

Experimental and Finite Element Analyses of an I-Shaped Prototype for Different Orientations and Thicknesses

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ABSTRACT: Rapid Prototyping (RP) has been a powerful technology for preparing Prototypes of complex parts and products. In the present work, Fused Deposition Modelling concept of RP is used to prepare I-Shaped prototype using Acrylonitrile Butadiene Styrene (ABS). Two orientations, namely, Horizontal-Vertical ($0^{\circ}/90^{\circ}$) and Criss-Cross ($+45^{\circ}/-45^{\circ}$) orientation for the layers have been used. Also different thicknesses of prototype are considered (3mm, 4mm, 5mm & 6mm) for experimentation. By preparing different orientation-thickness combinations of the prototype, vibrational analysis is carried out and frequencies and deflections are determined. Also, finite element analysis is carried out using ANSYS software, and the results obtained are compared with the experimental results.

KEYWORDS: Rapid prototyping, Fused Deposition Modelling, Fabrication, Vibration, Frequency, ANSYS WORKBENCH, Acrylonitrile Butadiene Styrene (ABS).

I. INTRODUCTION

Rapid prototyping is used to quickly fabricate a prototype of a part using 3D computer aided data with the layer-by-layer addition of the material. Fused Deposition Modelling (FDM) comes under the solid based Rapid Prototyping systems. The current range of materials include Paper, Wax, Resins, Nylon, Plastics, Thermo-plastics, Metals and Ceramics.

Among the various Rapid Prototyping systems, FDM has major advantages, since the FDM prototyped parts need not to be subjected to the post-processing tasks like cleaning and post-curing. FDM uses production-grade thermoplastics. Parts built from this 3D printing technology has high thermal, mechanical and chemical strengths when compared to the other Rapid Prototyping processes. In FDM machines head moves in X-Y direction and the build platform moves in Z direction which helps in printing the parts in different orientation as shown in fig 1[12]. FDM systems use two spools of material, one for the build material and second for the support material. The build material is supplied in the form of spools and is fed into the extrusion head where the material is heated just above melting point so that it solidifies easily after extrusion. Once the required part is printed completely, it is removed from the printer and the part is separated from its support structure [11]. The prototype exhibited different properties based on its printing orientation and layer thickness [5, 3].

As Vibration plays an important role in the engineering components, in this paper, an effort is made to find experimentally, the vibration properties such as frequency, deflection, and those frequencies are compared with the values obtained using ANSYS WORKBENCH.

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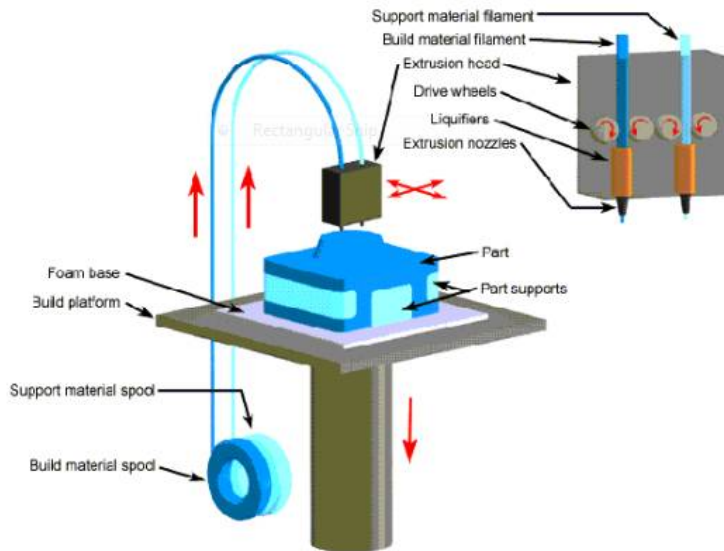


Figure 1. Schematic of FDM (Garg and Singh, 2011 [12])

Figure1 shows the Fused Depositing modelling process arrangement consisting of the extruders, print heads, material spools and support material spools, build platform which has movement in Z-direction.

