Process parameter optimization of SLM process and application of Taguchi approach– The Review

Rajnikant B. Rathod[1] R. I. Patel[2]
[1]ME Student [2]Associate Professor
[1, 2] Department of Mechanical Engineering
[1, 2] GEC, Dahod (GTU, Ahmadabad)

Abstract—Selective Laser Melting (SLM) is an emerging powder based additive layer manufacturing technology that used to fabricate three-dimensional fully functional parts from metal powders by fusing the material in a layer by layer manner as per a CAD model. The quality of SLM produced parts is significantly affected by various manufacturing parameters of SLM machine. Hence optimization of SLM process parameters is necessary in order to improve the quality of parts. The purpose of this paper is to explore the reviews for various optimization methods used for process parameter optimization of SLM process and application of Taguchi approach. This review of work can be helpful to the other researchers to carry out further work in the same era.

Keywords: Selective Laser Melting (SLM), Optimization, Taguchi approach, Regression analysis

I. INTRODUCTION

Reduction of product development cycle time is the major concern in industries for achieving competitive advantage. Thus the focus of industries has shifted from traditional product development methodology to rapid fabrication techniques. Selective Laser Melting (SLM) is an emerging powder based additive layer manufacturing technology that used to fabricate three-dimensional fully functional parts from metal powders by fusing the material in a layer by layer manner as per a CAD model. Selective Laser Melting (SLM) is an emerging production technology in the field of Rapid Prototyping (RP) and Rapid Manufacturing (RM). But, the quality of SLM produced part is highly depends upon various process parameters used in this process. So, there is a need for optimizing the process parameters both from technological and economic point of view. Because Optimization of process parameters helps to finding out correct adjustment of parameters which improve the quality of the prototypes. Taguchi method is powerful tool for optimization of process design. The primary advantages for design of experiments using Taguchi's technique include simplification of experimental plan and feasibility of study of interaction between different parameters.

II. PROBLEM FORMULATION

In today's competitive market the quality of parts like surface finish, mechanical strength, dimensional accuracy etc. is most important things to satisfy and attract the customers. But as discussed earlier the quality of SLM produced parts are highly depends upon various process parameters of the process. For that, process parameter optimization of SLM process should be carried out. There are different methods of optimization of process parameter like factorial design, Taguchi method, central composite design; response surface methodology etc. without brief review it is difficult to say which one is better. This paper helps to find out which method is better for its particular application and we will use best method to achieve our goal.

III. PROCESS PARAMETER OPTIMIZATION OF SLM PROCESS

Yongqiang Yang et al. have studied the effect of different SLM parameter on the density of Ti6Al4V Titanium material. They have selected SLM parameter such as laser power, scanning speed, hatching space and scan strategy to find their effect on SLM fabricated Titanium material. Taguchi method is selected for design of experiments. They have employed Analysis of variance (ANOVA) to find out the percentage contribution of each selective laser melting parameter. At last the microstructure and property of formed samples are tested. From the experiments, found that powder thickness is the most significant influence in processing parameters on density and sample with density higher than 95% and the microstructure of sample was mainly composed of acicular martensite, a phase and b phase. The micro-hardness was 492 HV 0.2 obtained. [1]

S. Dingal et al. have conducted the experiments in order to achieve optimum value of density, porosity and hardness of selective laser melting fabricated parts. Taguchi method is adopted for design of experiments. They have selected seven important SLM process parameters such as laser peak, power density, laser pulse on-time, laser scan speed, stepping distance, interval–spot ratio, size range of iron powder particles and powder layer thickness. Signal to noise ratio was selected in order to find out which parameter was highly significant to response characteristics. After the experimental work they have conclude that layer thickness had the most significant influence on the output responses. [2]

F.Calignano et al. have perform the experiments in order to achieve optimum value of surface roughness of DSLM processed aluminum specimens. They have selected three important SLM process parameters such as scan speed, laser power and hatching distance. They have employed Taguchi's L18 orthogonal array for design of experiments. Surface morphology was analyzed by means of field emission scanning electron microscope. After the experimental work they have conclude that the Scan speed have greatest influence on the surface roughness of aluminum samples produced by Direct metal laser sintering

(DMLS) compared to other parameter such as laser power and hatching distance. [3]

K. Abd-Elghany, D.L. Bourell et al. evaluate the different properties of products fabricated by SLM using 304L stainless steel powders. Using an experimental approach, 24 samples with different shapes and sizes were fabricated with layer thickness of 30, 50 and 70mm and laser scanning speed set at 70 and 90 mm/s. Part geometry, dimensional tolerance, surface quality, density, mechanical properties and microstructure were evaluated. After experiment result confirmed that the using small layer thickness and low scanning speed improved the properties by more than 20 per cent. At a layer thickness of 30mm and speed of 70 mm/s, density was 92 per cent and hardness was 190 HV. At layer thickness of 70mm porosity increases and cracks started to form which decreased strength and ductility. Also illustrated in general, that the 304L austenitic stainless steels have high ductility, low yield stress and relatively high ultimate tensile strength. [4]

