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EXPERIMENTAL INVESTIGATION ON CONCENTRICITY OF POLYAMIDE SINTERED PROTOTYPES, BY SELECTIVE LASER SINTERING PROCESS USING TAGUCHI METHOD

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ABSTRACT

In the present research paper, a 3D CAD model is created using CATIA V5 and exported to Rapid Prototyping machine and, by using Magics software; the facets are removed and sliced into layers. The model is build by layer, with polyamide PA2200 in powder form and sintered by co_2 laser. Total of nine (9) Experiments were conducted using taughi design of experiments L_9 orthogonal array approach. In present study, by optimizing the processes parameters laser power, Layer thickness and Temperature at three levels each factor and found to be maximum influence, on concentricity are Layer thickness at level 2, Laser Power at level 3 and last temperature at level 2 is +/- 0.030 microns. Main effects of Plots of Analysis of Mean, S/N Ratio single-to-noise with quality index smaller-the-better, regression Analysis and Predicted model are same.

KEYWORDS: Catia, Design of Experiments, Magics, Rapid Prototyping, Optimising

INTRODUCTION

Additive Manufacturing is one of the high end cutting edge technologies, to build prototypes and functional prototypes, in short time and minimum cost. In this research paper, Selective Laser Sintering process is used to build the prototypes, by sintering the polyamide PA2200 material in powder layer by co_2 laser. Taguchi design of experiments L_9 orthogonal array approach, by selecting three variable factors laser power, layer thickness and temperature at three levels each factor one Response variable Concentricity are compared with mathematical models Regression analysis, Predictive model, Analysis of Mean and Signal-to-Noise ratio.

Literature Survey

- Andreas Wegner□, Gerd Witt worked on Correlation of process parameters and part properties in laser sintering using response surface modeling
- C. Cajal*, J. Santolaria, J.worked on Volumetric error compensation technique for 3D printers
- Raju B S, Chandra Sekhar U worked on Optimizing Multiple Quality Characteristics of Stereolithography Process via Taguchi Method-Based Grey Analysis for SL5530 Epoxy Resin Material to Enhance Part Quality
- Raju B S, U Chandra Shekar Establishment of Process model for rapid prototyping technique (Stereolithography) to

enhance enhance the part quality by Taguchi method

- research work on Senthilkumaran, K Pandey, Pulak M Rao, P V Influence of building strategies on the accuracy of parts in selective laser sintering
- Ning, Y.; Wong, Y.S.; Fuh, J.Y.H.; Loh, H.T. Sercombe, T B Hopkinson, N Process shrinkage and accuracy during indirect laser sintering of aluminium
- Wenbin, H.; Tsui, L.Y.; Haiqing, G.A. Study of the staircase effect induced by material shrinkage in rapid prototyping. [1 – 7] lot of research work on part quality, errors by using taughci method was done but in this paper the main work is on concentricity which is the response variable by varying the process parameters were built total nine (9) experiments were conducted on polyamide PA2200 and tested on CMM. The optimal response variable is attained at optimal process parameters both the Experimental and Mathematical model of the response variable were compared

Experimentation

Taguchi design of experiment L_9 orthogonal array approach was conducted, as shown in table 1, three factors and three levels for each factor and experiment, set as shown in table 2. The material used is PA2200 is a white polyamide powder, as an excellent material properties, after sintering shown in table 3.Total of nine (9) experiments of the 3D model, created by using catia V5 are shown in figure 1 are built layer by layer, on Rapid Prototyping machine figure 2 and sintered parts are shown in figure 3 and tested for concentricity, using CMM as shown in figure 4.

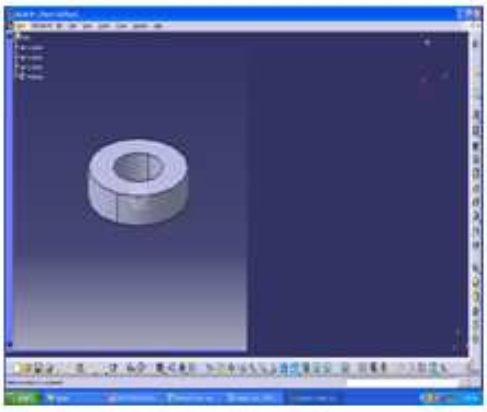

Figure 1: 3d Model

Figure 2: Rapid Prototyping Machine Sintered Pa2200 Prototypes

Table 1: Process Variable Factors at Three Levels

Parameter	Symbol	Units	Level 1	Level 2	Level3
Laser Power	LP	watt	67	68	70
Layer thickness	LT	microns	100	110	120
temperature	T	Degree centigrade	174.7	175	176

RESULTS AND DISCUSSIONS

The results of concentricity after testing on CMM are given below

Table 2: Experimental Setup for Concentricity L_9 Orthogonal Array Results

Experiment run	LP watts	LT microns	T degree centigrade	Concentricity
1	1	1	1	0.0954
2	1	2	2	0.0388
3	1	3	3	0.0458
4	2	1	2	0.0673
5	2	2	3	0.0784
6	2	3	1	0.0548
7	3	1	3	0.0383
8	3	2	1	0.0292
9	3	3	2	0.0524

Table 3: Pa2200 Material Properties

1	Izod Impact notched	4.4 KJ/metre square
2	Charphy impact strength	53 KJ/metre square
3	Melting temperatue	176 degree centigrade
4	Density (laser sintered)	930 Kg/metre cube

Table 4: Response for Means

Level	Laser [Pwer]	Layer Thickness	Temperature
1	0.05767	0.06210	0.06017
2	0.05550	**0.04363**	**0.04597**
3	**0.04177**	0.04920	0.04880
Delta	0.01590	0.01847	0.01420
Rank	2	1	3

The Laser power at level 3, Layer thickness at level 2and temperature at level 2 is the optimal level for concentricity and the maximum influence on concentricity is layer thickness, laser power and minimum influence is temperature the results of obtained from the Analysis of Mean as shown in table 4 and the figure 5.

Table 5: Response for Signal to Noise Ratios Quality Index Smaller Is Better

Level	Laser Power	Layer Thickness	Temperature
1	25.62	24.70	25.41
2	25.18	**27.67**	**26.82**
3	**27.85**	26.27	26.42
Delta	2.67	2.97	1.41
Rank	2	1	3

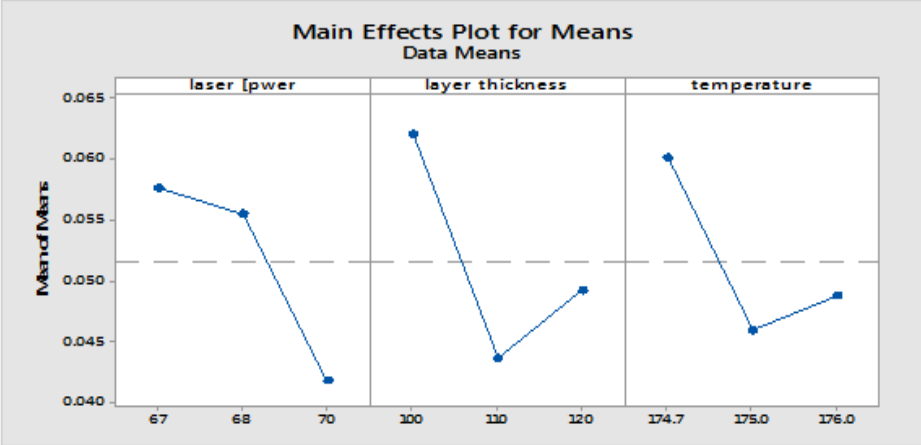

Figure 3: Concentricity Mean Effects of Plot

The Optimal process parameter for the concentricity for Signal -to –Noise ratio S/N ratio with quality index smaller-is-better is **Laser power level 3, layer thickness at level 2 and temperature at level 2** for maximimum S/N Ratio better quality prototypes are produced and same, as the analysis of mean as shown in table 5 with ranks and figure 6.

