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COMPARATIVE STUDY ON THE INFLUENCE OF PROCESS PARAMETERS USING FUSED DEPOSITION MODELING

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Abstract
Fused Deposition Modelling (FDM) is one of the additive manufacturing methods for making parts by depositing semi-molten plastics. The development of 3D printing technology has been a huge help to startups, students, and small businesses. Materials such as Acrylonitrile Butadiene Styrene (ABS), Polylactic acid (PLA), nylon, and polycarbonate are heated and forced through nozzles onto the construction platform to create a finished object. The primary goal of this study is to define the ABS optimum parameters in order to obtain a sufficient level of strength for usage in wheel rims. The typical materials used to make wheel rims include Al alloys, Mg alloys, steel, forged steel, and carbon fibres, all of which have drawbacks such as corrosion, weight, cracks, and cost. The objective of the current study is to develop robust mechanical properties that will produce the best results for 3D-printed rims. The test specimens were made in accordance with ASTM standards (D790, D695, and D256), and they had various built-up orientations, including raster angle, infill percentage, and infill pattern. The comparison of test specimens with various wheel rim specifications is presented in this study.

Keywords: Fused Deposition Modelling, Minitab, Rim Materials, Acrylonitrile Butadiene Styrene (ABS)

I. Introduction

A wheel is a circular part that is capable of rotating on its axis to provide movement or transportation while supporting a load or mass. Wheels are one of the vital components of any vehicle. Safety aspects are very important to be taken care of in the automobile industry as they concern the lives of passengers. In the automotive industry, many accidents are caused by alloy cracks (Failure) in rims. The rim is the frame or backbone of the tire that holds the force and stresses due to the vehicle's weight and the impact of various road conditions. In order to prevent any accidents caused by rim failure or deformation, we have carefully considered and increased the safety of the rim.

Even the slightest change can change the loads acting on the rim and cause the structure to break, so we need to keep the rim structure as strong as possible. Rims are manufactured in the following ways: Casting, Forging, rolled forging, Die Casting, Welding, Multi-piece rim (assembly), and Carbon fibres. Our process involves Fused Deposition Modelling for 3D printing of ABS (Acrylonitrile Butadiene Styrene) material. It is one of the typical plastics used in 3D printing and the manufacture of OEM parts. This paper discusses whether ABS material can be used for rims and whether it can undergo different tests like compression, flexural, and impact tests.
ABS stretches more easily than it breaks and it’s also corrosion-resistant too. Its tensile strength makes it an excellent choice for anyone looking to sand, polish, or glue the finished product. Because customers are always willing to pay so the strength is good and it looks better. High tensile strength, strong heat resistance, scratch resistance, shock absorption, and low cost. PLA degrades much faster than other plastics. While standard plastic bottles can take over a hundred years to degrade, PLA degrades completely within two years. PLA is better for basic, day-to-day printing, while ABS excels at building strong, impact-resistant parts that can be customized later.

For polymers, the traditional system is injection moulding thanks to which polymer-based production is possible. The complexity of injection moulding can be easily achieved using Fused Deposition Modelling (FDM). Common Fused Deposition Modelling materials on the market are industrial polymer Acrylonitrile Styrene Acrylate (ABS) and medical polymer Poly Lactic Acid (PLA). The parameters of the moulding process by fused wire deposition make it feasible to accomplish injection moulding performance in order to enhance the properties of these polymers. By changing the printing process's settings, several sorts of study have been done to enhance the mechanical, structural, and thermal properties of materials.

II. Literature

Arup Dey et al.,[1] Fusion deposition modelling (FDM), an additive manufacturing (AM) technology, is commonly used to produce prototypes and components with complex geometrical patterns. The traits of things produced by FDM are influenced by several 16 process factors, such as layer thickness, build orientation, raster width, or print speed. The kind of machine, nozzle size, and filament type all affect the range of different parameters. Including Omar Ahmed Mohamed et al.,[2] The following FDM process variables were considered in this study: build orientation 1, raster angle, layer thickness, and air gap. The results show that layer thickness, air gap, and number of contours are the key variables that influence the complex modulus and dynamic viscosity. Layer thickness of 0.3302 mm, air gap of 0.0 mm, raster angle of 0, build orientation of 90, and road width of 0.45 mm were discovered to be the ideal conditions.,[3] This article provides a survey of the many methods used to date for This article reviews the numerous methods that have been used to date to optimise various injection moulding parameters, along with their benefits and drawbacks. Carmita Camposeco et al.,[4] 3D printer's energy usage and the dimensional correctness of the items it produced were also examined. Finding the set of parameters that offered the best trade-off between the variables was made possible via a desirability analysis. Dinesh Yadav et al.,[5] Rapid manufacturing is now possible thanks to recent developments in this technology including Fused Deposition Modelling (FDM), Stereo Lithography (SLA), and Selective Laser Sintering (SLS). By layer by layer combining 50% ABS and 50% PETG in FDM 3D Printing.

