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Estimation of Electrical Conductivity of ABS and PLA Based EDM Electrode Fabricated By Using FDM 3D-Printing Process

L. Mahipal Reddy
Department of Mechanical Engineering
University College of Engineering (A)
Osmania University
Hyderabad (T.S.) [INDIA]
Email: l.mahipal@gmail.com

L. Siva Rama Krishna
Department of Mechanical Engineering
University College of Engineering (A)
Osmania University
Hyderabad (T.S.) [INDIA]
Email: lsrkou@gmail.com

S. Sharath Kumar
Department of Mechanical Engineering
University College of Engineering (Autonomous)
Osmania University
Hyderabad (T.S.) [INDIA]
Email: sankasharath@gmail.com

P. Ravinder Reddy
Department of Mechanical Engineering
Chaitanya Bharathi Institute of Technology,
Hyderabad (T.S.) [INDIA]
Email: reddy.prr@gmail.com

ABSTRACT

3D printing is a latest technology to make complex 3D objects by adding one layer over another layer. Fused Deposition Modelling popularly known as FDM is one of the important 3D printing technologies that is used for various applications like developing medical prototypes, prototype of Biological Implants, as well as master patterns for other engineering manufacturing processes and tools. In this paper an attempt has been made to estimate the Electrical Conductivity of ABS and PLA Based EDM Electrode fabricated by using FDM 3D printing process. ABS and PLA are the most popular materials used in FDM process. For using these electrodes in EDM process it is required to have electrical conductivity. In this work these electrodes are coated using electroless coating process. By chemical deposition techniques the conductive material is deposited on both PLA and ABS Material, which are placed in acidic bath for 48 hours. A comparison is made between these two electrodes in terms of resistance and conductivity. The result shows PLA Material has more conductive when compared to ABS Material.

Keywords: *— FDM, EDM, Conductivity, 3D printing*

I. INTRODUCTION

EDM is an Electro-Discharge Machining process, is one of the most widely used

Electro-Thermal Non- Traditional material removal process where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of spark. The tool and workpiece material should be electrically conductive in order to machine on EDM. EDM is used to machine complex shape and harder materials. There is no direct contact between the electrode and workpiece, so EDM eliminates the mechanical stresses developed during machining process. For utilizing the non-stressed machining feature we used 3D Printing Fused Deposition Modeling process to manufacture the electrode.

3D printing, also known as additive manufacturing (AM), refers to processes used to synthesize a three- dimensional object in which successive layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model. 3D Printing is a latest technology to make a complex 3D objects by adding one layer over another layer. Fused Deposition Modeling popularly known as FDM is one of the important 3D printing technology that is used for various applications. The basic material used to fabricate EDM electrode by FDM process are PolyLactic Acid (PLA) and Acrylonitrile Butadiene and Styrene (ABS) which has the melting temperatures below 220oC. The fabricated Electrodes are coated by Electro less process to achieve electrical conductivity. Electro less preliminary process undergoes four different stages i.e. are Cleaning, Etching, Neutralization and Acceleration are surface preparation processes. After the surface preparation these samples are dipped into an acidic baths which consists of CuSo4, HF and Distilled water for various time periods (24hr, 48hr and 72hrs). Then parts are removed and resistance values are noted at 10 different locations. By using these technologies the cost of production is reduced. The resistance values are tabulated and conductance is calculated.

II. LITERATURE REVIEW

Azhar Equbal [1] explains the Metallization of ABS (acrylonitrile-butadiene-styrene) parts has been studied on flat part surfaces. Cu deposition under different acidic baths used for both the routes is presented and compared based on their electrical performance, scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS). The result shows that chromic acid etched samples show better electrical performance and Cu deposition in comparison to samples etched via H2SO4/ H2O2. Fefar Savan D.et.al [2] explained the conventional methods of electrode manufacturing are not competent with the emerging demands of complex structures and shorter lead time. Fused Deposition Modeling (FDM) process of rapid prototyping is employed to develop the electrode for electro discharge machining. The ABS electrode produced by FDM process was metallized by electro less copper coating to make the RP-electrode conductive. Experimental work and analysis are carried out to investigate the feasibility of RP-electrode for EDM. Emanuel Sachs et.al [3] presents progress updates in four areas; i) thermal management using conformal cooling and related work on enhanced heat transfer using surface textures, ii) data on dimensional control, iii) improvements in surface finish, and iv) harder tooling. Significant improvements in surface finish were obtained using improved printing technology. Brent E. Stucker et al. [4] explained the production of electrical discharge machining electrodes using SLS: Preliminary results has been obtained by understanding how polymer coating thickness and uniformity on the powders, sintering variables in the SLS machine, and subsequent thermal sintering and infiltration affect dimensional control, surface finish, and electrode properties will be helpful not only in producing EDM electrodes with properties superior to today's standards, but will be generally useful information to further develop the rapid prototyping of metal and ceramic powders using SLS. John Kechagias.et.al [5] expressed rapid tooling is a new technology which uses rapid prototyping models to reduce the time and cost of tool manufacture. The various methods of manufacturing RT electrodes, with respect to different materials and the incorporated supplementary processes are classified.

