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Research paper

A Study on Effect of Process Parameters on Quality using Low Cost 3D Printer

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Abstract

Fused deposition modeling is a type of layered additive manufacturing technology in which parts are built by heating a thermoplastic filament above its melting point. The modern low cost 3D printers are based on this technology. This paper examines the effect of process parameters on the quality of parts produced using ABS (Acrylonitrile-Butadiene Styrene) material. A statistical design of experiments approach, using the central composite design, was used with the process parameters of layer thickness, speed of deposition and extrusion temperature, to quantitatively model their effect on the quality of the resulting parts produced. It was found that layer thickness and speed of deposition had significant effect on quality of parts produced.

Keywords: *Acrylonitrile-Butadiene Styrene (ABS), Central Composite Design (CCD), Extrusion temperature, Fused Deposition Modeling (FDM), Rapid Prototyping, 3D Printer, Layer thickness, Speed of Deposition.*

1. Introduction

Before a product is launched into the market, a prototype is made, which helps in checking any design problems associated with it and to modify accordingly to prevent the losses. Because of the increasing competition, there is a need to launch new products at a faster rate. Rapid Prototyping is one such technology where even complex prototypes are made at rapid rate. Fused Deposition Modeling is one of the Rapid Prototyping methods where a heated thermo plastic material is extruded by the nozzle and the desired part is fabricated layer by layer according to the CAD data.

The quality of the parts produced is vital and has been studied by several authors. Bharat [1] in his investigation using factorial design has found that layer thickness and orientation of part are important factors influencing the quality of surface. Also, Anitha [2] in her investigation has found that layer thickness is the prominent factor affecting the surface quality and speed of deposition also had considerable influence. Nanchariah [3] in his study using taguchi technique has found that layer thickness and road width are critical factors which had influence on the quality of parts produced. Luzanin [4] using a low cost 3D printer (Maker bot replicator2) has studied the effect of extrusion speed and extrusion temperature on the surface roughness of the parts produced using PLA (Poly Lactic Acid) material. It was found that speed of deposition had significant influence on the quality of parts produced and also explained the need to study curvature and interaction effects.

In the present study, a FCC Composite Design is used with inclusion of parameters layer thickness along with speed of deposition and extrusion temperature was used to study curvature and interaction effects of parameters on the surface roughness of parts produced using Makerbot Replicator 2x experimental 3D Printer with ABS (Acrylonitrile-Butadiene Styrene) material. Figure 1 shows the machine.

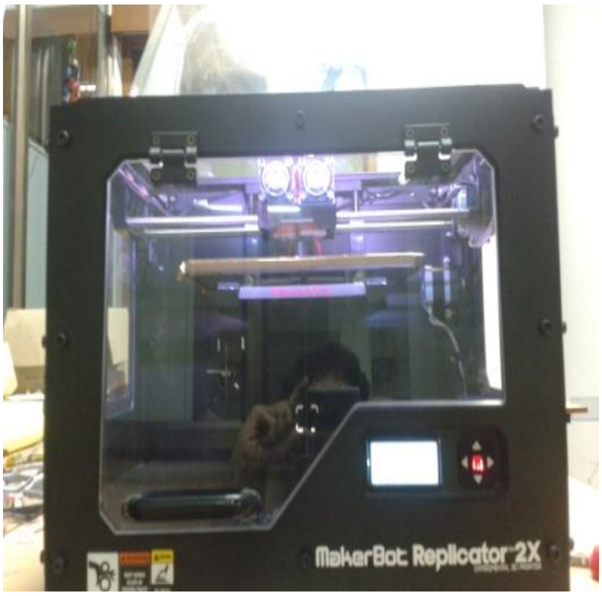

Fig.1: Picture of Makerbot Replicator 2X experimental 3D Printer

2. Experimental Procedure

2.1. Process Parameters Selection

The parameters selected for the process are layer thickness, speed of deposition and extrusion temperature. The description of parameters is given below.

