Optimization of EDM Electrode by Direct Metal Laser Sintering (DMLS) method for SS316L Material

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Abstract: EDM is one of the methods used in processing. It is a process in which the eroded material starts from the piece with the aid of a series of sparks to obtain the desired shape. It is useful for processing hard metals. The work done by several researchers helps in producing EDM electrodes through SLS, as a different method to conventional processing techniques, and to assess the action of electrodes produced with the technique. Due to this reason, experimental research is carried by SLS out on electrodes made from brass, copper alloy and nickel alloy of bronze and nickel, and steel alloy disintegration of a solid substance. EDM recital is evaluated in terms of material deposition (Vw), which represents the volume of extract from the piece per unit of time (cubic meters per second) and correlative magnitude wear (θ), which shows the relationship between the rate of electrode wear and the rate of material withdrawn. A comparative study between the electrodes produced by SLS and the electrodes made in a conventional manner with respect to SS316L material is made.

Keywords: Selective laser sintering, Direct metal laser sintering, EDM Electrode, SS316L;

1. Introduction

Direct laser sintering of metal is a technique just like selective laser sintering, but is only used in the production of a 3D metal prototype. RP and RM technology is a new technology in which 3D pieces are completed directly from CAD data without usage of any customary tools. Complex parts that cannot be built with the customary process can be created with much shorter delivery time. The different RP techniques, like SLS (Selective Laser Sintering), SLA (stereolithography), 3D preprint, FDM and DMLS capable of producing prototypes of different materials. DMLS implies laser sintering using a metal fine particle, and that blende parts are put together by a direct route during the construction proceeding [5]. Since high thermal energy is required to stimulate sanitation and concretion of material during sintering with an abundantly short period of time, complication such as deformation shall be generated [1]. To refrain such issue affecting the precision of the piece create, some specification must be considered, such as laser power, scanning speed, beam displacement, raster model and work piece inclination. It is noted that Direct Metal Laser Sintering technology not only helps to achieve high precise built parts, but also helps to easily upgrade the blooming and study of micro-reactors [3]. In addition, the machine permits parts of the building manipulate incompatible materials like chrome-cobalt nickel alloy, stainless steel and titanium. It requires management of process specifications to create a better mechanism by sintering the powder to achieve an agile structure in the parts. In Fig 1. Below is a simplified diagram of the Direct Metal Laser Sintering. For establishment of any part, the machine enacts the ensuing steps. The building and distributor platform drops one layer thick so that recovery blade can move without collisions. When the corrector is positioned in the correct position, the distributor scaffold rises to provide some amount of powder for the next layer. Thus, the recoil shifts from sideling position, through this process the metallic dust extends from the dispenser to the construction field and the remaining metal dust falls into a manifold [2]. Thereafter the scanning tip moves the laser beam through a 2D section and turns it on and off precisely throughout the exposure of the assigned areas. The blotting up of energy by the metallic dust will initiate the polymerization and the sintering of the already ossify sector. This process continues layer by layer up to the time of completion of all parts of a craft. In this way, within a few hours, the machine can manufacture 3D segments with great entanglement and precision. Moreover, throughout
the construction process, the mould parts can achieve roughly final patrimony, but depends on the requisition of the metal being machined, can be completed with a post-treatment treatment, such as hardening or surface treatment.

Fig 1: Direct Metal Laser Sintering process

2. Literature review
To understand previous works reported in the literatures, so as to adopt established methods to set a foundation for the present work. To have an insight into the production of EDM electrodes via SLS as an alternative technique to conventional machining processes[1]. To develop intricate shaped EDM tool by SLS technique which is not possible by conventional machining process.

3. Experimental details

3.1 MATERIAL SELECTION
The material selected for manufacturing of EDM electrode is Stainless steel 316L. Copper is the most widely used EDM electrode material due to the attractive properties like high patrimony and high mechanical strength. The major problem is that copper is difficult to laser sinter due to its high reflectivity. Copper is having high reflectivity of 0.99 to laser light of wavelength 10.6 μm. Because of which copper alloys or materials that give similar results copper is used as non-convectional electrode

3.2 Direct Metal Laser Sintering Machine (DMLS) Work
Laser sintering was done in Intech DMLS, Bangalore, with the EOSINT M 280 Xtended DMLS machine. The machine includes an ytterbium fiber laser power (Yb) of 400 W and a radius diameter of 0.4 mm. In the construction chamber, there is a construction platform through which a dust delivery platform and a recovery blade are used to spray dust in to the construction platform. The 3D CAD
model of a 10 mm diameter and 25 mm length sample for the DMLS process is modeled using the "Magics RP" software. The CAD model in STL format will be divided by the "EOS RP Tools" software. The thickness of the layer must be kept at a constant of 0.06 mm. The segmented data is uprooting to the proceeding computer of the DMLS machine where the laser path is initiated with the PSW software. A base plate of the required size of 250 mm X 250 mm X 22 mm in steel is mounted on the building platform with four screws and the base plate is leveled with a 10 μm resolution comparator with respect to the coated sheet.

