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EVALUATING THE MECHANICAL PROPERTIES OF 3D PRINTED POLYMER COMPOSITES WITH NANO FILLERS

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ABSTRACT

3D printing, also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid-freeform fabrication (SFF), is the fabrication of objects through the deposition of a material, layer by layer using a print head, or nozzle, to make objects from 3D model data,

3D printing provides the possibility of low volume and cost effect production as well as customized parts with extraordinary features such as multilateral fabrication, light weight hollow material and fabrication of complex structures which are not possible using traditional fabrication techniques such as CNC milling, casting or molding.

Additive manufacturing (AM) is one of the most popular in manufacturing of components from prototypes to functional structures with any complex geometry, started during the early1980s [9]. It is popular in industrial areas such as automotive, biomedical, aerospace applications.

The present study is focused on to evaluate the mechanical properties of PLA reinforced with bamboo nano particles 3D printing filament. Design of experiment taguchi method is used to minimize the experimentation time and cost. Twin screw extruder is used to blend the matrix and reinforment and develop a 3D printing composite filament. The tensile specimens are printed according to the ASTM standards and tested in UTM. From the results it was found that the level setting of Layer Height: 0.16 mm, Printing Temperature: 220 ^{O}C and Printing Speed: 90 mm/s provide the better ultimate strength in the components printed with 80% PLA and 20% bamboo powder filament.

Keywords: 3D printing, Bamboo powder, Polymer Composite.

INTRODUCTION

3D printing, also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid-freeform fabrication (SFF), is the fabrication of objects through the deposition of a material, layer by layer using a print head, or nozzle, to make objects from 3D model data,

Today Medical uses for 3D printing include: tissue and organ fabrication; creation of customized prosthetics, implants, and anatomical models, and pharmaceutical research regarding drug dosage forms, and delivery. A rapidly growing market for 3D printers is for use in biomedical applications.

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The present study is focused on to evaluate the mechanical properties of PLA reinforced with bamboo nano particles 3D printing filament. Design of experiment taguchi method is used to minimize the experimentation time and cost.

LITERATURE REVIEW

Additive manufacturing (AM) is one of the most popular in manufacturing of components from prototypes to functional structures with any complex geometry, started during the early1980s It is popular in industrial areas such as automotive, biomedical, aerospace applications.

Additive manufacturing (AM) uses the 3D CAD model to build the required prototype layer upon layer. As the name implies additive manufacturing adds material to create the object. The models created from AM can range from form-fit prototypes to fully functional products.AM can be implemented easily because of its low material wastage, less maintenance cost, rapid production of parts, less supervision is required, better tolerance.

Ample amount of investigation is made to evaluate the structural and dynamic mechanical characteristics for 3 D printing material using FFF. Some of the literatures relating to the topic is discussed below.

Letcher and Waytashek used the Maker Bot Replicator 2X machine to fabricate tensile and flexural test specimens using PLA with three different 100 percent infill (Solid) orientations with line breads oriented at 0^0, 45^0, and 90^0. The results of the tests revealed that specimens with line infill at 45^0 of the peak tensile stress were higher by 9% and 16%, respectively, than specimens with line infill at 0^0 and 90^0.

According to Janez Slapnik et al. , the addition of Core Shell rubber improved PLA filament by 10%. The findings revealed that a 3D printed specimen has a higher impact strength. The PLA/Core Shell rubber specimen does not break during the flexural test, and its toughness has improved.

According to Masood et al. , the tensile strength of Polylactic acid (PLA) was greater for the part built in the X direction, and the fatigue strength was greater at 45o to the X and Y directions.

Xiaoyong Tian et al. tested the tensile and flexural strength of recycled carbon fiber and PLA. The results revealed that flexural strength achieved the highest result (25%). From this experiment we come to know that the recovery rates for both PLA and carbon fiber were directly achieved due to CFRTPCs.

OBJECTIVE

The main objective of this work is to study the effect of 3D printed nano fillers reinforced PLA composites. The sub-objectives are considered to achieve the main objective of the work are as follows.

