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FUSED DEPOSITION MODELING REVIEW: THE STATE OF ART

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ABSTRACT
Additive manufacturing is the process of fabricating the three dimensional CAD data to real world product by using different group of technique. One of the most popular method of additive manufacturing is Fused Deposition modelling. In Fused Deposition Modeling, the CAD 3D data is visualise and fed to the printing system, which process on the data and manufacture the product layer by layer. In this competitive era, it is very important to reduce the cycle time of the production, reducing steps between designs to develop and limiting the cost requirement for tooling and accessories. Hence, additive manufacturing have been evolved with limiting steps, cost, accessibility and accuracy as the steps get reduced, and no special tooling required for manufacturing. Still it is very important to study about the topology, structural and mechanical properties of the component derived from this technology.

This review paper is an attempt to study the view of the investigators about the technology, process parameters and its effect.

Keywords: Fused Deposition modelling, additive manufacturing, 3D printing

1.0 INTRODUCTION
Additive manufacturing process is the process of manufacturing of any object, component or part layer by layer. It is completely opposite of subtractive manufacturing.

There are different additive manufacturing methods. They are as follows:
- Stereo lithography (SLA)
- Digital Light Processing (DLP)
- Fused deposition Modeling (FDM)
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Electronic Beam Melting (EBM)
- Laminated Object Manufacturing (LOM)
- Binder Jetting (BJ)
- Material Jetting

In this research paper, we are going to focus on the study of Fused Deposition Modelling.

1.1 Fused Deposition Modelling:
Fused deposition modelling is the process of deposition of material layer by layer as in the fused form. Fused Deposition modelling is used for rapid prototyping, modelling, and production purpose.

1.2 Working of FDM machine
In the fused deposition modelling process, a gantry-robot can move in two orientation i.e. X and Y which is fixed with extruder and the table in Z orientation. Table moves in Z orientation, down direction as per thickness of the layer and as layers are deposited.

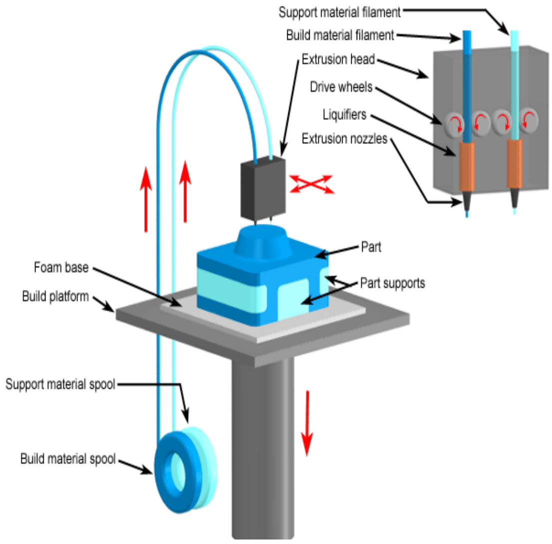

Fig 1 Working of FDM

Materials used in making FDM parts

The material used for fused deposition modeling are generally thermoplastic like ABS, PLA etc in filament.

2.0 LITERATURE REVIEW

M. Iliescu [2008] et al has applied finite element method simulation in 3D Printing. It have been simulated by using CFD and heat transfer. The process is been carried out by using method of finite element. Due to application of this method, the shape of the device can be enhanced due to which optimal functional characteristics of laser can be achieved

Mohammad Vaezi [2011] et.al have studied the influence of different properties of binder, thickness of the layer, level of saturation etc on the surface finishing and strength of the process of deposition. The aim of the study was to analyse the effect of the characteristics like thickness of layer and saturation level on strength of the object, its reliability, finishing and quality of surface of the process of deposition. The specimens are developed by different level of input parameters for tensile and flexural testing by utilising ZP102 and Zb56 binder of ZCorp.

Table 1 Input parameters and their levels

Parameters	Level 1	Level 2
printing layer thickness	0.87 mm	0.1 mm
binder saturation levels	90%	125%

From the experimentation, he have concluded that, with increase Binder saturation from 90-125%, flexural and tensile strengthincreases of the 3d printed object whereas accuracy and surface uniformity decreases, when layer thickness remains constant.

When the layer thickness is increased from 0.087 to 0.1 mm, at constant binder saturation, Uniformity of surface improves whereas tensile and flexural strength reduces.

