Status of recent developments and research issues of electrical discharge machining (EDM)

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Abstract - Electrical discharge machining (EDM) is considered one of the main non-conventional machining processes. It is based on thermoelectric power between the work piece and tool. The process involves a controlled erosion of electrically conductive work piece by the introduce of rapid and repetitive spark discharge between the tool and work piece by the use of dielectric medium. In order to generate the spark between the work piece and tool electrode both work piece and tool must be good conductor of electrical energy. EDM is used for machining of parts of aerospace, automobile, nuclear and surgical industry.EDM is also used for the machining of thin and fragile parts.

Keywords: EDM, EDM Characteristic.

I. Introduction

In the Electro-discharge machining (EDM) process electric current is to be converted into heat. The surface of the electrode material is heated in the area of the discharge channel at a very high intensity [1]. After that current is interrupted, due to which the discharge channel collapses immediately, as a result of that the molten metal on the surface of the work piece and the electrode both evaporates at a very high intensity and send liquid material into the dielectric [2]. The process forms craters on the surfaces of the work piece and the electrode [3], new craters are formed next to the last one and the work piece surface is continuous eroded, if one discharge is followed by another. The surface roughness of the machined surface depends on depth and the shape of craters [4]. The higher rate of material removal with desired accuracy and the minimal surface damages help the EDM more economically important [5]. This is achieved by the development of different types of spark generators and by optimizing production parameters. Although, due to a great number of variables and a variety of products, an optimal machining process performance is very difficult to achieve [6]. In addition to extensive experimental research, with the help of theoretical work we can explain the releation of current and voltage rates to the shape and depth of craters generated during machining. With the help of transistorized pulse generators in an EDM, due to which we can vary the frequency and energy of discharge with a greater degree of control. In 1770, English chemist Joseph Priestly found the erosive effect of electric discharges, after that in 1943 Lazarenko and Lazarenko at Moscow University found the destructive properties of electric discharge for the use of constructive work [7]. After that in 1980 the use of CNC (computer numerical control) brought various advances in working of EDM. With the help of CNC there is a tremendous advance in efficiency of EDM [7].

This paper gives a review of various research activities done in past time in EDM. The heart of the paper identifies the major EDM research area. The final part of the paper tells future direction for the EDM research.

II. Working Principle of EDM

Fig. 1 explains the working principle of EDM [8]. The machine consists of a power supply, a dielectric system; a control system with a servo-mechanism is to control the rate of feed of the quill where the tool holder is attached. The work piece is clamped on the machine table. Spark is produced between the work piece and tool electrode. The duration of spark is measured in micro second. In the spark area temperature is very very high due to which there is partly melting and vaporizing of work piece and tool electrode and results in removal of material in form of craters. The System moves in different axes and the movement is controlled manually or by a computer numerical controlled system [9]. The transistor pulse generator power supply is now commonly employed in EDM as Power supplier [10].

It changes the AC supply from the mains and provides a rectangular voltage wave. The amount of material removed from the surface of work piece depends on the magnitude of the electrical discharge voltage, current and time, pulse duration [11].
Pulse duration is the time interval between switching the generator on and off, while the pulse interval is time between switching the generator off and on for the next. The ignition delay time is defined as the time during which the voltage remains at the value of the ignition voltage while the current stays at zero [12]. Discharge voltage is defined as the mean value voltage value from ignition to power-off [13]. The mean value of the current from ignition phase to power-off phase is known as discharge current [14].Duty cycle measures the amount of time the energy is on during each pulse.

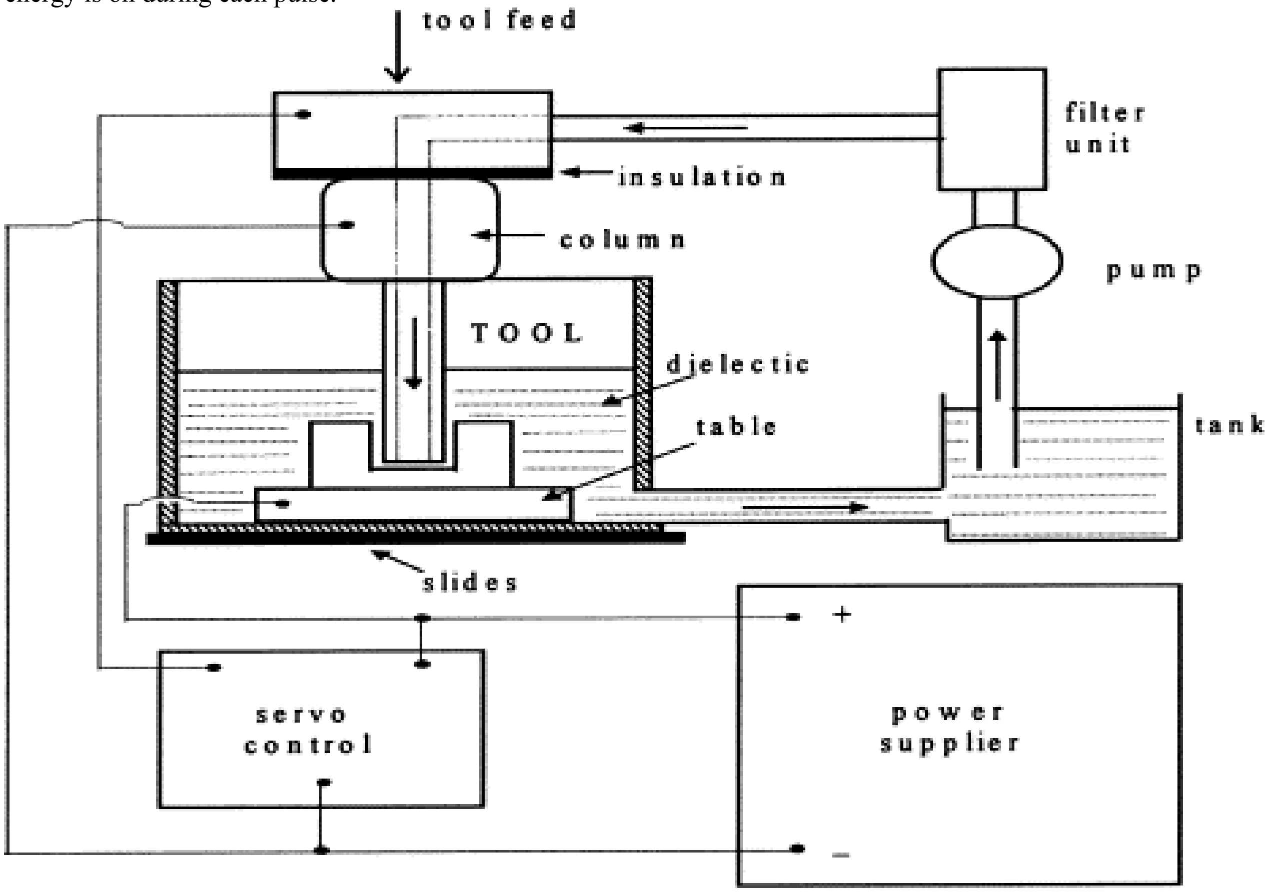

Fig - 1

III. General features of EDM

3.1 Details of work piece and tool material

The Work piece and tool electrode is the most critical part in the EDM. Copper is used as the electrode material because of its lower electrical and thermal resistance [15].

3.2 Selection of electrode materials

Copper (Cu) electrode is used as electrode material to machine their product for rough and finish machining. It is commonly used by industries, due to cheaper and produces good surface finish [16]. Cu is highly stable material under sparking conditions and having excellent electrical and thermal conductivity. Good electrode materials must be selected because it gives good surface finish, low diameter overcut, and high material removal rate (MRR) and less electrode wear when machining hardened material [17].

3.3 Selection of Dielectric System

1. Generally transformer oil, Kerosene oil is used as dielectric.
2. The dielectric must have high strength.
3. The dielectric should take minimum possible to break down when breakdown voltage is reached.
4. The dielectric should deionizer the gap as soon as spark has occurred.
5. The dielectric should be good cooling agent.
6. The dielectric should have high degree of fluidity [18].

