Electric Discharge Machine: From Mechanism to Applications

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Abstract: Electric Discharge Machine (EDM) based on electric arc machining process comes under the categories of unconventional manufacturing machines due to its inherent advantages of machining very hard material or difficult to machine materials as it is contactless machining and do not produces stresses on workpieces. This makes its applications in aerospace, defense, automobile, aeronautical industries and more. This paper reviews the basic mechanism of material removal, types of EDM, factors influencing performance of EDM, and latest development of new material with EDM.

Key words: EDM, TWR (Tool wear Ratio), SQ (Surface quality),SR (Surface roughness) .

1. INTRODUCTION

Electric Discharge machining (EDM) has wide advantages and applications over conventional machining processes for hard materials or difficult to machine materials. EDM is used for precise material removal and forming complex cavities using electric arc erosion process in electrically conductive material [1, 2].

The machine was accidentally invented by looking the effect of electric spark. Later researches were done to make use of this electric spark in controlled constructive manner. In 1943 the first spark generator used for controlled method using Lazarenko circuit named on its inventor. Researches were started on metal after Priestly detected erosive effect of electric discharge on metals. This was the rise of new era of researches in unconventional machining first by finding suitable applications like removal of broken tap and drills from hydraulic valves. This all were required a proper tool to workpiece gap to be maintained automatically using electronic circuit system using servo system as this is contactless machining .Vitality of EDM increased with involvement of automation that leads to automatic machining and tool changing capabilities due to advent of computer numerical control (CNC)(in 1980)[1].These events and cost benefits generated more interest leading to more researches in EDM. That all researches were related to the increasing the efficiency of EDM along with industrial applications. Lots of academic and industrial researches have already performed and are still in process in this time.

Result of this, It has been widely used to produce dies, molds, aerospace, automobile industry and surgical components. One of the main reasons for using EDM is that it is also useful for machining brittle materials, as there is virtually no contact between the tool and workpiece.

In this paper we have focused on the basics of EDM, Its various operative methods (Electrical circuits), flushing techniques, various parameters that affect it and provide suggestions to provide future directions.

2. BASIC PROCESS OF EDM

In EDM material removal (due to erosion) in workpiece occurs due to conversion of electrical energy into thermal energy through a succession of electrical discharges occurring in the gap between electrode (i.e. tool) and workpiece sinked in dielectric working as working fluid. The arrangement of common components of an EDM is shown in figure 1.The series of electric spark produced from DC pulse generator are clearly shown and proper gap

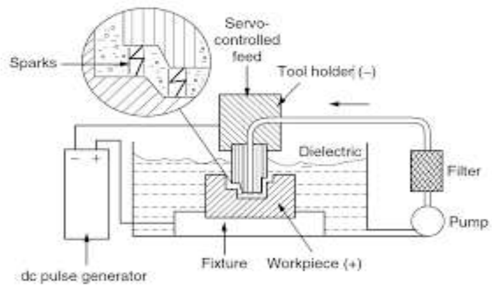

Fig 1:Schematic diagram of basic EDM

(Generally 10-100 μm) is maintained through servo controlled mechanism. When a suitable voltage is applied, due to ionization a narrow bridge is formed (refer fig 2-a). The Movement of electrons from their respected electrode surfaces towards each other occurs. This is accompanied by a momentary electrical discharge or impulse between the tool and workpiece .This discharge leads to release of high thermal energy which causes rise in temperature (usually 8000-12000 degrees) in the local zone starting melting of workpiece (refer fig 2-b) .