- To fabricate the test specimens of 3D Printed nano particles (Bamboo powder) reinforced PLA composites according to ASTM standards using Fused Filament Fabrication (FFF) process.
- To determine the mechanical Properties such as tensile strength.

METHODOLOGY

STEP1: IDENTIFICATION OF MATERIAL

Through detailed literature review polylactic acid (PLA) and Bamboo nano powder as reinforcement is identified for the present study. The objective of reinforced bamboo particle is to make the filament more biodegradable.

STEP 2: PREPARATION OF COMPOSITE FILAMENT

Composite polymer filament is produced by blending the matrix material PLA and nano particles of bamboo powder using twin extruder process as shown in figure 1. The material is blended with following blend percentage.

Matrix Material: PLA (80%)

Reinforcement: Bamboo Powder (20%)

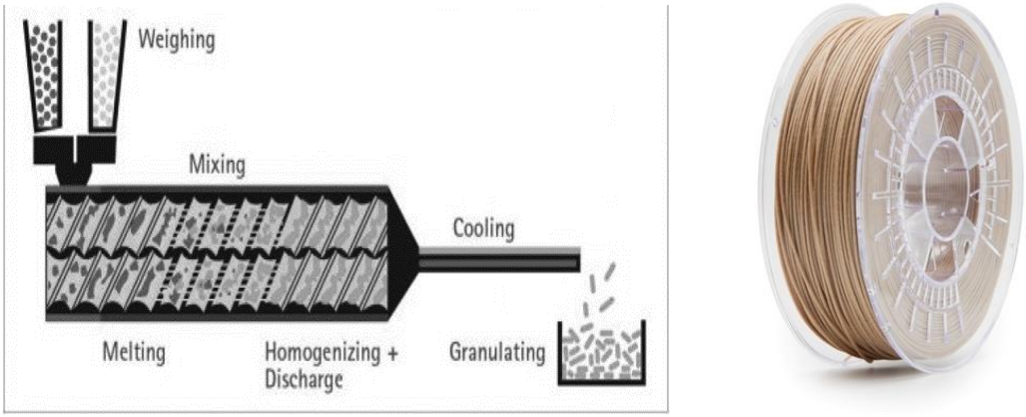

Figure 1: Twin Screw extruder is used to prepare the composite filament

STEP 3: DESIGN OF EXPERIMENT BY TAGUCHI METHOD USING MINITAB

Design of experiments (DOE) is a systematic, efficient method that enables scientists and engineers to study the relationship between multiple input parameters. The following table describes the input parameters and respective level setting chosen for this study.

TABLE 1: LEVEL SELECTIONS FOR TAGUCHI

CONTROL PARAMETERS	LEVEL SETTING		
Layer Height	0.16	0.20	0.24
Printing Temperature	180	200	220
Printing Speed	30	60	90

STEP 4: EXPERIMENT TABLE USING TAGUCHI IN MINITAB

The Taguchi method is an approach to engineering that emphasizes the roles of research and development (R&D), and product design and development in optimizing the process parameters with minimum number of experiments. For three factors and three levels setting L9 orthogonal array is developed to get optimum level setting. Table 2 shows Taguchi L9 orthogonal array design with three factors and three levels and experimental run order.

TABLE 2: EXPERIMENT TABLE

Experiment No	Layer Height	Printing Temp	Printing Speed
L1	0.16	180	30
L2	0.16	200	60
L3	0.16	220	90
L4	0.2	180	60
L5	0.2	200	90
L6	0.2	220	30
L7	0.24	180	90
L8	0.24	200	30
L9	0.24	220	60

STEP 5: PREPARATION OF TENSILE SPECIMENS

Fused deposition modelling / Fused Filament Fabrication is used to print the tensile specimens in accordance to ASTM standards. The Procedure for 3D Printing the samples is as listed below

- Creation of 3D model of sample
- Converting 3D model to STL format
- Slicing the 3D model into layers in slicing software
- Printing the samples in 3D Printer

ASTM D638: According to the ASTM D638, tensile test samples are prepared with the dimensions of 115x19x2.5 mm as shown in the figure 2 below. Figure 3 shows the nine specimens printed according to the experimental run as shown in table 2.

