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Effect on crystalline structure of AISI M2 steel using copper electrode through material removal rate, electrode wear rate and surface finish

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ABSTRACT

A detailed investigation on the crystalline structure of AISI M2 steel by using copper alloy electrode in electric discharge machining (EDM) process has been done. Also, material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR) of the steel material on the basis of three variable input process parameters were analyzed followed by analysis of variance (ANOVA), regression analysis and different characterization techniques. In X-ray diffraction (XRD) study, it has been observed that the peak has been broadened and shifted with the formation of new nano crystalline phases. Lowest surface roughness of 1.19 ± 0.9 μm and 9.25 ± 0.5 nm was observed through optical surface profiler (OSP) and atomic force microscopy (AFM), respectively. Higher MRR of 0.015276 mg/min and minimum EWR of 0.014113 mg/min were observed for sample having the same input parameters as current 7 A, pulse on time 45 μs and spark gap of 5 μm.

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1. Introduction

For obtaining sophisticated designs and intricate fine machined components by EDM process, every time various new tool materials like ceramic composites, tungsten based alloys, tool steel and other super alloys (with unique metallurgical properties like hardness, toughness, corrosion resistance and fatigue etc.) have been developed by researchers for machining advanced engineering materials.

A British Scientist named Joseph Priestley first discovered the effect of sparking between two electrical contacts lead to loss of material from both female and male parts in the year 1768 [1]. After the modification of the past in 1943, two Russian scientists B.R. Lazarenko and N.L. Lazarenko developed a controlled process for machining material that was conductive of electricity [2,3]. EDM is a thermal erosion process in which electrically generated spark energy, raised the temperature in the range 8000–12,000 °C [4], melting and vaporization in a very small area of both electrodes tool and work piece take place simultaneously. The spark occurs in narrowest gap filled with dielectric solution between both electrodes. Jeswani [5] had explained that no single property of electrode (tool) can predict its eroded volume, but both physical and thermal properties should be considered to evaluate the volume of erode metal removed accurately furthermore the author found that MRR and EWR depends on different dielectric fluids, it may be in liquid or gaseous form [6]. Generally graphite, copper and copper alloys are used as electrode materials because these materials have high melting temperature, and excellent electrical and thermal conductivity [7]. But these electrode materials had a major problem of low wear resistance which overcome by developing a metal matrix composite (ZrB_2–Cu), (Cu–W), (Cu–Cr) and (Cu–Al) to get an optimum combination of wear resistance, electrical and thermal conductivity [8–11]. The copper–tungsten alloy had been taken as work piece material and investigated on MRR

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and EWR, somewhere else [12]. According to some researchers electrode wear rate was a key factor for influencing the shape accuracy especially in complex 3D cavities [13].

The scientists have keen interest in the novel applications of EDM process since last decade, having particular emphasis on the potential of this process for surface modification [14]. The surface modification of 65 Mn steel (ASTM: 1566) material was investigated when prepared by EDM with silicon electrode due to the formation of an amorphous nano-crystalline alloy layer [15]. Some researchers improved the surface quality of the work piece by adding nano or micro particles (like Al, Cr, Cu, Si, SiC, TiC, WC etc.) in the dielectric fluid; they observed that the effect of additives formed a kind of coating which improved the mechanical properties of work piece materials and also effect on MRR, EWR and SR [16–20]. Always, it is a great challenge for the researchers for obtaining the best optimized results for the selection of paramount process parameters in multi-response situation. There are several methods for creating design of experiments like response surface methodology (RSM), Taguchi's technique, factorial design and mixture design. Further on the basis these designs, a series of machining operations have been done for data collection by varying input parameters. For the analysis of the data collection and selection of the optimal machining parameters the analysis of variance or multiple regression have been proposed in the literature to establish the effect of MRR, EWR and SR of the machined surface by the several scientists [21–27].

In this research paper, authors examined the influence of different input parameters on SR, MRR and EWR of particular tool and work piece materials to produce optimum fine surface quality and tried to understand the changes in crystalline structure of the work piece material prepared by EDM. However, till now there is a very few research has been done on the variable input parameters and their effect to change the material properties. Also, less work has been done on AISI M2 material machined by copper alloy electrode. Therefore, the authors are trying to fulfill this gap by optimizing minimum SR (R_a), higher MRR and EWR with proper combination of input parameters and working condition.

2. Experimentation and methodology

2.1. Experimentation

In this research work, the author tried to optimized best surface finish, higher MRR and lower EWR using in EDM with proper selection of process parameters on selected tool and work piece materials. The experimental work was performed on EDM (die-sinking type) supplied by Massive Engineering Pvt. Ltd, **Model 5030**, with servo head and positive polarity for electrode. Fig. 1 shows a schematic line diagram of the equipment. Commercial grade EDM oil D30 (specific gravity 0.763 and freezing point 940 °C) was used as dielectric fluid. Side flushing technique through jet with pressure 0.3 kg/cm^2 was used to remove the debris produced in the experiment.

2.2. Electrode (Tool) material used

Tool material used in this experiment was a Copper based alloy purchased from local market. The electrode material of cylindrical shape with is having 6 mm diameter and the Brinell hardness (BHN) of 111.35. EDX spectrum analysis for chemical composition of tool material is shown in Fig. 2.

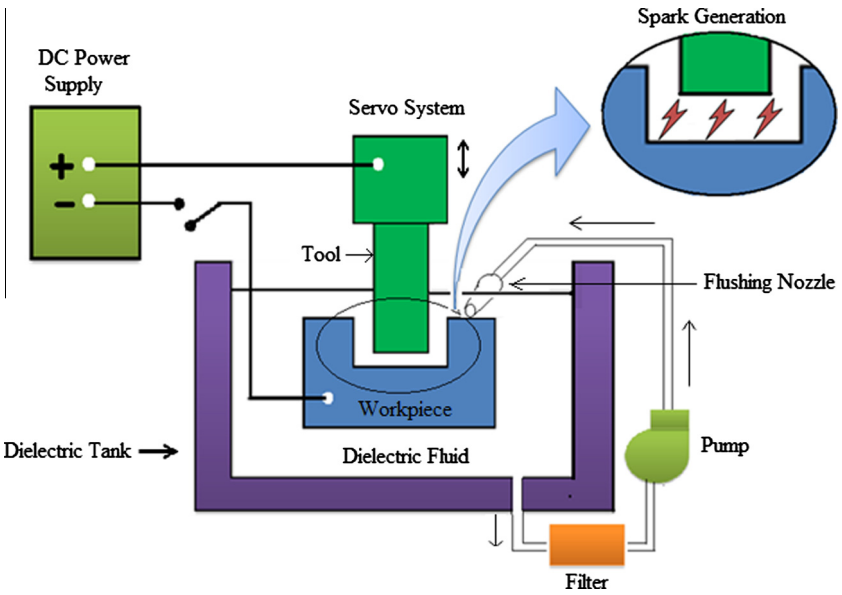

Fig. 1. Schematic diagram of experimental set-up for EDM process.

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