Azhar Equbal et al.,[6] The engineering polymer wheels for cars that are currently in use often have rims that are well-shaped for tyres. The rim is attached to a disc that has holes designed for securing the wheel to the car's hub with the use of fixing elements such threaded bolts. The polymer material in the area of the holes for the fixing components is squeezed and distorted when this well-known wheel is loaded and heated in service circumstances, which causes a reduction in the tightening torque in the fixing components. Jyothish Kumar et al.,[8] This book showcases a variety of articles on cutting-edge additive manufacturing and 3D printing techniques, showing how these techniques have altered the nature of direct digital technologies enabling the quick creation of models, prototypes, and patterns. Tiro et al.,[9] Thermoplastic material additive manufacturing is widely practised using fused deposition modelling (FDM). Because of its capability to develop intricate structural designs in a short amount of time during manufacturing. To reduce the overall number of trial runs and determine the ideal printing settings for the printed part's maximal hardness, Taguchi design of experiments (DOE) methodology is utilised. The ideal printing settings are determined via S/N ratio analysis, and ANOVA is used to calculate the percentage contribution of the control factors. Kale et al.,[10] Support the braking system over its body, disperse heat from the wheel rim's body to the environment, bear the weight of the entire vehicle, and resist repeated impacts from potholes and other road irregularities. body weight of the rider and consistent tyre pressure.

Ratiul et al.,[11] A table exposing the printing parameters used to print the samples is followed by a paragraph on the compression tests that includes both general and case-specific information. The research is still in its early stages, thus the initial set of results is reported. Subsequent tests and analysis will be conducted to achieve a thorough characterization of the behaviour of the 3D printed materials.

Industrial Engineering Journal
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Divyathej et al.,[12] The research study analyses the mechanical behaviour of ABS items created via 3D printing.A digital file can be used to create three-dimensional solid items via additive manufacturing, or 3D printing. The emergence of 3D printing technology is posing a threat to many traditionally manufactured goods. An object is made via an additive technique by adding layers of material one after another until the full entity is formed. Naim et al.,[13] In order to meet the demands of the market, we have conducted a thorough analysis of the various types of materials that can be used to manufacture alloy wheels in this research article. In this study, we investigated the fatigue analysis of wheels made of aluminium, magnesium, and titanium alloys based on the materials' maximum shear stress, equivalent stress, and deformation under load.

Durgun et al.,[14] For this objective, The FDM technique has been used to construct three component orientations (horizontal, vertical, and perpendicular) with five different raster angles (0°, 30°, 45°, 60°, and 90°). The parts have been evaluated for surface roughness, tensile strength, and Flexural toughness. The findings of this study are helpful in identifying the appropriate raster angle and part orientation for FDM components with the lowest feasible manufacturing cost based on their predicted in-service loads. SurajKumarVishwakarma et al.,[15] Acrylonitrile, Butadiene, and Styrene are the three monomer units that make up most Acrylonitrile-Butadiene-Styrene polymers. Plastic possesses a wide range of adaptable qualities, such as thermal resistance, light weight, ease of formability, reflectivity, and others. The traditional chromic acid bath for ABS material has been replaced by a green surface etching and activation method. Utilising this boosts peel strength and obtains maximum adhesion strength.

III. Materials And Methodology

3.1 Material

Acrylonitrile Styrene Acrylate (ABS) is an industrial polymer used in this study. It has the advantages of high impact resistance, structural strength, and high resistance to chemicals. It has excellent performance at both high and low temperatures. Royalite R20–Thermoplastic sheet is a rigid ABS product with a variety of properties that makes it ideal for the widest variety of applications. It has very high impact strength and stiffness, excellent high-temperature and low-temperature performance, and excellent formability. Table 1 describes the properties of the ABS material. Most common Applications using ABS material include control panels, housings(vacuum cleaners, food processors), Keyboard caps, pipes and fittings made from abs materials.

3.1.1 Advantages of using ABS Material

High hardness, resistance to fatigue and stress cracking, excellent mechanical and thermal qualities, and high impact strength. It resists chemical corrosion from acids and alkalis. It costs quite less compared to other materials and is simple to process and mould.

