A Review of Optimization- associated examine of Electrical Discharge Machining Aluminum Metal Matrix Composites

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Abstract

Electrical discharge machining is a flattering non-conventional material removal process which uses energy instead of tool to remove materials. This process has capability to machine virtually any electrical conductive and extremely hard metallic materials such as metal matrix composites, aluminum metal matrix composites, duplex steel, nickel, and titanium alloys. These materials are difficult to machine by conventional process because of high cost of tool, rapid tool wear, low materials removal rate which leads to formation of build-up edges, poor surface finish and burr formations. In order to machine these materials by electrical discharge machining, machining performance will be appropriate. Many researchers have suggested a lot of appropriate ways to improved machining of these materials by analyzing the process parameters of electrical discharge machining. These studies show that machining of these materials can be improved by proper selection of process parameters. This article shows the review of experimental and theoretical studies carried out so far in the field of electrical discharge machining. This article also explored the optimization techniques used to determine process parameters for EDMed aluminum metal.

Keywords: Electrical discharge machining (EDM) · Aluminum metal matrix

1 INTRODUCTION

EDM is broadly used non-conventional machining mechanism adapted for material removal of extremely hard metallic materials by the initiation of potential difference between conductive tool material and work piece in the existence of appropriate dielectric medium. Joseph Priestly developed an erosive method using electrical discharge in 1770s, and in 1943, N. I. Lazarenko scientist from Russian developed that a succession of sparks generates between two electrically conductive materials plunged into dielectric medium without any direct contact between them [1]. EDMis a thermal-based machining process in which electrical energy is converted to thermal energy through a bombarding of distinct current materializing between conductive tool and work piece dipped into a dielectric, in the presence of significant potential difference throughout electrodes. There is a small gap between electrode and work piece to provide electrical resistance between the gaps. Due to this small amount of materials melts and vaporized from both electrode and work piece material at the point of spark contact and by products of vaporization resulting a rapidly expansion of bubble. When electric pulse is terminated, heating and spark are paused; this provides vapor bubble collapsed, and the circulating dielectric fluid flushes out microscopic debris from both the electrodes. A brief description about material removal mechanism sequences is presented in Fig. 1. Figure 1a shows the development of strong electric field, when voltage is applied between both electrodes. When voltage reaches its peak point, insulating characteristics of dielectric medium decrease along with the strongest part of the field. As the number of ionic particles increases, current is established and discharge channel is formed as shown in Fig.1b. the vaporization of materials and formation of plasma channel is presented in Fig.1c. After this bubble formation takes place as shown in Fig..1d and when pulse voltage ceases, plasma channel collapses and 3 Optimization-Related Studies of EDMed Aluminum Metal Matrix molten cavities exploded into dielectric fluid as represented in Fig. 1e. At the last, surface cool instantaneously where vaporized and melted materials are flushed away by dielectric fluid [2].

