Experimental investigation for evaluating Process Parameters in Electric Discharge Machining of M2 Die Steel

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ABSTRACT

Electric Discharge Machining (EDM) process is a non-conventional and non-contact machining operation which is used in industry for high precision products. The present research investigates the effect of parameters such as discharge current, power, and spark gap on surface roughness. M2 tool steel used as work piece material in Electric Discharge Machining (EDM). Experiments are performed at different levels of discharge current and experimental results of MRR, EWR, surface roughness, and spark gap were taken. The primary objective of the study is to find out the important and combination of one or more factors that influence the machining process in order to achieve the best power setting in turn machining current. This procedure eliminates the need for repeated experiments which saves time and material unlike conventional machining process.

Key Words: EDM, MRR, EWR, Surface Roughness.

INTRODUCTION:

Electro discharge machining is a nonconventional machining process extensively used in industry for processing of parts having unusual profiles with reasonable precision [1]. Steel is a widely used engineering material. There are a variety of steels used for numerous applications. The steel is being divided into low carbon, medium carbon, and high carbon steel on the basis of carbon content. Low carbon steel contains a carbon content from 0.15% to 0.45%. It is the most common form of steel as it provides material properties that are acceptable for many applications [2]. EN 353 steel is cheaply available and widely used alloy. EN 353 is low alloy case car-burized steel, predominantly used for manufacturing heavy-duty gears, shafts, pinions, and especially crown wheel [3].Discharge current was the most significant controlling parameter in machining Al-15% SiC MMC using multi-hole electrode by grey relational analysis, while Taguchi method was employed to determine the relations between the machining parameters and process characteristics like MRR (material removal rate), EWR (electrode wear rate), and SR (surface roughness) [4]. The combination of maximum pulse on time and minimum pulse off time gives maximum MRR on Al-7075 alloy with brass electrode using Taguchi approach [5]. Amorim and Weingaertner concluded that the best results of MRR and surface texture for duty factor of 0.5 were obtained with tungsten-copper electrodes, no matter the machining conditions while machining copper-beryllium ASTM C17200 alloy [6]. Single-channel electrodes have comparatively better MRR and lower EW during fast hole drilling of Inconel 718 and Ti-6Al-4V with tubular electrodes of brass and copper, while copper electrode undergoes lower wear than brass electrode [7]. Discharge current, pulse on time and pulse of f time, had a significant influence on the machining characteristics such as MRR, EWR, and overcut while machining Inconel 718 [8] and on gap current while machining high strength low alloy steel (HSLA), respectively [9].Kerosene decomposes at higher temperature due to larger discharge energy and produces carbon particles that adhere to the electrode surface and this phenomenon restricts rapid tool wear during machining than deionized water [10]. Globules of debris, pockmarks, and melted drops were observed on the surfaces of blind holes which were more dispersed and pronounced. Most significant parameters like voltage and current in the optimization of a single quality characteristic are not being significant as in multiple quality characteristics.Patel et al. [11] done the multi objective optimization with copper electrode and concluded that lower value of parameters reduces the tool wear ratio substantially, while their higher values increase the MRR drastically on AISI tool steel.A. D. Patelet.al [12]MRR not only increases with increase in discharge current but also increases the micro cracks density on machining tungsten carbide with graphite electrode.P. Janmanee and A. Muttamara [13]. Increasing discharge energy increases instability and due to which, the quality of the workpiece surface becomes rougher and the white layer thickness increases. Also the amount of particles in the gap becomes too large and forms electrically con-ducting paths between the tool electrode and the workpiece causing unwanted discharges, which becoming electric arcs (arcing). These electric arcs damage the electrodes.
surfaces (tool and workpiece surfaces) and can create micro cracks.[14] During EDM processes, a significant amount of work-piece material was found to be transferred from workpiece surface to tool surface and vice versa. Also, a continuous burning of cutting fluid gives out a carbon residue, a visual black layer on machined surface, which decreases the EWR. M. Boujelbene, E. Bayraktar [14] reported that surface roughness of EN-31 tool steel with copper electrode gives the best surface finish if obtained at the lower level of peak current and pulse on time. A. K. Khanra, [15,16] while increasing the pulse current or reducing the pulse on duration suppresses the formation of surface cracks in the SKD11 machined surface and hence improves the fatigue life.Kumar et al. [17] revealed that intense heat conditions in the machining zone yielded higher crack densities and surface roughness while machining titanium at higher peak current along with a higher frequency of the globules of debris than on steel. Mathematical modeling of process using response surface methodology shows that the developed model can achieve reliable prediction of experimental results within acceptable accuracy. C.aydas and Hasç Alik [18,19,20] also added that RSM is an economical way for obtaining information for any system with the fewest numbers of experiments many researchers used RSM to quantify the effect of control factors on their problems [21–24]. Box-Behnken design gives us robustness to the unavailability of data over central composite design [25]. Reversing the polarity of sparking alters the material removal phenomenon with an appreciable amount of electrode material depositing on the workpiece surface [26]. Due to its structural integrity, copper has ability to produce very fine surface finishes, even without special polishing circuits. It also makes copper electrodes highly resistant to DC arcing in poor flushing situations [27,28]. Rajesha et al. [1] demonstrated that hollow tool is particularly useful for drilling holes with low tool wear rate. It was found that while machining the same length of the Inconel 718 with a solid tool, it takes approximately 40% more machining time than that taken by a hollow tool. It also helps in minimizing the dielectric fluid degradation. Consequently, the approach light is cost effective with higher yield and reduced material and energy loss.

