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Performance Parameters in FDM 3D Printed Parts

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***Abstract:** Rapid changes and evolutionary market has demanded the new ways of production such as adaptive manufacturing techniques. In this research work different response characteristics such as ultimate tensile strength, surface roughness and energy consumed have been investigated from the work piece fabricated using of three dimensional printing. Taguchi based L27 orthogonal array was used to carry out the investigation study using Minitab software. From experimental investigation it has been depicted that layer resolution is the most significant parameter.*

***Keyword:** production such as adaptive manufacturing techniques. In this research work different*

I. INTRODUCTION

Now days the manufacturing engineering faces day to day challenges as the technology and demand for robust design demand for the continues changes in the design and so as in the manufacturing and production of new components and porotypes. This rapid changes and evolutionary market has demanded the new ways of production as the conventional manufacturing process does meet the requirements as the cost involved in the manufacturing is much higher. To meet the requirements of this technology emerging era new measure for adaptive manufacturing techniques has to be made. There are number of Additive manufacturing techniques which are available in the market such as stereo lithography (STL), selective laser sintering (SLS), inkjet printing (IP) and fused deposition modelling (FDM). Among various techniques available FDM has been seeing attention of many small scale industrialist designers even student which are working in the field of rapid prototyping.

Three dimensional printing, also called adaptive manufacturing and rapid prototyping. This technology is very useful in many field like research, manufacturing, aerospace and medical industry. The scope for adaptive manufacturing technique has been increased in last few decades both in quantity and scope. In this technique shape form though three dimensional model using adaptive process in which successive layers of material are laid down under computer control. This technique was developed in 1990's and used for rapid production of tool using metal and ceramic but now a days it is being used in many adaptive fields.

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The main advantage of this technique is production of less scrap and due layer by layer model formation leads to uniform mechanical properties and better surface finish. This technique has been emerging as of the most cost effective technique. As being a new technique the output characteristics of FDM are still in the explanatory stage. The process parameters effect the output one parameter at one time leads to a large number of experimentation and also the interactive effect is also unraveled. As an alternative, the taguchi method experimentation with statistical analysis to study the several factors simultaneously and requires relatively a few experiments to evaluate the cause and effect of those factors.

II. METHODOLOGY

Machining of specimen has been carried out using 3-D has been used for conducting experimental investigation. Table-1 depicts the different input parameters and level of each input parameter used for experimental study. The Taguchi based L_{27} orthogonal array was considered to carry out the for experimental study. The ultimate tensile strength, energy consumed and surface roughness are determined.

Table I: input parameters and levels

Symbol	input Parameters	I	II	III
A	Layer resolution	70	200	300
B	Print Strength	Strong	Almost solid	Solid
C	Print Pattern	Cross	Diamond	Honey Comb

Dr. Taguchi has combined two components named desirable and undesirable for one characteristic termed as Signal to Noise (S/N) ratio.

The S/N ratio generally used for quality characteristics. This is also used to depict the the significant machining parameters using Variance Analysis.

Larger-the-better principle

Ultimate tensile strength is considered as the quality characteristic which is based on lager-the better principle and can be expressed as follow.

$$\eta = -10 \log_{10} . \left[1/n \sum_{i=1}^{n} 1/ y_i^2 \right] \quad ------------- 1$$

η shows the signal to noise (S/N)

n shows the of replication,

y_i shows the output value.

Smaller-the-better principle In three dimensional printing surface roughness should be is minimum and considered in smaller-the-better principle which is given as follows

$$\eta = -10 \log_{10} . \left[1/n \sum_{i=1}^{n} y_i^2 \right] ; \qquad \text{- - - - - - - - - - - - - 2}$$

A. ANOVA

ANOVA is a statistical tool which determines the significance of every factor help in controlling the outcome. The ANOVA calculations were done using the help of the MINITAB 16 software. The basic formulas for analysis of variance are given as follows;

Let 'A' is the response parameter.

$$SST = \sum_{i=1}^{N} (y_i - \bar{T})^2 \qquad \text{- - -- - - - - - - - -3}$$

Where N = Total number of response.

$\bar{T}$ depicts the mean for all observations

Sum of Squares (*SSA*) -

$$SS_A = \left[\sum_{i=1}^{k_A} \frac{A_i^2}{N_{A_i}} \right] - \frac{T^2}{N} \qquad \text{- - - - - - - - - - - - - -4}$$

Error Sum of Squares (*SSe*)

$$SSe = \sum_{j=1}^{k_A} \sum_{i=1}^{n_{Ai}} (y_i - \bar{A_j})^2 \qquad \text{- - - - - - - - - - 5}$$

B. Measurement of F-value of Fisher's F Ratio:

The F value determines the significance investigated

response. And is given as follows.

$$F = \frac{MS \text{ for the term}}{MS \text{ for the error term}} \qquad \text{- - - - - - - - - - - - -6}$$

III. EXPERIMENTS RESULTS

Based on the experimental layout experiments were performed. Threee characteristics namely Ultimate Tensile Strength (UTS) and surface roughness (SR) and Energy were measured.