III. PROBLEM DEFINITION

The Ultimate goal of any firm is to reduce manufacturing time and cost. Tool manufacturing is one of the major areas where the cost and lead time will increase with increasing complexity of tool shape and accuracy required. In this paper we prepared a electrical conductive electrode by electroless coating of non-conductive ABS and PLA based materials. In order to reduce the cost of manufacturing we opted for 3D printing Fused Deposition Modeling process.

IV. RESEARCH METHODOLOGY

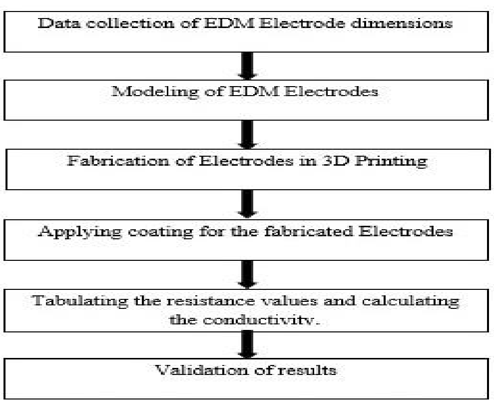


Figure 1: Flowchart of research methodology

4.1 Data collection

The dimensions of the tool in this work are of length 60mm and diameter of 15mm.

4.2 Modelling

Figure 2 illustrates the EDM electrode modelled using Creo Parametric design software as per the dimensions. The file is then converted into SterioLithography (.stl) format.

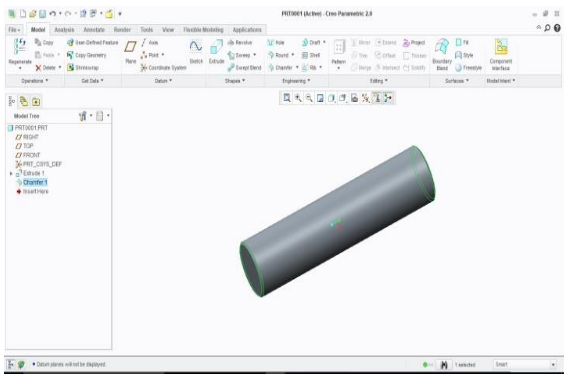


Figure 2: Modelling of EDM Electrode

4.3 Fabrication

The fabrication of the EDM electrode is done by using Flash forge Fused Deposition Modeling with the help of flash print software.

Flash print: It provides simple and easy to use interface for preparing your 3D Designs for printing on Flash forge printers. This software is most widely used software for Fused Deposition Modeling (FDM) 3D printing.

Step 1: Import the STL file in to flash print software.

Step 2: Since it is in exact position on the build platform, reducing of scaling is not required, click on the print show a popup message which contains print data settings

Step 3: The infill material is given as 30%. And 100%.

Step 4: Printing the component. The estimate time taken for printing and material consumed will be displayed at the top right side of the screen.

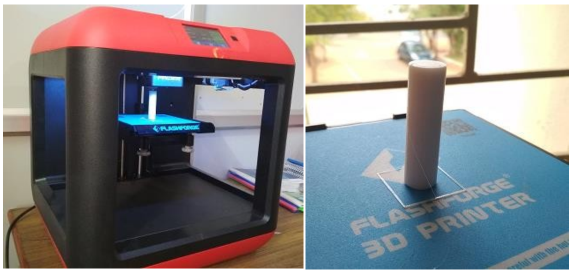


Figure 3: Fabrication of EDM Electrode on FDM

4.4 Applying coatings

Various researchers have found that electroless plating can be efficiently done on plastic surfaces if a proper etchant solution is used prior to the platting process.

Before undergoing for electroless plating few steps has to be followed:

Step 1; Cleaning: The Poly Lattice Acid (PLA) and Acrylonitrile-butadiene-styrene (ABS) was first cleaned with the sand paper to remove the dirt, oil, grease etc., also to develop micro-roughness for increasing the surface area.

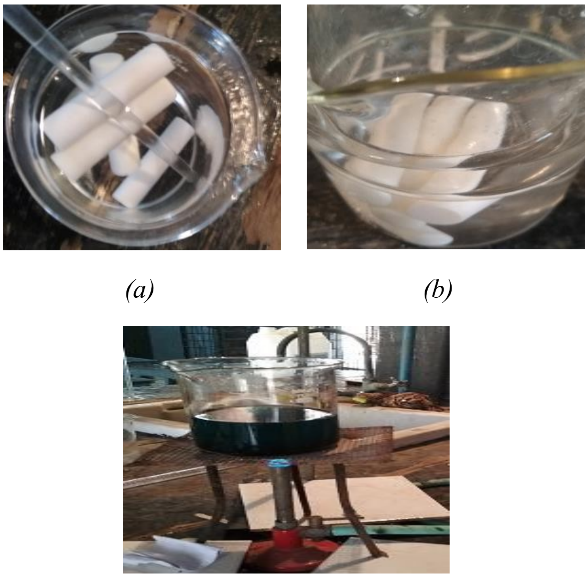
Step 2; Etching: In this step, the pre-cleaned PLA and ABS parts dipped in an aqueous solution consists of Sulfuric acid (H_2SO_4), Hydrogen peroxide (H_2O_2) and deionized water. The solution was prepared by adding hydrogen peroxide a sulfuric acid slowly into stirring deionized water. The PLA and ABS sample was immersed in the bath for 10-15min. The samples were taken out and washed 2-3 times carefully.