3.4 EDM machine

The models of EDM machines used vary from one company to another. Computer Numerical Control (CNC)-EDM machine are used by many of the industries [19, 20]. There are some industries which still use the manual machine [21]. CNC-EDM is used by some industries so that problem related with changing tools can be reduced [22]. Products produced are moulds and dies for injection moulding, stamping of metal electronic industries, automotive, defense, nuclear industries parts [23].

IV. ANALYSIS OF MATERIAL REMOVAL RATE

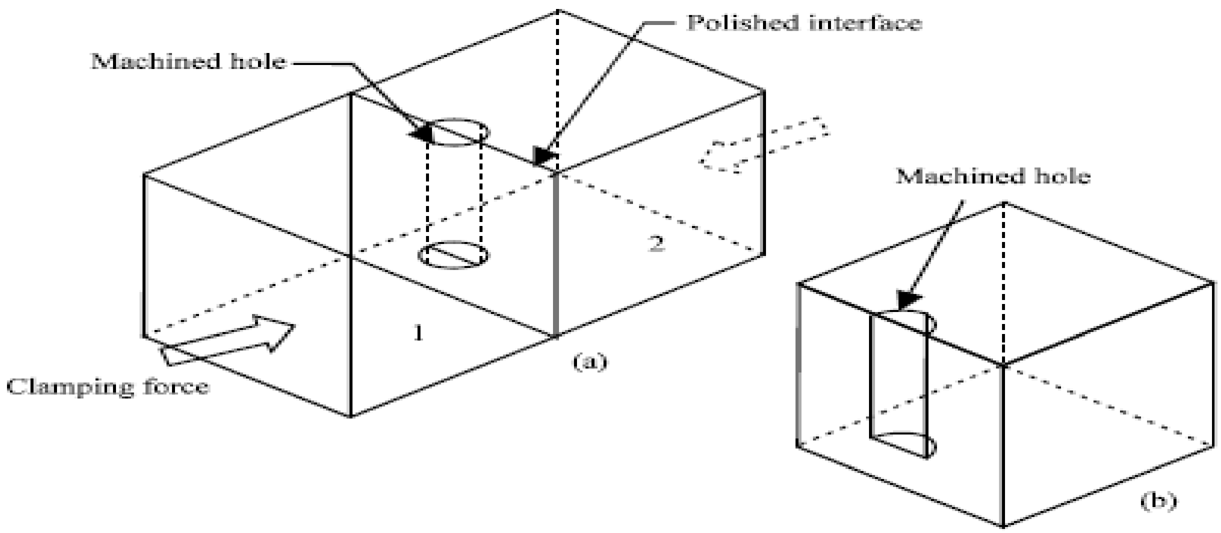

Fig. - 2 Material removal rate Analysis

Fig. 2 explains the mechanism of material removal rate [8].In the EDM process the sparks are produced by electrical circuits of several types and each of them has a different waveform of voltage and current of its own [24]. Since these successive waveforms are the same or at least similar to each other, the energy of each spark can be calculated by simple way. [25] Shows the variation of the material removal rate with respect to the current for various values of pulse duration time and interval time. [26] explains The material removal rate increases linearly with the discharge current as it increases for various values of pulse duration and interval times.[27]tells for the material removal rate with respect to pulse duration time for various values of discharge. [28] indicates that an increase in discharge pulse duration time gives an initial increase in material removal rate and the further increase only leads to a very slight increase in material removal rate.[29] shows the variation of the material removal rate with respect to discharge pulse interval time for the values of ts.30, 40, and 50 ms, respectively. [30]It explains that an increase in discharge pulse interval time causes a reduction in material removal rate. [31] Shows Variation of material removal rate with discharge current for discharge duration time and interval time.