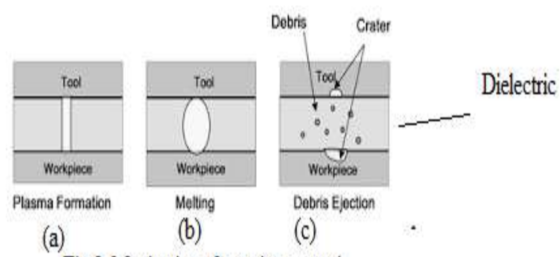

Fig 2-Mechanics of metal remoaval

Metal removal (in the range of 10^{-6} to 10^{-4} mm^3)[1] in the form of tiny drops gets done by melting and evaporation .This results in the formations of small craters at the point of discharge in the workpiece. The debris of material removed is get flushed by new dielectric and the process goes continuously until desired finishing is achieved (ref fig 2-c).

EDM variants:

Based of application and basic configuration EDM can be classified as

1. Wire cut EDM: where a think continuous wire electrode is used to cut or create profile on plates (of high strength and temperature resistive strength) having thickness up to 300mm where ever low residual stresses are required [15, 17, 22].
2. Sinking EDM: The most popular and basic version used to make complex cavities in precision works. This involves drilling and Die sinking by EDM. It is also used as a tool in surface textures and when used to produce cavities in micron level then known as micro EDM [4, 5, 6, 7].
3. Electric Discharge Grinding (EDG): It embraces the machining processes made with an electrode rotating around an axis in addition to the normal electrode feed [8, 23].
4. Dry EDM: This environment friendly EDM uses high pressure gas as dielectric medium [3, 4].

Applications of EDM

Table 1:- Applications of EDM (based on references)

Sr.No.	Application of EDM
1	Machining on Heat treated material
2	Complex profile trajectory
3	Ceramics
4	Advanced composite material
5	Rapid Tooling
6	Removal of broken inserted parts
7	Fitting of a pair of dies
8	Hybrid machining
9	Fast making cavities
10	Micro EDM

Most common applications have been summarized in table 1.With Brief we can find them as follows: Materials worked with EDM include hardened and heat-treated steels, carbide, ceramics, cermet, polycrystalline diamond, titanium, hot forged and cold rolled steels, copper, brass, and high temperature alloys [8,9,10,11,12,13,14,15,16,21,24,26].

EDM is the only option to perform machining operation (mill, drill etc.) on these types of hard materials as other conventional method will produce more stresses and lead the material in damaged condition. EDM allows tool steels to be treated for its maximum hardness and various types of surface treatment using forging methods applied to make it free from wear and inaccuracy in terms of dimension and surface finish, also making longer life of tools and advantage to intricate parts [4, 6, 10, 12, 13, 16]. Various types of tools (At the same time various researches have been conducted and going on to check the effect of harness on the surface integrity [11,12,15,17].Applications of EDM along with ECM has been surveyed across japan, Germany and United states in forging industry[24].

EDM also used to machining and finishing purposes on different types of Carbon fibre reinforced plastic(CFRP) composites used in aerospace,aeronautic,defence and automobile industry.Various types of tool material have been tested and in the process in the deburring operations to be performed in CFRP composites [6,10].For strengthig surface finish and improved MRR by EDM adding of powder of various materials are being used(Fig.3)[9].

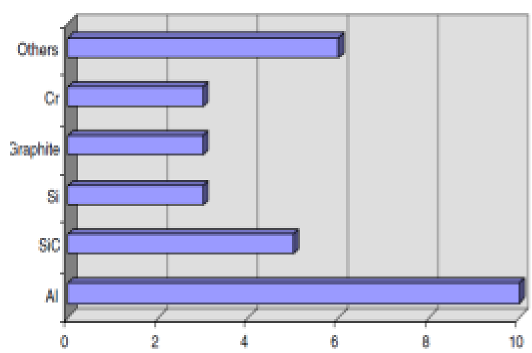

Fig. 3. Distribution of type of powder used based on the collected papers. [9]

Possibilities of complex Cavities (3D also)(fig. 4), holes of sizes in micron levels in intricate parts are the new application of EDM overcoming the limitations of laser machining [7, 18,19].

