International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(02), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Impact of layer thickness and Build orientation on Tensile Strength of a Component manufactured by 3DP

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ABSTRACT

The objective of this study was to build the Spectrum Z 450 using ZP 150 powder along with ZB 63 binder and to investigate the effects of layer thickness & build orientation on part strength of specimen fabricated. The orientations of specimen and layer thickness were considered as variable input process parameters while tensile strength was considered as output respond. Taguchi L9 orthogonal array method of design of experiments was used in this study to plan the experimental trials. The results showed that the layer thickness does not have significant impact on tensile strength. However, build orientation have higher effect as compared to layer thickness on tensile strength.

I INTRODUCTION

Additive Manufacturing (AM) is defined as the manufacturing process of building objects adding material to previous build areas, layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. Synonyms are additive fabrication, additive techniques, additive layer manufacturing, layered manufacturing and solid freeform fabrication. It's also good to mention that AM includes all applications of the technology, including modelling, prototyping, pattern-making, tool-making, and the production of end-use parts in volumes of one to thousands or more. It isn't just about prototyping as it were for almost two decades since layered manufacturing techniques started to be used. Additive Manufacturing (also known as layered manufacturing or additive fabrication) consists of several different types of technologies such as stereo lithography [1], selective laser sintering [1, 2], fused deposition modelling [3-5], three-dimensional printing (3DP) [6] and several others [1, 7]. These technologies are used to create physical prototypes, models, tooling components, and other physical parts from CAD data. Additive manufacturing was first introduced in 1987 in the form of stereo lithography it used a laser to cure UV sensitive material layer by layer. The Additive Manufacturing is being used in all different types of design and manufacturing organizations. In recent years, the industry has experienced a large push towards office friendly 3D printers, which are low cost office friendly AM machines. However, there is still a need for information on printing techniques, materials used, build orientation, and material strengths for 3DP [8].Z Corporation (Z Corp) introduced its first 3DP, the "Z402" in 1996 [9]. The first 3DP used a starch or plaster based powder material with a water-based binder [9].

In this study, Two parameters were optimized to enhance the tensile strength of the product, productivity and process reliability. The experimental trials were conducted on specimens. The orientations of specimen and layer thickness were considered as variable input process parameters while tensile strength was considered as output respond. Taguchi L9 orthogonal array method of design of experiments was used in the study to plan the experimental trials.

II EXPERIMENT

2.1 Materials and Equipment Used

Specimens were built in the Spectrum Z 450 using ZP 150 powder along with ZB 63 binder was for this thesis. The ZB 150 powder is a plaster-based high performance build material [10, 11]. There are numerous variables that can have an effect on the strength of parts.
Some variables that effect part strength [10, 12] that cannot be controlled with software are build to build variation, print head life, humidity, and other environmental variables for finding the tensile strength we are using universal strength machine.

2.2 Testing Equipment for measuring the tensile strength of the specimen universal strength machine shown in figure 1 was used in this study. The mechanism & specifications of the machine are given below:
Mechanism: Consists of hydraulic unit, high and low pressure gauge, set of compression pads,
Compression range high up to 13 kg/cm^2, low up to1600 g/cm^2
Strength measurement range:

Low pressure gauge
1) Compression (0 to 1600) g/cm^2
2) Shear (0 to 1300) g/cm^2
3) Tensile (0 to 6) kg/cm^2