3.1.2 Disadvantages of using ABS material

Compared to other materials, ABS has a lower melting point. However, it has inadequate weather resistance and inadequate heat resistance.

Table 1: Properties of ABS

Properties	Value
Density	1.05g/cm^3
Tensile strength	48 MPa
Young modulus	1360 MPa
Compressive strength	65 MPa
Flexural strength	75 MPa

Industrial Engineering Journal
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Thermal conductivity	0.1W/mk
Linear thermal expansion coefficient	$73.8x10^{-6}$m/mk

Figure 1: Printing machine
Ultimaker 3 Extended

Specifications :

Printer Technology : FDM
Build size : 215mm L x 215mm B x 300mm H
Build Resolution : 50 microns

3.2 Methodology

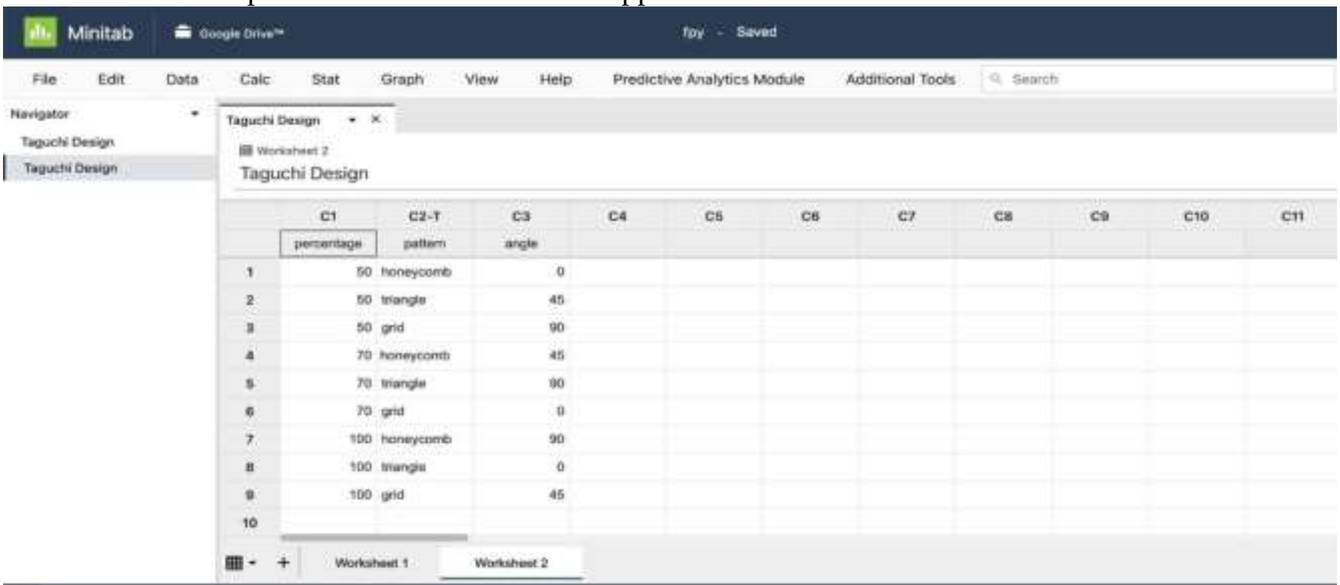
After reviewing some of the recent and relevant types of research in this area mentioned above and taking into consideration the available material capacities, we resorted to our study, by using a 3D printer, the ABS material used for the printing and twenty-seven types of samples with different printing parameters taken. Printing parameters such as Orientation, infill percentage, speed, nozzle diameter, filament diameter and layer thickness play a important role in determining the material properties. These six parameter values are taken from the optimised data of existing literature. Apart from these six parameters, material consumption and time consumption are also focused on in this study based on the manufacturing perspective.

Table 2: Process parameters of Ultimaker

Process Parameters	Ultimaker 3 Extended		
Default :			
Orientation	Horizontal	Horizontal	Horizontal
Layer thickness (mm)	0.100	0.100	0.100
Speed (mm/s)	100	100	100
Nozzle diameter (mm)	0.4	0.4	0.4
Filament diameter (mm)	2.85	2.85	2.85
Changed Parameter :			
Infill percentage (%)	50	70	100
Infill Angle	0°	45°	90°
Infill pattern	Honey Comb	Grid	Triangle

IV. Minitab

Minitab is used for data analysis and statistical and process improvement software. The Minitab tools are used by Six Sigma practitioners to solve real-world problems. They are widely used in various industries, including healthcare, manufacturing, and education. Minitab provides users to analysis analyse statistical tools, regression analysis, and ANOVA. Here we get 27 results by using Minitab we can reduce it to 9 optimized results for a better approach.



