STUDY ON THE INFLUENCE OF RAPID PROTOTYPING PARAMETERS ON PRODUCT QUALITY IN 3D PRINTING

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Abstract

This work aims at evaluating the relative significance of the input parameters on the product quality produced by Z510 3DP rapid fabricator. Taguchi's L_{18} orthogonal array was employed to investigate the possible process parameters including binder setting saturation value (shell & core), layer thickness, and build orientation. Using a surface profilometer and CMM, a series of measurements in evaluating the 3DP products surface finish and dimensional accuracy has been carried out. Nonlinear regression model was developed and a statistical analysis was done to determine the significant factors affecting the product quality of the fabricated products. Optimal process parameter settings were proposed using Particle Swarm Optimization technique. The results were validated by conducting the confirmatory experiments.

1. Introduction

Rapid Prototyping (RP) refers to a group of emerging technologies for fabricating physical objects directly from computer-based geometry descriptions of part designs. In RP a CAD file of an object is converted into a physical model using an additive or layered manufacturing technique. The evolution from prototyping to production is stressed for the inherent advantages of the layered method. The prototypes thus obtained permit better communications and more interactions within associates and between associates and customers. Also these physical models help to see, understand and analyze characteristics of the final product. Presently the trend is towards manufacturing functional models from RP process. This process is called Rapid Manufacturing (RM), which is slowly integrating into the commercialization cycle. Because of rapid manufacturing, there are no more shape or complexity constraints. Also, it is possible to customize objects for consumers, eliminating all tooling manufacturing. Three Dimensional Printing (3DP) is one of the layered manufacturing technologies developed for producing prototypes, end use products and tools directly and rapidly from CAD data. 3DP had gained competitive edge over other RP technologies in terms of build speed, larger choice of material selection, low operating cost, capabilities like producing models with colours and versatility in making prototypes. Thus it is widely used in concept modeling, rapid tooling and making surgical aids, implants, etc in medical field [2]. The effectiveness of a prototype for functionality is recognized from the quality characteristics imparted to it by the RP process. 3DP is one of the rapid prototyping technologies which have the application beyond concept modeling [3]. This intent of this work is to analyze the process parameters on product quality of the powder type 3DP RP system.

2. Powder type 3DP system

The 3DP process starts by depositing a layer of powder object material at the top of a fabrication chamber. To accomplish this, a measured quantity of powder is first dispensed from a similar supply chamber by moving a piston upward incrementally. The roller then moves over the powder bed, distributes and compresses the powder at the top of the fabrication chamber. The multi-channel jetting head containing nozzles subsequently deposits a liquid adhesive in a two dimensional pattern onto the layer of the powder which becomes bonded in the areas where the adhesive is deposited, to form a layer of the object. The Z-axis piston lowers a layer of the thickness unit so that the powder of the next layer can be spread and selectively bound as shown in figure 1. This process repeats until the part building is completed. Following a post processing step by air blow, the rest of unbound powder is removed, leaving the fabricated part. 3D printing has been extended to the fabrication of components with local composition control by printing different materials in different locations, each through its own ink-jet nozzles [2].

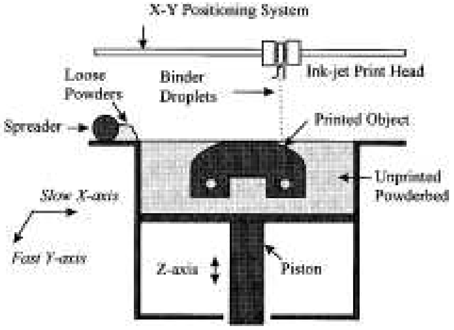

Figure 1. Schematic diagram of 3DP process [5]

3. Experimental Design

Experiments were carried in Zcorp Spectrum510 3D printer. A plaster and cellulose based powder (ZP250) and binder (Zb56) was used to print the models. The parameters and their levels that affect the performance of 3DP process are identified from the previous literature [1] and manufacturer's manual. The control factors and their levels considered in this study are shown in table 1. The experiments were conducted according to L_{18} orthogonal array [6] as shown in table 2 which reduces the number of factor combinations to 18 without neglecting any of the main effects. STL file of an evaluation model as shown in figure 2 was given as input to the 3DP machine.