II. FABRICATION OF SPECIMENS.

I Shape models have been fabricated for the present study and the material used is Acrylonitrile Butadiene Styrene (ABS) thermo-plastic. FDM principle based 3D printer is used to print the models of various part thicknesses in two different layer orientations (horizontal-vertical, criss-cross) with common layer thickness of 0.1mm for all the parts. The various dimensions of the I-Shaped prototype are shown in figure.2. The various part thicknesses considered in this study are of 3mm, 4mm, 5mm, 6mm. Hence a total of eight samples were fabricated. The table.I shows the details of no. of specimens fabricated for the respective orientations and part thickness.

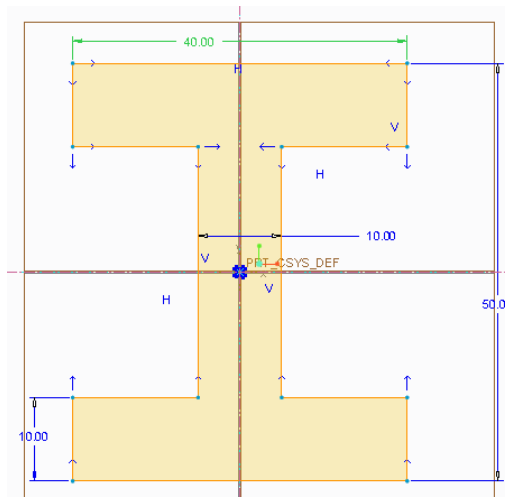


Figure 2. I-Shaped prototype with dimensions

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The detailed breakups of the number of specimens fabricated for each layer orientation and part thickness is given in Table I.

TABLE. I: Orientation-Thickness combinations for the Prototype.

Part Thickness (mm)	Layer Orientation	
	Horizontal & Vertical (0°/90°)	Criss-Cross(+45°/-45°)
3mm	1	1
4mm	1	1
5mm	1	1
6mm	1	1

Mechanical properties of ABS material obtained in Tensile test are as follows:

TABLE IIMECHANICAL PROPERTIES OF ABS PLASTIC

Yield Stress (Mpa)	Poisson's Ratio	Density (Kg/m ³)	Young's Modulus (Mpa)
29	0.3	1040	1635.185

III. EXPERIMENTAL SETUP AND EXPERIMENTATION

The fabricated models were set for analysing their natural frequency. The experimental system consists of three main components: 1. Impact Hammer, 2. Accelerometer, 3. Data Acquisition System(DAQ).

Figure3, Figure4&Figure5 shows the components employed for the present experimentation.



Figure3. Impact Hammer

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Figure4. Accelerometer



Figure5. DigitalAcquisition(DAQ)System

The Impact hammer is used to create an impact over the prototype. The accelerometer is used to convert the mechanical motion of the structure into an electrical signal. The DAQ system is used to convert the analog signals into digital format. Software, DEWESOFT 7.1.1. is used to execute signal processing and to analyse.

Free vibration is conducted on the test specimen to obtain its Dynamic characteristics includes natural frequencies and deflections. The prototype is supported as cantilever. The impact is applied by striking at the free end of the test specimen.

During free vibrations, the dynamic response of the beam is measured through the accelerometer. For this test, the location of the accelerometer is set at the free end of the prototype, in order to extract the signals of the vibrations. The accelerometer mounted is used primarily for measuring the response in terms of acceleration. A Data Acquisition system is used to store the record data and transfer the measured data to the system installed PC for analysing the results. From this Fast Fourier Transform [FFT] graphs are obtained and hence the natural frequencies are analysed.

The prototype is supported as a cantilever and hammering is done at the free end by using the Impact Hammer and the Accelerometer which is attached to the prototype with the help of wax, record the vibrations and the recorded vibrational signals are sent to the Digital-To-Analog conversion unit. Then the analog signals are sent to analysis in DEWESOFT 7.1.1. Thus the vibrational analysis is done and the natural frequency values are obtained. Also the deflection in terms of 'g' value are obtained and equivalent values are calculated in terms of 'mm' using an empirical relation.

IV. EXPERIMENTAL RESULTS

For the experimental setup and the process of experimentation done, the natural frequencies obtained are noted as shown in table.III. Finite Element Analysis [FEA] is also done for the same prototypes to analyse their frequencies and deflections. The values obtained from FEA are also noted. Hence the experimental results and FEA results are compared and as shown in table.IV.

