Investigation of properties of selective Laser sintering of Titanium alloy composite

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Abstract. A wide range of material utilized in Selective Laser Sintering (SLS) method opens the research thrust in the Additive Manufacturing (AM) or Solid Freeform Fabrication (SFF) technology for the researchers. There are many works done on materials like polymer metal composite ceramics & sand under SLS method to enhance the quality & mechanical properties of parts described through optimizing the process parameters. Still there is a wide scope to optimize the SLS process parameters which are using materials such as sand ceramics & metals. Also among the different response variables available the impact of surface roughness on SLS stainless steel metal parts & the quality of sand mould casting parts have not yet been analyzed. Further if the gap of the influencing process parameters on different materials is fulfilled, the operator can easily utilize the SLS process before carrying out the actual process. The main objective of this study focuses on the design & investigation of SLS process parameter & final part properties. Also a manual suggestive process parameter selection methodology has developed for the laser sintering processes.

Keywords: Algorithm, Laser sintering, titanium alloy.

1. Introduction

Despite the significant examination in CAD/CAM innovation, the hole between CAD and CAM has been distinguished in two angles. (1) Rapid age of 3D models and models (2) Cost viable creation of hardware needed for projecting industry. These issues are satisfied through the accompanying innovation in the current situation. SFF (or) AM framework is the cycle hardware which can quickly make 3D-molded items from CAD information utilizing various materials. Some author have characterized that SFF strategy utilizes layer-through-layer assembling to make 3D actual items straightforwardly from the PC produced models. Utilizing an AM approach, this framework joins fluid, powder or sheet materials to produce parts in various shapes. SLS is the SFF procedure through which the parts are constructed layer-through-layer through offering the critical benefit of the immediate assembling of utilitarian parts. Henceforth, the SLS cycle applied to the advancement of SFF framework is used to sinter a layer of powder materials which has a positive layer thickness through the laser filter. The SLS is additionally a dependable cycle to get exactness and strength of the item together [1].

As one of the quick prototyping measures, the SLS method assembles model parts through keeping and softening powder material layer through layer. Despite the fact that it is a generally helpful innovation, the RP based SLS measure difficulties the customary material expulsion measures [*]. AM innovation has arisen as an answer for abbreviate the item improvement cycle, accomplish adaptability for assembling little group sizes and do assembling of complex planned segments effortlessly. AM alludes to a gathering of advances used for working through adding layer through layer of actual models, models, tooling segments and completed parts, all from 3D CAD information or information from 3D
examining framework. Added substance frameworks, in view of slight and even cross areas taken from a 3D PC model, consolidate fluid, powder or sheet materials to deliver plastic, fired, metal or composite parts. [7].

RP can be characterized as a gathering of strategies used to rapidly manufacture items dependent on 3-D CAD information. The assembling interaction of RP innovation can create the programmed development of actual models along 3-D printers, sound system lithography machines and laser sintering (or) dissolving frameworks. [4].

The improvement of RP is RM, the programmed creation of items straightforwardly from CAD information. RM is additionally ideal for creating custom parts custom-made to the client's precise details. The other significant utilization of RM is for the items that can't be made through subtractive (machining, granulating) or compressive (fashioning, and so on) strategies. This incorporates objects along complex math, interior surfaces, and layered designs, for example, artistic channels that have multiple times the inward surface region of more established types. RM depends on RP measures and the techniques that comprise quick creation of utilitarian pieces of little arrangement. Some author examined the RM of EDM metal model (cathode) and the upgrades in anode machining quality. A parametric investigation has demonstrated that the wear pace of the terminal ways to deal with that of an overall cathode, and the surface harshness of the cavity delivered are worthy for the equivalent machining conditions. In the RP/RM/RT measures, surface completion and mechanical properties are basic variables, as they can influence the part dimensional exactness, lessen the post handling costs and improve the usefulness of the parts [5].

In this manner, the surface completion and the mechanical properties are the significant boundaries for parts (RP), end parts (RM) and tooling (RT) got through AM innovations. One of the strategy that is discovered to can possibly be used as RM measure is SLS. SLS and SLM measures are two creation advances offering extraordinary benefits and openings contrasted with conventional material expulsion strategies. The distinction between SLS and SLM concerns the limiting system that happens between the powder particles. It is described. Here; SLS is a particularly added substance layering measure which uses a CO2 laser and powder material (polymers, metals, pottery, and composites) to construct a 3-D part without molds or backing. A CAD model is first decorated and cut into numerous layers. It utilizes fine powder which is spread on the machine bed through a re-coater and filtered specifically through a CO2 laser to such an extent that the surface pressure of the grains is survived and sintered together. [6].

Other advantages of the SLS system are the speed of the production & the ability to produce components in a number of non-toxic materials. But in contrast, the SLM process uses high powered laser which leads to high temperature & causes an increase in spatter generation & metal vaporization. Moreover, it is a slow & costly process & hence, SLS has been chosen for this study [7]. This research organized as in section 2 research methodology described, in section 3 Results & discussion analysed, & final conclusion & future work described in section 4.

