International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Vol. 48, Special Issue, (TAME-2019, April 4-5, 2019)
(An Indexed, Referred and Impact Factor Journal approved by UGC- Journal No. 42581)
ISSN (Online): 2319-6564
www.ijesonline.com

COMPARATIVE ANALYSIS OF THE PARAMETERS FOR OPTIMISING THE SURFACE ROUGHNESS IN SELECTIVE LASER SINTERING

Ritesh Sharma[1], Sanjeev Kumar[2], Rajeev Saha[3]

[1]Research Scholar, J C Bose University of Science and Technology, YMCA, Faridabad, Haryana, India

[2]Associate Professor, J C Bose University of Science and Technology, YMCA, Faridabad,Haryana, India

[3]Assistant Professor, J C Bose University of Science and Technology, YMCA, Faridabad, Haryana, India

Email ID: [1]ritesharma1@gmail.com, [2]s.kumar.ymca@gmail.com, [3]rajeevsaha@gmail.com

Abstract

SLS is an additive manufacturing process which is considered to be one of the most versatile of all the AM methods. Mainly due to its ability to sinter a variety of materials which ranges from plastic to polymers, metals and even composites. Thus this machine has a significant role in transferal of rapid prototyping to additive manufacturing. Like most of AM techniques, it also creates a 3D entity layer by layer but in this method a laser selectively sinter the material on which it is focused. The process overall is satisfactory but the output part has some drawbacks like poor repeatability, high surface roughness, and slow production time. These drawbacks are studied by many researchers. In the present study, surface roughness optimization of SLS parts is reviewed as investigated in two independent researches. Both used polyamide as raw material and RSM as tool for design of experiments and ANOVA to study the significance of the process variables on surface roughness. The results and derivations from both the studies have been compared.

Keywords: Selective Laser Sintering, Surface Roughness, Process Parameters

1. Introduction

Growing competition, shrinking product life cycles, the desire for customized products cause the need for innovative manufacturing techniques. Additive Manufacturing offers possibilities for small series production of customized products and an increased liberty of design, due to the less privation of tools. The ASTM F42 Technical Committee defines additive manufacturing (AM) as the “process of joining materials to make objects from three-dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies”(EPMA Introduction to Additive Manufacturing Technology, 2017). There are several types of additive manufacturing processes which are available in market. According to additive manufacturing research group of Loughborough University there are The 7 Categories of Additive Manufacturing. Namely, VAT polymerisation, Material Jetting, Binder Jetting, Material Extrusion, Powder Bed Fusion, Sheet Lamination and Directed Energy Deposition(EPMA Introduction to Additive Manufacturing Technology, 2017). Each category has its own commercial form and selective Laser Sintering comes under the category of Powder bed fusion.

Laser sintering has reached a high technical level within the past three decades. Selective Laser Sintering is an additive manufacturing technique which enables complex solid parts to be manufactured fully automatically without the help of tooling(Choi and Samavedam, 2001). It creates the parts directly from a CAD model that is why it is also termed as desktop manufacturing(Gibson, Rosen and Stucker, 2010).It’s a layer–by-layer manufacturing technique in which powdered raw material which is to be sintered is spread on a bed in a closed chamber which is heated 4-5 degree below the melting point of the powder. A laser beam is then projected on the spread powder selectively along a path covering the full cross-section of the part to be sintered. This high energy laser fuses the powder particles to join together and one complete layer is formed. This layer is then allowed to solidify. The powder is again spread on the previous layer and laser then creates the next layer on the previous layer. Thus creating one layer at a time, a complete 3D object can be sintered.(Guo and Leu, 2013) After the whole geometry is created the model is allowed to cool in the chamber to avoid any sudden cooling and thus stress concentration or internal stresses on the model.(Singhal *et al.*, 2009) Although the technique is highly sophisticated and advanced but the models still shows bad surface finish and that can be even worse at critical positions(Calignano *et al.*, 2013).Similar problems also occur in SLA and FDM machines(Guidelines, 2017). Some studies have been conducted on the problem but the correct set of parameters which actually influence the surface roughness is still at long.(Launhardt *et al.*, 2016) Most of the studies have been done to find the influential and non-influential parameters as far as surface roughness is concerned.

