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TENSILE BEHAVIOUR ANALYSIS OF DOG BONE STRUCTURE OF 3D-PRINTED COMPONENTS USING FDM OF DIFFERENT MATERIALS

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Abstract :Additive manufacturing AM in the modern technique which is capable to manufacture complete shape geometries. It produces directly and use product which ultimately eliminates the post processing methods. Currently AM jingo the most promising candidate in the area by biomedical, industrial, space system and many other area. Specially fused depositing (FDM) method is the most easily available and easy hand-able AM process. And built the final product. The quality of the product depends upon due material which is used to built the component. Same other parameter like infidelity, infill, shape, geometry and other are responsible far component quality. In are due to improve the quality on component and to analyze the effect of use of different materials with different in fill shape geometry, this work is carried out. Here it confider three different material that is PVP, PEEK and nylon jar the printing of tensile sentiment. It each case of material, three different infill shape geometries (Triangle, concentric and time) and used. Total I set by experiment was done and analyze the tensile behaviour by different material and different shape geometry.

Keyword *:*- 3D Printing, FDM, Infill Shape Geometry, Deformation Behaviour

I. INTRODUCTION

3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model.There are a number of 3D printing methods, such as ones that deposit substance layer by layer, where a three-dimensional item is created via computer control with material being added together (e.g., plastics, liquids, or powder grains).

Rapid prototyping, a phrase with which the 1980s was saturated, is best defined as the process of quickly making technical and aesthetic prototypes. As of 2019, 3D printing has become feasible as an industrial-production technology, with certain 3D printing methods deemed suitable for industrial-scale usage. When using the phrase additive manufacturing to describe the process, it is no longer an industry standard to use 3D printing as a synonym. While it is feasible to hand-make complicated designs as well as hollow items, 3D printing allows for complex geometries as well as hollow components, particularly designs with inside trusses that are lighter than the same parts would be if produced without such supports. FDM, which is performed using a thermoplastic filament, is the most popular 3D printing method currently in use, as of 2020.

Fig 1. A three-dimensional printer

Succeeding with such a hack would require that the hacker simultaneously control and alter 51% of the copies of the block chain so that their new copy becomes the majority copy and thus, the agreed-upon chain. Such an attack would also require an immense amount of money and resources as they would need to redo all of the blocks because they would now have different timestamps and hash codes. We are on the brink of the so called "fourth industrial revolution". Building on the third industrial revolution, which used electronics and information technology to automate many manufacturing processes, the fourth will fuse many technologies together. Artificial intelligence, IoT, and block chain technology are among the technologies which can completely change the world as we know it.

1.1 GENERAL PRINCIPLES

Modeling

3D images may be captured in a 3D picture frame, and used to create 3D models. To produce 3D printable models, one may use a CAD programme, a 3D scanner, or a cameras as well as picture software to capture images and produce models from them. Compared to other design techniques, 3D models produced using CAD are often less error-prone. If 3D printing errors are caught early, they may be fixed prior to starting the print job. Just like sculpting with clay, manual modelling is the technique of creating geographic information for computer animation. Scanning using 3D imaging produces digital models of actual objects, accessing data about their size and shape.

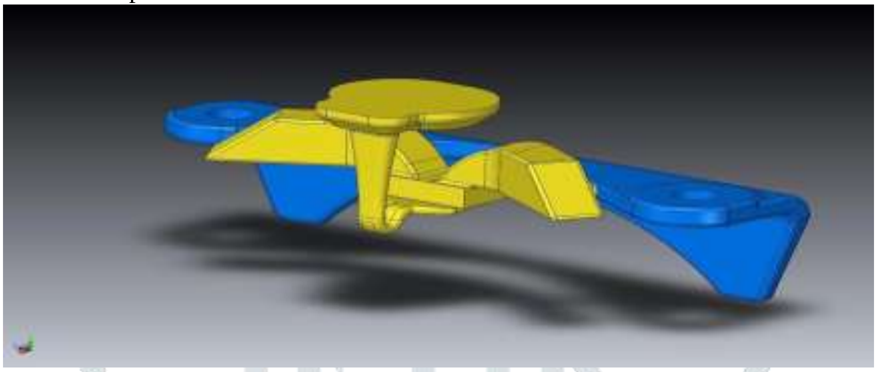

Fig 2. CAD model used for 3D printing

A de facto CAD file format for additive manufacturing, the stereolithography file format (STL) is used to preserve CAD objects based on triangulations of their surface. STL is not meant for additive manufacturing since it produces topology optimised component as well as lattice structures with high file sizes owing to the vast quantity of detailed.

