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Parametric Optimization of the Process of Selective Laser Sintering Process in Rapid Prototyping Technology- A Review

Effect of layer input parameter on quality of fabricated parts

[1]Falgun S Jani*, [2]Vidya Nair

[1],M.E scholar, [2]Associate Professor,
Department of Mechanical Engineering,
LDRP Institute of Technology and Research, Gandhinagar, Gujarat, India

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***Abstract* - Compared with traditional material subtractive manufacturing technologies, rapid prototyping is a layer-based material additive process and can produce a 3-D freeform object with a CAD-defined geometric model directly. As one of the advanced rapid prototyping and manufacturing processes, the direct metal laser sintering (DMLS) process gives designers the possibility to build parts of almost any complexity in a wide range of metallic materials. The quality of SLS made parts are highly depends upon various process parameters of process variable parameters of layer thickness (A), scan speed (B), scan spacing (C), laser power (D), and bed temptarture (E) Part Orientation on the mechanical properties viz. tensile, flexural, impact strength and hardness of part fabricated using selective metal laser sintering technology. To conduct this study, a full Taguchi experiment was used to obtain the test runs. A number of analytical methods Analysis of Variance (ANOVA), used to determine the influence of the variable SLS process parameter settings. Hence optimization of SLS 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 SLS process.**

***Keywords* - Selective laser sintering; Optimization, Roughness, Rapid Prototyping, Rapid Manufacturing, ANOVA**

I. INTRODUCTION

Additive layer manufacturing (ALM) has been used for more than 30 years and is now widely used for various materials. Laser Sintering (LS), as an important branch of Additive Manufacturing technologies, has been widely applied and rapidly developed .Direct Metal Laser Sintering (DMLS) is a new laser-based Rapid Tooling and Manufacturing (RTM) process developed jointly by the Rapid Product Innovations (formerly Electrolux
Rapid Development, Rusko, Finland) and EOS GmbH (Munich, Germany). Besides the ability to sinter plastic or sand materials, DMLS can also process metallic powder directly. The DMLS process uses liquid-phase sintering to bind metallic particles together and is a strong contender to SLS to further advance the application of RP in the manufacturing field.

II. PROCESS PROBLEM FORMULATION

The quality and cost of the product is most important things to satisfy the customer. But as discussed earlier the quality of SLS produced parts are highly depends upon various process parameters of the process. So, it is necessary to carried out the optimization of SLS parameters. It will improve the quality of functional parts. There are so many methods used for optimization, design of experiments and prediction purpose. 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. LITERATURE REVIEW ON SELECTIVE LASER SINTERING PROCESS

O. Ghita , E. James , R. Davies , S. Berretta , B. Singh , S. Flint , K.E. Evans (2014) (1) has been investigates the properties of Poly Ether Ketone (PEK) components using the commercial high temperature laser sintering system, EOSINT P800. The shrinkage and the mechanical performance of components across the entire build chamber have been analysed and a non-linear shrinkage profile has been obtained.The result indicates that mechanical strength in Z direction is lower than the value recorded in X and Y directions. the parts built are shrinking non-uniformly depending on thermal gradients and profile across the bed . the residence time of the parts in the bed chamber at high temperatures affects on the part appearance than previously noticed in nylon The results presented here are the first to show performance of laser sintered PEK components.
Noriko Read , Wei Wang , Khamis Essa , Moataz M. Attallah (2014) (2) has been analysed process parameters (laser power, scan speed, scan spacing, and island size using a Concept Laser M2 system) on the porosity development in AlSi10Mg alloy builds has been investigated,theyhave used statistical design of experimental approach, correlated with the energy density model. A statistical method has been used to evaluate the influence of process parameters on the porosity of SLMed AlSi10Mg, which shows the trends of porosity in the SLM fabricated samples .The build direction does not strongly influence the tensile or creep

strength of SLMed AlSi10Mg. Both building directions show higher strength than die cast A360, although the elongation is inferior to that of A360. Fracture surfaces show the presence of significant amounts of un-melted powder, which give rise to local cracking.

Mircea ancău & cristian caizar (2008) (3) has been investigated the effect of orientation on surface roughness.They have developed two different numerical methods to find out the optimal orientation of the 3D model on the working platform of the Rapid Prototyping system. so that the surface regions with higher staircase effect to be as small as possible. The first one will establish the orientation in an automate manner, while the second. The first variant is an entirely computerized one. The method is base on the minimum number of the triangular facets whose slope accomplishes an initial condition. The main disadvantage of the automated method is the fact that it does not take into account that somesurfaces are very important concerning the functional or aesthetic role, while other surfaces are not. The second variant proposed by this research require the manual part orientation by the designer. By rotation of the model around its horizontal axis, those regions of the surfaces which will result with a higher staircase effect, can be easy visualized. So the designer can easy decide which is the optimal orientation of the 3D model, while taking into consideration the importance of the surfaces by functional or aesthetic role.

Chetankumar M.Patel , Sandip.B.Patel, Mit K.Shah(2015) (4) has been emphasize on basic and advanced materials used for realization of parts by SLS In this paper use CL50WS material and measure output parameter (Tensile Strength, Yield Strength, Elongation, SR) for influence of input parameter layer thickness and orientation,They have concluded that Tensile Strength decreases with increasing Layer Thickness and Orientation. Yield Strength decreases with increasing Laye r.Thickness and Orientation. Surface Roughness increases with increasing layer thickness.

