Methodology for Controlling Selective Laser Sintering Parameters

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Abstract: SLS (selective laser sintering) is a powder-based rapid prototyping (RP) technique that involves selective sintering of powder layers using a CO2 laser. SLS is becoming more popular by way of a quick manufacturing technology for producing functional components in small numbers, especially in aerospace and rapid tooling. As a result, SLS prototypes must be extremely accurate in order to meet functional requirements. This research study demonstrates an effective strategy for determining the ideal SLS processing parameter in order to produce components with improved component integrity and lower overall costs. In this article, the factorial technique was used to create three input parameters for creating work components using the SLS process: layer thickness, orientation, and porosity (artificial porosity as honeycomb assembly). CL 20ES is the material that has been utilised (stainless steel-316). After creating work components, output metrics such as ultimate tensile strength (UTS), hardness, yield strength, elongation, and weight were used to test them. A study was conducted in order to determine the best parameter values for improved output.

Index Terms: Layer thickness; Rapid Prototyping; Honeycomb Structure; processing parameters.

I. INTRODUCTION

Rapid prototyping (RP) technology, which has been in use since the late 1980s, has found a home in CAD/CAM and is probable to deal with the dynamic industrial setting. SLA (Stereolithographic Apparatus), SLS (Selective Laser Sintering), LOM (Laminated Object Manufacturing), FDM (Fused Deposit Modelling), and SGC (Soling Ground Curing) are examples of material additive manufacturing (AM) or layered manufacturing (LM) processes in which a 3D computer model is sliced and reassembled in real space layer-by-layer based on the unique form of physical used and hardening method. One of the best approaches is to categorise RP systems generally based on the material's initial shape, i.e., the material from which the prototypes are made. As a result, all RP systems may be simply classified into three categories: (1) liquid-based (2) solid-based (3) powder-based.

The SLS is a powder-based RP technique that uses discerning sintering of succeeding layers of crushed raw materials to directly produce solid mechanisms according to a 3D CAD model. While SLS's ability to produce functional items directly from metals is still being researched, indirect methods of producing functional things from metals are widely used. DuraForm materials (such as GF plastics (glass filled polyamide), PA plastics (durable polyamide), EX plastic (impact resistant plastic), Flex plastic (thermoplastic elastomer with rubber), and AF plastic (polyamide)), Laser Form materials (such as A6 (steel) material, ST-200 material (special stainless-steel composite), and ST-100 material (powdered stainless steel), and Cast Form PS material) are the three types of materials used

II. CONTROLLING PARAMETERS IN SLM PROCESS

The SLM process is governed by the parameters given in Table 1, which have a significant impact on the finished part's quality. Laser power, hatch spacing, scanning speed, and layer thickness are the most important construction factors.

Table 1: Controlling Parameters in SLM Process

Process Parameters			
Laser Related	**Powder Related**	**Scan Related**	**Temperature Related**
• Laser Power • Spot Size • Pulse Duration • Pulse Frequency	• Particle Size • Particle Shape & Distribution • Powder Bed Density • Layer Thickness • Material Properties	• Scan Speed • Scan Spacing • Scan Pattern	• Powder Bed Temperature • Powder Feed Temperature • Temperature Uniformity

Powder properties, in addition to the impact of processing conditions, are a major problem. The melting and fusing process is heavily influenced by the form, size, particle dispersion, and chemical content of the powder. Powders with a low oxygen concentration, a high flow rate, and a high packing density are the best choices.

Aluminium-Silicon alloys are extremely light metals with excellent strength, weldability, and corrosion resistance. Al-Si alloys have been employed in a variety of industrial applications, including aerospace, automotive, and moulding, due to their appealing mix of mechanical qualities and high heat conductivity. The addition of magnesium to aluminum-silicon alloys improves mechanical characteristics as well as ductility and modulus of elasticity. Hence AlSi10Mg has a Mg content of 0.3 to 0.5 wt. % and may be hardened using the T6 cycle of solution annealing, quenching, and age hardening to improve mechanical characteristics.

III. METHODOLOGY

The methods utilised to conduct the experiments is explained in this section. The first step is to design the work item, which may be done in any CAD software. Then there's the experiment design, which was done utilising the factorial approach. Then there's the stuff.

3.1 Design of work pieces

The work components are created using a sophisticated design programme called CREO 3.0®.