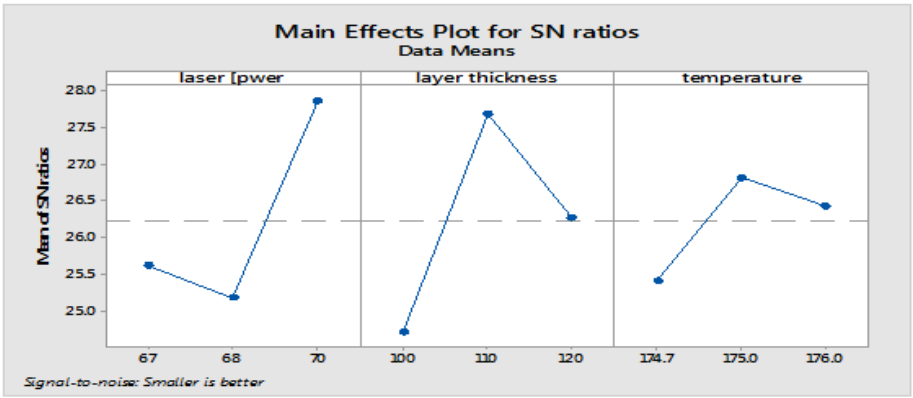

Figure 4: Concentricity Effect S/N Ratio

S/N ratio = -10log$_{10}$ (1/n $\Sigma Y^{2)}$) n= recurrence =1 and Y is the measured concentricity for each trial.

Regression Models

Regression Analysis: concentricity versus laser power

The regression equation is concentricity = 0.4291 - 0.005524 laser power

Table 6: Model Summary

S	R-sq	R-sq(adj)
0.0192169	14.18%	1.92%

Table 7 Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0004272	0.0004272	1.16	0.318
Error	7	0.0025850	0.0003693		
Total	8	0.0030122			