Table 1 Control factors and their levels

Control Factors	Levels		
	1	2	3
Layer thickness in mm (A)	0.0889	0.1016	-
Saturation value -Shell (B)	1	0.75	0.5
Saturation value -Core (C)	1	0.75	0.5
Build orientation (D)	0	45	90

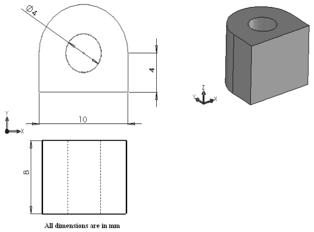

Figure 2. Evaluation model

Table 2 Experimental layout using L_{18} orthogonal array

Exp. No.	Factors			
	A	B	C	D
1	A_1	B_1	C_1	D_1
2	A_1	B_1	C_2	D_2
3	A_1	B_1	C_3	D_3
4	A_1	B_2	C_1	D_1
5	A_1	B_2	C_2	D_2
6	A_1	B_2	C_3	D_3
7	A_1	B_3	C_1	D_2
8	A_1	B_3	C_2	D_3
9	A_1	B_3	C_3	D_1
10	A_2	B_1	C_1	D_3
11	A_2	B_1	C_2	D_1
12	A_2	B_1	C_3	D_2
13	A_2	B_2	C_1	D_2
14	A_2	B_2	C_2	D_3
15	A_2	B_2	C_3	D_1
16	A_2	B_3	C_1	D_3
17	A_2	B_3	C_2	D_1
18	A_2	B_3	C_3	D_2

4. Measurements

Eighteen models were built with different parameter settings in 3DP machine as per the experimental layout shown in table 2. The dimensional parameters i.e. model thickness and hole diameter were measured using Co-ordinate Measuring Machine (CMM). The form parameters such as circularity, cylindricity of the profile and flatness of the top surface in the experimental model were also measured using CMM. Surface finish is evaluated by measuring the average surface roughness (R_a) on the top surface of the model using a Surface Profilometer, a contact type surface roughness measurement system. The cut-off length used for measuring R_a is 0.25mm. A series of three trials were conducted for each response characteristic evaluated in this study. The measured values of all the responses analyzed in this study were tabulated in table 3 shown below.

Table 3. Measured values of responses

Exp. No.	Surface roughness (R_a) (μm)	Circularity Deviations (mm/mm)	Cylindricity Deviations (mm/mm)	Flatness Deviations (mm/mm)	Hole diameter (mm)	Model thickness (mm)
1	12.801	0.052	0.181	0.075	3.385	8.289
2	14.740	0.092	0.241	0.074	3.497	8.687
3	12.938	0.139	0.204	0.012	3.501	8.141
4	12.300	0.043	0.122	0.022	3.465	7.921
5	14.125	0.089	0.189	0.075	3.513	8.327
6	12.985	0.162	0.195	0.07	3.468	7.91
7	16.470	0.146	0.239	0.045	3.602	8.052
8	13.546	0.191	0.215	0.051	3.562	7.811

9	12.425	0.087	0.179	0.010	3.468	8.129
10	15.80	0.098	0.184	0.196	3.451	8.495
11	10.396	0.067	0.091	0.197	3.453	8.695
12	13.926	0.124	0.189	0.087	3.529	8.169
13	18.985	0.102	0.144	0.252	3.438	8.797
14	18.137	0.086	0.142	0.097	3.534	7.845
15	10.530	0.041	0.136	0.057	3.509	8.729
16	18.756	0.141	0.257	0.134	3.537	8.009
17	13.995	0.041	0.087	0.042	3.599	8.561
18	17.765	0.107	0.154	0.017	3.602	8.014

5. Results and Discussion

5.1 Average surface roughness

5.1.1 Analysis of Variance for Surface roughness

From the ANOVA shown in the table 4 it is clear that F-statistic for layer thickness, binder saturation value of core and build orientation is greater than the F-statistic obtained at 95% confidence interval. Hence they are significant in influencing the R_a values of the products obtained from the 3DP. Build orientation was found to have maximum contribution of 44.86%, next comes the binder saturation value of core with 15.63%. Error contributes to about 16.87% which includes the factor interactions, experimental errors and noise factors.