V. VARIOUS PROCESS PARAMETERS IN EDM

Voltage: this is the potential which is measured by volt. The general range of voltage is 60v [32].
Duty cycle: it is ratio of on time to the total cycle time. The duty cycle is calculated by dividing the on time by the total cycle time. We multiplied by 100 for the percentage of efficiency which is called duty cycle [33].
Pulse time: It is defined as the duration of time for which the current is allowed to flow per cycle
Pause time: it is defined as the duration of time between the spark.
Arc Gap: This is the distance between tool and work piece. This is called as the spark gap.
Intensity: it is defined as the different levels of power that can be supplied by the generator of the EDM machine.

VI. Main research area of EDM

In this part the researcher has explained the research area in EDM under three major titles. The first explains the machining performance like material removal, material removal rate and tool wear. The next paragraph explains the the effect of process parameters both electrical and non electrical variables [34]. At last research of design and manufacturer of electrodes is explained [35].

VII. Measurement of EDM performance

A large no of papers have been studied on ways of yielding optimal EDM performance like high MRR and low tool wear rate[36].This chapter tells about each of the performance measures and various methods of improvement.

MRR Mechanism: The mechanism of material removal of EDM deals with conversion of electrical energy into thermal energy. The spark is produced between the work piece and tool [37]. So each spark produces a tiny crater by melting and vaporization and erodes the work piece to the shape of tool electrode [38].

As we know that MRR is the process of transformation of material elements between the work piece and tool electrode [39]. This transformation is converted in solid, Liquid and gaseous state and then alloy is formed with the contacting surface by the phase reaction of solid, liquid or gaseous state [40].

VIII. Various methods of improving MRR

With the application of CNC to EDM we can explore the possibility of using optional types of tooling to improve the MRR [41]. In EDM process generally 3 D profile electrodes are used which are very costly and time consuming for the manufacturer for the sparking process, however, by the experiential work has been performed with a frame electrode producing linear and circular swept surfaces by means of controlling the electrode axial motion [7,42,43]. We can improve theMRR by some modification in the the basic principles of EDM which give single discharge for each electrical pulse [44]. With the help of oxygen combined EDM process, the MRR can be improved by supply oxygen into the discharge gap [45].