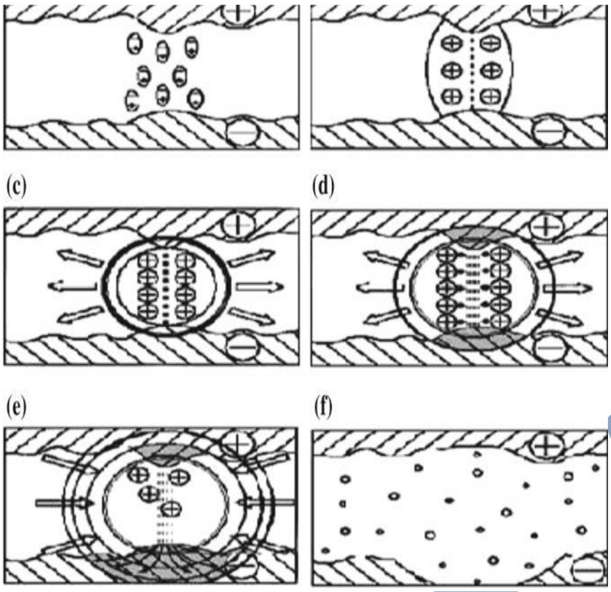

Fig.1 Plasma of EDM Process

1.1 Parameters of Electrical Discharge Machining

The input parameters such as discharge voltage, peak current, electrode gap, polarity, pulse interval (Toff), and pulse duration (Ton) while performance parameters like MRR, TWR, and surface roughness (SR) are used for EDM. Other influences of machining parameters are flushing condition, electrode, and work piece rotation. The amount of power used in EDM represents as peak current, and it is expressed as an increased level of current toward its preset value for every single pulse-on time. The consumed amount of electrical current is supervised on the basis of machined surface area. Higher strength current is used in roughing operations and in cavities or broad surface areas [3]. The time period, on which electrical discharge occurs, is known as pulse-on time or pulse duration. In this time, potential is applied for the machining between the tool and work piece. On the other case, the time interval between two pulses is referred to as pulse-off time. It is the time that allowed molten metal to solidified and flushed out from arc gap portion [4]. The portion between tool and work piece in EDM process is shown as arc gap which is basically utilized for the purpose of spark generation and controlled by EDM servo system [5]. EDM process work piece shows either positive or negative polarity. In the positive scenario, work piece will be on the positive terminal portion and tool on negative on the other side, negative polarity behave inverse to positive one [6]. Work piece rotation technique is used for the proper dielectric fluid circulation and temperature distribution while electrode rotation is performed for exceeds flushing action and spark [7, 8]. The removal of material from machining zone per unit time represents as MRR while TWR is wear rate of tool per unit time. The parameters like current, supply voltage, and pulse-on time are directly influenced the MRR and TWR both while pulse-off-time case is inverse.

1.2 Review on Experimental and Theoretical Studies of EDM

This section shows the experimental and theoretical studies of various EDM parameters such as *T*on, *T*off, dielectric medium, electrode, additive powder for different materials under various circumstances during machining from various researches. Prabhu et al. conducted an experiment on Al-TiB2 using EDM for machining parameters such as *T*on, *T*off, pulse current vibration of tool and flushing pressure. They found that discharge current influenced the MRR and TWR while higher value of current provided higher MRR, on the other hand, increased value of *T*on provided slightly increase in TWR. They also found that white layer and induced stress both got increased with increased value of *T*on while there is a high deviation in white layer thickness for increased pulse current [9]. Kathiresan et al. explored an experiment on AMC prepared by the combination of vortex method and pressure die-casting approach. They used copper as tool electrode for machining using *T*on, *T*off, voltage, and peak current as input parameters. They found that MRR and SR got improved with an increase in peak current; on the other hand, MRR got decreased with the increase in vol.% of SiC. Further, they also revealed that SR of machined surface got improved with an increase in % wt of Si_C [10]. Nanimina et al. worked on AMC material to evaluate the EDM machining parameters such as peak current, T_{on}, and T_{off} for performance characteristics. They found that MRR got increased rapidly for higher *T*on and peak current in case of Al6061 rather than AMC material while it decreases with increasing T_{off}. They also revealed that low peak current and low *T*on provides low tool wear as compared to T_{off} [11]. Mohan et al. explored an experiment to investigate the effect of electric discharge current, *T*on, concentration %, tool hole, and electrode rotation speed on machining properties during EDM of metal matrix composite material using a tube shape electrode. They found that rotating blind tube electrode with drilling effects provided more MRR comparing to solid electrode. They also found that the higher value of SiC% was resulted in reduced MRR, SR, and higher tool wear. Their other finding is as the rotational speed of tube electrode got higher it provided higher MRR, TWR, and better surface quality. They also conclude that MRR and tool wear rate were improved for the injection flushing method on comparing with side flushing [12]. An experiment was conducted on the Al metal matrix composite reinforced with Si_C particles using an EDM process by Islam et al. They used solid and hollow copper tool electrodes and kerosene as dielectric medium for their study. The process parameters were considered as discharge current, arc gap, and electrode shape. The value of input voltage, pulse frequency, and *T*on was constant during experiments. They observed that with hollow tool electrode, improved MRR was found at 6 A discharge current with 10-µm spark gap and with solid electrode improved MRR/TWR ratio was 21.36 at 3 A discharge current and 10-µm spark gap. They also confirm that small spark gap with solid electrode provides minimum surface roughness while the discharge current has lesser effect on work piece surface

