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A Review on to Study the Performance of Fused Deposition Modelling Electrode for EDM Process with EN8 Material

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***Abstract*: Electro discharge machining (EDM) is a non-traditional machining process which is used for manufacturing of complex and hard material parts that are difficult to machine by traditional machining methods. Due to enhancement in material science there is a need to find out alternative machining processes like EDM. During this process the electrode shape is mirrored on the work piece, and hence manufacturing of electrode having complex shape becomes crucial. There is a need to find out alternative electrode manufacturing method which can be reusable also. There is a high demand for complex shapes, high accuracy and shorter time to market by the industries in today's competitive environment.**

Conventionally the electrodes are manufactured using regular subtractive methods. Rapid prototyping is an innovating additive technology for creating functional prototypes and physical models directly from CAD model. Rapid Tooling is a process which uses a Rapid Prototyping (RP) process directly to fabricate a tool and to overcome the shortcomings of subtractive electrode manufacturing. Out of various additive manufacturing processes Fused deposition modelling method is selected. Where, ABS electrode is manufactured and followed by electroless copper coating to make the electrode conductive. This approach offers both designers and manufacturers the advantages of time compression and cost reduction. Time saving is of vital significance in production of EDM electrode for the fabrication of moulds and dies. The performance of FDM electrode is compared with conventional in term of, Surface Roughness (Ra), Tool Wear Rate (TWR), Material Removal Rate (MRR) by using input parameters such as discharge Current, Spark On time, Spark Off time. Regression and ANOVA is used for data analysis and validation is done by using Artificial Neural Network.

***Keywords*: EDM, FDM, Rapid Prototyping, Artificial Neural Network.**

1. Introduction

Rapid prototyping (RP) is an innovating additive technology for creating functional prototypes and physical models directly from CAD model. Rapid Tooling (RT) is typically used to describe a process which uses a Rapid Prototyping (RP) process directly to fabricate a tool. Since tool manufacturing is critical task in EDM where the required precision and cost associated with the production is very high so the efforts have been made to produce variety of rapid tooling techniques in order to meet the needs of today's era. Rapid Prototyping and Tooling helps to reduce production time and increase efficiency and accuracy in developing manufacturing prototypes compared to traditional manufacturing which helps the organizations to save time and money [18].

In this study, attempts have been made to produce an electrode using Additive manufacturing for Electro discharge machining (EDM). Here ABS electrode is manufactured and followed by electroless copper coating to make the RP electrode conductive. Applying a thin coating of copper to prototyped parts by electroless metallization has provided direct method for making it conductive so that it can be used as an electrode for EDM.

Fused deposition modelling (FDM) process of rapid prototyping is employed to develop the electrode for electro-discharge machining (EDM). This approach offers both designers and manufacturers attractive advantages of time compression and cost reduction. EDM process is mainly used for the fabrication of moulds and dies or for generating complex shapes on hard materials which are difficult to manufacture with traditional methods [2]. The performance of these new type of electrode will be compared with the conventional electrode in terms of Surface Roughness (Ra), Tool Wear Rate (TWR), Material Removal Rate (MRR) by using input parameters such as discharge Current, Spark On and Off Time [9].

2. Literature review

A. Part I: Papers related to fused deposition modelling

P. Chennakesava and Y. Shivraj Narayan [11] had published a paper in Dec. 14 on Fused Deposition Modelling - Insights, states that Rapid-Prototyping (RP) is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional Computer Aided Design (CAD) data. Additive manufacturing processes are used because these processes do not require special tooling and do not remove excess material from blank which helps in material saving.

This paper lays emphasis on the working process of the FDM

and various parameters involved in it and their effects on physical properties like Dimensional accuracy, surface roughness, strength of the components made through the process. The study showed that the parameters like orientation, layer thickness, bond formation and the infill and temperature profile are the primary parameters that directly affect the quality of the part. Also some of the methodologies like adaptive slicing, machining, and chemical processing are discussed for the minimization of the problem.

Deepa yagnik [12], 2014 investigated Fused Deposition Modeling – A Rapid Prototyping technique for Product Cycle Time Reduction cost effectively in Aerospace Applications. RP has evolved from producing prototypes for form, fit and functional testing to producing final end products for functional use. FDM can produce difficult geometrical part in cost effective manner. It can be used as a pilot product to confirm performance prior to implementation.

This Paper Focus on Fused Deposition Modelling (FDM) Technique, Use of FDM for Aerospace applications with a case study of Aeronautics Engineering depicting FDM as sole way for product cycle time reduction cost effectively. (Courtesy DRDO & Stratasys). FDM is additive manufacturing method mainly used in the medical, technology, automotive, military, aerospace, consumer goods, toy, and architecture fields because of its capability to build products in durable ABS plastic. The inexpensive and rapid development of FDM prototypes greatly reduces design-to-production time and allows for much higher return on investment (ROI).