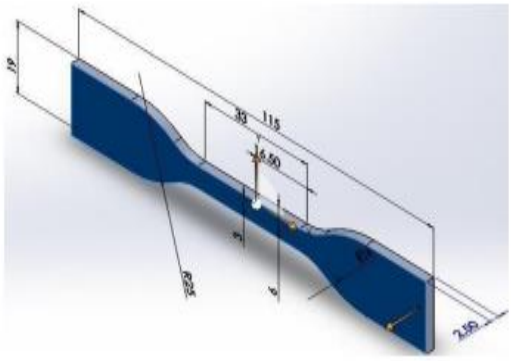

Figure 2: CAD Model of tensile specimens

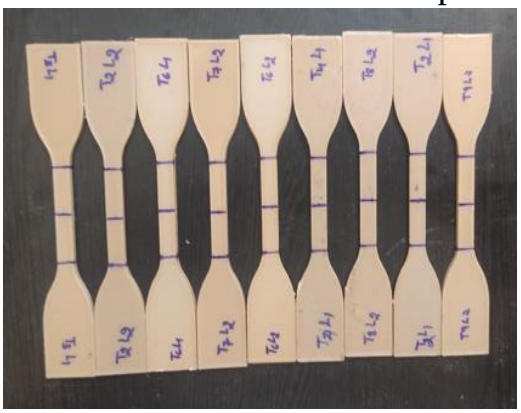

Figure 3: Samples printed according to design of experiments (DOE)

STEP 6: TESTING OF SPECIMENS IN UTM

The prepared specimens are tested in computerized universal testing machine to capture the tensile properties of developed novel composite filament PLA + bamboo powder for 3D printing.

STEP 7: IDENTIFYING OPTIMUM LEVEL SETTING

After testing the specimens in accordance to the experiment run developed using the taguchi method, the data in analysed in MINITAB to obtain the optimum level setting of the input parameters.

RESULTS AND DISCUSSION

The prepared tensile specimens are testing in accordance to the experiment table developed using taguchi method. The figure 4 shows the fractured specimens. The test results are tabulated as shown in table below.

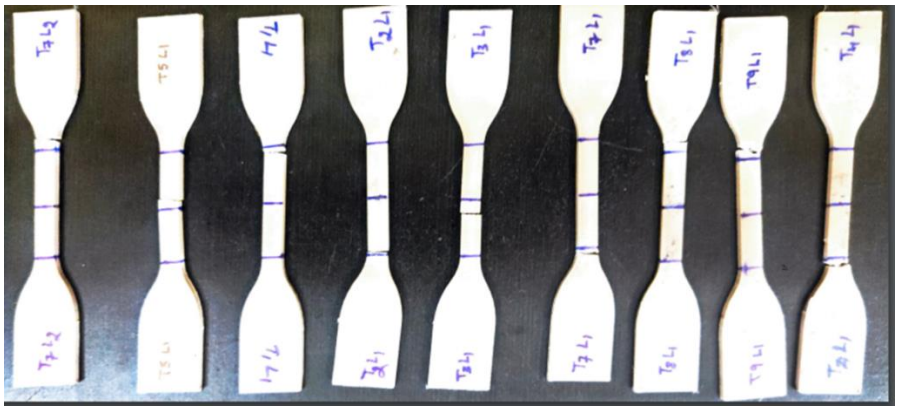

Figure 5 : Tested Specimen

TABLE 5: TENSILE TEST RESULTS

Orthogonal Array	CS Area (mm2)	Peak Load (N)	%Elongation	Stress (N/mm2)	Strain	UTS (N/mm2)