P.S.Panchal, N.R.Patel, H.J.Patel (2014)(5) has been emphasize on basic and advanced materials used for realization of parts by SLS. In this paper use CL20ES material and measure output parameter (Tensile Strength, Yield Strength, Elongation, SR) for influence of input parameter layer thickness and orientation. Generally SLS materials are available in powder form. SLS machines can fabricate objects in a wide range of materials, such as plastics, glass, ceramics and metals. SLS basic materials are Carbon-Fibre,Glass Filled Polyamide, Nylon 11 derivative, Fine Polyamide, Nylon 12, Alumina-ammonium phosphate. Metal objects can be fabricated by Direct Metal Laser Sintering and materials are Aluminium, Cobalt Chrome Alloy, Nickel Alloy, Maraging Steel, Stainless Steel, and Titanium Alloy for variety of structural, electro ceramics and bio-ceramics applications.

Byeong-Don Joo, Jeong-Hwan Jang, Jae-Ho Lee, Young-Myung Son and Young-Hoon Moon (2010)(6) has been investigated of study on fabricating a line with Fe-Ni-Cr powder on AISI H13 tool steel has been performed by selective laser sintering The line was fabricated with various laser power,scan rate and layer thickness. Line width and surface quality were investigated. They have conclude that With increasing power or decreasing layer thickness, the laser energy affects lower layer more easily and the range of line connection was widened. Line width increased with increasing layer thickness. Increased layer thickness increases the energy input to make connection with under layer and particles around laser beam are melted and line width increased. Lower scan rate than optimized scan rate causes balling and higher scan rate causes weak connection more easily With power increasing or layer thickness decreasing,line width was decreased and line surface quality was improved with scan rate optimization. And the optimized line width was 2.2 times larger than the laser spot diameter.

Marissa Castoro (2013) (7) they have explores the effect of varying the build parameters on the mechanical properties of parts built on a selective laser sintering machine Four build parameters of selective laser sintering machines that are modifiable are: laser power, scan spacing, laser speed, and build orientation .and output data are Young's modulus, ultimate tensile strength, and percent elongation was collected for each set of tensile bars.They have concluded that optimum orientation, this research has found that the initial orientation provides for the best mechanical properties. Parts built in this orientation tested substantially better than those built in the vertical or horizontal orientations.

S.L. Campanelli, G. Casalino, N. Contuzzi, A.D. Ludovico,(2013) (8) have studied laser speed, power, focus and the number of removed layer and out.The output parameter is surface roughness. The powder material had the typical composition of the AISI 316L steel. They have conclude that *Ra* has the tendency to decrease with the increase of the number of removed layers. the higher scan speeds affected the surface finish only for the larger number of the removed layers. The lower scan speeds did not influence the roughness. Laser defocus affected roughness only for the lower values of removed layers.

I.Vijay arasu , K.Chockalingam, C.Kailasanathan and M.Sivabharathy (2014) (9) has investigated the effect of process parameter like laser power, orientation and scan spacing on surface roughness. ST-100 powder material was utilized in this experimental work they have conclude that three parameters considered for the analysis, the scan spacing was the important contributing factor affecting the upward-facing surface roughness The confirmation experiment was done at an optimum level of parameters and confirmed that the estimated values in both methods were close enough themselves and also in experimental values.It has been found that as the layer thickness increase the surface finish decrease.

Majewski, C.E. and Hopkinson, N (10). has analysed whether the same is true of tensile properties, and whether the orientation of parts within the build volume has any effect on this. Results are presented for three different orientations of tensile specimens at a range of thicknesses.The investigated output parameter is tensile streangth,yield streangth ,yield break .they found that When considering Tensile Strength and Young's Modulus, the orientation of the parts showed no demonstrable effect on the values achieved, demonstrating that they are more robust to changes in build layout. the Elongation at Break in the YX and YZ direction, with a decrease in the property when parts were produced in the ZY direction

N. Raghunath, Pulak M. Pandey (11) has investigated Shrinkage is one of the major factors which influence the accuracy of the SLS parts. To compensate for shrinkage, the material shrinkage coefficient or scaling factor is to be calculated in each direction and is to be applied to STL file. The amount of shrinkage encountered is found to be governed by the process parameters during processing and cannot be kept constant as it is a usual practice in today's SLS technology. In the present work, the relationship between shrinkage and the various process parameters namely laser power, beam speed, hatch spacing, part bed temperature and scan length in SLS have been investigated. Empirical models for predicting shrinkage along X, Y and Z directions are derived using regression One case study of bench marking part is also presented to show that shrinkage model developed in the present work confine more accurate parts.

IV. CONCLUSION

From the above reviews conclusion can be drawn that the optimization of FDM parameters is necessary to achieve higher quality parts. Taguchi method is best approach for experimental design. Its tool such as orthogonal array, S/N ratio and ANOVA analysis is helpful to determine most significant factor which affect performance characteristics. Many researcher work have worked on different type of materials with various types of Rapid Prototyping technology. There are many different D.O.E methods are used like Box-Behnken design and different types of techniques for optimization like GLA technique, Grey relational technique. Some research conducted on various behaviours like effect of process parameters on different types of material like CL20ES, 316L SS,CL50WS and output parameters like Tensile Strength, Yield Strength, Elongation, Surface roughness,shrinkage measurement.

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