3.3 Electrical Discharge Machining (EDM) Work

The machine used for the work is V3525 a 500 X 300 Series Spark Erosion type die sinking EDM machine.

3.4 Experimental Details

The hypothesis test was conducted on the V3525 precision electric discharge machine, which consists of a working plane, a servo control system and a dielectric power supply system. For the experimentation the current position was varied from 5 A to 20 A, 9 timed power areas, 9 pulse duration position and a 50-75-micron spark. Grade 30 EDM oil is used as a dielectric fluid and tests have been accomplished for a peculiar set of input variables. The number of hypothesis tests and input levels are decided based on the experiment design and input variables and their stages presented in Table 1. MRR and TWR are calculated using precision digital balancing of 1 mg and the processing time with the digital clock with precision 1 thousandth of a second and the roughness of the surface is measured using a machine that measures the roughness of the surface for a sampling length of 5 mm.

| Input Parameters | Current (amp) | Pulse on Time (μs) | Pulse off Time (μs) |
|------------------|--------------|--------------------|--------------------|
| Symbol           | A            | B                  | C                  |
| Level 1          | 10           | 5                  | 4                  |
| Level 2          | 15           | 6                  | 5                  |
| Level 3          | 20           | 7                  | 6                  |

4. Results and Discussions

OPTIMIZATION USING TAGUCHI METHOD

The S / N ratios for MRR are premeditated as indicated in equation 1. The Taguchi method is pre-owned for the investigation of the result for the response of the processing parameter for wider and better criteria. The bigger, the better: $S / N$ ratio = -$10 \log (1 / n \sum_{i=1}^{n} y_i)$. . . . . . . . . . (1)

When the S / N ratios can be purposive from the discern values, yi, which constitute the empirically discern value of dissection i and n = 1 is the frequent number of each appraisal in L-9 OA that is performed.

The scrutiny of the variance for the consideration is determined by the Minitab software and the results are shown below and the table of answers is shown below.
### Table 2: Signal to noise ratio table

| SI NO. | I (Amps) | Pulse ON | Pulse OFF | MRR(g/min) | EWR(g/min) × $\left[10\right]^3$ | Ra(µm) | S/N Ratio |
|--------|----------|----------|-----------|------------|---------------------------------|---------|-----------|
| 1      | 10       | 5        | 4         | 0.0268    | 0.514                           | 10.47   | -15.6382  | 3.6702     |
| 2      | 10       | 6        | 5         | 0.0285    | 0.596                           | 11.09   | -16.14    | 3.9048     |
| 3      | 10       | 7        | 6         | 0.0281    | 0.519                           | 12.3    | -17.0346  | 4.2823     |
| 4      | 15       | 5        | 4         | 0.0424    | 0.785                           | 13.4    | -17.7858  | 4.7424     |
| 5      | 15       | 6        | 5         | 0.0455    | 0.839                           | 14.49   | -18.4647  | 5.1248     |
| 6      | 15       | 7        | 6         | 0.0397    | 1.071                           | 15.04   | -18.7957  | 5.3835     |
| 7      | 20       | 5        | 4         | 0.0825    | 1.449                           | 15.7    | -19.1837  | 5.7438     |
| 8      | 20       | 6        | 5         | 0.0811    | 1.698                           | 16.12   | -19.4241  | 5.9663     |
| 9      | 20       | 7        | 6         | 0.0803    | 2.565                           | 15.82   | -19.3257  | 6.1551     |

### Table 3: Analysis of Variance of MRR

| Source      | DF | Seq SS  | Contribution | Adj SS | Adj MS | F-value | P-value |
|-------------|----|---------|--------------|--------|--------|---------|---------|
| Regression  | 3  | 15.0605 | 93.85%       | 15.0605| 5.0202 | 25.45   | 0.002   |
| Amps        | 1  | 13.8647 | 86.40%       | 13.8647| 13.8647| 70.28   | 0       |
| Pulse on    | 1  | 1.0824  | 6.74%        | 1.0824 | 1.0824 | 5.49    | 0.066   |
| Pulse off   | 1  | 0.1134  | 0.71%        | 0.1134 | 0.1134 | 0.58    | 0.482   |
| Error       | 5  | 0.9864  | 6.15%        | 0.9864 | 0.1973 |         |         |

### Table 4: Response for Mean

| Level | Amps | Pulse on | Pulse off |
|-------|------|----------|-----------|
| 1     | 31.12| 26.85    | 27.09     |
| 2     | 27.45| 26.52    | 26.75     |
| 3     | 21.8 | 26.99    | 26.51     |
| Delta | 9.32 | 0.46     | 0.58      |
| Rank  | 1    | 3        | 2         |
5. Conclusions

It is determined that current is the vital factor between the different process parameters involved in the EDM process and the contribution is high in both cases. Based on hypothesis testing, the following conjecture are furnished: With the increase in current, the value of MRR and EWR is cautiously expanding. To have a favourable condition, i.e. an increase in MRR and a decrease in EWR, it is necessary to select a nominal current and also the roughness of the surface increases. With magnifying current and to maintain a moderate finish superficial together with a moderate TWR and MRR.

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