A. S/N Ratio and Parametric Optimization consumption

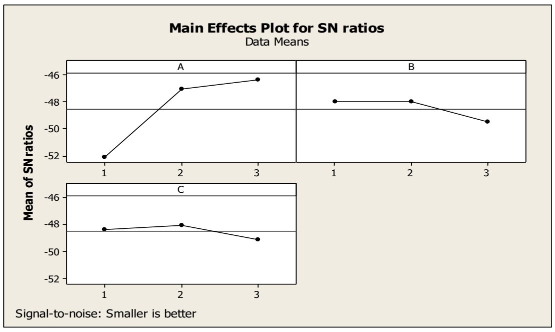

Figure-I S/N ratio graph for energy consumption

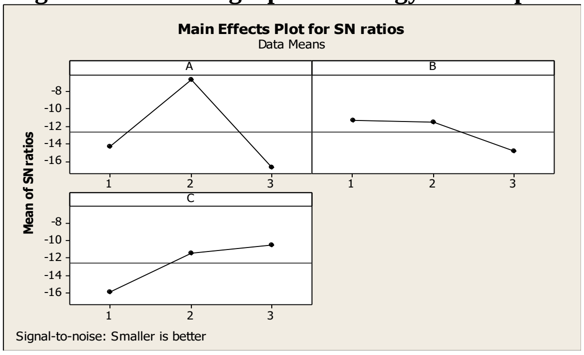

Figure-II S/N ratio graph for surface roughness

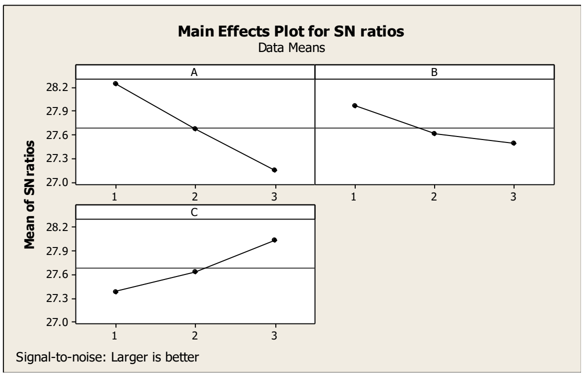

Figure-III S/N ratio graph for ultimate tensile strength

A. Analysis of Variance For energy consumption

The results obtained from experimental investigation was analyzed using ANOVA technique to check significance. The optimized value of response are established using statistical technique which comprises ANOVA, response graphs.

Table-II ANOVA for energy consumption

Source	DF	Seq SS	Adj SS	Adj MS	F- Value	P- Value	% age
A	2	172803	172803	86401	4089.81	0	85.95967
B	2	17940	17940	8970	424.6	0	8.92413
C	2	9624	9624	4812	227.78	0	4.787393
A*B	4	211	211	53	2.5	0.126	0.104961
A*C	4	137	137	34	1.62	0.261	0.06815
B*C	4	143	143	36	1.7	0.243	0.071134
Error	8	169	169	21			
Total	26	201028					

Table-III ANOVA for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F- Value	P-Value	% age
A	2	74.665	74.665	37.332	220.89	0	36.62688
B	2	18.182	18.182	9.091	53.79	0	8.919172
C	2	94.416	94.416	47.208	279.32	0	46.31573
A*B	4	12.684	12.684	3.171	18.76	0	6.222131
A*C	4	2.181	2.181	0.545	3.23	0.074	1.069889
B*C	4	0.373	0.373	0.093	0.55	0.704	0.182975
Error	8	1.352	1.352	0.169			
Total	26	203.853					

Table-IV ANOVA for ultimate tensile strength

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P- Value	%age
A	2	29.5136	29.5136	14.7568	53.84	0	50.22984
B	2	6.0084	6.0084	3.0042	10.96	0.005	10.22583
C	2	19.6464	19.6464	9.8232	35.84	0	33.43664
A*B	4	0.6954	0.6954	0.1738	0.63	0.652	1.183517
A*C	4	0.2792	0.2792	0.0698	0.25	0.899	0.475177
B*C	4	0.4214	0.4214	0.1054	0.38	0.814	0.71719
Error	8	2.1927	2.1927	0.2741			
Total	26	58.7571					

IV. REGRESSION

A polynomial mathematical model has been developed using input output results obtained from experimentation.

Energy = 352 - 92.6 A + 38.2 B + 30.1 C + 0.35 A*A + 0.09 B*B - 1.20 C*C - 2.90 A*B - 0.47 A*C - 0.61 B*C --------- 7

SR = 6.43 - 0.694 A - 0.408 B - 1.13 C + 0.011 A*A + 0.899 B*B + 0.755 C*C - 1.02 A*B + 0.324 A*C - 0.146 B*C ----------8

UTS = 27.2 - 1.56 A - 1.04 B + 0.429 C - 0.027 A*A - 0.022 B*B + 0.028 C*C + 0.108 A*B + 0.086 A*C + 0.166 B*C-------------9

1. The surface roughness and ultimate tensile strength at different levels of control factors such as infill percentage, outline parameter shell and type of material are analyzed through ANOVA (analysis of variance). The ANOVA reveals that the infill percentage is the most significant control factor with 51-71 % contribution.
2. The optimization (maximization / minimization) of the output parameters surface roughness and ultimate tensile strength at different levels of control factors such as infill percentage, outline parameter shell and type of material analyzed through S/N response graphs. The S/N response graphs reveal that minimum surface roughness is achieved at parametric combination **A3 B2 C2** and maximum value of ultimate strength was observed at parametric combination **A3 B1 C1**.
3. Mathematical model based on regression analysis have been developed using input out experimental results.

V. CONCLUSION

- The optimal setting of process parameters were obtained as **A3 B1 C2** for energy consumed, **A2 B1 C3** for surface roughness and **A1 B1 C3** for ultimate tensile strength.
- ANOVA has been applied to find the significant process parameters. Using ANOVA, process parameters namely layer resolution (A), print strength (B) and print pattern (C) were found significant. Layer resolution was found the most significant parameter whereas layer pattern was found significant in case of surface roughness.
- Regression based mathematical model were developed for all the output parameters namely surface roughness, ultimate tensile strength and energy consumed.

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