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EXPERIMENTAL STUDY ON FUSED DEPOSITION MODELING PROCESS PARAMETERS FOR CARBON FIBER IMPACT STRENGTH

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ABSTRACT

FDM is a filament extrusion-based process that combines a CAD system, materials science, computer numerical control, and the extrusion process to fabricate 3D parts directly from a CAD model. The computer-controlled head moves in the X-Y plane while the form moves in the z-direction as specified by the layer thickness. Sin clade slice height (layer thickness), model tip diameter, model build temperature, part fill style, part interior style, raster width, raster angle, and raster air gap are the main process parameters. The effect of FDM process parameters, such as layer thickness, print temperature, infill density and infill pattern non-Impact strength, and printing time of PLA, has been studied in this work. The printing process will be carried out with three levels for each parameter and a full factorial design of experiments. The specimen design and process parameter setting were completed in the Ultima ker Cura software. STL files are supplied to 3D printers for the printing of impact specimens. ANOVA will be used to analyse the impact test data. As a result, layer thickness is very important in the additive manufacturing scenario. Layer thickness is found to be the most important controlled process parameter when calculating the impact strength and printing time of 3D printed specimens.

KEYWORDS: *Fiber 1, Impact Strength 2, Deposition 3, Modeling4, Carbon 5*

INTRODUCTION

Additive manufacturing (AM) or additive layer manufacturing (ALM) is the industrial production name for 3D printing, a computer-controlled process that deposits materials in layers to create three-dimensional objects. Additive manufacturing uses computer-aided design (CAD) or 3D object scanners to create objects with precise geometric shapes. These are built layer by layer, similar to a 3D printing process, as opposed to traditional manufacturing, which frequently requires machining or other techniques to remove excess material. A computer, 3D modelling software (Computer Aided Design or CAD), machine equipment, and layering material are all used in AM technologies. After creating a CAD sketch, the AM equipment reads data from the CAD file and lays downs or adds. Binder Jetting is a technique that deposits alternating layers of powdered material and a liquid binder as an adhesive using a 3D printing style head that moves on the x, y, and z axes.

Material Extrusion: Spooled polymers are extruded or drawn through a heated nozzle mounted on a movable arm in this common AM process. As the nozzle moves horizontally and the bed moves vertically, this builds melted material layer by layer. Temperature control or chemical bonding agents are used to keep the layers together. Powder Bed Fusion: Powder bed fusion includes several AM techniques such as direct metal laser melting (DMLM), direct metal laser sintering (DMLS),

electron beam melting (EBM), selective laser sintering (SLS), and selective heat sintering (SHS).
Sheet Lamination: There are two types of sheet lamination technologies: laminated object manufacturing (LOM) and ultrasonic additive manufacturing (UAM). Laminated object manufacturing, which employs alternate layers of paper and adhesive, is well suited to producing items with visual or aesthetic appeal. UAM joins thin metal sheets using ultrasonic welding; a low energy, low temperature process, UAM can be used with a variety of metals including aluminium, stainless steel, and titanium.
Vat Polymerization: This method involves layering an object in a vat of liquid resin photo polymer. Mirrors are used to direct UV light, which cures the successive layers of resin via polymerization.
Additive Manufacturing by Wire Arc (now known as Directed Energy Deposition Arc (DED-arc)): Arc welding power sources and manipulators are used in wire arc additive manufacturing to build 3D shapes through arc deposition. This method typically employs wire as a material source and follows a predetermined path to achieve the desired shape. This method of additive manufacturing is typically carried out with robotic welding equipment.