2. Research methodology

A detailed experimental procedure adopted in the present study. In addition, a model formulation & confirmation test on surface roughness involved for the various process parameters are also discussed.

2.1. Research Development

The minimum lead time & the production cost, which offer an affordable price of products, have always been give key importance of the recent market trend. The RP technology application in global competition has greatly reduced the design complication, manufacturing lead time & consequently reduced the cost of the products.

Today, there are lots of RP technologies commercially available in market. The most popular RP technologies utilized worldwide are SLA, SLS, 3DP & LOM etc. The variety of material utilization
scope extends SLS is an emerging technology in RP / RM/ RT & casting industries. Generally, parts made through SLS are largely utilized as a functional part & for the product development purpose. So, SLS is such an additive layering process utilizing a laser & powder material (polymers, metals, ceramics & composites) to build a 3-D part & it is utilized in particular research.

The DMLS or Metal Laser Sintering (MLS) is similar to SLS technique from the powder deposition method point of view. But, it does not use any plastic binder mix to hold the powder together in this process. Also, any further sintering or infiltration process is not required to produce the metal parts for different applications. However, shot-preening process to control residual stresses through compressing surfaces & polishing to reduce the roughness are utilized as secondary finishing operations.

In the RP\ RM\ RT measures, surface completion is basic, as it can influence the part precision, lessen the post preparing cost and improve the usefulness of the parts. Accordingly, the parts ought to have excellent surface completion just as feel to keep away from extra completing activity to upgrade it. Yet, because of flight of stairs step impact of part during sintering measure, the surface unpleasantness has considerable and it is to be limited as could really be expected. The surface completion is a particularly significant reaction variable of parts (RP), end parts (RM) and tooling (RT) acquired through added substance innovations. As a matter of fact, two sorts of surfaces are framed at the fabricated part during the SLS interaction. The two sorts of surfaces in 3-D advanced model are appeared in Figure 1. One is characterized as the sintering layer α-surface that is the side countenances amassed through the external surfaces of layers. It is appeared in Figure 1 (a). The other kind isn’t the layer surface however a gathering of the shape of each layer is characterized as form aggregation β-surface as demonstrated in Figure 1 (b).

2.2. Sintering Layer Surface Quality

A few pieces of layer surfaces are uncovered outside without covering through others. The nature of these surfaces is chiefly decided through the sintering cycle. During the cycle, the softened powder will stream to the pores and interface the construction powder. In the wake of chilling off, the leftover pores stay at the surface. The state of the design powder and the re-cementing liquid along the contamination residue will likewise obliterate the levelness of each layer. Fame as the math mean deviation of the deliberate surface profile is the most usually used boundary to depict the normal surface unpleasantness and is characterized as a fundamental of the supreme estimation of the harshness profile estimated over an assessment length. The normal unpleasantness is the all out distance of the pinnacles and the valleys separated through the assessment length and is communicated in μm.
Since this sort of surface is an amassing of the layer form along a fixed thickness, the sintering quality isn't the fundamental factor to impact the harshness of the last part. A mistake known as step case blunder is the primary factor to influence the surface quality. The step case blunder, which unequivocally impacts the surface quality truly, is unavoidable when utilizing the limited layer thickness to cover parts. The estimation of the step case mistake is essentially influenced through the calculation state of the form part, the part direction and the thickness. Three unique strategies are used to evaluate the blunder.

2.3. Experimental plan

Trials are arranged through utilizing Taguchi technique, as it is consider as an incredible asset, when a cycle is influenced through number of boundaries. Montgomery suggests that Taguchi procedure is a helpful strategy for fragmentary factorial analysis in DOE. A standard methodology utilizes the full factorial strategy for trial plan. All things considered, a full factorial is acceptable just when not many boundaries are to be examined. On the off chance that more number of boundaries is there, the full factorial strategy is tedious and costly, as it is the situation along RP. Here lies the significance of Taguchi strategies for the plan of investigations. Taguchi techniques for exploratory plan give a basic, effective and precise methodology called partial factorial strategy for limiting the quantity of all out test runs.