Printing

One must check an STL file prior to 3D printing it for mistakes. CAD programmes may generate the following kinds of STL file errors:

1.holes;
2.faces normals;
3.self-intersections;
4.noise shells;
5.manifold errors.

Repair is one of the steps of STL creation that corrects errors in the original model. STLs that are created from a 3D scanned design are frequently full of these mistakes since they are often generated via point-to-point allocation. Due to a tendency to make mistakes, 3D reconstruction is frequently inaccurate.

Fig. 3. 3D models can be generated from 2D pictures taken at a 3D photo booth.

The STL file is then run through a slicer, which turns the model into a sequence of thin layers as well as generates a G-code file with customised printer instructions (FDM printers). Using 3D printing client software, the G-code file may be printed (which loads the G-code, and uses it to instruct the 3D printer during the 3D printing process)

Finishing

In order to create a slightly enlarged item with the same precision as the printer's normal resolution, use a larger subtractive technique to remove items from an ordinary resolution version of the target image.

All additive manufacturing techniques include a stair-step impact on components that are angled relative to the building platform, and this is caused by the design of the 3d printing. The consequences of the construction process are greatly dependent on the orientation of a portion surface. Chemically smoothing the interface of ABS or other printing materials may be done using acetone-based solvent vapour techniques. Some additive manufacturing techniques allow for components to be built from different materials. Multiple-color printing as well as colour combinations may be printed concurrently, but that's not necessary to paint.

Materials

Because polymers are easier to work with and manufacture, classical 3D printing has utilised them to make 3D objects. Even while the technique used to print several polymers used to be slow, it has since developed to include the printing of metals and ceramics, making 3D printing an excellent choice for production. the construction of three-dimensional physical models using layer-by-layer manufacturing is a contemporary idea "the CAD business has seen continued growth, with its solid modelling branch being a major factor.

Fig. 4 Detail of the Stoofbrug in Amsterdam, the world's first 3D-printed metal bridge.

1.2 MATERIAL EXTRUSION - FDM

The process of extruding substance A thermoplastic concrete is used by 3D printing technology. Filament is supplied from a coil, and it is drawn through a moving heated printer extruder head, which is also referred to as an extruder. The extruder forces the molten material out of its nozzle as well as deposits it first onto a 3D printing platform, which may be heated for better adherence. The first layer is finished, and the extruder its substrate are separated, allowing the second layer to be deposited directly onto the expanding workpiece. The extruder head is connected to the computer. In the Conventional design, at least 3 axes are needed for the extruder to operate, although both polar and delta technologies are gaining traction. Fabrication occurs as each layer is placed over the preceding one.

The Fused Filament Fabrication (FFF) method is a favourite among hobbyist-grade 3D printing enthusiasts because it is a great material extrusion technique. In the late 1980s, Stratasys developed the proprietary term Fused Deposition Modeling (FDM) and began commercialising technology in 1990. Since the patent on this technology expired, it has been used to create a huge community of open-source developers as well as commercial and DIY versions. As a result, prices have decreased significantly.. However, the material extrusion technique has dimensional accuracy limitations and is very anisotropic.

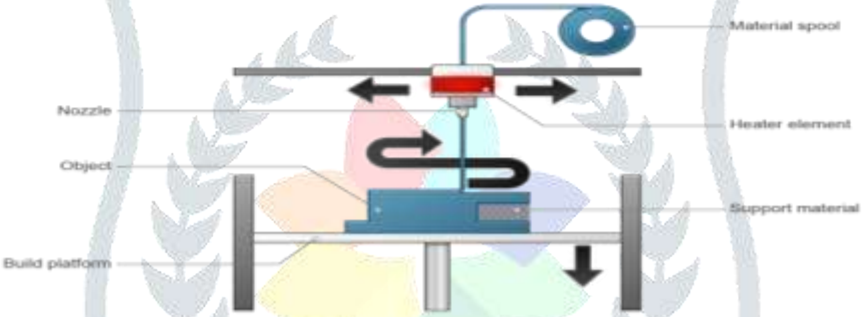

Fig. 5 Material extrusion - FDM

Extrusion is done with different materials, including thermoplastics such as Acrylonitrile Butadiene Styrene (ABS), PolyLactic Acid (PLA), High-Impact Polystyrene (HIPS), Thermoplastic PolyUrethane (TPU), aliphatic PolyAmides (PA, also known as Nylon), and high-performance plastics such as PolyEther Ether Ketone PEEK or PolyEtherimide PEI. Also, 3D printing may be used to extrude paste-like substances like ceramics, concrete, as well as chocolate.

II. EXPERIMENTAL ANALYSIS AND SAMPLE PREPARATION

2.1 Sample Preparation

In order to check the tensile strength and to analyzed the deformation behavior of different materials at different infill geometric shapes, dog bone geometric samples was prepared through FDM at different parameters. First the dog bone structure was prepared through Solidwork then it is imported in to the 3D printing software as a STL file. The dog bone specimen dimension is shown in the below figure.6.

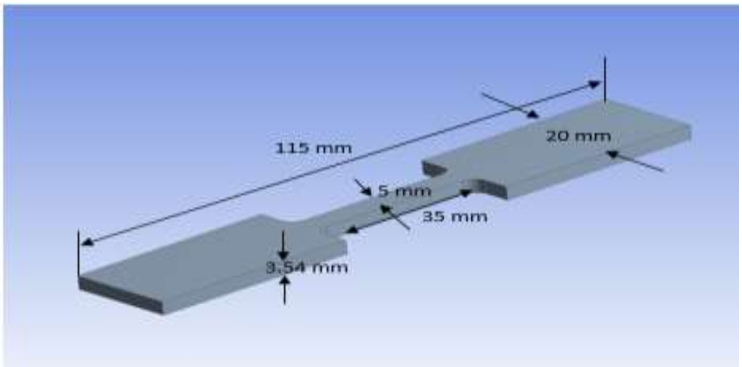

Fig. 6 Shows the geometric specification of dog bone structure used for 3D printing

In order to print the dog bone structure through FDM certain process parameters was considered during printing. The process parameters that are considered during the FDM printing is mention in the below table.

Table. 1Different process parameters that were considered during FDM printing

Parameters	Value
Filament Materials	PVA, PEET, Nylon
Modelling process	FDM
Layer height	0.1 mm
Infill density	80 %
Infill geometric shapes	Lines, concentric, triangular
Raster angle	0 degree
Nozzle diameter	0.25 mm
Nozzle temperature	225 degree
Printing speed	30 mm/s
Printing bed temperature	60 degree
Room temperature	25 degree
Relative humidity	50 (%RH)

As per the previous research work, effect of infill density on a particular material was already done. But up to our knowledge nobody has analyzed the effect of different infill shapes geometry on the mechanical properties of FDM printed components. In this work three different infill shape geometry was considered to analyzed the effect of different infill shape geometry on different material. For FDM printing different materials was considered in this work that is polyvinyl alcohol (PVA), polyetheretherketone (PEEK) and Nylon. In each case of material three different infill shapes was considered that is lines, triangular and concentric. During printing the infill density of the specimen was remaining constant that is 80%. All the samples were prepared according to ASTM D628-10 standard which is technique used for the tensile test of plastic. During tensile test of each sample uniaxial stress was applied on the sample and stretched until the complete sample get broken out.

The experimental work of 3D printing was carried out at MCUBE, 3D printing Pvt. Ltd. MP Nagar, Bhopal. The FDM printing was carried out on J-hot end type printer. The experimental lab setup used for doing experimental work is shown in the below fig.7.

Fig. 7 Shows the lab setup for doing Experimental work

2.2 Importance of infill percentage and different geometrical shapes used for infill

In 3D printing, each component during printing is divided in to two zones that is shell and fill (infill). Shell includes the outer most layer of the components, whereas infill includes the internal parts of the component. Optimization of these two parameters is very important because the mechanical resistance, surface finishing, printing time and cost of the component depends on them. Normally with the help of controlling or operating software, the infill percentage can bet set from 0 (hollow) to 100% (complete solid). For non-functional prototypes application mostly 20 % infill density was considered which is cost effective, low weight and main thing is effective printing time. In order to make 3D printed component stronger everyone knows that they have to print the component with 100% infill density. But with increasing the percentage of infill density the cost and time required for building the components should get increased. So, to reduce the cost and printing time of components it is necessary to first the know the end requirements of user for which they are using the 3D printed components and according to that optimization of infill density can be done. Many of the researchers have already studied the effect of infill percentage on different components.

2.3 Experimental work

Here nine set of experiments was performed with three different materials having three different infill shapes. The design of set of experiment that was considered during specimen printing is mention in the below table.

Table. 2 Set of experiments considered during FDM printing

S. No.	Material	Infill Density (%)	Infill pattern
1	PVA	80	Lines
2	PVA	80	Concentric
3	PVA	80	Triangular
4	PEEK	80	Lines
5	PEEK	80	Concentric
6	PEEK	80	Triangular
7	Nylon	80	Lines
8	Nylon	80	Concentric
9	Nylon	80	Triangular

2.4 Tensile testing

After preparing the FDM printed samples, tensile test was performed. For doing unidirectional tensile test of the samples Tinus and Olsen UTM of ST-series was used. During tensile testing, the strain rate is considered as 0.1/S which remains constant for all the samples. The test was conducted in to 3 sets of experiments which is categorized on the basis of shapes of infill geometries. The three-set used for tensile testing of FDM printed samples is shown in the below figure.8.

