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Effect of Process Parameters on the Mechanical Properties of the Components Made From Acrylonitrile Butadiene Styrene (ABS) Using 3D Printing Technology

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Abstract:- **3D printing is one of the latest technologies used in the development of prototypes. Many researchers have carried out a lot of work on the materials used and also on the type of 3D machines. In the present investigation, a 3D printing machine was used based on Cartesian coordinates. The material used was Acrylonitrile Butadiene Styrene (ABS). The process parameters infill and layer thickness were varied to find out the structure and strength of the product. Around 9 samples were prepared by varying the infill and layer thickness. The prepared specimens were tested for surface roughness and hardness. The specimens were also observed under scanning electron microscopy (SEM) for their structure. It was observed that the specimen with the highest infill and least layer thickness has produced better results in terms of roughness and the specimen with the highest infill and largest layer thickness has produced better results in terms of hardness.**

Keywords- 3D printing, Infill Percentage, Layer Thickness, ABS.

I. INTRODUCTION

Traditionally manufacturing of components for automobile are done by casting, powder metallurgy etc. The traditional method is time consuming in getting a standard object as lot of machining has to be done to get a prototype. During this process there is wastage of material and time to get the prototype. It also involves die making which increases the cost of the machining operation. All these limitations of the traditional method of manufacturing are eliminated in additive manufacturing process. Using additive manufacturing, complex and intricate 3D parts can be built without any die and in short time. Many 3D printers produce parts which can be used as prototypes.

II. LITERATURE SURVEY:

3D Printing, also known as Additive Manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and typically are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file. Various 3D printing methods are Stereolithography, Digital light processing, Selective laser melting, and Selective laser sintering, laminated object manufacturing, and fused deposition modeling. Out of these above methods fused deposition modeling (FDM) is widely used in getting prototype using Nylon, ABS, and PLA etc in laboratories. The process parameters that control FDM are bed temperature, Nozzle temperature, feed rate, layer thickness, infill pattern, infill percentage, orientation of object. Thomas, et.al. has studied the effect of process conditions on mechanical properties of laser-sintered nylon[1]. Antonio et.al., has observed the impact of process parameters on mechanical properties of parts fabricated in PLA with an open-source 3-D printer [2]. Hwang made studies on thermo-mechanical characterization of Metal/Polymer composite filaments and printing parameter study for fused deposition modeling in the 3D printing process [3]. Kaufui [4] et.al., has made elaborative review of additive manufacturing by taking into account all parameters. Materials used in this process are polycarbonate (PC), Acrylonitrile butadiene styrene (ABS), polyphenylsulfone (PPSF), PC-ABS blends, and PC-ISO, which is a medical grade PC. The main advantages of this process are that no chemical post-processing required, no resins to cure, less expensive machine, and materials resulting in a more cost effective process. The disadvantages are that the resolution on the z axis is low compared to other additive manufacturing process, so if a smooth surface is needed a finishing process is required and it is a slow process sometimes taking days to build large complex parts. To save time some models permit two modes; a fully dense mode and a sparse mode that save time but obviously reducing the mechanical properties. Nannan [5] has given examples of

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application of FDM. Omar [6] has worked on optimization of fused deposition modeling process parameters.

III. EXPERIMENTAL STUDIES:

The FDM process starts by designing the part on a CAD workstation using a suitable CAD package (I-DEAS,). This design is then imported into the slicing and tool path generating software (Protoslice™) which slices the design mathematically into layers. This program then creates the deposition paths or roads. The Protoslice ™ software controls the motion of the nozzle and the motion of the feed wheels. In general, the outer perimeter of the part is laid down first, after which the plane is filled. The layers are deposited consecutively at different angle to the previous one to improve homogeneity. For proper plane or volume filling, the characteristics of the hardware, such as the nozzle diameter, must be considered when the slicing routine and tool path are generated. If, for instance, a road width is chosen that does not match the nozzle size, this will lead either to gaps or too much material being deposited. Generally, the firmware sets certain default parameter values, once the nozzle diameter is chosen. During deposition, the nozzle needs to move very efficiently in the x and y direction to assure a uniform road width. However, at the start and stop of a road, the nozzle and material flow needs to be controlled even more accurately to ensure complete filling. The printing speed was set to 150mm/s and the infill pattern was straight.
AHA 3D printing machine was used to print the specimens is shown in Fig 1. The machine works on Cartesian coordinates. The specimens are made out of ABS (Acrylonitrile butadiene styrene) Plastic. The process parameters, infill percentage and layer thickness were varied keeping all other parameters constant. The infill was varied in steps of 20, 33.33 and 50. The layer thickness was varied in steps of 0.15, 0.20, and 0.30mm. The specimen dimension is 30x30x10mm.

Fig1. AHA 3D Printing Machine

The specimen's roughness was measured using talysurf roughness tester under JIS 1994 standard for Ra (average) and Rq (root mean square) values. The specimen's were tested for hardness using Rockwell hardness tester. The specimens were later observed under scanning electron microscopy for their structure.

IV. RESULTS & DISCUSSIONS

Table 1 gives surface roughness with constant layer thickness. It was observed that with increase in infill with constant layer thickness both Ra and Rq value has decreased. This may be due to proper filling of gaps by material. Table 2 gives surface roughness for constant infill. With increase in layer thickness with constant infill both Ra and Rq has increased for 20% infill. Similar values are observed for 33% infill and 50% infill. Therefore for higher layer thickness with same infill gives coarse surface.

