduct a tensile test of FDM built ABS part an UTM-20 was used. To gain an accurate result ASTM test specimen were subjected to tensile test and results are shown in graphs (a) and (b). The graph (a) shows that, the load has largest effect on the surface of the ABS material. As the load increases from 0 to 1280 N the displacement also increases linearly from 0 to 6mm and the graph (b) shows the plots for behaviour of the ABS material subjected to tensile load, the stress has largest effect on the surface of the material. As the stress increases from 0 to 33 N/mm². The strain also increases linearly from 0 to 6%. It is evident from the above plot that stress and strain are directly proportional to each other.



(a) Load v/s displacement graph of tensile specimen

(b) Stress v/s Strain graph of tensile specimen

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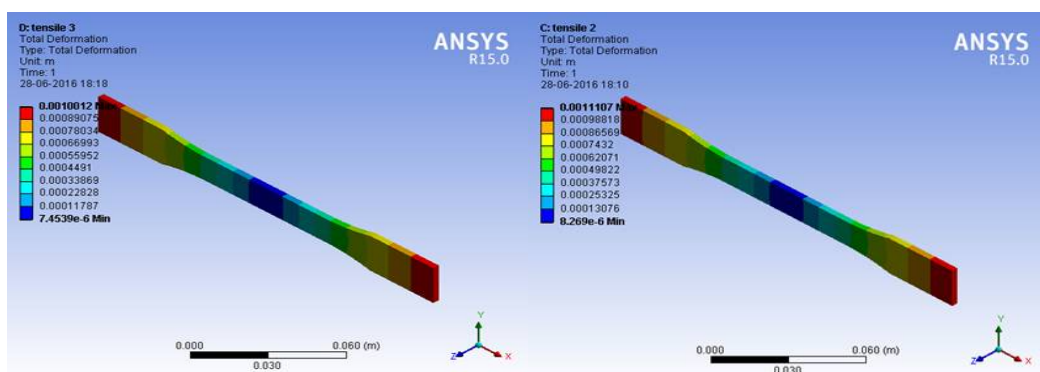
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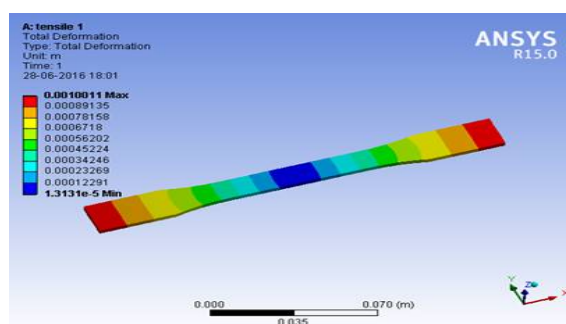
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V. EXPERIMENTAL RESULTS OF FEM ANALYSIS

Experimental result showed that ASTM standard tensile and compression specimens made of ABS (Acrylonitrile Butadiene Styrene) built in different orientation i.e., 0°, 45° and 90°. The stress distribution was investigated using ANSYS 15 workbench. Maximum stress developed in the edges of the component and in the region of gage length due to the sudden change in the cross section near the gage length and sharp corner in the edges which leads to high stress concentration as shown in the figure. Total Deformation, Equivalent Stress and Maximum Principle Stress is obtained for each specimen and outcomes were obtained as shown in the below figures. The fracture paths of the tensile samples were depending on the layer orientation, where fractures occurred due to de-lamination. This was because by the weaker inter lamination bonding and/or interlayer porosity.



(a) Total deformation on tensile Specimen 0° (b) Total deformation on tensile Specimen 45°



Total deformation on tensile Specimen 90°

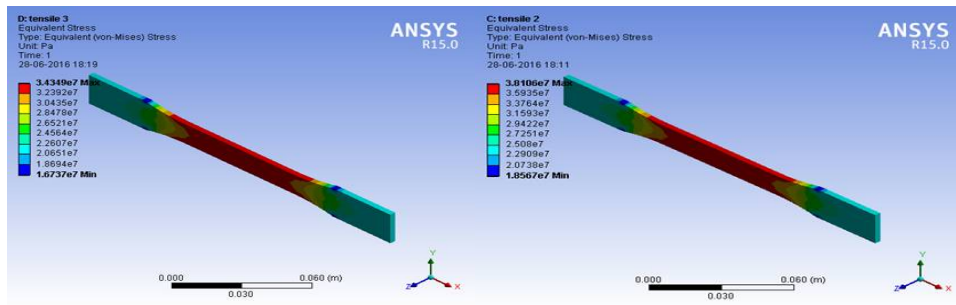
Above figure shows the static structural analysis of the ABS component built by FDM process. Total deformation is maximum in the ends of the component where tensile forces are applied. It is shown in figures (a), (b) and (c). Total deformation is greatly affected by the build orientation angle, hence the total deformation can be seen more in 45° build oriented specimen and less in case of 0° & 90°.

