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EXPERIMENTAL STUDY FOR EFFECTS OF PROCESS PARAMETERS OF SELECTIVE LASER SINTERING FOR ALSI10MG

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Abstract: Aluminium alloy porous structures has vast applications such as heat exchanger and lightweight aerospace products. Basic manufacturing methods such as casting, however, faces difficulty in making Aluminium alloy. SLS is an AM process where layer-by-layer, fine powder is spread and sintered to build a part. The powder is equally distributed and spread evenly with a recoater to create a level uniform surface that completely covers the build area. A laser beam is then directed at the powder layer and scans over the cross-section of the part. The build platform is lowered and the process is repeated until all layers have been printed. The research will be focused on study of effects of key process parameters such as layer thickness, scanning speed, and laser power for SLS AlSi10Mg Components. The quality response parameters like hardness, surface roughness and geometrical accuracy of printed specimen investigated. The research will contribute for technology development in the field of Additive manufacturing for producing full functional parts.
Keywords: Selective Laser Sintering (SLS), AlSi10Mg.

I. INTRODUCTION

AM technologies build components layer by layer using 3D model data. [1] AM technologies are the direct plunging of the work in 3D printing and could revolutionize many sectors of U.S. manufacturing by reducing part lead time, cost, material wastage, energy consumptions, and carbon footprint. For the aerospace industry it could lead to a reduction of required raw materials usage to fabricate an in-service component, which is known as the "buy-to-fly" ratio. AM can also prime to new innovations for lightweight structures that could see application in unmanned aerial vehicles. For the medical industry, AM is already important to a revolution in customized medicine where dental implants, orthopedics, and hearing aids are manufactured to fit an individual's unique physiology. For consumer products artistic and aesthetic designs can be directly manufactured without concern for standard manufacturing practice.

ASTM has defined additive manufacturing (AM) as [2] ''a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. Synonyms: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication.''

II. LITERATURE SURVEY

J.P.Kruth [1] said that Rapid prototyping methods produce designed part by adding of material layer by layer and its differing essentially from forming and material subtraction manufacturing methods. He classified broad classification of Additive manufacturing. E. Herderick [2] said that there are more possibilities for AM are there which having unique applications cannot be fabricated by standard machining practices. For examples tailored medical implants that can be built with exact bodily geometry output using MRI. Innovative functionally gradient materials could be generated using these techniques that will help in new applications. William E. Frazier [3] said AM is a process of making parts from 3D model data. AM is currently favored in small production lots in which the higher cost of AM specific raw materials is offset by a reduction in fixed costs associated with conventional mfg. AM is projected to have a positive impact on the environment by reducing energy consumption and carbon footprint. K.R.Bakshi, A.V. Mulay [4] said that various techniques of rapid prototyping selective laser sintering is the most malleable process that provides large variability of materials being processed. It is advantage to industrial application like aerospace and aircraft hardware, medical and health-care, electronics, wrapping, connectors, security, soldierly hardware, prototypes, and efficient proof of concept prototypes, design evaluation models, invention performance & testing, engineering design verification, wind tunnel Test mode. Farooq I Azam [5] stated that AM is growing, more and more AM equipments available in markets. There approximately 130 different parameters affecting SLM process. Among of that 13 parameters are critical to quality characteristics of the final manufactured parts. Proper understanding of the final product application is necessary for choosing the right AM process. Panagiotis Stavropoulos, Panagis Foteinopoulos [6] To find some of the most important matters hindering today, keener numerical models, proficient of providing precise calculations of the thermal history and the oversizing of the printed parts, while reducing the necessary computational expenses, have to be created. From those models, we will enable the assortment process parameters that will capitalize on the quality of the produced parts, along with providing the necessary facts for the optimization of the processes themselves. Sanjay Kumar [7] with the advent of the exclusive processes and materials for sintering and extensive research on various aspects of the process. Comparatively little work has been done in computational modelling for the SLS of the metals and alloys and most of the experimental works executed are commercial machine specific. Chirag mahesh kumar sedani [8] In this paper, they stated that the optimum value of the input parameters for the SLS is 30µm layer thickness, 0° orientations, 0µm porosity because at this parameters output gives maximum UTS and Yield Strength for CL20ES. A. stwora, G. Skrabalak [9] said that the best result (High Hardness, High density, High Compression Strength) was achieved by parameter point distance PD = 50µm, Exposure time ET = 100µs, and laser power P = 200W. Similar results were achieved for both used machines (EOS 250xt and Renishaw AM250). Andrzej Stwora [10] stated that increase in density and the reduction of porosity in the surface layer of SLS/SLM produces samples have significant effect on their strength. Luca Gerilli [11] stated that as - produced AM Parts exhibits superior mechanical properties than GC ones due to the grain refinement, the presence of Nano-sized Si particles and Mg2Si Precipates related to the production technology. They observed best performance obtained after solution at 540°C for 1h, Water quenching at 65°C and ageing at 180°C for 2h. Despite for AM the density decreases of about 2% comparison with the as-produced Condition. Manickavasagam Krishnan [12] in this paper, author stated that hatch distance is most significant parameter influencing the mechanical properties of the parts fabricated by DMLS. The experimental investigation proves that with hatch distance of 0.17mm the scanning speed can be increased up to 900mm/s without a substantial effect on part properties. Combination of the 195W Laser power, 700mm/s scanning speed and 0.17mm hatch distance yields highest density. M. Akhilesh [13] in this paper, Authors stated that they considered polyamide (Nylon-DuraForm PA: 12) for the experimental investigation. The SLS process parameters were optimized and optimal values of the process parameters were found to be 15W for Laser Power, 133°C for bed temperature, and 0.15mm for layer thickness. Mohsen Mohammadi [15] In this paper, they said that Surface 1 sample with more energy density applied on the upskin layers revealed better surface roughness then regular Sample, where surface two sample with same applied energy density as surface 1 but lower beam offset yielded the best surface quality for DMLS-Alsi10Mg-200C. The Porosity level obtained in Surface 1 sample was less than regular sample and surface 2 sample had the least porosity level.