Table 4. Analysis of Variance for R_a

Factors	SS	df	MSS	F	F at 95%	% Contribution
Layer thickness	14.2	1	14.2	7.063	4.96	11.92%
Binder saturation value-Shell	12.7	2	6.4	3.177	4.1	10.72%
Binder saturation value -Core	18.6	2	9.3	4.632	4.1	15.63%
Build orientation	53.3	2	26.6	13.292	4.1	44.86%
Error	20.036	10	2.004			16.87%
Total	118.743	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.1.2 Effect of control factors on surface roughness

At lower layer thickness the surface roughness is low and at higher layer thickness it is high. At lower layer thickness the powders are evenly distributed and printed and also the stacking effect is less. Hence a good surface finish is obtained at lower layer thickness as shown in figure 3.At higher saturation value of shell the R_a value is less. As the saturation value of shell increases, the shrinkage will be more and effective bonding of particles takes place and hence better surface finish is obtained at higher saturation value of shell. At 0^0 i.e. the axis parallel to the build direction, better surface finish is obtained. At higher orientations the gravitational effect and the staircase effect will be more predominant and so the surface finish is poor at higher orientations.

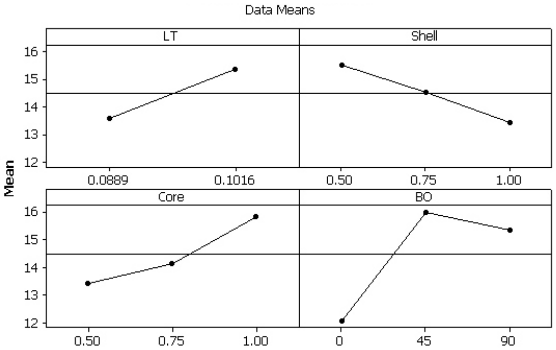

Figure 3. Main effects plot for surface roughness

5.2 Circularity deviations

5.2.1 Analysis of Variance for circularity deviations

ANOVA for circularity deviations shown in table 5 indicates that F-statistic for layer thickness and build orientation is greater than the F-statistic obtained at 90% confidence interval. Hence they are significant in influencing the Circularity deviations of the products obtained from the 3DP. The results of ANOVA show that the Build orientation was found to have maximum contribution of 63.64%.Error contributes to about 17.31% which includes the factor interactions, experimental errors and noise factors.

Table 5. Analysis of Variance for Circularity deviations

Factors	SS	df	MSS	F	F at 90%	% Contribution
Layer thickness	0.0021	1	0.0021	3.773	3.28	6.53%
Binder saturation value-Shell	0.0032	2	0.0016	2.859	2.92	9.90%
Binder saturation value -Core	0.0008	2	0.0004	0.758	2.92	2.62%
Build orientation	0.0206	2	0.0103	18.386	2.92	63.64%
Error	0.006	10	0.001			17.31%
Total	0.032	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.2.2 Effect of control factors on Circularity deviations

At higher layer thickness, there will be more time for curing, thereby there is more chance to control error and hence the deviations are lesser at higher layer thickness. From the figure 4 it was observed that at 75% binder saturation level the deviations are lesser. As the saturation increases above 75%, more shrinkage takes place and thereby the deviations increases. At lower saturation level, there will not be perfect binding of powder which leads to warpage. At 0^0 i.e. the axis parallel to the build direction, the deviations are lesser. At higher angles there will gravitational effect and stair case effect as the curved dimensions are built in z – direction. Hence the deviations are more at higher orientations.

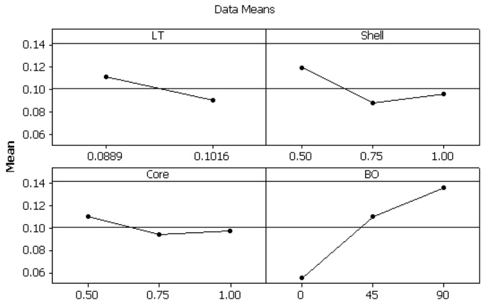

Figure 4 Main effects plot for circularity deviations

5.3 Cylindricity deviations

5.3.1 Analysis of Variance for cylindricity deviations

ANOVA indicates that F-statistic for layer thickness and build orientation is greater than the F-statistic obtained at 95% confidence interval as shown in Table 6. Hence they are significant in influencing the Cylindricity deviations of the products obtained from the 3DP. Build orientation was found to have maximum contribution of 40.38%, followed by layer thickness contributing to about 20.10%. Error contributes to about 24.35%.

Table 6. Analysis of Variance for Cylindricity deviations

Factors	SS	df	MSS	F	F at 95%	% Contribution
Layer thickness	0.0081	1	0.0081	8.257	4.96	20.10%
Binder saturation value-Shell	0.0039	2	0.0019	1.975	4.1	9.62%
Binder saturation value -Core	0.0022	2	0.0011	1.139	4.1	5.55%
Build orientation	0.0163	2	0.0081	8.293	4.1	40.38%
Error	0.010	10	0.001			24.35%
Total	0.040	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.3.2 Effect of control factors on Cylindricity deviations

At lower layer thickness the deviations are more. At higher layer thickness, there will be more time for curing, thereby there is more chance to control error and hence the deviations are lesser at higher layer thickness. At lower layer thickness the binder penetrates quickly to the bottom of the layer, but the previous layer printed prevents the binder from further spreading. In lateral direction the binder spreads without such limitation. Hence the deviations are more at lower layer thickness. From the figure 5 it was observed that at 75% binder saturation level the deviations are lesser. As the saturation increases above 75%, more shrinkage takes place and thereby the deviations increases. At lower saturation level, there will not be perfect binding of powder which leads to warpage. Hence the deviations are more. At 0^0 i.e. the axis parallel to the build direction, the deviations are lesser. At higher angles there will be gravitational effect and staircase effect as the curved dimensions are built in z – direction. Hence the deviations are more at higher orientations.

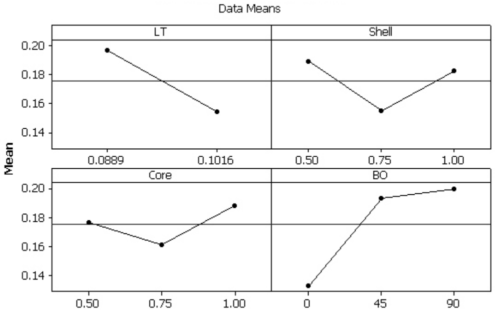

Figure 5.Main effects plot for Cylindricity deviations

5.4 Flatness deviations

5.4.1 Analysis of Variance for Flatness deviations

From the ANOVA shown in the table 7 it is clear that F-statistic for layer thickness and Binder saturation value of core is greater than the F-statistic obtained at 90% confidence interval. Hence they are significant in influencing the Flatness deviations of the products obtained from the 3DP. Layer thickness was found to have maximum contribution of 28.90%, followed by Binder saturation value of core contributing to about 21.64%. Error contributes to about 33.12% which includes the factor interactions, experimental errors and noise factors.

Table 7. Analysis of Variance for Flatness deviations

Factors	SS	df	MSS	F	F at 90%	% Contribution
Layer thickness	0.0248	1	0.0248	8.726	3.28	28.90%
Binder saturation value-Shell	0.0108	2	0.0054	1.906	2.92	12.62%
Binder saturation value -Core	0.0186	2	0.0093	3.267	2.92	21.64%
Build orientation	0.0032	2	0.0016	0.560	2.92	3.71%
Error	0.028	10	0.003			33.12%
Total	0.086	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.4.2 Effect of control factors on Flatness deviations

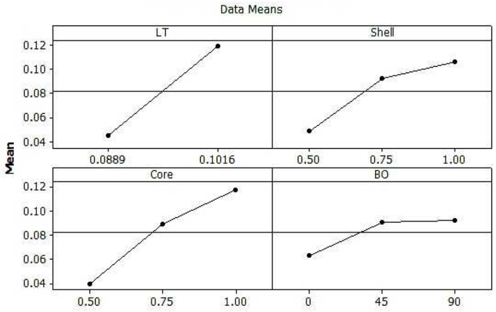

Figure 6.Main effects plot for Flatness deviations

At higher layer thickness the stacking and staircase effect will be predominant. And at higher layer thickness, the successive layers may not be bonded effectively and this leads to delamination. Hence the flatness deviations are more at higher layer thickness. As the binder saturation value increases, the deviation from true plane increases which can be seen from the figure 6. At higher saturation level, more shrinkage and curling takes place over the layer and when consequently other layers are built, it leads to unevenness on the surface. Hence the deviations are more.