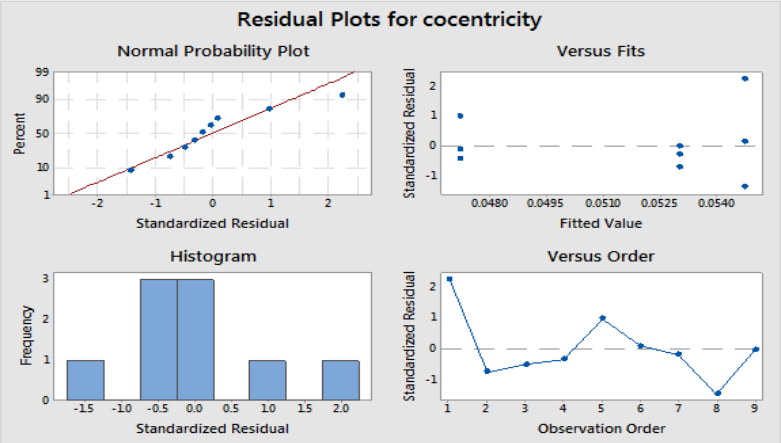

Figure 5: Concedntricity for Laser Power

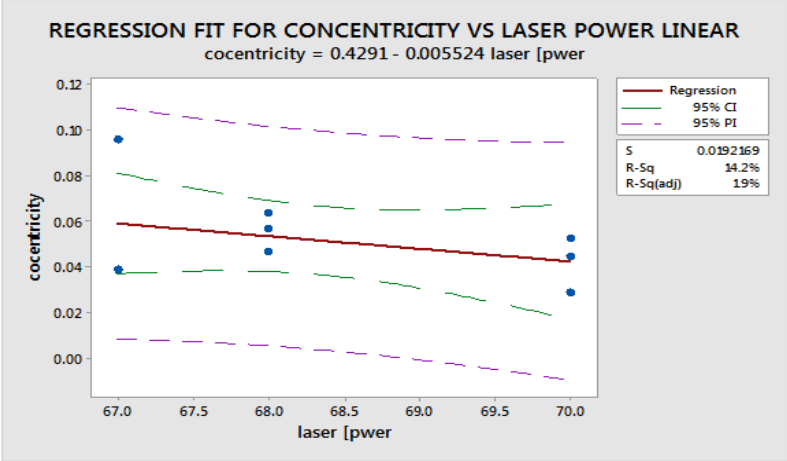

Figure 6: Regression Fit

Polynomial Regression Analysis: concentricity versus layer thickness the regression equation is concentricity = 1.569 - 0.02708 layer thickness + 0.000120 layer thickness^2

Table 8: Model Summary

S	R-sq	R-sq(adj)
0.0203051	17.87%	0.00%

Table 9: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	0.0005384	0.0002692	0.65	0.554
Error	6	0.0024738	0.0004123		
Total	8	0.0030122			