L1	17.78	608.436	15.668	20.4975	0.0993	34.17
L2	17.40	671.175	17.865	21.2875	0.097	35.47
L3	18.645	656.314	17.841	21.116	0.0101	35.18
L4	19.15	634.255	16.283	19.875	0.081	33.12
L5	19.18	630.582	15.605	19.738	0.0975	32.89
L6	18.415	661.959	15.010	21.577	0.0975	35.95
L7	18.615	596.521	13.413	19.713	0.0895	32.85
L8	19.765	565.095	13.615	17.617	0.089	28.61
L9	19.165	595.437	13.665	18.599	0.0875	3.06

The corresponding graphs of % elongation, stress, and ultimate tensile stress is as shown in figures

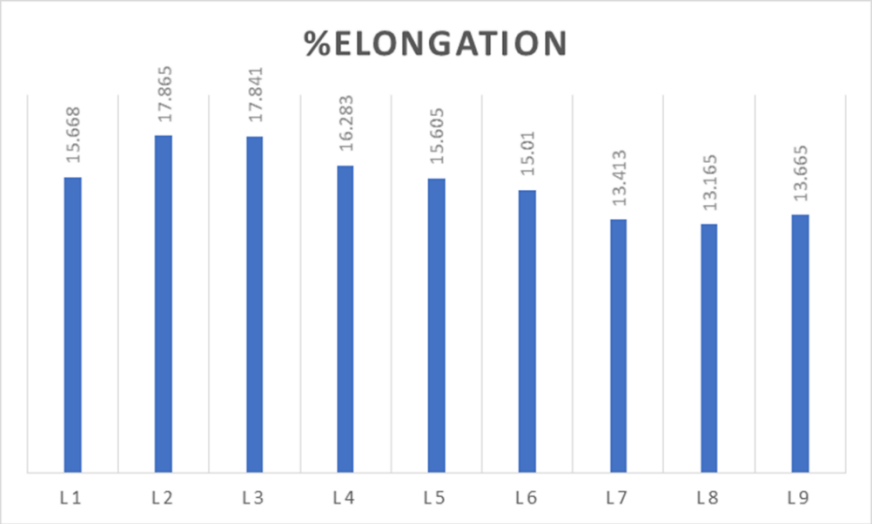

Figure : variation of % elongation

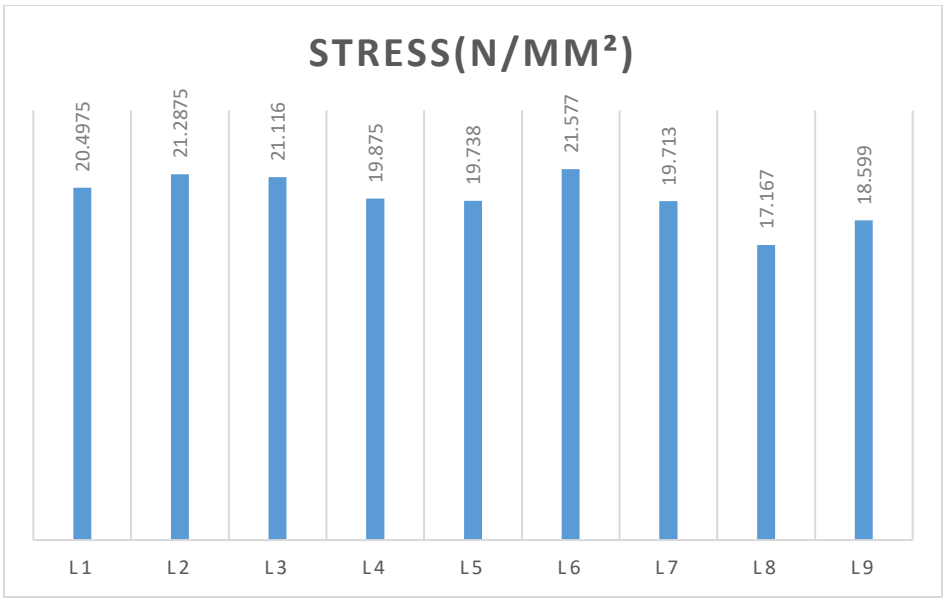

Figure : variation of stress

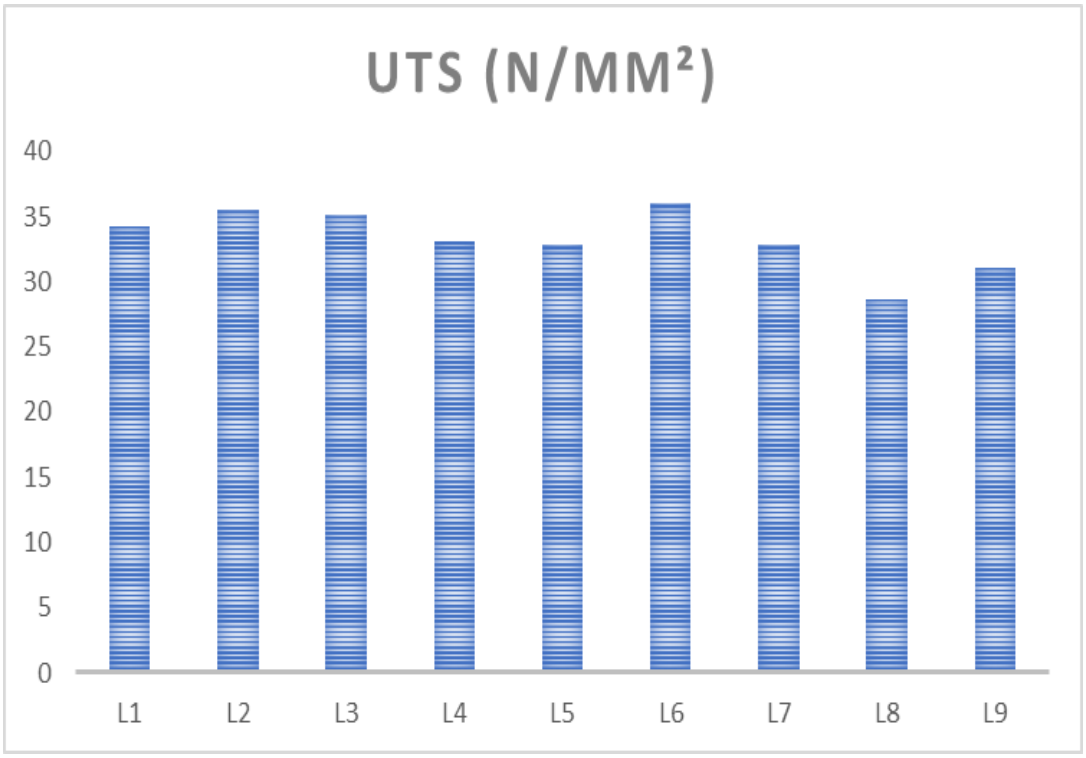

Figure : variation of ultimate tensile strength (UTS)

TAGUCHI ANALYSIS

Taguchi analysis is carried out using Minitab software to understand the effect of controlled parameters on the output parameter (Ultimate Tensile Strength) . From the analysis it was identify the level setting of Layer Height : 0.16 mm, Printing Temperature : 220 ^{O}C and Printing Speed : 90 mm/s provide the better ultimate strength in the components printed with 80% PLA and 20% bamboo powder filament. It was also observed that layer height is more significant parameter for enhancing the UTS in the 3D printed components. Figure shows the mean effect plot of SN ration, from which we can identify the optimum level setting of control parameters.