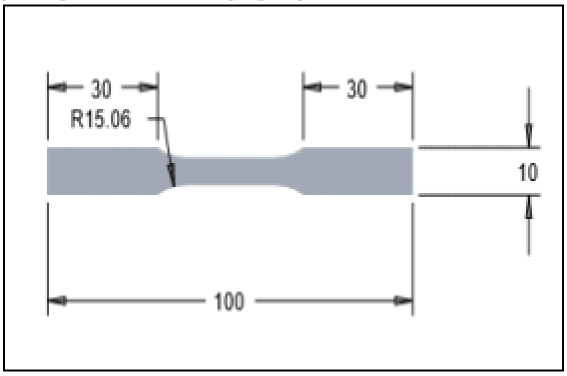

Figure 1: Design of work piece with dimensions

Fig. 1 Shows the 2D work piece with dimension designed in CREO 3.0®. The total length of the work piece is 100mm, thickness is 3mm and width is 10mm.

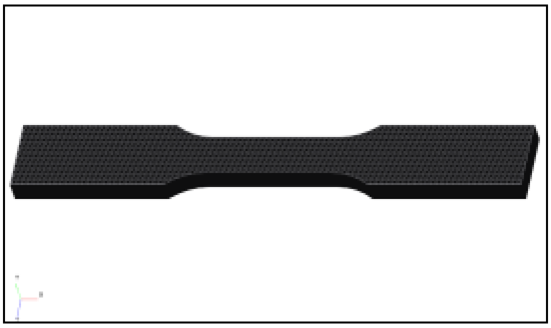

Figure 2: 3D model in CREO 3.0®

The 3D model created in CREO 3.0® is shown in Figure 2. The work piece is a conventional tensile bar with little dots visible to illustrate the artificial porosity that was determined during the work piece's design.

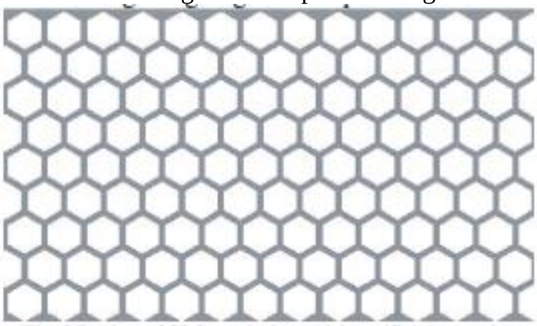

Figure 3: Design of SLS workpiece with artificial porosity (Honeycomb structure)

The artificial porosity defined in the work piece in the form of a honeycomb structure is shown in Figure 3.

3.2 Design of experiments (DOE)

The use of a factorial design to investigate the effects of numerous factors on a response is a common practise. Experiments are used to investigate the impact of a single variable on a single response. By addressing numerous factors at the same time, factorial design can decrease the number of experiments required. It may also be used to identify both main effects (from each independent component) and interaction effects (from each dependent factor) (when both factors must be used to explain the outcome). However, factorial design can only provide relative values; in order to get real numerical values, regressions (which involve the minimization of a sum of values) must be undertaken. The factorial design examines all conceivable scenarios. Factorial design is best utilised for a limited number of variables with few states since it can lead to a large number of trials, which can be costly and time-consuming (1to3). Regardless, in both laboratory and corporate contexts, factorial design is a beneficial tool for designing research.

Table 2: Factorial Method Design

Sr.no.	Standard order	Run order	Central Park	Block	Layer thickness (μm)	Orientation (o)	Porosity (mm)
1	1	1	1	1	30	0	0
2	2	2	1	1	70	0	0
3	3	3	1	1	30	90	0
4	4	4	1	1	70	90	0
5	5	5	1	1	30	0	600
6	6	6	1	1	70	0	600
7	7	7	1	1	30	90	600
8	8	8	1	1	70	90	600
9	9	9	0	1	50	45	300
10	10	10	0	1	50	45	300
11	11	11	0	1	50	45	300

Table 2 shows that the design of elements technique is utilised to produce the outcome with the fewest number of tests possible. First, the minimal number of experiments must be chosen, and then the output must be verified. In the event of poor results, the number of experiments will be increased. As a result, a total of 11 tests will be carried out. As illustrated in Table 2, there are three input parameters: layer thickness, location, and absorbency. The factorial approach has provided this type of input parameter combination to carry out the studies. Layer thickness (30-70 m), orientation (0°-90°), and porosity (0-600 m) are among the input factors.**3.3 Materials Employed**

The warpage-sensitive sections are made of CL20ES material. It warms up to 550°C in 3 hours and keeps that temperature for 6 hours. In comparison to stainless steel, CL20ES has a homogenous, dense structure after being made using the metal laser melting technique laser CUSING®. The component is allowed to cool in the oven or at room temperature once it has been heated.