5.5 Hole diameter

5.5.1 Analysis of Variance for Hole diameter values

F-statistic for Binder saturation value of Shell is greater than the F-statistic obtained at 90% confidence interval. Hence it is significant in influencing the hole diameter values of the products obtained from the 3DP. ANOVA tabulated in table 8 indicates that binder saturation value of shell was found to have maximum contribution of 45.95%, followed by build orientation contributing to about 12.29%. Error contributes to about 27.40% which includes the factor interactions, experimental errors and noise factors.

Table 8. Analysis of Variance for Hole diameter values

Factors	SS	df	MSS	F	F at 90%	% Contribution
Layer thickness	0.0020	1	0.0020	1.187	3.28	3.25%
Binder saturation value-Shell	0.0286	2	0.0143	8.385	2.92	45.95%
Binder saturation value -Core	0.0069	2	0.0035	2.026	2.92	11.10%
Build orientation	0.0077	2	0.0038	2.242	2.92	12.29%
Error	0.017	10	0.002			27.40%
Total	0.062	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.5.2 Effect of control factors on Hole diameter values

Higher the layer thickness, the hole diameter values are also higher. This is due to size effect i.e. higher the layer thickness, curing will be less and hence hole diameter values increases. Higher binder saturation level leads to longer spreading distance. For vertical spreading the binder progresses only from top to bottom of the printing layer, whereas in lateral direction the binder spreads in all horizontal directions without such limitation. Hence as the binder saturation value increases the hole diameter values decreases as shown in the figure 7. At higher binder level, better heating conditions, there will be more shrinkage i.e. as the binder evaporates the powder tends to shrink and thereby the hole diameter decreases. At 0^0 i.e. axis parallel to the build direction, the hole diameter values are lesser and at higher orientations the value increases due to lateral effect i.e. lateral spreading of powder (shape obtained will be oval).

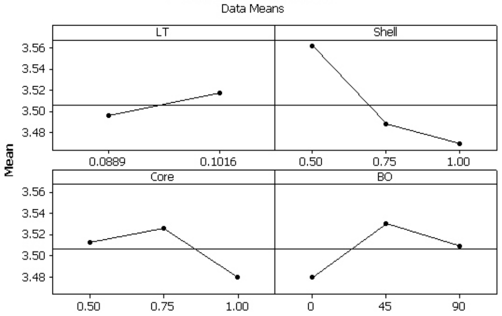

Figure 7.Main effects plot for Hole diameter values

5.6 Model height

5.6.1 Analysis of Variance for Model height values

From the ANOVA shown in the table 9 it is clear that all the individual effects of the factors considered in this study were insignificant in influencing the model thickness values of the products obtained from the 3DP. Build orientation (D) was found to have maximum contribution of 23.78%, followed by binder saturation value of shell (B) contributing to about 16.28%.

Table 9. Analysis of Variance for Model height values

Factors	SS	df	MSS	F	F at 95%	% Contribution
Layer thickness	0.2328	1	0.2328	2.850	3.28	12.60%
Binder saturation value-Shell	0.3008	2	0.1504	1.842	2.92	16.28%
Binder saturation value -Core	0.0583	2	0.0291	0.357	2.92	3.15%
Build orientation	0.4394	2	0.2197	2.690	2.92	23.78%
Error	0.817	10	0.082			44.20%
Total	1.848	17				

where SS = Sum of squares, df = Degrees of freedom, MSS = Mean sum of squares

5.6.2 Effect of control factors on Model height values

For lower layer thickness, powders are evenly distributed and printed. At lower layer thickness, binder penetrates quickly to the bottom of the layer, but the previous layer prevents the binder from further spreading. Hence at lower layer thickness, the values are closer to nominal value as shown in figure 8. As the binder saturation value of shell increases the powder tends to shrink in lateral direction which obviously indicates that it enlarges in the longitudinal direction. Hence at higher saturation value the model thickness values are higher. At 90^0 i.e. the axis of the part perpendicular to the build direction, the values are closer to nominal value. At 90^0 the vertical dimension is built in x – y plane where the accuracy of the machine is high.