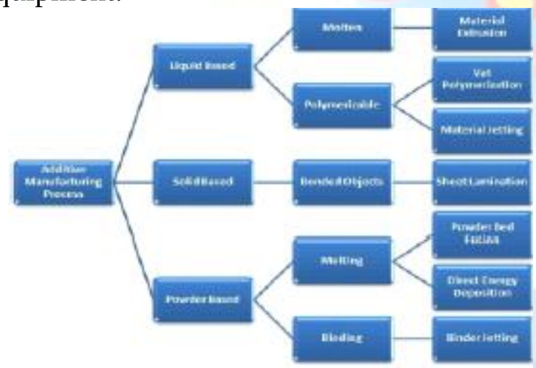

Figure 1.1: Classification of Additive Manufacturing

1.1 3D PRINTING TECHNOLOGIES

1.1.1 SLA: Stereo lithography 3D printers (also known as SLAs or stereo lithography apparatus) position a perforated platform just below the surface of a vat of liquid photo curable polymer. A UV laser beam is then used to trace the first slice of an object on the liquid's surface, causing a very thin layer of photo polymer to harden. The perforated platform is then slightly lowered, and the laser is used to trace out and harden another slice. Then another slice is made, and another, and so on.

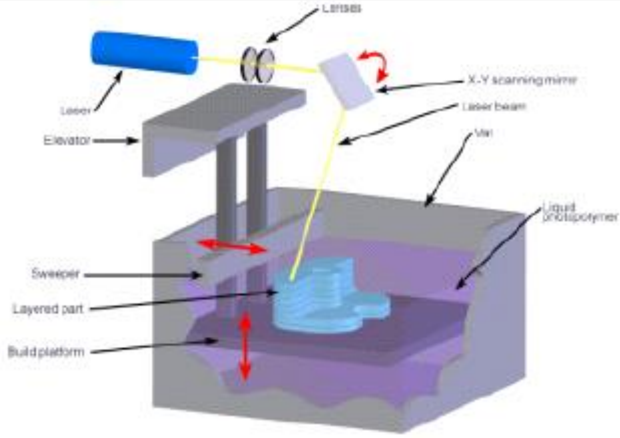

Figure 1.2: stereo lithography

1.1.2 MANUFACTURING OF LAMINATED OBJECTS (MOLO)

The layered material is rolled on the building platform using LOM technology. When the feeding roller begins heating to melt the adhesive, the material is coated with an adhesive layer. The top layer will then be glued to the previous one. To facilitate the extraction of the final objects, a blade or a laser will be used to draw the geometry of the object to be built and crosses on the rest of the surface.

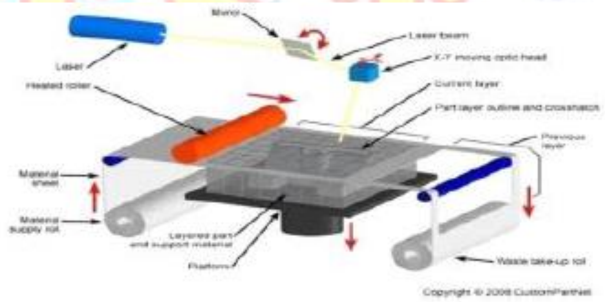

Figure 1.3: Object Manufacturing Lamination

Laminated Object Manufacturing involves stacking sheets of material on top of one another and gluing them together. The printer then cuts an outline of the object into that cross section, which will be removed later from the surrounding excess material. The object is built up one layer at a time by repeating this process. Objects printed with LOM are accurate, strong, and durable, with little to no distortion over time, making them appropriate for all stages of the design cycle. They can even be further customized after printing by machining or drilling. The material feed stock determines the typical layer resolution for this process, which typically ranges in thickness from one to a few sheets of copy paper.

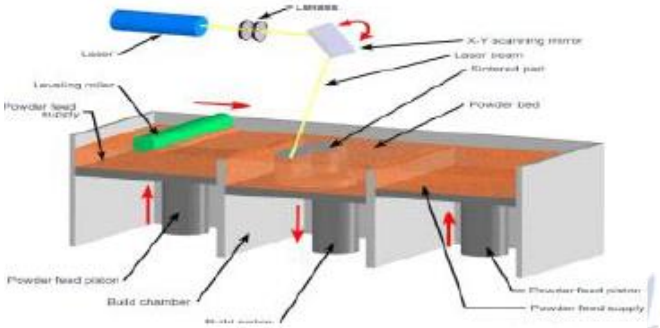

Figure 1.4: Selective Laser Sintering

Before printing, the powder is heated to a temperature just below the melting point of the material. The powder from one layer height is then deposited on the build platform by the re-coating blade. SLS frequently employs layer heights of 0.1mm / 100 microns.