2. Experimental Procedure

Experiments were conducted on a die sinking EDM SPARKONIX S 35 machine, as shown in Fig. 1. In this study, M2 tool steel is selected as the work material. Chemical composition of the workpiece material is given in Table 1. A cylindrical electrode with circular section having 12 mm diameter cooper and graphite were used as the electrodes (tool). Fig. 2 shows a typical copper and graphite electrodes used in the experimentation. Fig. 3 shows the work pieces of M2 Die steel after machining with the copper and graphite tools. EDM-30 oil is taken as dielectric fluid. A total of 16 readings are taken for each tool i.e., copper & graphite. The effect of discharge current and pulse duration has been taken into consideration. Discharge current is varied from min to maximum of EDM machine range i.e., 5 amp to 34 amp. Voltage is kept constantfor every four readings, from 40 V-60 V, for four different pulse on & pulse off times 7,8,9,10 sec. Depth of cut is taken as 0.5 mm. Surface Roughness is measured with METRIX + Surface Roughness TESTER. Finally MRR, EWR and Surfaceroughness is calculated and plotted the graphs with respect to power.

Fig. 1: EDM
Fig. 2 Graphite

Fig. 3 Copper Tool

Fig. 4 Work Pieces

Chemical Composition of M2 Die Steel:

Table 1

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<th>Contents</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Mo</th>
<th>S</th>
<th>P</th>
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Results and Discussions:

The variation of MRR with respect to Power for machining M2 Die steel is shown in figure. The graph shows that MRR increases with respect to power for both Copper and Graphite tools. When Copper tool is used for machining, MRR is varied from minimum of 20 mm³/min to maximum of 128 mm³/min. Maximum MRR is at 2040 watts. For Graphite tool MRR is raised in a linear manner with a maximum MRR of 117 mm³/min at 2040 watts.

Figure 4 Effect of Power on MRR
Figure. 5 Effect of Power on EWR

The variation of EWR with respect to Power for machining M2 Die steel is shown in figure.

Electrode wear rate for Graphite electrode raises from power 200 watts to 1000 watts exponentially and then decreases. Copper electrode MRR is varied linearly up to the power 1300 watts and then to 2040 watts with a higher slope up to 0.56 mm³/min.

The graph shows that EWR increases with respect to power for Copper and reduces from certain power for Graphite tool.

Figure. 6 Effect of Power on Surface Roughness

The variation of Ra with respect to Power for machining M2 Die steel is shown in figure. For the surface is very rough at 1000 watts for Graphite electrode and 1920 watts for Copper electrode. Whenever Current is raised roughness is increasing with a higher rate for Graphite, compared with Copper.

The above graph shows that Ra increases with respect to power for both Copper and Graphite tools.

Conclusions:

Experiments on EDM of M2 Die steel were carried out. Pulse on, Pulse off, peak current, voltage are the primary parameters and dielectric fluid, flushing pressure, electrode rotation of the non electric parameters are considered in EDM. Most of the research work has been carried out for improving the performance on EDM are measured in terms of Material Removal Rate, Electrode Wear Rate and Surface Roughness. The major conclusion from this investigation can be summarized as follows:

1. Metal Removal Rate (MRR) increases with increase of power.
2. Surface Roughness (Ra) decreases with increase of power.
3. Electrode Wear Rate (EWR) increases with increase of power.
4. Copper Tool is efficient for M2 tool steel when we considered the parameters MRR, EWR, Ra.

References:


