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Effect of Infill Density on Surface Quality of ABS Material in FDM Technology

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***Abstract*—Additive manufacturing (AM) is a method of manufacturing process where layers of raw materials are built up to create a solid object from computer aided design (CAD) design to the final part. It is also called as rapid prototyping or 3D printing. The AM in recent years has covered almost all the materials in manufacturing industry including medical sector. There are different types of AM technologies which are utilized by different industry for the purpose of product development and prototyping. Out of various AM techniques, Fused Deposition Modelling (FDM) used widely. FDM is a technology in which the melted thermoplastic materials are squeezed from the nozzle and any type of complex geometry can be obtained by tracing boundaries of the design with squeezed material. This paper presents an experimental analysis of Acrylonitrile Butadiene Styrene (ABS) material used with FDM to prototype a specimen. The major parameters considered are infill density, fill pattern and material consumption. Specimen is designed in SOLIDWORKS software. The results are discussed based on the effects and inter-relation of the mentioned parameter on surface quality.**

***Keywords*— FDM, Additive Manufacturing, 3D printing**

I. INTRODUCTION

AM technology is the manufacturing process where metals are joined to form 3D objects, generally layer upon layer[1]. It is also defined as rapid prototyping or rapid manufacturing process. It is different from conventional manufacturing process where final products are formed by removing materials from raw materials whereas in additive manufacturing final product is created by adding materials layer upon layer[2]. AM has efficient ability to use raw materials and generate minimal wastage to reach satisfactory geometric accuracy[3]. A designed CAD model is transferred to a finished part without the use of additional jigs and fixtures[4]. AM has ability to make complex geometries into a single object. The steps involved in additive manufacturing process are shown in figure 1.

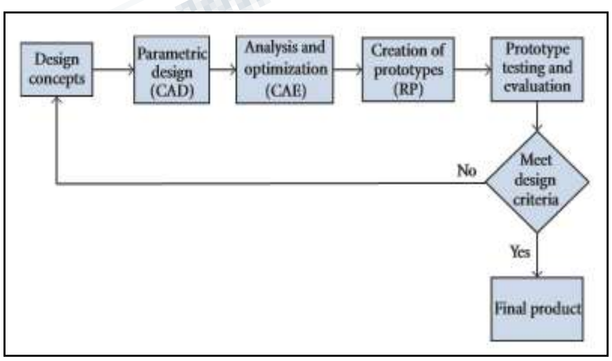

Figure 1: Steps Involved in Additive Manufacturing[1]

There are various advantages of additive manufacturing like this technology only requires single step manufacturing, customization or modification of products at a faster rate than conventional manufacturing, requires less skilled labour than conventional manufacturing to operate the machine, initial cost of production is very less compared to conventional manufacturing, requires less space for operation of machine and consumes less electricity[4], [5].

II. FUSED DEPOSITION MODELLING:

There are different types of 3D printing techniques like, Vat Photopolymerization, Powder Bed Fusion, Fused Deposition Modelling/Material Extrusion, Binder Jetting and Direct Energy Deposition[6]. While FDM is one of the fast-growing AM technology that it is now used for large manufacturing companies around the world. It has versatility and low cost, high manufacturing flexibility and resource efficiency. FDM manufactures the parts using strings of solid thermoplastic material, which comes in a filament form. The filament is pushed through a heated nozzle where it is melted. 3D printer continuously moves the nozzle as per the pre-determined path laying down melted material, When the material cools it solidifies, building the part layer-by-layer. Different materials are used in FDM technology such as polylactic acid (PLA), ABS, polyethylene terephthalate (PET), nylon and many other thermoplastics[7].

The first step in manufacturing process with AM technologies is the designing of CAD model in the

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appropriate designing software. After that CAD model is sliced into an STL (Stereolithography) file. STL is also known as Standard Tessellation Language[8]. Once STL file is generated and is imported in slicer program. The STL file generates the programing language of G-codes which are used in computer numerical control programing. Once the parameters are fed in computer software and printing setting the printing process can be executed. After printing, post processing can be done if required else it will be tested as required. FDM is mostly used AM technologies due to its low cost and ease of application[9]. FDM is one of the most widely AM technology.

However, it is not completely adapted by industries yet due to the various parameters that govern the process, as well as the lack of standardization[10]. One of the major concern with infill density parameters that affects the surface quality as well as strength of the printed parts.

III. EXPERIMENTAL METHODOLOGY:

The aim of this study and experiment is to investigate the surface quality by changing the infill density, materials, on finished product of mentioned design. Experiment methodology schematic preview is presented in Fig. 3. The sliced view of design in software is shown in Figure 2. The experiment was conducted on single extruder printer, the filament used was ABS, design was prepared on Solid Works and Repetier Host was utilized to slice the design.

There are two widely used technology these days SLA (Stereolithography apparatus) and FDM. FDM was chosen due to its low machine cost and less effects by the environmental conditions. The experimental data was recorded five times with different infill density as shown in table 1.