Layer thickness: The thickness of each layer deposited by the nozzle.
Speed of deposition: The speed at which thermoplastic material is deposited through the nozzle.
Extruder temperature: The temperature to which the thermo plastic material is heated.
Table I shows factors and their levels

Table 1: Factors and their levels

Factor	Units	Low level (-1)	Centre level (0)	High level (1)
Layer thickness (A)	mm	0.1	0.2	0.3
Speed of deposition (B)	mm/s	40	60	80
Extruder temperature (C)	°C	225	230	235

2.1. Response

The objective is to investigate the effect of the above selected parameters on the surface roughness of the parts produced.

3. Cad Model of The Part

3D CAD Model, as shown in Fig. 2, was created using PRO-E software package and was given as an input to Makerware software for slicing and adjusting the parameters.

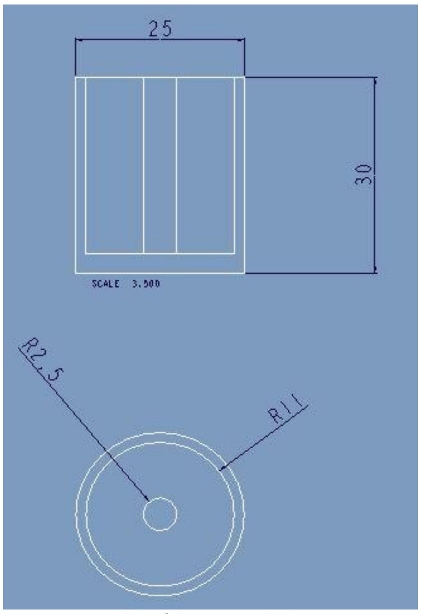

Fig .2: 3D CAD Model of the part. All dimensions are in mm

4. Design of Experiments

A Face Centered Central Composite Design (FC-CCD) with three factors and three levels for each factor which involves 20 experiments. By this design main effects and interaction effects of process variables on the response can be found.
as identifiers in trade, such as “3½ in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oversteps. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.
The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to separate compound units, e.g., “A•m2.”

5. Fabrication and Measurement of Surface Roughness

5.1. Fabrication

After CAD Model is converted into STL(Standard Triangulation) format using PRO-Engineer software, it was imported to Makerware software for slicing the model and the desired parameters were varied for each case. After the parameters were set ,the information was fed to the machine with the help of a SD card in x3g format. The build plate was heated to 110°C and the part was manufactured layer by layer. After each part is made it is removed safely and the build plate is cleaned properly and was given sufficient time for carrying out further experiments. A total of 20 parts, as shown in Fig. 3, were produced by conducting the experiments.

Fig. 3: Picture showing 20 fabricated parts.

5.2. Measurement of Surface Roughness

Surface roughness of the parts are measured by Handysurf surface roughness measuring instrument.Table II. shows mean values of surface roughness (Ra)

Table II: Mean Surface Roughness (Ra) of parts

Order of experiments	Ra (Mean) µm
1	7.45
2	23.82
3	19.20
4	7.15
5	12.40
6	16.96
7	12.68
8	5.45
9	12.32
10	12.48
11	12.62
12	23.26
13	16.30
14	5.26
15	12.32
16	12.40
17	6.71
18	11.70
19	12.36
20	16.44

6. Results and Discussions

6.1. Significant Factors

Table III. shows the significant factors and their interactions that are to be considered, R-Sq and R-Sq (adj) values indicate that the model is a good fit.

Table III: Estimated regression coefficients in coded units

Term	Coeff	SE Coeff	t	p
Constant	12.65	0.1347	94.218	0.000
Layer thickness	6.700	0.1270	52.756	0.000
Speed of deposition	2.349	0.1270	18.496	0.000
Extruder temperature	0.051	0.1270	0.402	0.695
Layer thickness *layer thickness	-0.085	0.2693	-0.317	0.758
Speed of deposition* speed of deposition	1.257	0.2245	5.601	0.000
Extruder temperature* extruder temperature	0.712	0.2245	-3.174	0.007
Layer thickness*speed of deposition	1.306	0.1420	9.200	0.000
Speed of deposition*extruder temperatue	-0.008	0.1579	-0.055	0.957
Layer thickness*extruder temperature	0.101	0.1579	0.641	0.536

R-Sq = 99.60% R-Sq(pred) = 98.98% R-Sq(adj) = 99.42%

The statistical level of significance (α) chosen for the analysis was 0.05. P-value for each coefficient tests the null hypothesis that the coefficient is equal to zero (no effect). Low p-value for a model term (or coeff.) suggests that the particular predictor is a meaningful addition to the model. The model term (or coeff.) for which the p-value is less than α is inferred to have a significant effect on the surface roughness. It may be observed that the p-value for extruder temperature (0.695) is considerably greater than α. However it is still retained in the model, since its presence is significant via the quadratic term.