Tool wear

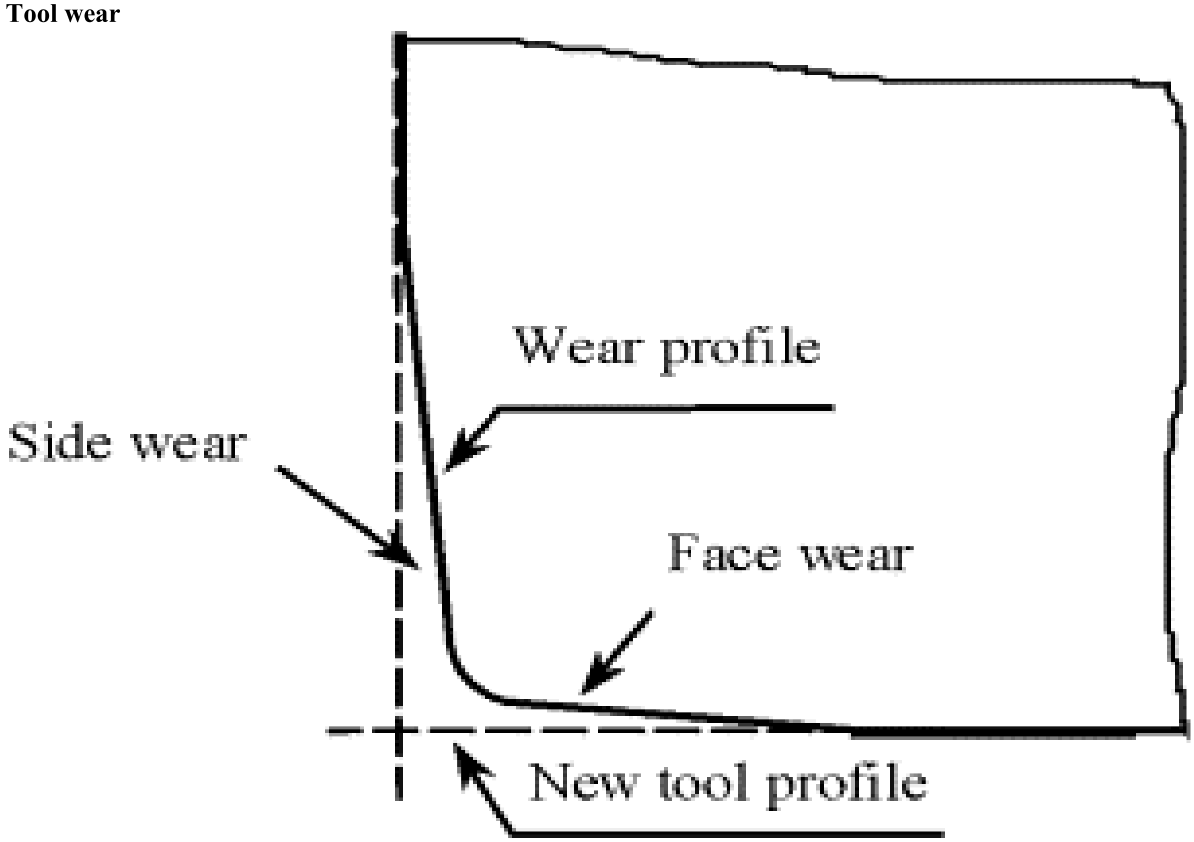

Fig- 3

8.1 Process of Tool wear: Fig. 3 explains the process of tool wear (8). Both tool wear process and MRM are almost same. In both process tool and work piece are considered as a set of electrodes in EDM [46]. From the simple understanding of tool wear process some useful applications explaining both the advantages and disadvantages of electrode wear have been developed [7,47].

Different methods of improvement tool wear rate: The movement of the electrode relative to the work piece is the most common machining techniques of compensating tool wear [48]. It involves the electrode making a planetary motion producing an effective flushing action which improves the efficiency of process, however this also decrease the number of different electrodes also decrease the number of different electrodes required for initial roughing and final finishing operations [7, 49, 50].

IX. Future EDM research direction

The EDM research area can be divvied into three different major areas.

9.1 Performance measurement improvement:
This can be done by the use of CNC to EDM for facilitating the MRR and improving the tool wear compensation techniques, it results the potential of using simple tooling to generate complex 3D cavity without employing a costly 3D profile electrode [7, 51]. This technique benefits the EDM process by reducing the large proportion of cost and time factors of producing the electrode which account for almost 45% of the total machining cost.

9.2 Development of EDM:
With the help of different advances in the EDM machine has increased the applications of EDM process. It is used in the automotive industry, nuclear industry, mould making industries. EDM is also used in machining of medical equipments, jewellery industries. For this we need the machining req. such as the machining of HSTR materials, which generate strong research interest and increase the EDM machine manufacturers to improve the machining characteristics [52].

9.3 Optimizing the process variable:
The optimization of process releates the process parameters with the response parameters like maximization the MRR as well as minimization the TWR. Sometime with the help of analysis of variance (ANOVA) technique we measure the amount of variation from the desired performance and find out the various important process variables affecting the process response [53].

Various techniques for control and monitoring of EDM process:
The monitoring and control of the EDM process can be done by the identification and regulation of adverse arcing occurring when sparking takes place. Here we measure the pulse and time domain parameters to find out the difference between arc pulses from the rest of EDM Pulses. Adaptive control system can be used to maintain the machining process and effective control strategy that replaces a skilled operator by the use of fuzzy logic application [7, 54, 55].

X. Conclusions

The following conclusions may be drawn:

1. EDM can be used as viable machining operations for producing complex parts.
2. When assigning process tolerances for EDM all aspects of the process, such as type of electrode, type of dielectric and duration of the operation, should be considered. All these activities may give errors, which should be taken into account.
3. EDM is independent on the mechanical properties of work piece.
4. To remain competitive as a micro-manufacturing technology, EDM process should use computer numerical control. This should make the new strategy attractive to industry.

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