	C1	C2-T	C3
	percentage	pattern	angle
1	50	honeycomb	0
2	50	triangle	45
3	50	grid	90
4	70	honeycomb	45
5	70	triangle	90
6	70	grid	0
7	100	honeycomb	90
8	100	triangle	0
9	100	grid	45

Figure 2: Optimized Parameter using Minitab

V. Results And Discussion

5.1 Impact Test

The impact test is also known as the crash test which is essential when it comes to vehicle safety. In the event of an accident, the vehicle wheel may experience a sudden momentum caused by an external object. According to the standardization system, this test is performed from different angles. ISO 6603 specifies a test method for the determination of puncture impact properties of plastics, in the form of flat specimens

An impact test is used to examine the mechanics that a material will exhibit when it experiences a shock loading that results in the specimen deforming, fracturing, or totally rupturing. To perform this test the sample is placed into a holding fixture typically but not always in the form of a pendulum, and is released from a known height so that it strikes the sample with a sudden force. This collision between the weight and the specimen, the energy exchange between the two is used to ascertain the material's fracture mechanics.

Figure 3: Printed Impact Specimens

Figure 4: Tested Impact Specimens

Industrial Engineering Journal
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Impact testing of test specimens

Sample ID	Value (Joule)
01	0.8
02	0.8
03	0.7
04	0.9
05	0.7
06	0.8
07	0.8
08	0.7
09	0.8

5.2 Compression Test

The compressive strength of a 3D-printed object can be evaluated using a compression test. You will need a testing device with a load cell and a piston, as well as a sample of the 3D-printed object, to conduct a compression test. This research uses an Ultimaker 3 Extended printer with a single extruder to apply the FDM process and test the compression properties of ABS specimen samples. The ASTM D695 standard is the reference standard for determining the compression properties of plastic materials. A minimum of five specimens should be evaluated for isotropic materials. Nine specimen samples were used in this test as a result.

Depending on the features that need to be assessed, this international standard suggests two different types of specimens. The specimens should be in the shape of a straight cylinder or prism if compressive strength is required. For the current compression test research, a sample with a cylindrical section of the first kind has been chosen. It is done using the ASTM D 695 test procedure.

1. Prepare the sample: The 3D-printed object should be cut into a cube or cylinder shape.
2. Set up the testing machine: The sample is placed on the testing machine, and the piston is positioned directly above it.
3. Apply the load: The machine applies a compressive load to the sample at a constant rate until it deforms or fractures. The load is recorded at various points during the test to create a stress-strain curve.

Figure 5: Printed Compression Specimens

COMPRESSION STRENGTH :(Test method - ASTM D 695)
Test Speed : 1.3mm/min

Table 4 : Readings for Compression testing of test specimens

No.	Specimen	σ_M MPa	ε_M %
1	01	27.0	4.5

Industrial Engineering Journal
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2	02	27.7	10
3	03	30.3	4.9
4	04	32.9	10
5	05	34.7	8.5
6	06	34.6	6.8
7	07	39.9	6.8
8	08	38.8	5.2
9	09	40.7	5.2

Stress & Strain graph :

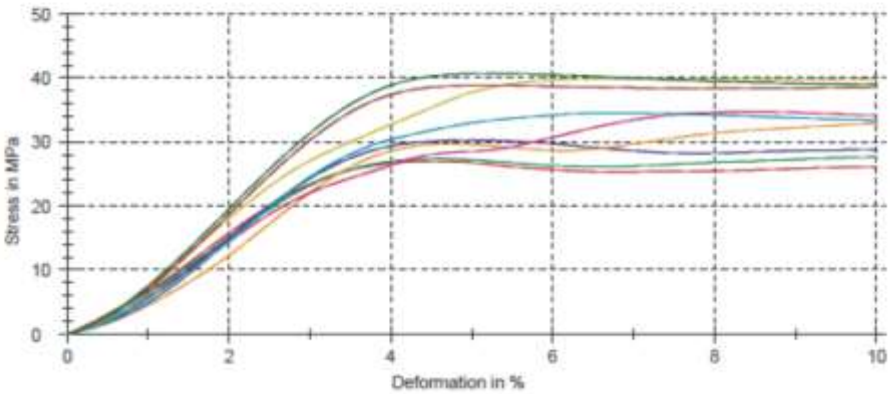

Figure 6: Graph of Compression Strength

5.3 Flexural Test

The capacity of a material to withstand deformation under load is known as flexural strength. Set up the testing equipment: The three point bending test arrangement is generally used to conduct the flexural test. This involves placing the specimen on two fixture supports and applying a load to the centre of the specimen using a loading fixture. Make sure that the testing apparatus is properly calibrated and aligned.