The way of thinking of Taguchi proposes three significant advances in particular framework plan, boundary plan and resilience plan for streamlining an interaction. To limit the surface harshness in SLS measure, the boundary configuration proposed through Taguchi is received in the current work. The OA trial configuration proposed through Taguchi is used to investigate the impact of various interaction boundaries on the trait of value through decreasing the quantity of examinations. It is a significant region for the test research work. The quantity of DOF decides the base number of treatment conditions. As indicated by Taguchi's technique, the all out DOF of the chose OA should be more noteworthy than or equivalent to the absolute DOF needed for the trial. For the current work, the quantity of boundaries along their assignment and the qualities at three levels are depicted in Table 1.

| Table 1. Levels of process parameters for experiments. |
|--------------------------------------------------------|
| Parameter (i) | Designation | Unit | Level 1 | Level 2 | Level 3 |
|---------------|-------------|------|---------|---------|---------|
| Laser Power   | P           | Watts | 58      | 60      | 62      |
| Orientation   | O           | Degree | 0       | 45      | 90      |
| Scan Spacing  | SS          | mm   | 0.08    | 0.09    | 0.10    |

3. Results & discussion

An evaluation of mechanical properties and surface unpleasantness of the parts delivered through projecting in the SLS sand form has been done along the accompanying trials. A factorial test plan along three boundaries and two levels is finished to contemplate the impacts of post preparing boundaries and covering on the SLS form for the mechanical properties and surface unpleasantness of projecting parts. For this investigation, the quantity of boundaries along their assignment and their qualities at two levels are portrayed in figure 2.
The all out DOF of the examination is the summation of individual boundary's DOF and DOF because of cooperation impact between the boundaries. In this investigation, every boundary has 1(number of levels-1) DOF and the DOF for the 3 individual boundaries gets 3(1+1+1). The association between the boundaries isn’t considered in this investigation. Thus, the complete number of DOF is 3 and L8 symmetrical exhibit (which has eight exploratory runs, seven DOF) is picked in this examination. Henceforth, the all out number of test runs ought to be more prominent than the complete DOF of the examination. The relegated boundaries, their degrees of L8 OA, the estimations of estimated surface unpleasantness and mechanical properties for each examination are appeared in figure 3.

**Figure 2.** Process Parameter & Levels.

**Figure 3.** Experimental Results of L8 OA.
The mechanical properties of the giving parts such a role as hardness and rigidity are the significant factors to choose the shape interaction boundaries and their levels in SLS measure. There are numerous boundaries, for example, laser power, examine speed, incubating and powder size, and so on which effectly affect part quality and properties. Nonetheless, these boundaries are outside the extent of the examination and are kept consistent during every one of the analyses in this investigation. The analyses are led utilizing the L8 OA and the aftereffects of the reaction factors are appeared in figure 4 for the RC innovation. The microstructures of the four chose shape tests have been investigated through utilizing SEM. Presently, the mean and S/N proportion estimations of elasticity, hardness and harshness got at each degree of interaction boundaries are appeared in figure 5.

![Figure 4. Mean Value of Each Parameter at Each Level for Tensile Strength.](image-url)
Figure 5. S/N Ratio of Each Parameter at Each Level for Tensile Strength.

The comparison of the results obtained by this present study and previous studies, it has been shown that a significant improvement of the presentation of the SLS cycle, in comparing with other sintering methods, through methods for controlling distinctive interaction boundaries that influence the quality and mechanical properties, such as hardness and rigidity, of the titanium alloy composite as shown in Table 2.

Table 2. The comparison of the results of the present study and previous studies.

| Type of composite                      | Sintering method          | Features                                                                 | References |
|---------------------------------------|---------------------------|--------------------------------------------------------------------------|------------|
| Ti6Al4V/CoCrMo Composites             | Semi-solid Sintering (SSS)| The densification is achieved by the formation of a liquid phase due to a eutectic point formed by the Ti and Co at around 1130 °C. | [8]        |
| Titanium alloy composite              | field-assisted sintering technology (FAST) | The interdiffusion region between Ti-5553 and TiFeMo particles showed that the effect of graded composition on mechanical properties and formation of a, intermetallic, and γ phases, resulted in a >200 MPa strengthening benefit over unreinforced Ti-5553. | [9]        |
| Graphene-Reinforced Ti-6Al-4V Composites | Spark Plasma Sintering (SPS) | Most of the GNP's were still retained at high pressure and temperature, and a new phase of TiC was presented due to the in-situ reaction between TiC and GNP's. Also, the strength of the composites was depended on the concentration of GNP's in TC4 matrix. | [10]       |
| Titanium alloy composite              | Selective Laser Sintering (SLS) | A significant improvement of the presentation of the SLS cycle through methods for controlling distinctive interaction boundaries that influence the quality and mechanical properties of the titanium alloy composite. | Present study |

4. Conclusion & future work

The primary point of this examination work is to improve the presentation of the SLS cycle through methods for controlling distinctive interaction boundaries that influence the quality and mechanical properties of the last part delivered. In future, more profound investigation is needed to recognize the impact of various cycle boundaries for various reaction factors. Specifically, the material properties affect the subsequent properties of the sintered part. Subsequently, significant material boundaries, for example, molecule size, shapes, the substance extent of the fastener and construction material, and so on ought to be upgraded together along the cycle boundaries concentrated in this exploration. In the current examination, just two levels are used to consider the surface harshness and strength of sand form projecting parts. Be that as it may, more levels ought to be considered to improve and check the created strategies for future work.

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