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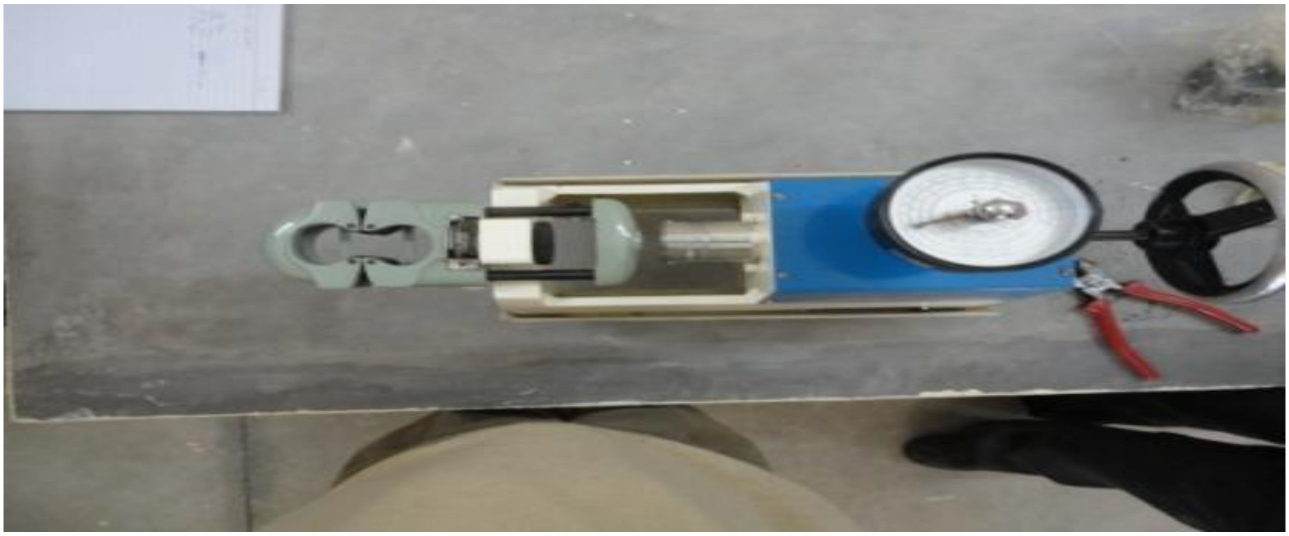

Figure 1: Universal strength machine after fixing die which is used for measuring the tensile strength

2.3 Method

The experiments were planned in accordance with Taguchi L9 orthogonal array method of design of experiments. Two control parameters namely orientations of specimen and layer thickness were considered as input variable. Three levels were considered for each control input parameter. Table 1 shows the control parameters and their level used in the study.

Table 1 shows the control parameters and their level

Level → / Parameters ↓	Level 1	Level 2	Level 3
Orientation of specimen	(XY)=0	(YZ)=90	(ZX)=45
Layer thickness (mm)	0.089	0.1	0.1125

III RESULTS AND DISCUSSION

Taguchi L9 orthogonal array was used in the study to plan the experiments. In our case the numbers of levels are 3 and two numbers of input variable parameters were considered. Total 9 nos. sets of experiments were conducted and results for tensile strength were represented in table no.2. It is clear from the table no.2 and as well as from the

Figure no.2 Maximum tensile strength is on reference at (xy) = 0, for each layer thickness. Minimum tensile strength is after rotating at yz =135 & then at xy = 45 , for each case shows if specimen oriented at inclined position, then it gives minimum tensile strength as compare to others.

Result 2 & 3 clearly shows that as layer thickness decreases, number of layers to fabricate increases. Hence, strength is higher because the specimen is now more compact. The test shows decrease in strength of specimen when its position is changed from 1 to 2 and further decrease in strength when position is changed from 2 to 3 because of the distribution of force applied during tensile test on specimen. Layer thicknesses selected in the work were 0.089, 0.1and 0.1125 mm.

If we change the shape of the specimen there would be decrease in strength of specimen because of stair stepping problem.

The analysis of variance (ANOVA analysis) was carried out to determine the rank of the factors and the percentage contribution of different input control variables on the tensile strength. The percentage contribution of different factors on tensile strength was represented in figure 3. From the figure it can be clearly observed that orientation is very predominating parameter in this study. For Tensile strength orientation is the major contributors having the percentage contribution of 90.638% and 9.362% contribution is contributed by the layer thickness.