6.2. Forming a Regression Equation

A regression equation for a full quadratic model is developed to establish a relationship between response and process parameters Regression coefficients in un coded units are Obtained by method of least squares where sum of squared residuals are minimized.
Regression equation is

$$Y= -1498.60 + 27.80A -0.390B +0.003B*B -0.028C*C + 0.653 A*B \quad (1)$$

Y indicates Ra value, whereas A, B, C indicate layer thickness, speed of deposition and extrusion temperature respectively.

6.3. Residual Plots

Figure4 shows the residual plots for surface roughness. The normal probability plot shows that residuals follow a normal distribution as all the points are fairly close to the straight line, indicating goodness of the fit. The "Versus Fits" plot shows a random pattern of residuals which indicates that the assumption of constant variance for the error term in the regression model is valid. The "Versus order" plot again shows a random distribution of residuals on both sides of zero which indicates errors are random, and have no pattern with respect to experimental sequence or time

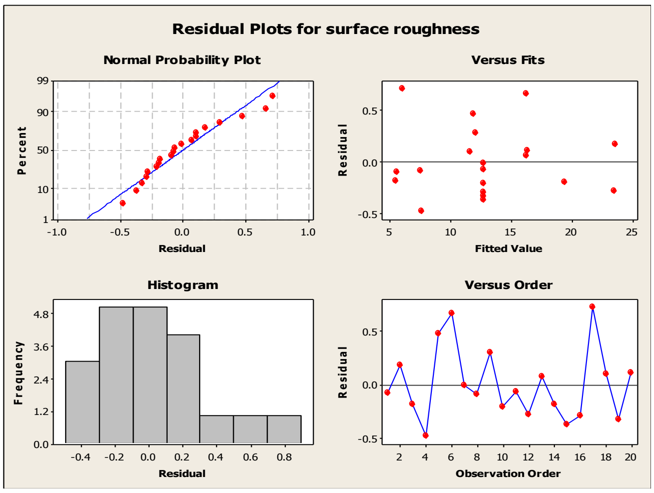

Fig.4: Residual plots for surface roughness

6.4. Interaction and Main Effects Plots

As that the regression analysis showed that the layer thickness and speed of deposition have an interaction effect on surface roughness, an interaction plot is plotted in Fig .5. This shows that the value of surface roughness is minimum at lower layer thickness and lower speed of deposition. Fig.6 shows the mean value of Ra increased as temperature is increased, but the relationship is quadratic rather than linear. The contour plot in Fig.7 shows the variation in surface roughness with variation in the speed of deposition and layer thickness.

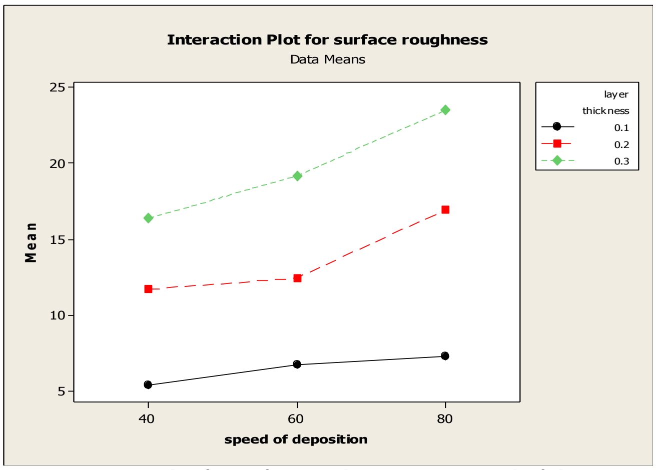

Fig.5: Interaction plot for surface roughness (versus speed of deposition and layer thickness)