EDM

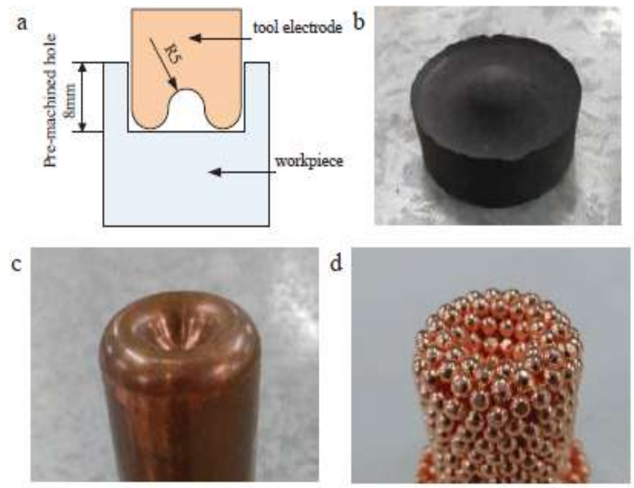

Fig. 4. (a) Profile to machine ;(b) graphite block ;(c) solid electrode;(d) Porous electrode.[19]

EDM electrodes for better productivity are being made new techniques (rapid tooling, sintering techniques etc.) and materials are being used [24, 28]. Further it can combine other unconventional machines also called hybrid machining. Delicate workpieces, such as copper parts for fitting into vacuum tubes can be produced by this method [22].

3. RESEARCH FOCUS CLASSIFICATION

The expectation from any EDM arises from the product, that defines the accuracy to be achieved, depth of cavity, orientation of cavities, size of the workpiece, and number of repetitions of shape .This all leads to the development of research areas in EDM making it most viable economic and feasible optimized option. Generally this further classified as (Ref Fig. 6) performance parameters such as material removal rate (MMR), tool wear rate (TWR), surface characteristics (quality, roughness, Heat Affected zone and recast layers thickness) and process parameters that include electrical parameter, non-electrical parameter and power based parameters. Besides the previously mentioned parameter there are some electrode(Design and performance) based parameters that also needed to be optimized for sparking process on the performance measure [1,8,9].The study of optimization of machining/performance parameters helps to improve the fatigue life and setting standards[11,15].

Investigation of metal removal mechanism is always a keen research area for newly developed composite ceramic materials besides regular materials also comparing the recast layers obtained [25].EDM control mechanism is also a latest topic where researchers are comparing the effects of various types of control system[26,27] .

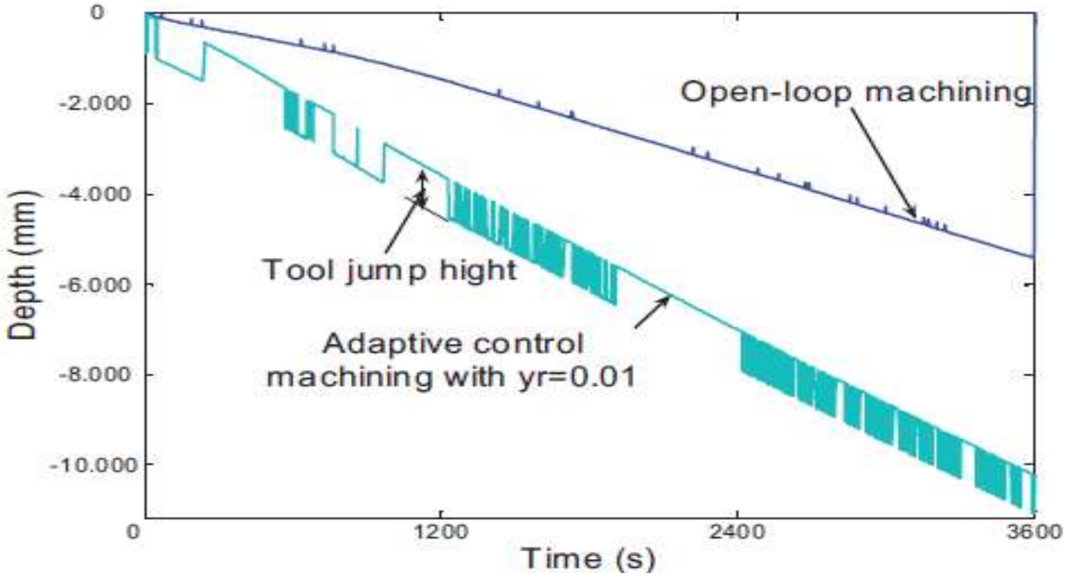

Fig.5 .Comparison of machining rates [26]