Table 10: Sequential Analysis of Variance

Source	DF	SS	F	P
Linear	1	0.0002496	0.63	0.453
Quadratic	1	0.0002888	0.70	0.435

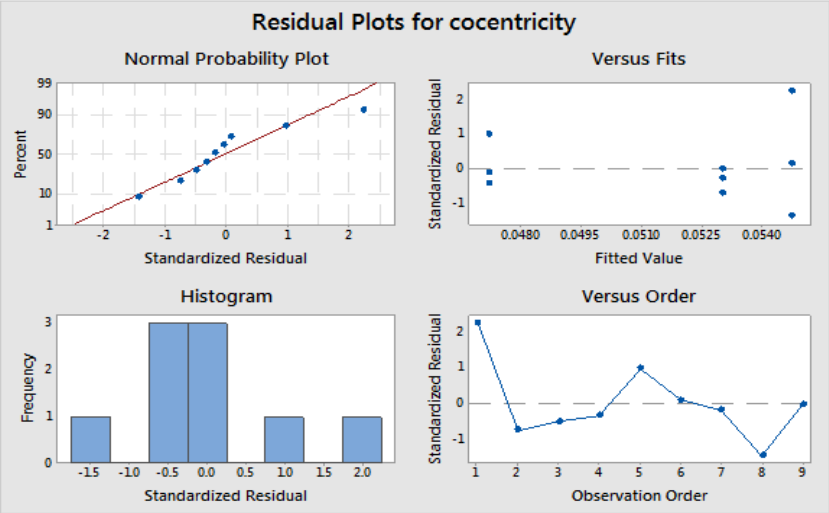

Figure 7: Concentricity for Laer Thickness

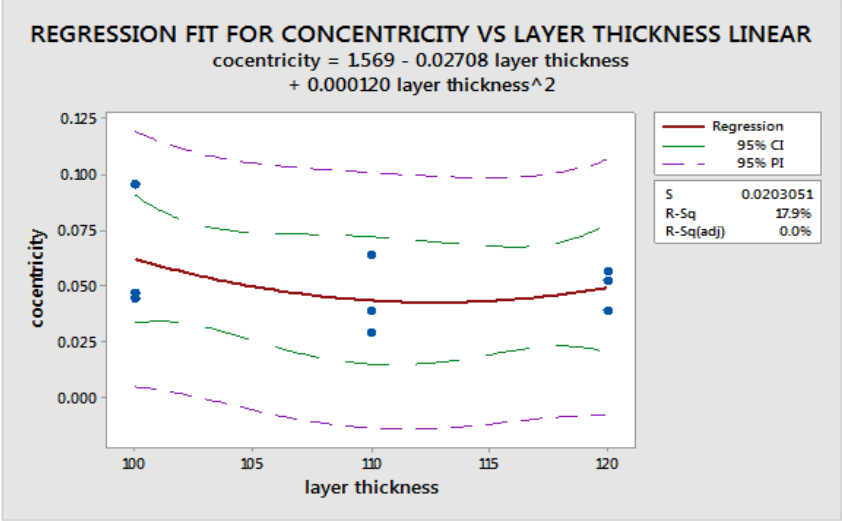

Figure 8: Regression Fit

REGRESSION MODEL 3

Regression Analysis: concentricity versus temperature

The regression equation is concentricity = 1.073 - 0.00583 temperature

Table 11: Model Summary

S	R-sq	R-sq(adj)
0.0204162	3.14%	0.00%

Table 12: Analysis Of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0000944	0.0000944	0.23	0.649
Error	7	0.0029178	0.0004168		
Total	8	0.0030122			