Poly carbonate (PC): Poly carbonate (PC) is a high-strength material used in engineering. The material is temperature resistant, withstanding physical deformation up to around 150oC. However, PC is susceptible to absorbing moisture from the air, which can have an impact on performance and printing resistance. As a result, PC must be stored in airtight containers. The AM industry values PC for its strength and transparency. It has a much lower density than glass, making it ideal for designing optical components, protective screens, and decorative objects.

• PLA is easy to print because it has low warping.
• It can also be printed on a cold surface.
• It can print with sharper corners and features than ABS material.

2. LITERATURE REVIEW

Chamil Abeykoon's (1) Title: FDM parameter optimization for improved PLA and ABS 3D printed structures The purpose of this study is to investigate the properties of 3D printed specimens with varying processing conditions such as infill pattern, infill density, and infill speed, as well as printing materials. A variety of testing techniques were used, including tensile, bending, compression, differential scanning calorimetry (DSC), thermal gravimetric analysis (TGA), thermal imaging, and scanning electron microscopy (SEM).

Chamil Abeykoo's (2) Title: Optimization of FDM parameters for improved PLA and ABS 3D print processing conditions, including infill pattern, density, and speed, as well as with different printing materials. A variety of testing techniques were used, including tensile, bending, compression, differential scanning calorimetry (DSC), thermal gravimetric analysis (TGA), thermal imaging, and scanning electron microscopy (SEM).

Shivraj Yeole's (3) TITLE: ASTM D638 Type-IV Tensile Testing and Evaluation of 3D Printed PLA Specimens This paper describes the tensile strength of ASTM D638 Type IV PLA specimens additive manufactured using an FDM-based MakerBot desktop 3D printer and its simulation in ANSYS software.

G Ćwikła (4) TITLE: The impact of printing parameters on selected mechanical properties of FDM/FFF 3D-printed parts The printer was calibrated to produce the highest quality prints. A series of tests were performed, which resulted in samples with no visible defects or imperfections, such as layers de-lamination, discontinuities of the specimen's shell and infill.

Ferenc Ronkay and Imre Fekete (5) TITLE: The suitability of natural rubber (NR) toughened poly (lactic acid) (PLA)-based blends for additive manufacturing applications was investigated. Using a twin-screw extrude, filaments for fused deposition modelling (FDM) were prepared with an NR concentration of 0... 20 wt.%. Specimens were then created using a desktop 3D printer machine that operates on FDM principles.

3.0 DESIGN SOFTWARES USED

Taguchi robust design methodology is used in this work to obtain the optimum experimental data conditions. Mini tab 15.0 statistical software is used to generate results for Analysis of Mean (ANOM) and Analysis of Variance (ANOVA) (ANOVA). The confirmation test is performed under ideal conditions to validate the results. The engineering design activity is founded on knowledge of scientific phenomena and previous experience with similar product designs and manufacturing processes. However, for a number of new decisions related to the specific design, process architecture, and manufacturing process parameters, a significant amount of engineering effort is expended in conducting experiments (either with hardware or by simulation) to generate the information required to guide these decisions. The ability to generate such information efficiently is critical for meeting marketing deadlines, keeping development and manufacturing costs low, and producing high-quality products. Robust design is an engineering methodology for increasing productivity during design and development in order to produce high-quality products at a low cost.

3.1. Taguchi's robust design:

In industrial practice, the scientific approach to quality improvement is becoming more common. The engineer faces an economic and technical challenge in designing high-quality products and processes at a low cost. A method of design optimization for performance, quality, and cost known as robust design is a systematic and efficient way to meet this challenge.