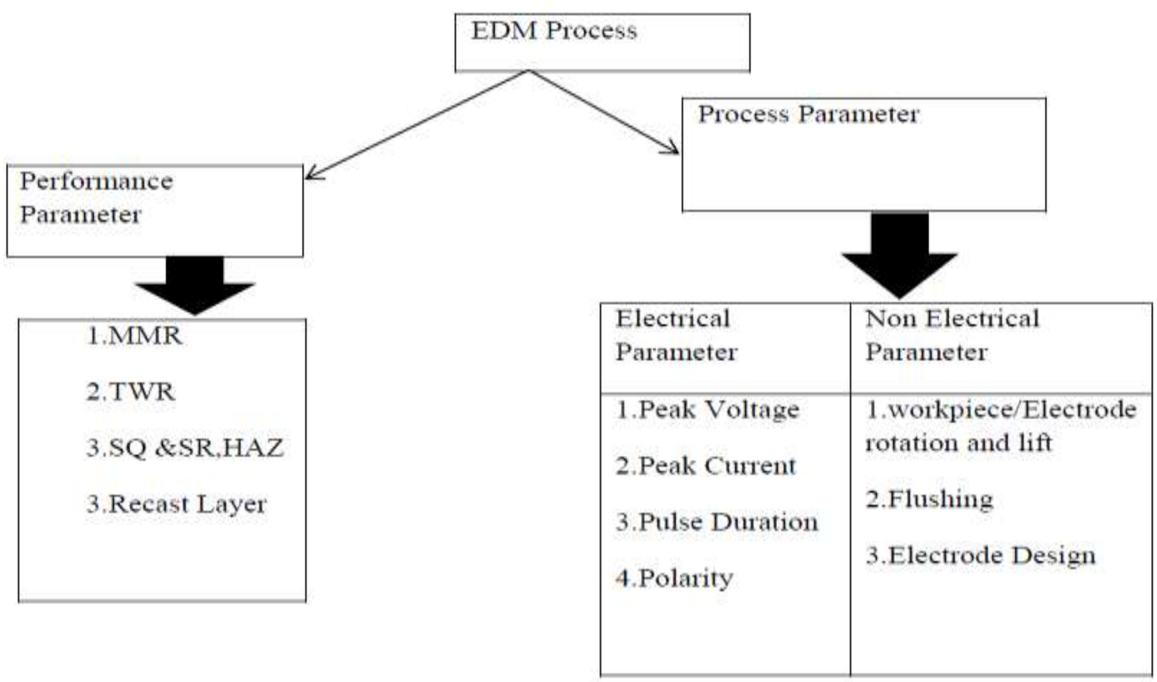

Fig.6. Process and performance parameters of EDM

4 DISCUSSION AND CONCLUSION

After knowing the several process and performance parameters there is need to compare them with standards and finding optimized parameters. The best results are the objectives of finding maximum material removal rate, minimum Tool wear ratio and yield to desired surface quality. This also to find the optimum sparking characteristics of the process and simultaneous flushing of removed material particles. Dielectric also play key role in the material removal phenomenon and at the same time has environmental impact also. Design and selection of electrode also plays major role in achieving minimum TWR. For improving the performance of retrofitting of EDM for effective control of tool feeding mechanism can be performed and can lead to adaptive control. We can conclude that Development of new application based EDM can open break its current horizon. Taking consideration of all salient points EDM will remain valuable and essence of manufacturing production system.

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