Ivan Gajdos [2013] et al have investigated the influence on 3D printed object of temperature and layout of plate. To study and analyse the effect of the temperature at the time of the process various heads and cover temperature were introduced for object under construction. Investigator implemented tomography methodology for analysing Structural and dimensional aspects of the specimen created from Acrylonitrile Butadiene Styrene.From the experimentation, it was found that specimen created by fused deposition modelling had non-uniformity in structure .

TomislavGaleta[2013] et al have studied to find the most optimal input factor combination to attain highest tensile strength. The researcher have experimented by varying Object Orientation of deposition, Thickness of the layers, and type of infiltrant.

From the experimentation investigator concluded that, type of infiltrant also effect on tensile strength significantly. In comparison of genuine infiltrant and Alternative infiltrant, alternative infiltrant found equivalent.

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B. M. Tymrak [2014] et al studied for ABS and PLA made 3D printed object's tensile strength and modulus of elasticity and found:

Table 2 Results for ABS and PLA [5]

Material	Average Tensile Strength (MPa)	Average Modulus of Elasticity (MPa)
ABS	28.5	1807
PLA	56.5	3368

David D. Hernandez [2015] et al
Have studied Design of experimentation using Full factorial method and analysis of Variance for Polylactide and acrylonitrile Butadiene Styrene having different factors as an input and dimensional accuracy as an output. He have aim to evict the factors that are not significant for getting consumer grade 3D printing for application.

F. Roger [2015] et al has used the combination of the material like Virgin ABS and ABS with carbon black. Fused deposition modelling have been used for preparation of specimen. Topological analysis have been done to study geometrical aspects. Properties like stiffness and reduction in stress concentration can be achieved by optimising infillment of the input material.

Wenzheng Wu[2015] et al finds the shortcomings occurred using the materials in used. And to cope up with shortcoming, he selected the new material for 3d printing i.e. polyether-ether-ketone (PEEK). The input parameters were layer thickness and raster angle and output parameters were tensile, compressive and tensile strength. Levels of layer thickness selected were 200, 300 and 400 microns and for raster angle 0, 30 and 45 degree. From the experimentation, it was found that, PEEK materials used for fused Deposition modelling exhibits better results in terms of properties against ABS.

Aron Foster [2015] have studied the recent additive manufacturing methods for polymers and their composites and checked the suitability of the process for mechanical properties and failures with ASTM and ISO standard test methods. But this standards are developed to test the existing material manufactured by using traditional method. Hence, significant guiding principle should be made for additive manufacturing material. The program should be developed for focusing molecular architecture of additive material measurement.

Filip Górski [2015] et al carried out the experimentation for testing tensile, bending and compressive strength on specimens developed by using fused deposition modelling for Acrylonitrile Butadiene styrene. The input parameter selected was orientation of deposition. With variation of orientation some unique variation have found with macroscopic structure along with its mechanical properties under load. Variation of elastic material to brittleness at an orientation found, the orientation have been termed as "critical orientation" by investigator.

Jochen Mueller [2015] et al used inkject 3D printer for the process of manufacturing the component. The parameter taken under study were Material storage, deposition, evaluation, and storage of the components. The aim of the study was to understand the effect of different input parameter and its effect on mechanical properties and topological aspects of the object derived. It have been concluded that mechanical properties have been majorly influenced by interstion number between deposition layer and nozzle with direction of load followed by Time of ultraviolet exposure, position and material expiry date. Storage time do not have significant effect. Surface roughness is not been influenced by any factor. Warm up time is significant factor. Width and waviness of the product is been influenced by nozzle blockage.

HadiMiyanaji [2016] et al have studied on the material used for dental applications. Investigator accomplished the research to realization of optimal process parameters for porceline material used in dentistry, which have been developed by via ExOne binder jetting system and also exhibited guidance for developing glass ceramic material.

K.G. Jaya Christiyan[2015] et al has used composite material made from ABS and hydrous magnesium silicate. Flexural and tensile testing have been carried out for the specimen prepared by standard ASTM D638 and ASTM D760. Input parameters were layer thickness and speed of deposition. It has concluded that, specimen derived with low speed of deposition and low layer thickness, exhibits higher tensile and flexural strength.

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CONCLUSION

From above literature review, it has been understood that ABS, PLA, PEEK resins are used for FDM machines, these materials are tested with respect to process parameters to find mechanical properties. In recent year new materials like Z-UltaT, HIPS are also introduced in market. Its need to investigate the effect of process parameters on these types of newly introduced material. It is also understood from the above literature that there is no mathematical model developed till yet in terms of process parameters like layer thickness, rate of deposition, percentage infill etc with respect to orientation.

Hence there is scope to know the effect of process parameters for newly introduced materials as well as to develop mathematical or empirical models.

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