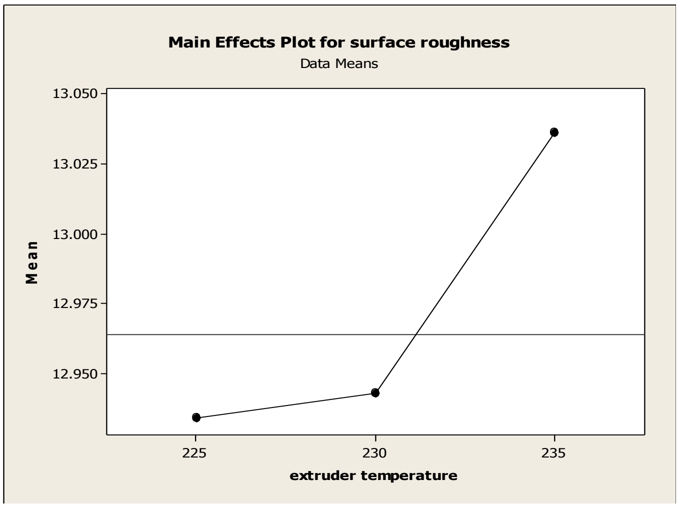

Fig.6: Main effect plot for surface roughness versus extruder temperature

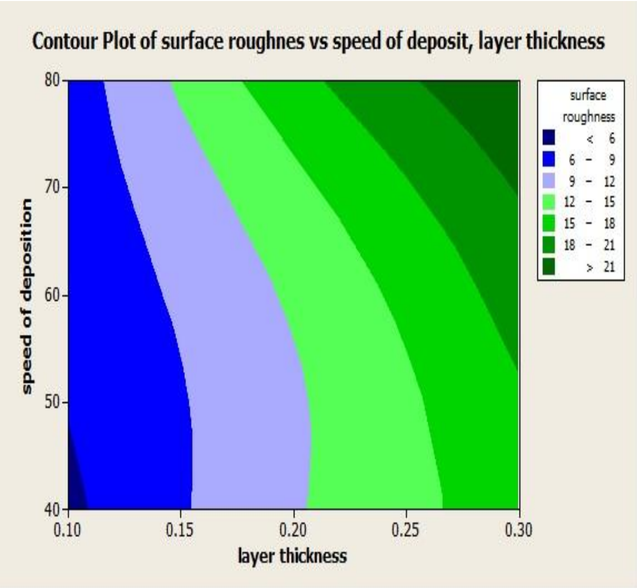

Fig.7: Contour plot for surface roughness (versus speed of deposition and layer thickness)

7. Conclusions

A Central Composite Design was conducted to experimentally investigate the effects of parameters layer thickness, speed of deposition and extruder temperature on surface roughness of FDM-based 3D printer parts. A regression equation was obtained, that established a relation between the influential process parameters and surface roughness. Layer thickness, speed of deposition and their interaction effects were found to be significant. Results indicated that minimal surface roughness was obtained at lower values of layer thickness, speed of deposition and extruder temperature.

References

[1] Bharath Vasudevarao, Dharam Prakash Natarajan and Mark Henderson,'Sensitivity of RP surface finish to process parameter variation', in: Solid Freeform Fabrication Proceedings, pp. 251-258 (2000).

[2] Anitha R., Arunachalam S. and Radhakrishnan P., 'Critical parameters influencing the quality of prototypes in fused deposition modelling', Journal of Materials Processing Technology, Vol.118, pp.385-388 (2001).

[3] T. Nancharaiah and D. Ranga Raju, "An experimental investigation on surface quality and dimensional accuracy of FDM components", International Journal on Emerging Technologies, 1(2): pp.106-111 (2010).

[4] OgnjanLužanin, DejanMovrin, MiroslavPlančak "Experimental investigation of extrusion speed and temperature effects on arithmetic mean surface roughness in FDM built Specimens" Journal for Technology of Plasticity, Vol. 38,Number2(2013).