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Increasing the Performance of EDM Process Using Tool Rotation Methodology for Machining AISI D3 Steel

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Abstract

Electric Discharge Machining is one of the most accurate unconventional manufacturing processes used for cutting or creating intricate shapes in very hard or difficult-to-cut, electrically conducting materials. The adoption of tool rotation methodology increases the material removal rate by increasing the spark efficiency and effective debris clearing.

The experiments have been performed on AISI-D3 Steel. Results show that the tool rotation phenomenon significantly improves the average MRR and surface finish by 41% and 12% respectively. Moreover, the final surface is more uniform in structure with less number of microcracks and thinner recast layer as compared to the stationary tool EDM.

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Keywords: Electric discharge machining (EDM); Material removal rate; Scanning electron microscope (SEM); AISI D3 steel.

1. Introduction

Electric Discharge Machining (EDM) is an acclaimed process for the machining of geometrically complex or hard and electrically conducting materials which are difficult to machine by any other conventional machining processes.

The EDM process originated around 1770 when the erosive effects of the electric discharges (sparks) were being studied by an English Scientist Joseph Priestly. Since then the developments started in the EDM process and for the first time in the year 1930, electric discharges were used to machine metals and diamonds, this process was then called as the “spark machining or arc machining”[1].

B. R. Lazarenko and N. I. Lazarenko, two Russian Scientists in the year 1943 during the Second World War, did pioneering work on this process. They introduced the concept of resistor-capacitor (RC) circuits and also defined the capacitor charge energy in the EDM process [2]. These days advanced EDM machines equipped with adaptive control monitoring systems can be operated round the clock [3].

Nuclear, automotive and aeronautical industries are among the leading users of very hard alloys for machining purposes. EDM is used to machine such alloys easily with a high level of accuracy. The discharge current is the most influential parameter which affects the material removal rate (MRR), whereas the pulse on-time highly affects the electrode wear rate [4, 5].

The primary drawbacks of this process are its low MRR and poor surface finish. In the recent past people have adopted various methodologies to overcome these flaws by using powder mixed dielectric solution, vibration assisted machining etc. Tool rotation methodology has been a good alternative to overcome these drawbacks, but in the past years there has been very less use of it. The present work highlights the increment in the performance of the basic EDM process by using the tool rotation methodology. The material removal rate and the surface integrity analysis have been carried out on the AISI D3 steel specimens (5 mm in thickness) using rotating copper tool (10 mm in diameter) on the EDM for

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drilling purpose. The circularity of the obtained geometries has been checked using a shadowgraph.

1.1. Working Principle

The EDM system consists of two electrodes, i.e., the cathode (tool) and the anode (workpiece) and other components like power supply, servo system, reservoir, pump filter etc. as shown in Fig. 1. The power supply creates a potential difference between the two electrodes and in the inter electrode gap (IEG) the dielectric acts as a charge conducting medium. As soon as the circuit becomes complete, an electric spark occurs between the two terminals which cause the surrounding electrode material to melt. The material gets removed in the form of very fine particles from the workpiece at a controlled rate. The dielectric flushes away the material from the melt cavity when the tool electrode moves up during the on-time.

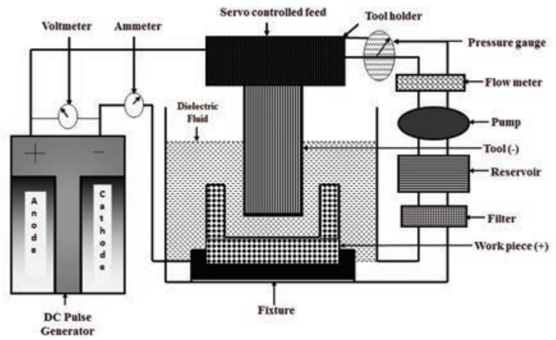

Fig. 1. Schematic diagram of Electric Discharge Machining Process

1.2. Process Mechanism

The basic mechanism of the EDM process involves the melting and vaporization of the electrode material due to the high-intensity electric spark produces in the IEG. Due to the high thermal energy of the spark the material gets melted and the molten material present in the melt cavity is being carried away with the flush of the dielectric. The process involves repeated discontinuous sparks between the workpiece and the tool, submerged in the dielectric fluid [6]. The spark temperature is high enough to melt materials of any hardness. This temperature can reach as high as 20000 C [7].

The volume of material removal per discharge is approximately around 10^{-6} to 10^{-4} mm^3 and the MRR is around 2 to 400 mm^3/min [1]. The accuracy level of the parts produced by the EDM process is good. We can also say that EDM can also be tagged as a shape reproduction process, which involves the tool electrode form to be mirrored in the workpiece [8]. With the increase in the input current, the value of MRR increases and simultaneously the value of tool wear rate (TWR) also increase, resulting in higher Ra value of the machined surface, i.e., rougher surface at higher values of the input current. The tool rotation methodology in the EDM process provides better MRR and surface finish as compared to the stationary tool EDM process [9].

1.3. Process Characteristics:

The EDM process has the following main characteristics:

(a) The process can be used for machining any electrically conducting material in the required form, irrespective of its hardness and other physical properties.
(b) The process can be used for creating intricate shapes in the workpiece which are difficult to create using the other conventional process.
(c) The exact tool shape can be replicated in the workpiece with high accuracy level.
(d) Thermal properties of the workpiece play a major role in the MRR during the EDM process.
(e) During the process the workpiece and the tool are never in contact with each other, they are separated by a small inter-electrode gap.
(f) The tool also needs to be conducting in nature so as to complete the circuit for the flow of current.

2. Experimental Set-up

The experimental set-up used for the present study is shown in Fig. 2. It includes the Electronica Z-axis Numerical Control (EZNC) EDM and a rotary tool arrangement mounted on it. The motorized set-up for providing rotary motion to the tool electrode was fabricated and mounted on the ELEKTRA 5535-EZNC EDM.

Fig. 2. EDM with rotary tool set-up

The tool rotation helps in improving the flushing difficulty encountered during the machining of small holes and cavities. The flushing efficiency is improved by producing a pumping effect of the dielectric fluid through the gap. The quality of the holes produced with the rotary EDM is better than the ones produced by the stationary tool EDM. Moreover, it also increases the MRR, flushing efficiency and quality of the holes produced during the EDM process, as compared to the stationary tool EDM [9]. With the increment in the current,