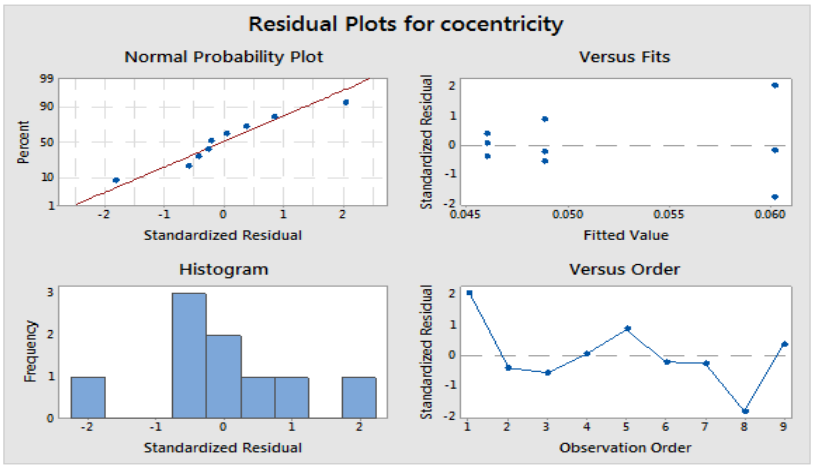

Figure 9: Concentricity for Temperature

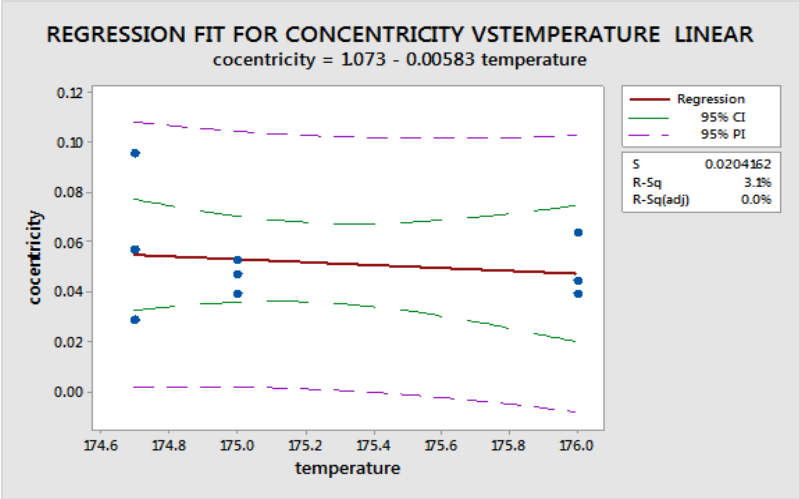

Figure 10: Regression Fit

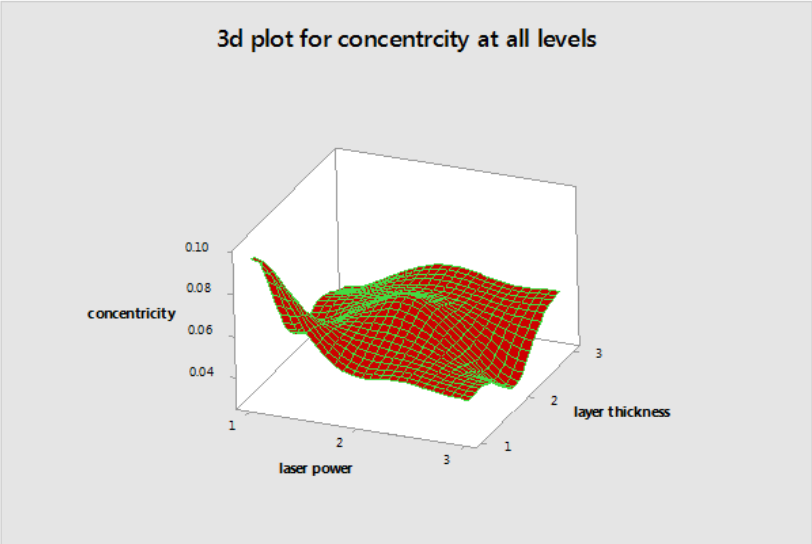

Figure 11: 3d Plot for Concentricity

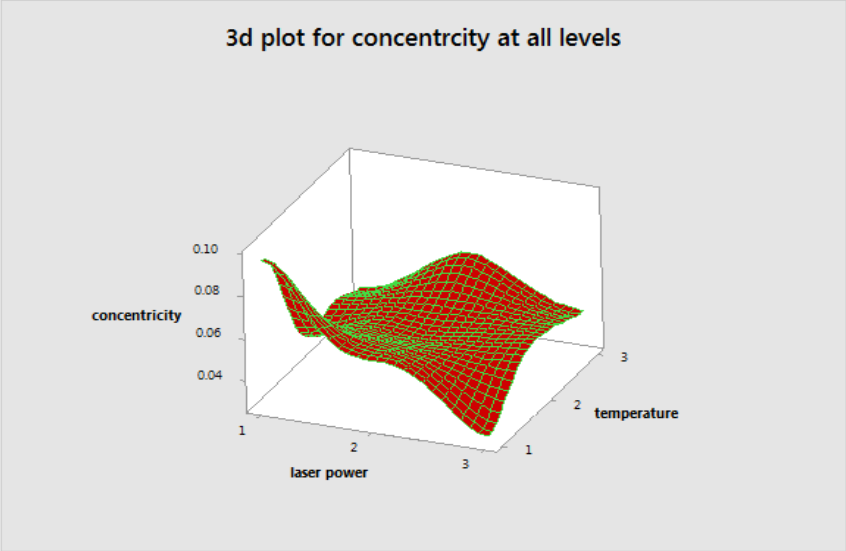

Figure 12: 3d Plot for Concentricity

PREDICTIVE MODEL

The predictive model is constructed from the results of orthogonal array analysis and it is formed, by the optimum level of cotribution of each fator in related to deviation from overall mean is

$Y(P,L,T) = Y_{mean} + (Y_{mean\ P} - Y_{mean}) + (Y_{mean\ L} - Y_{mean}) + (Y_{mean\ T} - Y_{mean})$ at optimum parameters.

$Y(P_3\ L_2\ T_2) = 0.05162+(0.0139-0.05162)+(0.0145-0.05162)+(0.0153-0.05162) =$ **-0.059 microns.**

Table 13: Comparison of Results

Parameters	LP	LT	T	Experimental Value	Mean Value
Optimal setting	70 watts	110 microns	175 degrees	**0.030 microns**	**0.059 microns**

CONCLUSIONS

- The influence of process parameters on concentricity, at the optimal level using taguchi design of experiments L_9 orthogonal array approach is Laser power at level 3, Layer thickness at level 2 and temperature at level 2 both experimental and predictive model is +/-29 microns.
- The maximum influence is Layer thickness, Layer power and last Temperature on concentricity.
- The Experimental value at optimal process parameters is 0.030 microns on concentricity
- The Predictive model at optimal process parameter is -0.059 microns on concentricity.

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