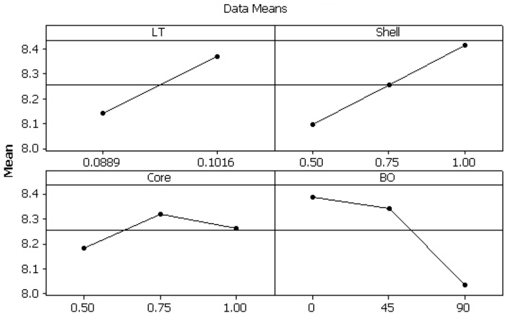

Figure 8.Main effects plot for Model height values

6. Optimization

The Particle Swarm Optimization (PSO) is an evolutionary computation technique inspired by behaviour of bird flocking and fish schooling. The system is initialized with a population of random solutions and searches for optima by updating generations. In PSO, the potential solutions, called particles, are “flown” through the problem space by following the current optimum particles. By incorporating the search experiences of individual agents, the PSO is effective in exploring the solution space in a relatively smaller number of iterations. The nonlinear regression models developed were given as the objective functions.

Nonlinear regression models for response variables

a) Average surface roughness (R_a)

The nonlinear regression model developed for the Average surface roughness (R_a) from the experimental data is shown below in equation 1. The R^2 value for the developed nonlinear model is .9662.

$$R_a = 9.6501 + 44.1585*A + 21.1865*B - 21.6719*C - 0.1717*D - 50.1539*A^2 - 327.9547*A*B + 294.42*A*C + 3.7422*A*D + 2.1579*B^2 + 1.9001*B*C + 1.2051E\text{-}02*B*D - 1.3597*C^2 - 6.4724E\text{-}02*C*D - 1.2581E\text{-}03*D^2. \qquad \text{.........}\ (1)$$

b) Circularity (C_1)

The nonlinear regression model developed for the Circularity deviations from the experimental data is shown below in equation 2. The R^2 value for the developed nonlinear model is .9944.

$$C_1 = 0.9235 - 1.2499*A - 1.3012*B - 0.9413*C + 6.15E\text{-}03*D - 50.971*A*A + 8.7635*A*B + 5.9638*A*C - 3.01E\text{-}02*A*D + 0.3524*B*B - 6.30E\text{-}02*B*C - 1.55E\text{-}03*B*D + .2850*C*C - 7.42E\text{-}04*C*D - 8.82E\text{-}06*D*D. \qquad \text{.........}\ (2)$$

c) Cylindricity (C_2)

The nonlinear regression model developed for the Cylindricity deviations from the experimental data is shown below in equation 3. The R^2 value for the developed nonlinear model is .9754.

$$C_2 = 0.4247 - 0.9047*A + 0.5203*B - 0.3879*C - 1.52E\text{-}03*D + 9.6713*A*A - 7.8215*A*B - 1.7363*A*C + 1.64E\text{-}02*A*D + 0.3261*B*B - 0.2268*B*C - 1.48E\text{-}03*B*D + 0.3713*C*C + 3.64E\text{-}03*C*D - 1.08E\text{-}05*D*D. \qquad \text{.........}\ (3)$$

d) Flatness (F)

The nonlinear regression model developed for the Flatness deviations from the experimental data is shown below in equation 4. The R^2 value for the developed nonlinear model is .9754

$$F = 1.1571 - 3.0549*A - 0.7195*B - 3.2223*C + 9.61E\text{-}03*D - 113.202*A*A + 12.2350*A*B + 31.9009*A*C - 6.17E\text{-}02*A*D - 0.2519*B*B + 0.2420*B*C - 2.93E\text{-}03*B*D + 9.96E\text{-}02*C*C + 2.35E\text{-}04*C*D - 2.07E\text{-}05*D*D. \qquad \text{.........}\ (4)$$

e) Hole diameter (HD)

The nonlinear regression model developed for the Hole diameter from the experimental data is shown below in equation 5. The R^2 value for the developed nonlinear model is .9886.

$$HD = 1.8437 + 9.7559*A - 0.3277*B + 3.4309*C + 1.54E\text{-}03*D + 76.7293*A*A - 3.6341*A*B - 25.2328*A*C - 2.85E\text{-}02*A*D + 0.4250*B*B - 0.3504*B*C + 2.64E\text{-}03*B*D - 0.5351*C*C + 3.92E\text{-}04*C*D - 5.10E\text{-}06*D*D. \qquad \text{.........}\ (5)$$

f) Model Height (MH)