In each set of experiment three different materials samples was considered having different infill shapes geometries with same infill density percentage. Above figure shows the set of samples in which blue color samples represents the PVA, White represents the PEEK and black color represents the nylon material.

Fig. 8 Shows the line, triangular and concentric set of samples for tensile testing

III. RESULT AND DISCUSSION

After sample preparation and unidirectional tensile testing of each sample, result was evaluated. The tensile strength of FDM sample depends on material used, infill density percentage, infill pattern, bonding in between two adjacent layer and others. This work is mainly focusing on deformation behavior and tensile strength of different material having different infill shape geometry. The results are categorized in to two section, first section considered the tensile strength and deformation behavior of same material at different infill shape geometry, whereas in the other section tensile strength and deformation behavior of different material at same infill shape geometry was evaluated.

3.1 For PVA material

The compressive stress and strain graph of PVA material at different infill structure is shown in the below figure 9.

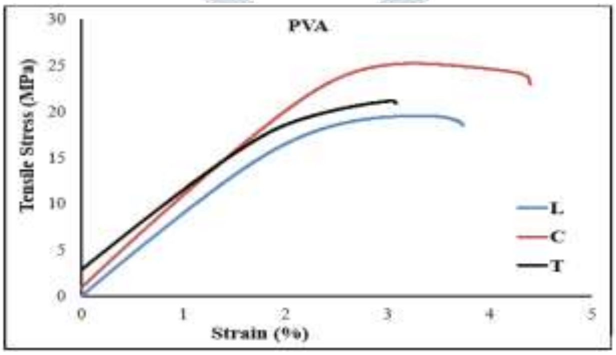

Fig. 9 tensile Stress-strain graph of PVA material at different infill structure design

From graph it is found that there is a marginal different of tensile strength in between lines and triangular shape of geometry. Whereas for PVA material concentric shape structure shows the highest compressive strength as compared to other infill structure geometry. Through graph it is analyzed that for each case of infill structure, the compressive stress increases with increase in strain and after reaching to yield stress it starts decreasing. Beyond yield stress gradual decrement of stress is found which shows the indication of permanent plastic deformation. Through graph it is found that for PVA material, concentric shape of infill geometry shows the maximum strength as compared to other shape of infill geometries.

3.2 For PEEK Material

The stress-strain graph for PEEK material at different infill structure is shown in the below figure. PEEK material specimens having 3 different infill structure geometry was tested at same strain rate as considered during the PEEK material specimen testing.

From above graph it is found that for PEEK material, concentric structure infill geometry shows the maximum tensile strength as compared to triangular and lines shape structure geometry. The elongation of concentric material is also more as compared to other two materials. PEEK material with different infill structure shows the plastic deformation behavior and after certain percentage of elongation it gets break.

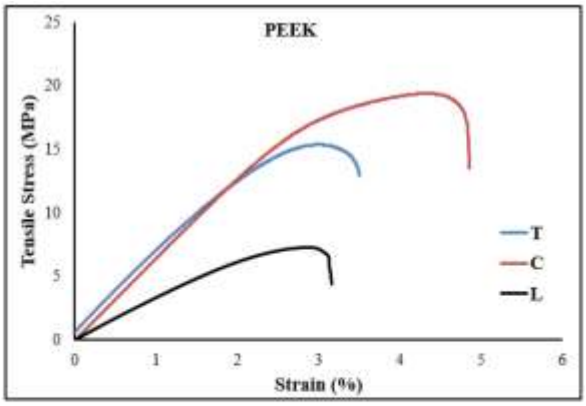

Fig. 10 Stress-strain graph of PEEK material having different infill structure geometries

3.3 Comparison of different FDM printed materials

After evaluating the performance of particular material at different infill structure geometry, the performance of different material at a particular infill structure geometry was also analyzed. It is also important to analyzed the deformation behavior of different material at particular infill shape geometries.

IV. CONCLUSION

Through experimental analysis it is found that the strength of the FDM printed components depends on the infill shape geometry and filament material.The deformation behavior of the Specimen is mainly depending on the base materials and have less influence of infill shape geometry.For PVA material, concentric shape of infill geometry shows the maximum tensile strength, whereas for PEEK material same thing is happing.In case of nylon material, line shape of infill geometry shows the maximum tensile strength as compared to concentric and triangular shape of infill geometries. As the deformation behavior of the tensile specimen is mainly depending on the material, PVA and PEEK material shows less ductile nature as compared to nylon material.

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