Apply a load to the centre of the specimen using the loading fixture. The load should be applied at a constant rate until the specimen fractures or reaches a predetermined displacement or strain value. Overall, performing a flexural test on a 3D printed specimen can provide valuable insights into the mechanical properties of the material and can help to optimize the printing parameters for specific applications.

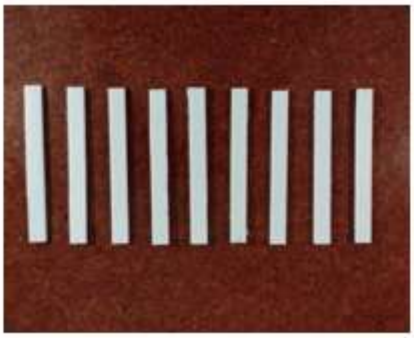

Figure 7: Printed Flexural Specimens

Figure 8: Tested Flexural Specimen

Industrial Engineering Journal
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FLEXURAL STRENGTH :(Test method - ASTM D 790)
Test Speed : 1 %/min

Table 5 : Readings for Compression testing of test specimens

No.	Specimen ID	E_H MPa	S_M N	r_{max} mm
1	01	1760	56.7	10
2	02	1400	51.0	10
3	03	1200	48.8	10
4	04	1520	54.5	10
5	05	1490	57.4	10
6	06	1360	49.4	10
7	07	1130	45.1	10
8	08	970	39.6	10
9	09	1990	77.2	10

Stress & Strain graph :

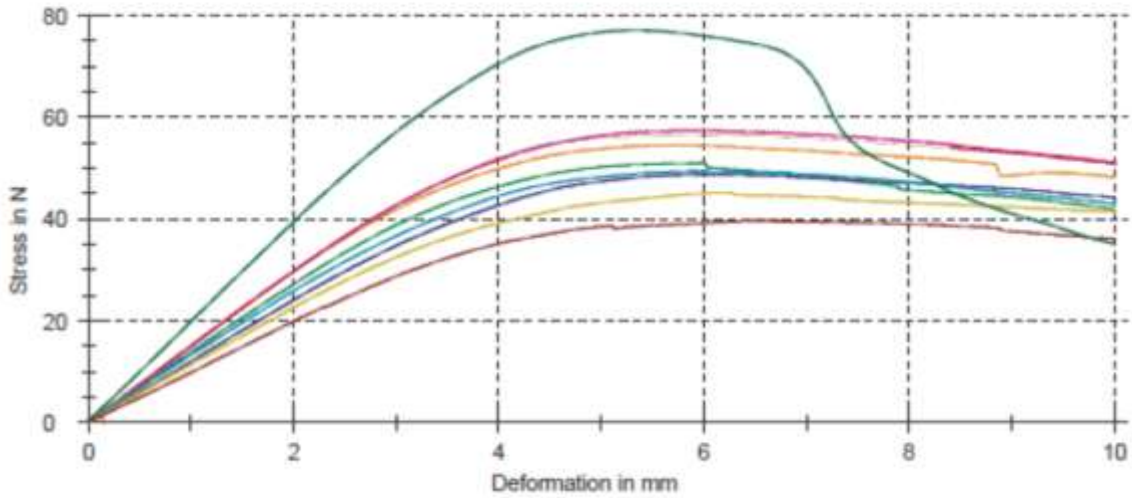

Figure 9: Graph of Flexural Strength

VI. Conclusion

In this study we have determined the strength of ABS plastic material is printed tested in a number of ways to check if it can be used to manufacture rims. For off-road vehicles and other applications, this characteristic can be taken into account. Before manufacturing the actual rim, We determine the parameters helps to achieve highest strength. This study is also based on comparing various parameters in nine different samples and three different tests such as compression, flexural, and impact strength have been done. In three tests, the raster angle was the same, but the pattern & percentage was different, as we discovered. In the impact test, 70% of the printed area is used and a change in pattern (Honey Comb) causes this specimen to solidify and lose all air. However, in flexural and compression testing, 100% printing and a grid pattern are employed. The specimen therefore need structural gap to increase its strength.
From the findings of this research, it is understood that if a product needs to withstand impact then we can go for fourth specimen. If it needs to undergo all three compression, flexural, impact test then ninth specimen is considerable.

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