III. EXPERIMENTAL PROCEDURE

EOS EOSINT M280 was used for the manufacturing of specimen. Machine is equipped with 250×250mm exposure area, 400W Yb Fibre Laser and 90µ Beam diameter. Specimens were manufactured from LPW-ALSI10MG – AAGG Powder, where the chemical composition found in table 1.

		Min.	Max.	Result	Approval
Cu	Copper		0.05	0.05	Pass
Mn	Manganese		0.01	<0.01	Pass
Mg	Magnesium	0.25	0.45	0.35	Pass
Ni	Nickel		0.05	<0.01	Pass
Zn	Zinc		0.1	<0.1	Pass
Pb	Lead		0.02	<0.01	Pass
Sn	Tin		0.02	<0.01	Pass
Si	Silicon	9.00	11.00	10.00	Pass
Al	Aluminium		Balance	Balance	Pass

Table 1 LPW – ALSI10MG – AAGG Powder Chemical Composition.

Experiment design were done using Taguchi method because for the small sample size and similar to other method can be achieved by Taguchi method. In this experiment Laser power, Layer thickness, Scan speed were taken into consider to see effect of parameter on dimensional accuracy, Surface roughness and higher hardness. Process parameter matrix shown in table 2.

Sr. No.	Laser Power (Watts)	Layer Thickness (µm)	Scan Speed (mm/s)
1	80	20	800
2	80	40	1150
3	80	60	1500
4	225	20	1150
5	225	40	1500
6	225	60	800
7	370	20	1500
8	370	40	800
9	370	60	1150

Table 2 Taguchi design matrix

Experiment were conducted in standard condition and experiment design matrix parameter. And responses were recorded in the Table 3. Sample manufactured shown in Figure 1 as below.

Sample	Diameter (mm)	Roughness Value (Ra)	Hardness Before HT (HRB)	Hardness After HT (HRB)
S1	14.92	8.432	45	47
S2	14.87	12.895	41	43
S3	14.80	13.677	38	43
S4	14.94	6.289	46	51
S5	14.92	10.234	41	46
S6	14.93	16.885	36	41
S7	14.98	3.389	44	49
S8	15.07	10.128	37	43
S9	14.95	14.217	33	41

Table 3 Response Table

Figure 1 Manufactured Samples

IV. TAGUCHI ANALYSIS

Diameter versus Laser Power, Layer Thickness, Scan speed

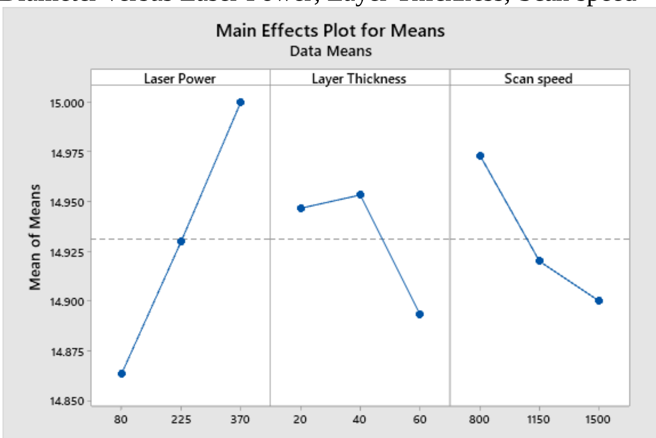

Figure 2 Main effects plot for means for diameter

From the graph we can conclude that Laser Power 370W, Layer thickness 40µ, Scan speed 800 mm/s are effecting parameters for diameter. Among of all them Laser Power is most influencing factor for diameter. Roughness Value versus Laser Power, Layer Thickness, Scan speed

Roughness Value versus Laser Power, Layer Thickness, Scan speed

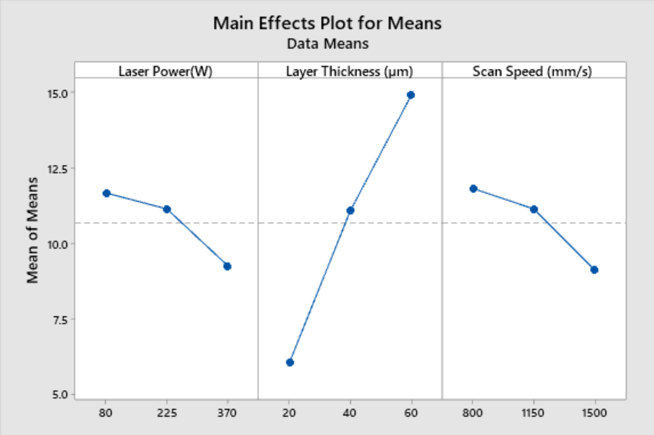

Figure 3 Main effects plot for means for Roughness Value

From the graph we can conclude that Laser Power 370W, Layer Thickness 20μ, Scan Speed 1500mm/s are effecting parameters for Roughness Value. Among of all of them Layer Thickness is influencing factor for Roughness Value.

Hardness versus Laser Power, Layer Thickness, Scan speed

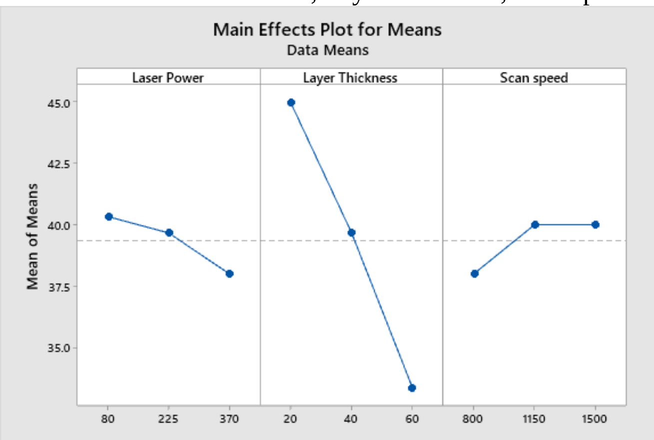

Figure 4 Main effects plot for means for Roughness Value

From the graph we can conclude that Laser power 80W, Layer thickness 20μ, Scan speed 1500 mm/s are effecting parameter for the Hardness. Among of all of them Layer thickness is Influencing factor for Hardness.

Regression Equation is formed, for the same condition for the output parameter. Regression Equations formed as below -

Diameter = 14.9311 - 0.06778 Laser Power_80 - 0.00111 Laser Power_225 + 0.06889 Laser Power_370 + 0.01556 Layer Thickness_20 + 0.02222 Layer Thickness_40 - 0.03778 Layer Thickness_60 + 0.04222 Scan speed_800 - 0.01111 Scan speed_1150 - 0.03111 Scan speed_1500

Roughness Value = 10.683 + 0.985 Laser Power_80 + 0.453 Laser Power_225 - 1.438 Laser Power_370 - 4.646 Layer Thickness_20 + 0.403 Layer Thickness_40 + 4.243 Layer Thickness_60 + 1.132 Scan speed_800 + 0.451 Scan speed_1150 - 1.583 Scan speed_1500

Hardness = 39.333 + 1.000 Laser Power_80 + 0.333 Laser Power_225 -1.333 Laser Power_370 + 5.667 Layer Thickness_20 + 0.333 Layer Thickness_40 - 6.000 Layer Thickness_60 -1.333 Scan speed_800 + 0.667 Scan speed_1150 + 0.667 Scan speed_1500

The ANOVA was carried out to inspect influence of process parameter on

- Diameter Laser power (64.73%) has the key influence on the Diameter, Shadowed by the Layer thickness (14.99%) and Scan speed (19.92%).
- Surface roughness value the layer thickness (83.47%) has the major influence followed by scan speed (8.38%) and the laser power (6.81%).
- Hardness, Layer thickness (92.19%) has the major influence followed by laser power (3.90%) and the scan speed (3.60%) for Aluminium alloy (AlSi10Mg).

To fulfil the above condition like higher dimensional accuracy, Lower surface finish, Higher Hardness there is optimized set of parameter which can fulfil the requirement.

Laser Power	Layer Thickness	Scan speed	Hardness Fit	Roughness Value Fit	Diameter Fit	Composite Desirability
370	20	1500	44.3333	3.01556	14.9844	0.933102

V. CONCLUSION

From the analysis we can conclude that –

Laser Power (64.73%) is influencing parameter for dimensional accuracy, Layer Thickness is influencing parameter for Roughness Value (83.47%) and Hardness (92.19%).

To fulfill the specified condition (Higher dimensional accuracy, Lower surface roughness and higher hardness) can be fulfilled by using parameter Laser Power 370W, Layer Thickness 20μm, Scan Speed 1500mm/s.

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