In present study two independent works on the investigation of surface roughness in selective laser sintering machine has been critically analysed and a competitive study is done as both the researchers used five input process parameters with different combinations and different design of experiments and the results they have shown are contradictory at some points.

2.1 Work 1

Anish Sachdeva et al(Sachdeva, Singh and Sharma, 2013)studied the effect of laser power, scan spacing, bed temperature, hatch length and scan count on surface roughness on a SLS sintered part. The material used was polyamide withcommercial name of Duraform with a ratio of 7:3 i.e. 70% used powder and 30 % virgin powder. Response Surface Methodology was used to create the design of experiments. Three stage design was used and total 60 combinations were employed for total five parameters.

Table 1 shows the process variables and their range taken for the experiment purpose.

Table 1

Process Variable	Range
Laser Power (Watt)	24 – 28 –32
Scan Spacing (mm)	0.1-0.2 – 0.3
Bed Temperature (^{0}C)	172 - 175– 178
Hatch Length (mm)	40 –100- 120
Scan Count	1 – 2

The output parameters were selected as i) R_a (arithmetic mean deviation of SR) ii)R_z (average peak to valley height for 5 highest and 5 deepest valleys) and iii) R_q (root mean square value of SR). To test the output,Analysis of Variance (ANOVA) was used on the data collected from the output i.e. surface roughness for testing the significance of model coefficients.

As per the study conducted, the F value came out as 7.09, which showed that the model was significant. The smallest value for R_a came out as 5.06 and largest value was 14.95 microns. The largest and smallest values for R_q were 7.08 and 17.64 respectively. Similarly, the smallest and largest values for R_z were 30.87 and 74.99 microns. All this data shows that the surface roughness of the process is on higher side and within small range of process parameters the output variation is large.

In the study it was concluded that Laser power, Scan spacing and bed temperature proved to be most significant as far as surface roughness is concerned. Hatch length and scan count were least accountable for the variation in the surface finish.

2.2 Work 2

Bacchewar P. et al(Bacchewar, P. B.; Singhal, S. K.; Pandey, 2007)used polyamide as the sintering material with commercial name duraform or PA 2200.proposed central composite second order design in surface response methodology. In the study total five control variables were selected namely laser power, beam speed, orientation, layer thickness and hatch spacing. As per RSM design of experiments 32 combinations were tested for the surface roughness with five stage model. Table 2 shows the process variables and their range for the experimental design.

Table 2

Process Variable	Range
Laser power (W)	25 28 31 34 37
Beam speed (mm/s)	2500 3000 3500 4000 4500
Layer thickness (mm)	150 160 170 180 190
Orientation (degrees)	0 22.5 45 67.5 90
Hatch spacing (cm)	0.025 0.03 0.035 0.04 0.045

The output parameter was surface roughness but for the same two models were developed. One for upward facing surface and second for downward facing surface. The average surface roughness (R_a) was measured for every sample for both upward facing surface and for downward facing surface. The ANOVA for both the conditions was developed independently for checking the consistency of the models. The F value for upward facing model passed the adequacy test only after neglecting the less significant parameters. As per the study, the interaction of laser power and layer thickness are less significant in case of upward faces. In case of downward faces laser power and orientation are dominating factors as per the ANOVA analysis.