The nonlinear regression model developed for the Model thickness from the experimental data is shown below in equation 6. The R^2 value for the developed nonlinear model is .9874.

$$MH = 5.2974 + 26.5219*A + 7.3710*B - 8.0955*C + 6.58E\text{-}02*D + 52.1463*A*A - 60.7567*A*B + 69.2411*A*C - 0.8675*A*D - 1.0848*B*B + 1.0888*B*C + 4.07E\text{-}03*B*D + 0.2037*C*C + 2.39E\text{-}02*C*D - 9.96E\text{-}05*D*D. \quad .... (6)$$

Where A = Layer thickness in mm, B = Saturation value of Shell,
C = Saturation value of Core, D = Build orientation in degrees.

The software to find the optimal values for process parameters using PSO have been implemented in MATLAB. The algorithm has been simulated for many times with 50 particles and 20 iterations each with termination criteria as the number of iterations. Table 10 shows the Optimized process parameter settings for response variables.

Table 10. Optimized process parameter settings for response variables

Response	Optimum values			
	Layer thickness (mm)	Saturation value of Shell (%)	Saturation value of Core (%)	Build orientation (degrees)
Surface roughness	0.0889	1	0.5	0
Circularity	0.1016	0.5	0.7892	0
Cylindricity	0.1016	0.5859	0.7205	0
Flatness	0.0889	0.5	0.5135	0
Hole diameter	0.1016	0.5	0.6546	22
Model thickness	0.0889	0.5	0.5	90

7. Validation

Validation was done by conducting an experiment using a set of optimal process parameter settings for each response variable obtained using PSO. The corresponding response was measured for each validatoty model. The optimal values for each response variable with particle swarm optimization technique have been compared with experimental results and errors in percentage are shown in table 11. The percentage error between the simulated and the experimental results was found to be minimal. Hence the proposed optimum process parameter settings can be used to produce quality products from 3DP process.

Table 11. Optimum results for all responses

Response	Simulation	Experimental	Error (%)
Surface roughness (μm)	10.39	10.26	1.25
Circularity (mm/mm)	0.041	0.045	9.75
Cylindricity (mm/mm)	0.091	0.083	8.79
Flatness (mm/mm)	0.012	0.013	8.33
Hole diameter (mm)	3.611	3.566	1.24
Model height (mm)	7.554	8.012	6.06

8. Conclusions

According to L_{18} orthogonal array the experiments were carried out in Zcorp 510 3DP machine. The responses Surface roughness R_a, Dimensional accuracy and Form accuracy indicators were measured using Surfcoder and CMM respectively. A mathematical model for all the responses was developed using nonlinear regression analysis. Using ANOVA it was found that layer thickness, binder setting saturation value-core, and build orientation were significant in influencing R_a. Surface finish obtained at higher build orientation is poor because the gravitational effect and staircase effect will be more predominant at higher orientations. Incase of the form parameters build orientation has direct influence on circularity and cylindricity. Hence to obtain a cylindrical feature at its best in 3DP process, it should be oriented in such a way that its axis is parallel to build direction in machine. Flatness was mostly influenced by layer thickness and saturation value of core. At higher layer thickness, delamination takes place which leads to flatness deviations. Binder setting saturation value-shell was most significant factor in influencing hole diameter values. In vertical direction the binder progresses only from top to bottom of the printing layer, whereas in the lateral direction the binder spreads in all directions without such limitation. At higher binder saturation value, better heating conditions there will be more shrinkage and hence the hole diameter values decreases. Build orientation contributes more incase of model height values. To obtain a best linear dimension, it should be built in such a way that it is parallel to the powder bed in the 3DP machine. Based on PSO analysis the optimal parameter settings for obtaining better surface finish, Dimensional accuracy and Form accuracy were suggested. Thus the optimal set of parameters will be beneficial for designer to judiciously select the process parameters to obtain quality 3DP models. The obtained results reflect the necessity to adequately respond to process parametric variations for clearly meeting surface finish and dimensional tolerances. Finally the results were validated.

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