Table1. Surface Roughness for constant layer thickness

Layer Thickness(mm)	Infill%	Ra(µm)	Rq(µm)
0.15	20	11.28	13.84
0.15	33.33	10.98	13.5
0.15	50	9.99	11.88
0.20	20	15.58	18.65
0.20	33.33	15.18	18.27
0.20	50	15.17	18.22
0.30	20	20.93	24.98
0.30	33.33	18.36	22.34
0.30	50	16.21	19.55

Table2. Surface Roughness for constant infill

Layer Thickness(mm)	Infill%	Ra(µm)	Rq(µm)
0.15	20	11.28	13.84
0.20	20	15.58	18.65
0.30	20	20.93	24.98
0.15	33	10.98	13.5
0.20	33	15.18	18.27
0.30	33	18.36	22.34
0.15	50	9.99	11.88
0.20	50	15.17	18.22
0.30	50	16.21	19.55

Table 3 gives hardness values for constant infill. It is observed that with increase in layer thickness for constant infill the hardness has increased. With increase in infill the hardness has further increased.

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Table3. Hardness values for constant infill

Infill %	Layer Thickness(mm)	HRL
20	0.15	29.00
20	0.20	29.67
20	0.30	39.00
33.33	0.15	45.17
33.33	0.20	46.25
33.33	0.30	48.32
50	0.15	51.00
50	0.20	55.67
50	0.30	56.33

Fig 2 shows graph of increase in hardness with increase in infill. Fig 3 shows indentation mark on the specimen. Bigger diameter indentation marks are observed.

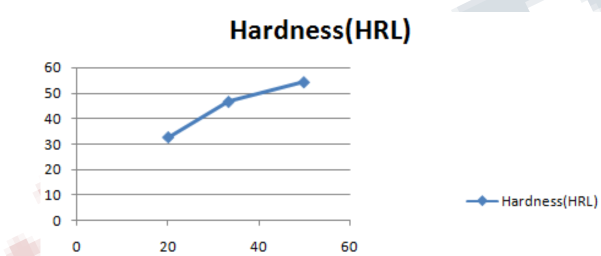

Fig 2 Increase in hardness with increase in infill.

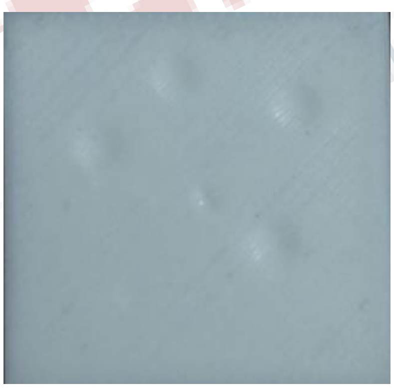

Fig 3 Indentation mark

Figure 4 is a SEM micrograph showing the presence of sub perimeter voids in ABS part in the x, y build plane for 0.15mm layer thickness. Figure 5 shows SEM micrograph for 0.20mm layer thickness. Figure 6 shows SEM micrograph for 0.30mm layer thickness. Voids and road thickness variation are caused by inconsistent material flow due to both slipping in the filament feed mechanism and variations in the filament diameter. However by carefully changing the process parameters it is possible to remove these defects altogether, as can be observed in Figures 5 and 6. This shows that the process can be optimized and that these unique defects can be removed without changing any of the hardware or the necessity of using any post processing steps.

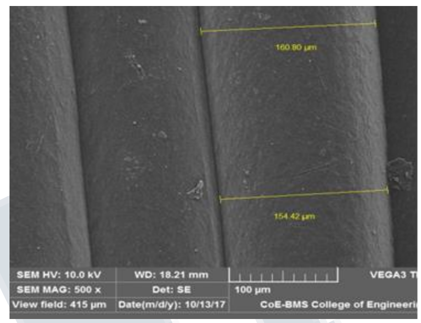

Fig 4 SEM Microphotograph for layer thickness of 0.15mm

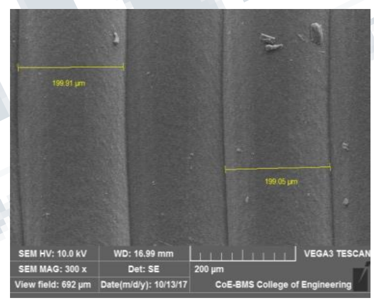

Fig 5 SEM Microphotograph for layer thickness of 0.20mm

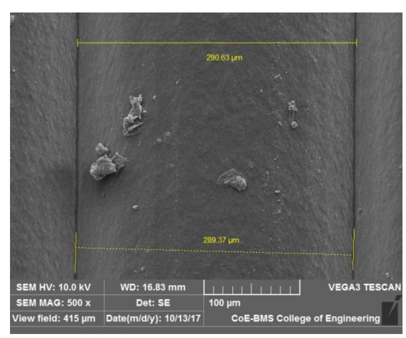

Fig 6 SEM Microphotograph for layer thickness of 0.30mm

V. CONCLUSION:

(i)The process parameter affects the output of specimens made by Cartesian coordinate 3D printing.

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(ii)It was observed that with increase in layer thickness with constant infill both Ra and Rq has increased.
(iii)It was observed that with increase in infill with constant layer thickness both Ra and Rq value has decreased.
(iv)It is observed that with increase in layer thickness for constant infill the hardness has increased. With increase in infill the hardness has further increased.
(v)With increase in infill voids defects can be reduced.

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