Fawaz Alabdullah [8], investigated Fused Deposition Modeling (FDM) Mechanism. This research explains the foundation, mechanism and the economy efficiency of Fused Deposition Modeling (FDM). It also covers the parameters which affect the performance of this process.

Mercedes Pérez, Gustavo Medina-Sánchez ID, Alberto García-Collado, Munish Gupta and Diego Carou[1], analised "Surface Quality Enhancement of Fused Deposition Modeling (FDM) Printed Samples Based on the Selection of Critical Printing Parameters", Aug 2018, shows an experimental study on additive manufacturing for obtaining samples of polylactic acid (PLA). Surface quality of products made by additive manufacturing processes has given less attention by the researchers. So, this paper aims to focus on that area. The goal of the study is the recognition of critical factors in FDM processes for reducing surface roughness. Two different types of experiments were carried out to analyse five printing parameters. This research found that layer height and wall thickness are the most important factors affecting surface roughness, while printing path, speed and temperature have no influence on surface roughness.

B. Part II: Papers related to EDM optimization

Vaibhav Gaikwad, VijayKumar S. Jatti [10], have done Optimization of material removal rate during electrical discharge machining of cryo-treated NiTi alloys using Taguchi's method. NiTi alloy is advanced material which has unique properties such as biocompatibility, high strength, high corrosion resistance, shape memory effect etc. Due to such property these alloys have wide application in the field of defense, aerospace, and medicine. As these applications required high accuracy, precision and high strength of NiTi these are difficult to machine by conventional machining processes. This study focuses on optimization of electric discharge machining process parameter for maximization of material removal rate while machining of NiTi alloy. Here gap current, pulse on time, pulse off time, workpiece electrical conductivity, and tool conductivity were considered as process variables. Experiments were carried out as per Taguchi's L36 orthogonal array and it was found that work electrical conductivity, gap current and pulse on time are the significant parameters that affect the material removal rate. The optimized material removal rate obtained was 7.0806 mm3/min based on optimal setting of input parameter.

M. A. Razak, A. M. Abdul-Rani, Rao, Pedapati, Kamal [9], have investigated Electrical Discharge Machining on Biodegradable AZ31 Magnesium Alloy using Taguchi method. Magnesium alloy is used for biodegradable implant application. Electrical discharge machining (EDM) die sinking process is used to produce intricate shape with tight tolerance on magnesium alloy. It was found that pulse on-time was the most significant parameter affecting the surface roughness (Ra) of the machined surface. The optimum EDM input obtained was 47 A peak current, 80 V voltage, 16 µs pulse on-time and 512 µs pulse off-time. A confirmation test was conducted and the result shows 95.5% similarity with the predicted Ra. However, the formation of cracks and craters were found on the machined surface area. It is proposed to solve this problem by applying powder mixed EDM method in future research work.

Shailesh S. Shirguppikar, Uday Dabade [3], have done Experimental Investigation of Dry Electric Discharge Machining (Dry EDM) Process on Bright Mild Steel. Dry EDM is an environment-friendly modification of the oil based EDM process. In this work, a unit has been developed to implement dry EDM process on existing oil based EDM machine. All experiments are performed on bright mild steel with the help of hollow copper electrode. Response variables analysed are material removal rate, tool wear rate and surface roughness using process parameters such as current, pulse on time and oxygen gas pressure. The statistical analysis of results show that current and pulse on time significantly influence MRR and TWR.

Vikas, Apurba Kumar Roy, Kaushik Kumar [13], investigated the effects and did the optimization of various machine process parameters on the surface roughness in EDM for an EN41 material using Grey-Taguchi. This research was focused on different types of surface roughnesses. They presented an idea about the effect of the various input process parameters like Pulse ON time, Pulse OFF time, Discharge Current and Voltage over the Surface Roughness for an EN41 material. Here, 5 different output parameters concerned with

surface roughness like Ra, Rq, Rsk, Rku and Rsm are taken and optimized accordingly, using the Grey-Taguchi method. It was found that the Current had larger impact over the Surface Roughness value, followed by the Voltage. The experimental results thus, obtained were compared with the theoretical results and they were found very close to one another. The effect of the other parameters was significantly less and can be ignored.