Table 3: Chemical Composition of CL 20ES for SLS

Component	Indicative value (%)
Fe	Balance
Cr	16.5-18.5
Ni	10.0-13.0
Mo	2.0-2.5
Mn	0-2.0
Si	0-1.0
P	0-0.045
C	0-0.030
S	0-0.030

In the following sectors, Table 3 indicates the chemical composition of the material used to manufacture acid and corrosion resistant prototypes, one-of-a-kind or series production parts: Plant engineering, automotive industries, medical technology, jewellery, and mould components are just a few of the fields in which we work.

IV. EXPERIMENTATION

4.1 SLS machine (M1 CUSING®)

Fig. 4 shows the M1 CUSING machine to make work pieces.

Figure 4: SLS machine (M1 CUSING®)

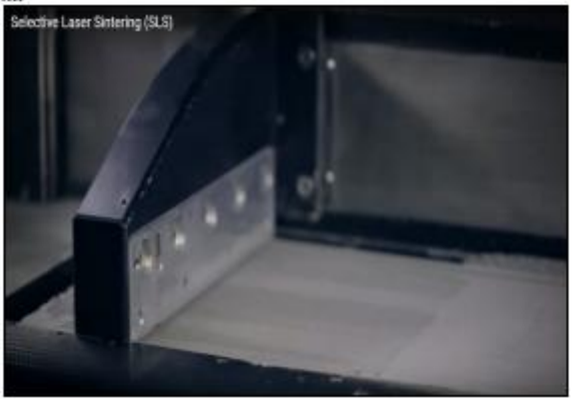

Figure 5: Layer formation

The machine has the range of the layer thickness is from 20µm to 80µm. as shown in fig, 5 the layer gets formed using slider mechanism which is able to move horizontally as well as vertically. The movement of slider is controlled by piston cylinder arrangement.

Figure 6: Laser focusing

Fig. 6 shows the process when laser gets concentrated over the layer of powder material and generates different shape of workpiece.

Table 4: SLS Machine specification

Build envelope Laser CUSING®	250 x 250 x 250 mm (x, y, z)
Layer thickness Laser CUSING®	20 – 80 µm
Production speed Laser CUSING®	2 – 10 cm3/h (depending on material
Laser system	Fiber laser 200 W (cw)
Max. scanning speed	7 m/s
Focus diameter	50 – 200 µm
Reference clamping system	50 – 200 µm
Connected loads	EROWA, System 3R / others on request Connected loads Power consumption 7.4 kW Power supply 3/N/PE AC 400 V, 32 A
Laser CUSING® materials	CL 20ES Stainless steel (1.4404) CL 50WS Hot-work steel (1.2709) CL 91RW Stainless hot-work steel CL 100NB Nickel-based alloy (Inconel 718) CL 110CoCr Cobalt-chromium alloy (F75) remanium® star CL Cobalt-chromium alloy (by Dentaurum)

Table 4 shows the SLS machine specification. It has range of layer thickness 20-80µm and focus diameter of range 50-200µm. Maximum scanning speed is 7m/s.

V. RESULTS

Table 5: Experimental outputs of SLS workpieces

Job no.	Yield strength (N/mm2)	UTS (N/mm2)	Hardness (HRB)	Elongation (mm)	Weight (gm)
1	637.76	739.11	98.36	30.44	23.203
2	115.56	227.66	55.66	4.64	18.792
3	630.31	730.59	96.36	27.8	24.38
4	100.42	234.02	41.56	9.4	18.922
5	37.64	63.78	35.37	3.8	7.028
6	23.9	37.75	34.76	4.8	5.902
7	40.91	76.77	36.23	4.24	7.265
8	87.96	31.71	37.14	5.24	6.198
9	72.11	105.95	37.74	1.64	17.374
10	73.01	148.74	36.46	1.32	16.453
11	90.99	188.73	37	7.48	17.052

Table 5 shows the experimental outputs which have been performed in standardized laboratory by considering such output limits like yield strength, UTS (Ultimate Tensile Strength), elongation, hardness, and weight.

VI. CONCLUSION

The most influencing process parameters for which the best superficial finish, dimensional correctness and rigidity are found. The design of experiments is developed. According to the DOE the specimens were produced by using SLS. From experimental results and analysis, we can conclude that, the optimum value of the input parameter for the SLS is 30 µm layer thicknesses, 0 º orientations, 0 µm porosity (artificial) because, at this parameters output gives maximum UTS and yield strength. As layer thickness increases the strength of workpiece decreases also production time decreases because, (at molecular level) the bonding between the molecules becomes weak due to increases in distance between them. Orientation has no major effect on output parameters, because in horizontal plane change in orientation changes hatch spacing only so that there is no effect on strength of work piece.

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