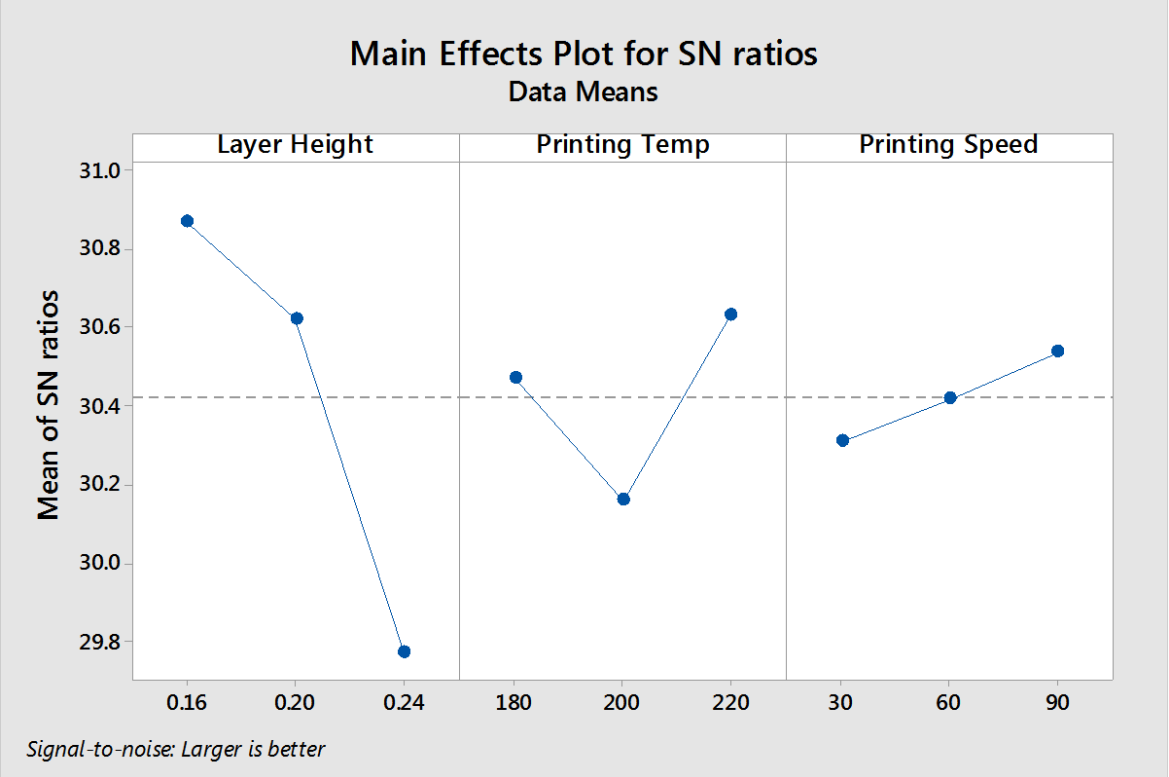

Figure: Mean effect plot of SN ratios

From Taguchi analysis the OPTIMUM **LEVEL SETTING of Layer** Height : 0.16 mm, Printing Temperature : 220 ^{O}C and Printing Speed : 90 mm/s is used to get better mechanical properties in the PLA + Bamboom powder reinforced composite filament.

CONCLUSION

Additive manufacturing (AM) is one of the most popular in manufacturing of components from prototypes to functional structures with any complex geometry, started during the early1980s [9]. It is popular in industrial areas such as automotive, biomedical, aerospace applications.

The present study is focused on to evaluate the mechanical properties of PLA reinforced with bamboo nano particles 3D printing filament. Design of experiment taguchi method is used to minimize the experimentation time and cost. Twin screw extruder is used to blend the matrix and reinforment and develop a 3D printing composite filament. The tensle specimens are printed according to the ASTM standards and tested in UTM. From the results it was found that the level setting of Layer Height: 0.16 mm, Printing Temperature: 220 ^{O}C and Printing Speed : 90 mm/s provide the better ultimate strength in the components printed with 80% PLA and 20% bamboo powder filament.

SCOPE FOR FUTURE WORK

From the present investigation the mechanical properties of PLA reinforced with bamboo powder are evaluated. For future work the study can be extended for different reinforcements. Further, thermal and fatigue studies can also be performed on novel filaments developed with different reinforcements.

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