3.2. Robust design methodology:

Robust design is an engineering methodology for increasing productivity during design and development in order to produce high-quality products at a low cost. The robust design method's main idea is to choose the levels of design factors to make product or process performance sensitive to uncontrollable variations like manufacturing variations, deterioration, and environmental variations. Dr. Genichi Taguchi popularized the robust design method, which uses experimental design techniques to identify improved factor levels. Experimental design techniques are extremely effective for improving quality in problems with many variables. Engineers in many leading Japanese and American companies have successfully used Taguchi's approach to improve the performance and competitiveness of their key products.

4. EXPERIMENTAL DESIGN AND SETUP

The Taguchi method was used in this study to investigate the effects of important parameters such as layer thickness, printing temperature, infill density, and infill pattern.

FACTORS	LEVELS		
	1	2	3
Layer Thickness (A)	0.1	0.2	0.3
Printing Temperature (B)	200	210	220
Infill density (C)	75	85	95
Infill pattern (D)	Triangular	Cubic	Quarter cubic

Table No: 4.1 Process Parameters

Table shows the selected process parameters and their levels. The effects of parameters such as infill density and printing pattern on the mechanical properties of 3D printed specimens are investigated in this work.

No. of Experiments	Layer Thickness (A)	Printing Temperature (B)	Infill Density (C)	Infill Pattern (D)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	2	3
9	3	3	1	1

Table No: 4.2 Taguchi L9 Orthogonal experimental setup.

STEP 1: PART DESIGN IN AUTOCAD

The use of computer systems to assist in the creation, modification, analysis, or optimization of a design is known as computer-aided design (CAD). CAD software is used to increase designer productivity, improve design quality, improve communication through documentation, and create a database for manufacturing. CAD output is frequently in the form of electronic files that can be used for printing, machining, or other manufacturing operations. CAD software for mechanical design either uses vector-based graphics to depict traditional drafting objects or may produce raster graphics that show the overall appearance of designed objects. It is, however, more than just shapes. CAD output, like manual drafting of technical and engineering drawings, must convey information such as materials, processes, dimensions, and tolerances based on application-specific conventions. CAD can be used to create curves and figures in two dimensions (2D) space, as well as curves, surfaces, and solids in three dimensions (3D). CAD is a vital industrial art that is widely used in a variety of industries.

STEP 2: CONVERSION TO STL FILE FORMAT

An STL file is a 3D surface geometry triangular representation. The surface is logically tessellated into a set of oriented triangles (facets). Each facet is defined by the unit outward normal and three points listed in anticlockwise order as the triangle's vertices. While the surface curvature governs the aspect ratio and orientation of individual facets, the size of the facets is determined by the tolerance controlling the quality of the surface representation in terms of the distance of the facets from the surface. The tolerance value is heavily influenced by the intended application of the STL file. To make the produced 3D part precise with highly worked out details in industrial processing, stereo-lithography machines perform a computer-controlled layer by layer laser curing of a photo-sensitive resin.

CONCLUSION

The following conclusions are drawn from the current experimental investigations: High impact strength is observed in the low layer thickness condition of 0.1mm, average impact strength in the medium layer thickness of 0.2mm, and very little impact strength in the high layer thickness. When compared to other process parameters, layer thickness has the greatest influence. No other parameter is of significant importance. The parameter level with the highest S/N ratio is the optimal level. Individual factors with a significant impact on impact strength include layer thickness (95.94%), infill pattern (2.95%), infill density (0.402%), and printing temperature (0.391%). Printing time is longer when the layer thickness is low, but it is much shorter when the layer thickness is high. In the case of average layer thickness, printing time is moderate. Layer thickness also has a significant impact on component printing time when compared to other process parameters. No other parameter is of significant importance. Some parameters are significant, while others are insignificant.

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