2. REVIEW ON OPTIMIZATION STUDIES OF EDM

Optimization plays an important role for improving performance parameters of EDM. The appropriate value of process parameters which results desired and maximum output can be determined and identified by optimization techniques. This section deals with various optimization technique uses to explore the input parameters of EDM process [14].Optimization-Related Studies of EDMed Aluminum Metal Matrix… 27 Al-SiC12% metal matrix composite parametric optimization was carried out by Bhuyan et al. using EDM process. They investigate the outcome of input parameters such as Ton, peak current, and flushing pressure for SR, TWR, and material removal rate. They used central composite design (CCD)method under different combination of process parameters during the experiments. They used RSM method for modeling and ANOVA to check the significance of the developed model. They conducted a validation test to compare the predicted and experimental value which find the effectiveness of developed model and found the predicted error of MRR, TWR, and Ra which are within the acceptable limit. They observed that MRR and SR increased with increasing value of Ton, and flushing pressure while TWR decreased with them [15]. An experiment on multi-objective optimization of input parameters of Al/Si/10Mg/9 wt%, Al2O3/3 wt% graphite in EDM for obtaining minimum SR, minimum TWR, and maximum MRR was performed by Radhika et al. Peak current, flushing, and Ton were selected as input parameters for EDM. The experiment was conducted on different operating levels of process parameters according to Taguchi method and GRA which was used for the multi-objective optimization. ANOVA technique was used to conclude the significant contributing machining parameters. They observed that the most significant parameter is peak current with 61.36 % contribution. The obtained optimal level of input parameters such as 20 A peak current, 100 kPa flushing pressure, and 190 µs pulse duration was found to lead to good surface finish, reduced TWR, and improved MRR in the EDM of aluminum hybrid composites [16]. Prasanna et al. used principal component analysis (PCA) for optimization of performance parameters like relative wear ratio, MRR, TWR, and SR of AA7075-Si_C metal matrix composite material using EDM process. Copper material electrode and kerosene as dielectric medium were used in the experiment. The experiments were performed using various values of peak current, T_{on}, T_{off}, and voltage. They observed that by improving the value of current increased, the MRR and TWR increased with lower surface finish Anand et al. worked for WEDM on Al/ZrSiO4 MMC to determine the optimal value of cutting rate using Ton, Toff, servo voltage, and peak current as process parameters. They used ANOVA and F-test for process parameters. The optimized value for maximum cutting rate was as Ton 120 µs, T_{off} 51 µs, peak current 169 A, and servo voltage 54 V. They found that cutting rate increases as Ton and pulse current increases, whereas for the increased value of Toff and servo voltage, cutting rate decreases. They also found large-size craters and cracks on the machined surface, as Ton was increased to high level and T_{off} was kept on low level [18]. The optimal process parameters of AMC was carried out by Senthil et al. using TOPSIS method considering discharge current, Ton, and Toff as input parameters. They used situ casting method for workpiece preparation and L18 OA approach for the input parameter optimization. They optimized performance characteristics as 0.1534 g/min MRR, 0.00034 g/min TWR, and 4.49 µm SR considering input parameters such as discharge current 35 A, Ton 99 µs, and T_{off} 6 µs [19]**.**example of a datasheet in [9] example of a master's thesis in [10] example of a technical report in [11] example of a standard in [12] Wang et al. worked to optimize the blind-hole drilling of AMC material using rotary EDM. They used Taguchi approach for the machining performance using input parameters such as polarity, ton, tool rotational speed, flushing, peak current, supply voltage, and number of eccentric through hole in electrode. The optimized value for blind-hole drilling conditions was eccentric through hole in electrode 1 hole, flushing pressure 0.6 kg/cm^2, electrode rotating speed 1000 rpm, and working time 14 min. They confirmed that blind hole drilling EDM using rotational eccentric whole electrode provided higher MRR, and this technique is more appropriate than other machining processes [20]. The performance optimization was carried out on AMC material by Ming et al. using multi-regression modeling and two types of neural network such as back propagation (BPNN) and radial basis. They used cutting parameters such as T_{on}, T_{off}, peak current, and servo voltage for MRR and SR. They observed that BPNN delivered best-predicted error for MRR and SR. They found that their proposed models can also show the effect of process parameters on Optimization-Related Studies of EDMed Aluminum Metal Matrix 29 the performance and build an intelligent optimization system with graphical user interface which was based on soft computing, GA, and desirability function. They also suggested that the optimized cutting parameters under the desired SR can obtain through their developed optimization system The Input parameters such as additive concentration, peak current, an Ton were taken for their experiment to investigate the MRR and SR. Their ANOVA out com show that the concentration and peak current are the most effective parameters for output characteristics. They observed maximum MRR was achieved at an additive concentration of 3 g/l. Furthermore, they also found minimum SR at a concentration between 2 and 3 g/l and at 1 A peak current [22]. Udaya et al. conducted an experiment on aluminum cast alloy reinforced with Boron carbide, to optimize the process parameters using wire EDM in which 0.25-mm-diameter Brass wire was used as the electrode. They used Taguchi technique to analyze optimal machining process parameters for minimum SR and maximum MRR. They observed that MRR was maximum at increasing Ton and decreasing T_{off} while increasing spark voltage provides lower material removal rate. They also explored that MRR was minimum at first level of Ton and maximum at first level of T_{off}. For obtaining maximum MRR and minimum SR, the optimum value of parameters was found as spark voltage 30 V, Ton 10 μs, T_{off} 2 μs, wire feed 4 m/min and 3% reinforcement.

3. CONCLUSION

The machining of advanced materials using EDM provides more precise performance that is appraised by SR, MRR, and tool wears. This performance is mainly affected by the working parameters like *T*on, *T*off, additive powder, and electrolyte. There are various techniques such as Taguchi, RSM, and GRA used to optimize the performance parameters of EDMed AMC. From the previous work, it is found that GRA is the most appropriate technique among other methods. This article provides brief information of EDM process along with theoretical and experimental reviews that have been done by researchers. Moreover, this also discussed various optimization techniques which are used to optimize the process parameters of EDM. This article halted and optimum parameters of EDM accommodated the satisfactory performance parameters such as material removal, surface roughness, and TWR.

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