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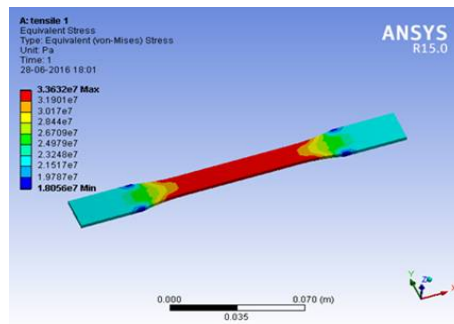
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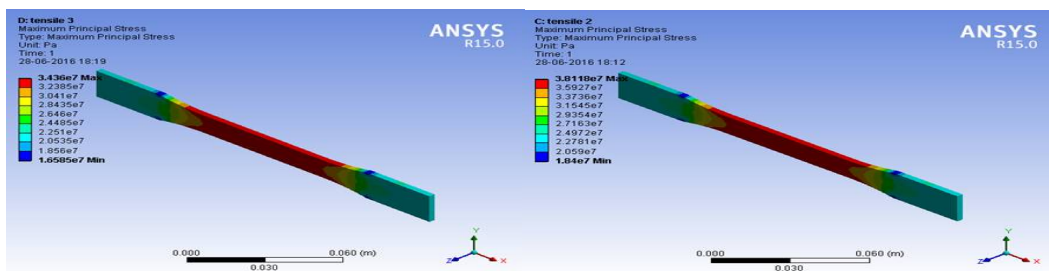
(a) Equivalent stress on tensile Specimen 0°

(b) Equivalent stress on tensile Specimen 45°



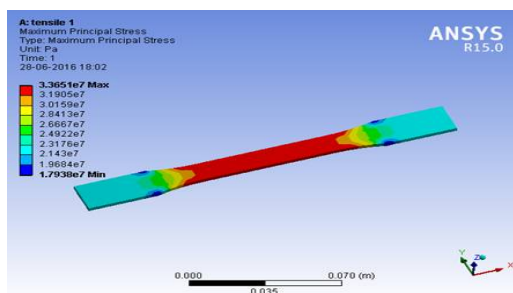
(c) Equivalent stress on tensile specimen 90°

Above figure shows the static structural analysis of the ABS component built by FDM process. Equivalent Stress is maximum in the region of gage length and it is due to the sudden change in the cross section near the gage length which leads to high stress concentration as shown in the figure (a), (b) and figure (c). Equivalent stress greatly affected by the build orientation angle hence the equivalent stress can be seen more in 45° build oriented specimen and less in case of 0° & 90°.



(a) Maximum principle stress on tensile Specimen 0°

(b) Maximum principle stress on tensile Specimen 45°



(c) Maximum principle stress on tensile specimen 90°

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Above figure shows the static structural analysis of the ABS component built by FDM process. Principle Stress is maximum in the region of gage length and it is due to the sudden change in the cross section near the gage length which leads to high stress concentration as shown in the figure (a), (b) and figure (c). Maximum principle stress greatly affected by the build orientation angle hence the maximum principle stress can be seen more in 45° build oriented specimen and less in case of 0° & 90°.

VI. CONCLUSION

ABS material was successfully fabricated using aha! Proto center 999 FDM machine by varying temperature, feed rate and layer thickness. Specimens were fabricated using 0° 45° and 90° orientation. Tensile test were performed, also FEM stress analysis was done using ANSYS workbench. Based on the results following are the conclusions.

- Conducted tensile test on the test specimen.
- Based on maximum tensile test, it is found that 230°C temperature, 16 mm/s feed rate and 0.15 mm layer thickness are the optimum level for building the models in different orientation.
- FEM analysis performed using ANSYS Workbench software on the tensile test specimens showed that the model at 45° orientation has maximum tensile stress.
- It is found that stress magnitude of theoretical values closely matches with experimental stress values.
- The model built at 0° orientation and model built at 90° orientation has less tensile strength.

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