3. Derivations

In both the studies polyamide Duraform was used as powder material for sintering. Both the studies have taken surface roughness as the focus of study with their chosen set of process parameters. In both the studies laser power proved to be the major significant parameter for influencing the surface roughness. But the value of optimized condition for best possible surface finish is totally different. P. Bacchewar et al predicted that R_a value of 5.65 µm can be achieved at 31.8 W of laser power but on the other hand Anish Sachdeva et al predicted the value of R_a of 6.9 µm at 24W. Other parameter which is scan spacing is considered significant in the study conducted by Anish Sachdeva et al according to their study, the less spacing can cause the overlapping of layers and more spacing can cause poor packaging both the conditions can result in more surface roughness. Bacchewar et al. consideredscan spacing less significant by concluding that this phenomenon takes place in XY plane while the surface roughness is measured at top surface only.
In the study carried out by Anish Sachdeva et al bed temperature was considered as another influential parameter for governing surface roughness and might be a reason for less power usage in his study. Rest two parameters viz. hatch length and scan count were considered as insignificant in the study.
Bacchewar et al proved mathematically that apart from orientation both the remaining process variables beam speed and hatch spacing were less significant. Orientation had a part to play in defining the surface roughness as it caused stair stepping effect and hence a main cause of poor surface finish especially in round and transverse shapes.

4. Conclusions

The studies of both the researchers have agreed upon the influence of laser power but do not have a consensus on the influence of scan speed. Also laser power has to be optimized as less laser power means less energy density and thus less penetration. More laser power can cause more penetration and thus the surface finish deteriorates due to the formation of curls.
Table 3 gives the tabulated comparison of both the studies and their stand on the significance of their chosen process variable.

Process variable	Researcher 1	Researcher 2
Laser power	Significant	Significant
Scan Spacing	Significant	Less Significant
Bed Temperature	Significant	--
Layer thickness	--	Significant
Beam Speed	--	Less Significant
Orientation	--	Significant
Hatch Length	Less Significant	--
Scan Count	Less Significant	--

Furthermore other parameters are totally different thus a lot cannot be compared on that scale. Thus aninclusive study on this subject need to be done taking the significant factors of both the studies andaccordingly as per the study of these studies, the required set of process variables may be as Laser power, Scan Spacing, Bed Temperature, Layer Thickness and orientation to get the improved knowledge on the influence on the surface roughness by the process parameters.

References

1. Bacchewar, P. B.; Singhal, S. K.; Pandey, P. M. (2007) 'Statistical modelling and optimization of surface roughness in the selective laser sintering process', 221, pp. 35–52. doi: 10.1243/09544054JEM670.
2. Calignano, F. *et al.* (2013) 'Influence of process parameters on surface roughness of aluminum parts produced by DMLS', *International Journal of Advanced Manufacturing Technology*, 67(9–12), pp. 2743–2751. doi: 10.1007/s00170-012-4688-9.
3. Choi, S. H. and Samavedam, S. (2001) 'Visualisation of rapid prototyping', *Rapid Prototyping Journal*, 7(2), pp. 99–114. doi: 10.1108/13552540110386763.
4. EPMA Introduction to Additive Manufacturing Technology (2017) 'Introduction to Additive Manufacturing

Technology', pp. 15–19.

5. Gibson, I., Rosen, D. W. and Stucker, B. (2010) 'Additive manufacturing technologies: Rapid prototyping to direct digital manufacturing', *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*, pp. 1–39. doi: 10.1007/978-1-4419-1120-9.
6. Guidelines, A. (2017) 'A review on quality control in additive manufacturing', *Rapid Prototyping Journal*, 24(3). doi: 10.1108/13552540810896175.
7. Guo, N. and Leu, M. C. (2013) 'Additive manufacturing: Technology, applications and research needs', *Frontiers of Mechanical Engineering*, 8(3), pp. 215–243. doi: 10.1007/s11465-013-0248-8.
8. Launhardt, M. *et al.* (2016) 'Detecting surface roughness on SLS parts with various measuring techniques', *Polymer Testing*, 53, pp. 217–226. doi: 10.1016/j.polymertesting.2016.05.022.
9. Sachdeva, A., Singh, S. and Sharma, V. S. (2013) 'Investigating surface roughness of parts produced by SLS process', *International Journal of Advanced Manufacturing Technology*, 64(9–12), pp. 1505–1516. doi: 10.1007/s00170-012-4118-z.
10. Singhal, S. K. *et al.* (2009) 'Optimum part deposition orientation for multiple objectives in SL and SLS prototyping', *International Journal of Production Research*, 47(22), pp. 6375–6396. doi: 10.1080/00207540802183661.