S.No.	Infill Density	Fill Pattern	Manufacturing/Printing time	Layer count	Materials need	Material
1	20%	Honeycomb	16 minute 8 Seconds	23	2477 mm	ABS
2	40%	Honeycomb	16 minute 33 seconds	23	2604 mm	ABS
3	60%	Honeycomb	16 minute 40 seconds	23	2670 mm	ABS
4	80%	Honeycomb	16 minute 55 seconds	23	2766 mm	ABS
5	90%	Honeycomb	17 minute 14 seconds	23	2849 mm	ABS

Table 1: Experimental Result

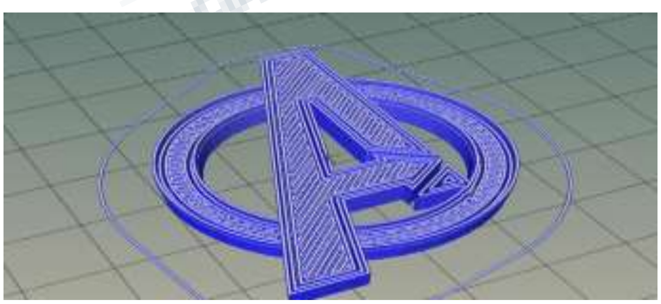

Fig. 2: Sliced View On Repetier Host

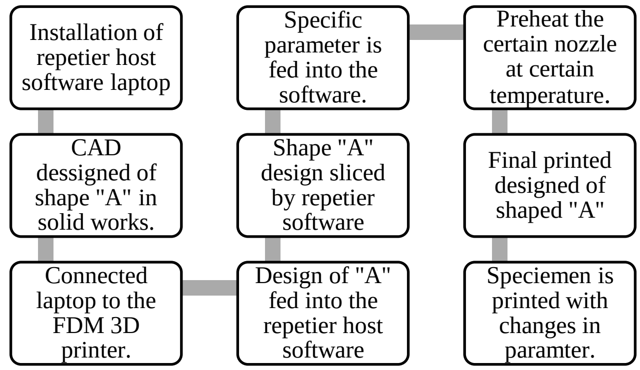

Fig. 3: Methodology

IV. RESULT & DISCUSSION

In this experiment, the design is printed with different infill density such as 20%, 40%, 60%, 80% and 90% with ABS materials. The results for different parameters are shown in table 1. The surface quality and the manufacturing time of the specimens significantly increasing with the increasing of infill density. The number of layers are kept same in all the printed specimen. Infact strength increased by increasing the infill density as used materials are same for all. The images of three printed parts are shown in figure 4. The surface quality of the product was also upgraded with the increase in infill density as the void between the layers decreases. The manufacturing printing time as well as material consumption is increased by increasing the infill density as shown in figure 5 (a) & (b) respectively.

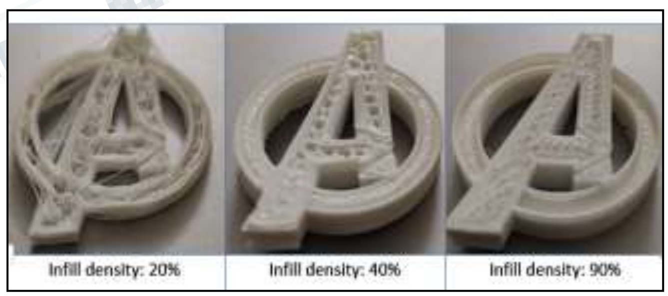

Figure 4: Printed Parts with Different Infill Density

Figure 5: Effect of infill density: (a) Graph Between Manufacturing Printing Time with Infill Density (b) Materials Consumptions with Infill Density

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V. CONCLUSION

Currently lots of industries are working on the improvement of various parameters to establish the standardization. Infact FDM is one of the cheapest technology due to which it has captured the market very aggressively. It can be noticed in this experiment that variation in infill density affects the surface quality of printed specimen, strength of specimen, material consumptions of raw materials and printing time.
After printing the same design "A" with different infill density, it can be concluded that, the infill density affects the surface quality of the printed parts. The infill density affects the manufacturing printing time duration by increasing the infill density, manufacturing time duration is increased. The infill density also affects the aesthetic view as shown in figure 5. By increasing the infill density aesthetic view is also increased. Material consumptions are increased with increase in the infill density. More materials consumption led to more manufacturing cost. It's a very good observation that unnecessary consumption of materials can be avoided. We can print the specimen as per our requirement. It can save additional consumption of materials as well as manufacturing time too. Infill density directly proportional to material consumption as shown in figure 9.
This experiment analyses only influence of infill density on surface quality of ABS materials in FDM technology. In future research, parameters such as different materials with same infill density should be examined. Standardization of parameters are required to maintain the quality of the printed parts. Otherwise heat and trail method always waste the materials to find the required surface quality for the first printed part..

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