It is found the experimental results, analysed, that the frequencies of prototypes increased with increase in part thickness. This might be due to that the molecules accumulated increase with part thickness and hence the moment of molecules might be increased. Also, the stiffness of the prototypes increases may also results in the increase of frequencies.

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Also, the variation in frequencies is observed with the change in layer-orientation. For the layer orientation of Horizontal ($0^0/90^0$), the frequencies obtained were greater compared to criss-cross ($+45^0/-45^0$) orientation. This shows that the criss-cross layer oriented parts have greater stability.

From the comparison of the Experimental results & FE Analysis results, small variation in the results observed. This might be due to process-errors occurred/encountered during fabrication of prototypes.

The Frequency graph as shown in Figure 5 was obtained from ANSYS WORKBENCH 17.0 for I-shape model with 3mm thickness. The frequencies of the remaining specimens are driven out of ANSYS as the present one.

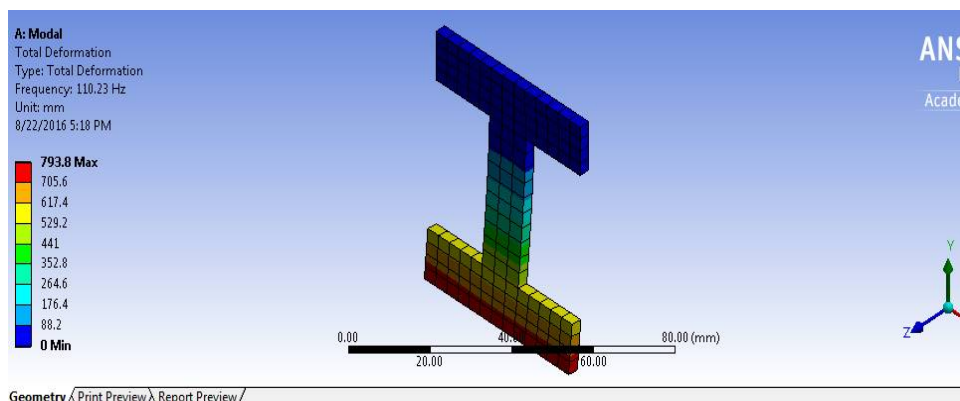


Figure 6 ANSYS Frequency

TABLE III FREQUENCY AND DEFLECTION

Part thickness (mm)	Layer Orientation	Frequency(HZ)	Deflection (mm)
3mm	Horizontal & Vertical (0/90)	140	0.00313
	Crisscross (45/-45)	117.5	0.01041
4mm	Horizontal & Vertical (0/90)	152.5	0.000170
	Crisscross (45/-45)	117.5	0.00381
5mm	Horizontal & Vertical (0/90)	172.5	0.00122
	Crisscross (45/-45)	170	0.00387
6mm	Horizontal & Vertical (0/90)	237.5	0.00263
	Crisscross (45/-45)	237	0.00240

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TABLEIV COMPARISON OF NATURAL FREQUENCY

Part Thickness(mm)	Layer Orientation	Natural Frequency (Hz)	
		Experimental	ANSYS
3mm	Horizontal and Vertical (0/90)	140	110
	Crisscross (+45/-45)	117.5	
4mm	Horizontal and Vertical (0/90)	152.5	145
	Crisscross (+45/-45)	117.5	
5mm	Horizontal and Vertical (0/90)	172.5	164.97
	Crisscross (+45/-45)	170	
6mm	Horizontal and Vertical (0/90)	237.5	215.99
	Crisscross (+45/-45)	237	

V. CONCLUSIONS

The experimental modal analysis is done to find out the vibrational properties of 3D printed I-shaped prototype supported under cantilever conditions. The results obtained from the ANSYS analysis are matching with those obtained experimentally. The natural frequency of the prototype obtained from experimentation indicates that the value changes when the part thickness and layer orientation of the model changes. This indicates that catastrophic failures may occur if proper layer orientation and part thickness are not selected in real life situations. Further experiments are needed to verify the vibration properties of the Rapid Prototyped components.

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