IV. TAGUCHI APPROACH FOR OPTIMIZATION

Ulas et al., were developed, artificial neural network (ANN) and regression model to predict surface roughness in abrasive water jet machining (WAJM). They have consider machining parameters such as traverse speed, water jet pressure, standoff distance, abrasive grit size and abrasive flow rate. They have used Taguchi's design of experiments in order to collect the surface roughness values. Analysis of variance (ANOVA) was used to check the validity of regression model. At the end of the study, both the ANN and regression analysis results were comparing with experimental data. It can see from the Fig.4 that both the models ANN and regression presents a good agreement with the experimental data. Based on the ANOVA, the most dominant parameter on the surface roughness was found as water jet pressure. Abrasive flow rate and standoff distance were less effective on surface roughness, while effect of abrasive grit size can be negligible. [5]

Anoop et al., have optimized the efficiency of pulsed ND: YAG laser for the laser surface structuring of porous alumina ceramic. The laser processing parameters like the pulse width, repetition rate and the scanning speed were evaluated. The Taguchi's standard L9 orthogonal arrays were used to identify the combination of process parameters for optimize physical attribute of the ceramic. ANOVA is carried out to identify the processing parameters that contributed the most to minimize the porosity and maximize the grain size. After the experimental work they have conclude that the pulse repetition rate was the most significant factor in minimizing the interdendritic porosity while the scanning speed played a vital role in increasing the grain size. [6]

S. Shaji et al., have investigated the possibility of using graphite as lubricating medium to reduce the heat generated at the grinding zone in surface grinding. They have studied the effect of parameters such as speed, feed, in feed and mode of dressing on the performance characteristics of surface finish and force developed. Factors and their levels selected for the study is indicate in Table 3.Total nine experiments were carried out by using Taguchi's standard L9 orthogonal array design to find out the effects of parameters on force developed and surface quality. After the experimental work optimum condition has been found out and they observed that the result obtains in the conventional coolant grinding is in good agreements with the results obtained graphite assisted grinding. It has been observed that with the graphite application, the tangential force and surface roughness are lower compare to those in conventional grinding. [7]

D. Chakradhar et al., have investigated the effect and parametric optimization of process parameters for electrochemical machining of EN-31 steel. The process parameters consider are electrolyte concentration, feed rate and applied voltage and are optimize with considerations of multiple performance characteristics including material removal rate, over cut, cylindrical error and surface roughness. They used Taguchi's standard L9 orthogonal array design for performing experiments. They performed the ANOVA to get the contribution of each parameter on the performance characteristics. After the experimental works they found that the best combination of process parameters are electrolyte concentration at 15%, feed at 32 mm/min and voltage at 20 V. From the results they have conclude that the material removal rate can be maximize and the over cut, cylindercity error and surface roughness can be minimized through this method. [8]

V. CONCLUSION

From the above exhaustive literature review we can say that optimization of SLM process parameters is necessary in order to achieve higher quality of the parts. Taguchi approach is a versatile tool for experimental design optimization. Taguchi's tool signal-to-noise ratio is most important tool to find out highly significant factor to output responses. There are different optimization methods but as shown in above reviews researchers got better results with Taguchi's approach because of it can be provide systematic, efficient and simplification of experimental plan with minimum experiments so the time and cost are reduced concerned with manufacturing.

REFERENCES

[1] Jianfeng Sun, Yongqiang Yang, Di Wang. Parametric optimization of selective laser melting for forming Ti6Al4V samples by Taguchi method; in Optics & Laser Technology 49 (2013) 118-124.
[2] S. Dingal & T. R. Pradhan & J. K. Sarin Sundar & A. Roy Choudhury & S. K. Roy. The application of Taguchi‟s method in the experimental investigation of the laser sintering process; in Int J Adv Manuf Technol 38 (2008) 904–914.
[3] F. Calignano & D. Manfredi & E. P. Ambrosio & L. Iuliano & P. Fino. Influence of process parameters on surface roughness of aluminum parts produced by DMLS; Springer-Verlag London 2012.
[4] K. Abd-Elghany, D.L. Bourell. Property evaluation of 304L stainless steel fabricated by selective laser melting; Rapid Prototyping Journal Vol.18 Iss: 5 (2012) 420-428.
[5] Ulas Caydas, Ahmet Hascalık. A Study On Surface Roughness In Abrasive Water Jet Machining Process Using Artificial Neural Networks And Regression Analysis Method. Journal Of Materials Processing Technology 202(2008) 574-582.

[6] Anoop N.Samant, Sameerr.Paital, Narendrab.Dahotre. Process Optimization in Laser Surface Structuring Of Alumina. Journal Of Materials Processing Technology 203 (2008) 498-504.
[7] S.Shaji, V.Radhakrishnan. Analysis of Process Parameters in Surface Grinding With Graphite As Lubricant Based On the Taguchi Method. Journal Of Materials Processing Technology 41(2003) 51-59.
[8] D.Chakradhar, A.Venu Gopal. Parametric Optimization in Electro Chemical Machining of EN-31 Steel Based on Grey Relation Approach (2011).Applied Mechanics and Materials.110-116, 1649.