Step 3; Neutralization: The PLA and ABS parts were dipped in the solution of 10g/l of Sodium sulfite at 25°C for about 2mins and, finally washed carefully with water.

Step 4; Activation: The solution contains a mixture of Sodium Hydroxide (NaOH), Copper Sulphate ($CuSO_4$) and ethylene diamine tetra acetic acid disodium ($EDTANa_2$). This was done at 55° C about 7mins. The samples were finally washed with water and then dipped in the acidic bath.

The bath containing 5%wt. $CuSO_4$ and 15% wt. of HF (Hydro fluoric acid) were prepared. The Electroless copper deposition is obtained by immersing the component for particular duration of time.

Electrical performance Measurement: A digital multi-meter was used to measure the resistance of the metalized PLA and ABS parts at different points on the surface.



(a) *(b)*

(c)

Figure 4: (a) Etching process of both PLA and ABS parts, (b) Neutralization of PLA and ABS, (c) Acceleration process

4.5. Equations

Conductance (G) is inversely proportional to resistance (R): **G =1/R**

Conductivity (σ) = **GL/A**

Where, L = length of electrode, A=area of electrode.

V. Results and Discussion

Electrical performance of Electroless coated ABS Electrode:

Table-1 shows the electrical performance of the samples whose surfaces were prepared and coated with two different chemical compositions. These readings are taken by DMM at room temperature after 24hrs and 48hrs of deposition time. For both individual baths, the best conductivity is obtained with the 100% fill material in concentric bath after 48hrs of deposition time.

Electrical performance of Electroless coated PLA Electrode:

Table-2 shows the electrical performance of the samples whose surfaces were prepared and coated with two different chemical compositions. These readings are taken by DMM at room temperature after 24hrs and 48hrs of deposition time. For both individual baths, the best conductivity is obtained with 100% fill material in concentric bath after 48hrs of deposition time.

Table 1: Electrical Performance of ABS Sample with Different Infill Material

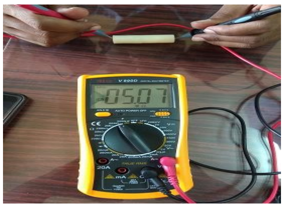
S.No	Infill Percentage	Bath type	Deposition time in hours	Resistance($\bar{R}$) in MΩ	Conductivity (σ) in mho
1	30	Concentric	24	5.947	0.057
2	30	Concentric	48	4.872	0.069
3	30	Diluted	24	5.877	0.057
4	30	Diluted	48	4.745	0.071
5	100	Concentric	24	2.098	0.161
6	100	Concentric	48	1.931	0.175
7	100	Diluted	24	3.015	0.112
8	100	Diluted	48	2.812	0.120

Table-2: Electrical performance of PLA sample with different infill material

S.No	Infill Percentage	Bath type	Deposition time n hours	Resistance($\bar{R}$) in MΩ	Conductivity(σ) in mho
1	30	Concentric	24	0.534	0.636
2	30	Concentric	48	0.472	0.719
3	30	Diluted	24	0.624	0.544
4	30	Diluted	48	0.574	0.591
5	100	Concentric	24	0.486	0.698
6	100	Concentric	48	0.359	0.946
7	100	Diluted	24	0.514	0.660
8	100	Diluted	48	0.456	0.774

(a)

(b)



(c)

Figure 5: (a) Concentrated acidic bath with PLA and ABS, (b) Diluted acidic bath with PLA and ABS, (c) DMM Readings

Note: where as Diluted means 20gm $CuSO_4$, 60gm HF and 200ml Deionized water, Concentrated means 100gm $CuSO_4$ and 300gm HF.

VI. CONCLUSIONS

The parts fabricated on the Fused Deposition Modeling are non conductive materials which are converted to conductive materials by electroless coating process. In the coating process we have conducted experiment by taking two different chemical compositions i.e. Diluted solution (20gm $CuSo_4$, 60gm HF and 200ml Deionized water) and Concentrated solution (100gm $CuSo_4$ and 300gm HF). After surface preparation using these two samples, Cu is deposited electrolessly using two different chemical compositions in different durations.

A better Conductivity of EDM electrode is observed in the 100% fill material which is immersed for 48hrs in concentric bath than compared to other fill materials, chemical composition and deposition duration. It is also important to state that a varying amount of conductivity was obtained for different chemical compositions used. The reason for the varying conductivity is due to different infill material and non uniform distribution of Cu over the electrode surface. It is observed that electrical conductivity of PLA with 100% fill is found to be 0.946mho when compared with ABS. Furthermore an important observation is that the conductivity improves with the deposition time.

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