N. Radhika, A. R. Sudhamshu, G. Kishore Chandran [14], have done optimization of electrical discharge machining parameters of aluminium hybrid composites using taguchi method. Metal matrix composites utilize the combined properties of the constituent material that finds applications in various fields. This experiment investigates the influence of peak current, flushing pressure and pulse-on time on Electrical Discharge Machining of AlSi10Mg alloy reinforced with 3wt% graphite and 9wt% alumina hybrid metal matrix composites. For material removal rate, the major parameter was flushing pressure followed by peak current and pulse on time. The most significant parameter of tool wear rate was pulse on time followed by peak current and flushing pressure. And peak current is the most dominant factor in influencing surface roughness.

Vikas Gohil, Y. M. Puri [7], have done Optimization of Electrical Discharge Turning Process using Taguchi-Grey Relational Approach. Electrical discharge turning (EDT) is specially developed to generate cylindrical forms and helical profiles on difficult to machine materials at both macro and micro levels. In EDT process a precise spindle is incorporated with conventional die-sinking EDM machine to rotate the workpiece. This study presents an experimental investigation of electrical discharge turning of titanium Ti-6Al-4V alloy. The objective was to investigate the influence of machining parameters including peak current, pulse-on time, gap voltage, spindle speed and flushing pressure on performance characteristics at reverse polarity. Among input parameters, voltage and FP have been found to be the most influencing parameter for output performance parameters i. e. material removal rate and surface roughness.

Mohan Kumar Pradhan, Chandan Kumar Biswas [16], Used Response Surface Methodology to investigate Machining Parameters for MRR in EDM. Experiments are conducted on AISI D2 tool steel with copper electrode and three process variables as discharge current, pulse duration, and pulse off time. It was found that discharge current, pulse duration, and pulse off time have significant effect on the MRR.

C. Part III: General papers

Fred L. Amorim & Armin Lohrengel & Norbert Müller [15], has carried out experiments on sinking EDM electrodes made by selective laser sintering technique. The production of geometrically complex EDM electrodes is difficult, time consuming, and it can account for about 50 % of the total process costs. Selective laser sintering (SLS) is an alternative technique used to produce EDM electrodes in a faster way. This work conducted an experimental study on the performance of EDM electrodes made by SLS using pure copper, bronze–nickel alloy, copper/bronze–nickel alloy, and steel alloy powders. Important EDM performance measures such as material removal rate and volumetric relative wear were investigated and discussed for finishing, semi finish, and roughing regimes. The bronze nickel powder electrode showed best results whereas SLS copper electrode showed the worst.

Yucheng Ding, Hongbo Lan, Jun Hong, Dianliang Wu [17], investigated an integrated manufacturing system for rapid tooling based on rapid prototyping to reduce the time and cost of moulds fabrication, a novel integrated developing and manufacturing system of rapid tooling (RT) based on rapid prototyping (RP) is proposed. The architecture of system consists of four building blocks: digital prototype, virtual prototype (VP), physical prototype and RT system, is presented. A digital prototype can be established by 3D CAD software packages or reveres engineering technique. A VP is employed to guide in optimization of the mould design and manufacturing process planning. A physical prototype, which is built using RP technology, generally serves as a pattern for producing RT. By integrating these building blocks closely, the system can aid effectively in mould design, analysis, prototyping, simulating, and manufacturing process development. Three typical cases are discussed in detail to illustrate the application of the system. It has been shown from a number of case studies that the system has a high potential to reduce further the cycle and cost of die development while minimizing error introduction. As a result, the integrated system provides a feasible and useful tool for companies to speed up their product development.

Ricky Blom, Prasad KVD and R. M. Iyer [18], investigated and evaluated rapid tooling for electric discharge machining using electroforming and spray metal deposition techniques. Electroforming and spray-metal deposition offer an alternate option to traditional machining of electrodes. Electroforming can be used to produce multiple electrodes simultaneously gives it the advantage of saving on costs when multiple electrodes are needed. Spray-metal deposition offers another alternative that is much cheaper and relatively faster to manufacture. These two methods are compared to the performance of traditional solid electrodes in terms of machining time, material removal rate, tool wear rates and surface roughness at several standard machining settings. Solid electrode performance was better than spray metal electrode but at the same time its cost is also almost six times greater.

S. O. Outh, Y. Y. Yusuf [19], discussed Rapid prototyping technology: applications and benefits for rapid product development. Rapid prototyping technology (RPT) has been implemented in the area of product development. Existing processes provide the capability to rapidly produce a tangible solid part, directly from three dimensional CAD data from a range of materials such as photo curable resin, powders and paper. This paper gives an overview of the growth and trend of the technology, areas of applications and its significant benefits to manufacturing industries.

3. Conclusion

This paper presented an overview on the performance of fused deposition modelling electrode for EDM process with EN8 material.

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