Table 2: Showing different tensile strength for different layer thickness

S. No	Orientation of specimen	Layer thickness (mm)	Tensile Strength (kg/mm$^{2)}$
1	Reference at (xy) = 0	0.089	6.3
2	Rotate at (yz) = 90	0.089	5.9
3	Rotate at (xz) = 45	0.089	3.0
4	Reference at (xy) = 0	0.1	5.9
5	Rotate at (yz) = 90	0.1	5.2
6	Rotate at (xz) = 45	0.1	2.1
7	Reference at (xy) = 0	0.1125	5.3
8	Rotate at (yz) = 90	0.1125	4.7
9	Rotate at (xz) = 45	0.1125	1.4

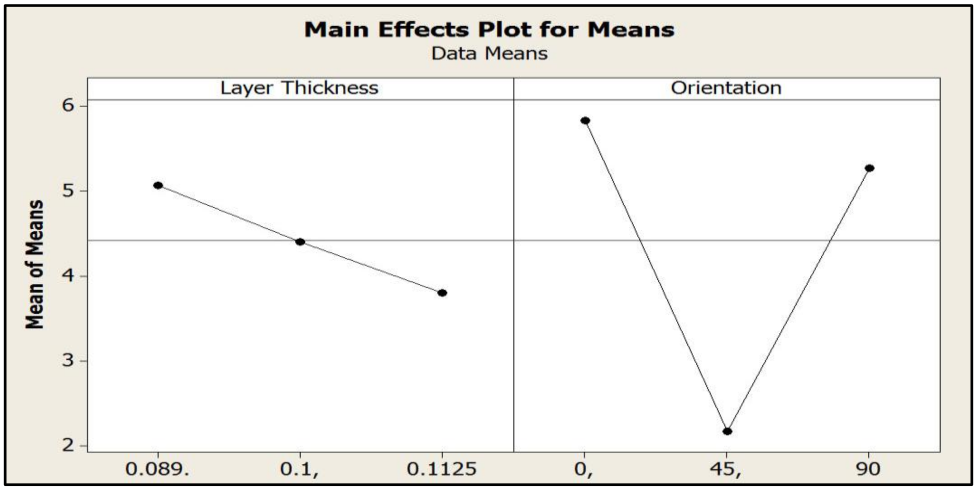

Figure 2: Effect of layer thickness & orientation to the tensile strength

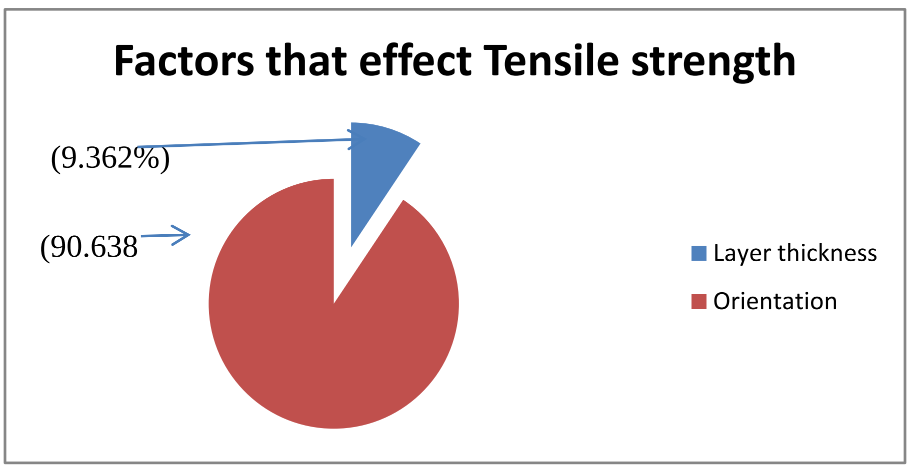

Figure 3: Shows the percentage contribution of process parameters on tensile strength

IV CONCLUSION

In this study the effects of layer thickness & build orientation on part strength of specimen fabricated in 3DP were investigated. Based on this study it is observed that the layer thickness does not have significant impact on tensile strength. It is shown via pie chart that build orientation have higher effect as compared to layer thickness on tensile strength.

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