Review Paper on Electrochemical Discharge Machining: Mechanism and Future Scope

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***Abstract*— It is basically a hybrid process combining the principles of Electric Discharge Machining (EDM) and Electro-Chemical Machining (ECM). It is mainly used for micro-machining and scribing hard and brittle, non-conductive materials. In this process the basic material removal done by spark erosion i.e. rough machining (stock removal) and electro-chemical affect – smoothens the surface of the work piece. Different aspects of the electro-chemical discharge machining have been studied and their efficiency. This paper comprehensively reviews applications, variants of process, chemical composition at work piece and tool electrode materials, theories of sparking, studies on gas film formation, breakdown behavior, Material Removal Mechanism in ECDM as reported by authors. It was concluded that proper gas film formation with controlled input parameters like current and voltage, tool electrode shape and motions will result in improved machining efficacy. Further the paper underlines the future scope of improvements in ECDM performance.**

Keywords—ECDM, MRR, gas film, Non conductingmaterials

I. INTRODUCTION TO ECDM

It is basically a hybrid process combining the principles of Electric Discharge Machining (EDM) and Electro-Chemical Machining (ECM). It is mainly used for micro-machining and scribing hard and brittle, non-conductive materials. In this process the

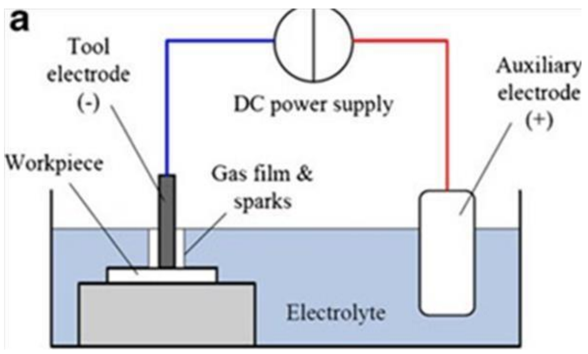

Figure 1: a: Schematic of Electrochemical discharge machining

basic material removal done by spark erosion i.e. rough machining (stock removal) and electro-chemical affect – smoothens the surface of the work piece. The first work on electrode effect, anode or cathode effects was reported by Fizeau et.al. and Foucault et.al [12] in1844. It was introduced in 1968 as electrochemical discharge drilling by Kura Fuji and Suda. It is known by different names such as:

- ECSM - Electrochemical Spark Machining
- SACE - Spark Assisted Chemical Engraving
- ECAM - Electro Chemical AnodeMachining
- DMNC - Discharge machining of Non-Conductors
- SAE - Spark Assisted Etching

II. WORKING OF ECDM

The tool electrode (-ve) and auxiliary electrode (+ve) are immersed in an electrolyte solution [typically NaOH/KOH]. D.C. Power is supplied to both electrodes. When applied voltage > than critical voltage (Vcr typically 25V), bubbles becomes dense and coalesce into a gas film on the tool electrode. Gas film allows sparking between tool and electrolyte. If the w/p is brought close to the tool, material removal occurs by thermal melting and chemical dissolution. A typical spark in ECDM contains 2000J/cm^2 of power and last for 100μs. This intensive energy input causes a sudden temperature rise in the local area of the w/p and the material is removed by thermal melting. Meanwhile alkaline in the electrolyte etches silicate in the glass. This chemical action is enhanced by temperature as well.[13]

III. WORKPEICE MATERIALS

Various researchers have reported the non-conducting materials that can be machined using the ECDM process are mentioned below:

Glass: Borosilicate Glass, Pyrex Glass, Optical glass
Ceramics: Alumina Refractory bricks, Quartz
Composite Materials: Fibre-reinforced-plastics, Kevlor-Fibre-Reinforced composites

IV. ELECTROLYTES

Various electrolytes used by researchers for the process of ECDM reported various researchers are as below:

Sodium Hydroxide, Sodium Chloride, Sodium Nitrate, Potassium Hydroxide,

V. THE MACHINE OF ECDM:

It is a table top fabricated machine or a specialized set up comprising all necessary features. The power supply: A/C to D.C converter and voltage modulator

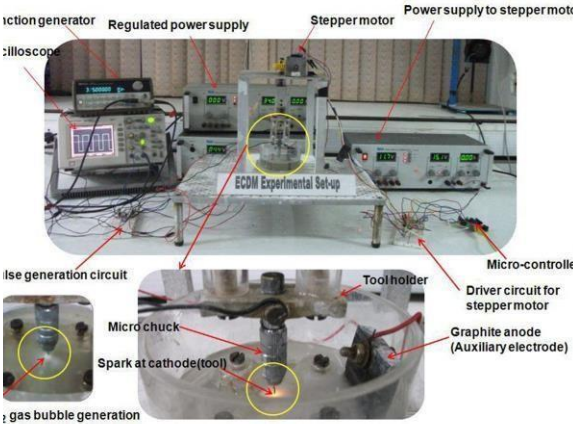

Figure 2: experimental set up

or pulsed modulator, Continuous electrolyte flow. The tool must be continuously dipped in the electrolyte. The current required is generally in the range of 5- 20 ampere and voltage is varied in the range of 25- 150 V. The schematic diagram of the process is shown in figure 1 and 2.

VI. MATERIAL REMOVAL MECHANISM

The material removal mechanism is shown in figure 3 [6].Material removal mechanism as put forth by various researchers is as under:

- The most acceptable mechanism for ECDM is due to thermal mode, primarily by melting and vaporization due to discharge sparking
- Chemical Mode: Material removal is due to etching process (predominantly at grain boundaries where densities of atoms are less)
- Mechanical wears.

The process involves a complex combination of the electrochemical (EC) reaction and electrodischarge (ED) action. The electrochemical action helps in the generation of the positively charged ionic gas bubbles, e.g. hydrogen (H2). The electrical discharge action takes place between the tool and the workpiece due to the breakdown of the insulating layer of the gas bubbles as the d.c. power supply voltage is applied between the tool (or cathode) and the anode, resulting in material removal due to melting, vapourisation of the workpiece material and mechanical erosion [06]

VII. THEORIES OF SPARKING IN ECDM

Sparking phenomenon in ECDM has been explained by different theories, yet none of them are completely acceptable and the process is still in research stage:

1. Sparking occurs due to the generation of electrolytic gas at electrodes through the chemical reactions as suggested by Crichton and McGeough [5]. It occurs due to switching phenomenon in

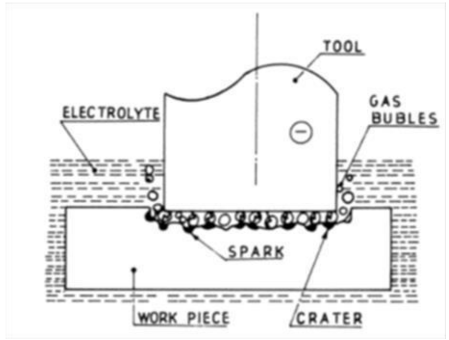

Figure 3: Material removal mechanism of ECDM operation

electrical circuits at high voltage and temperatures, this was suggested by Basak and Ghosh [1,2].

2. Sparking occurs due to discharge of bubbles acting as a valve operating at high electric field as postulated by Jain.et. al [4].

3. According to Kulkarni et. al [3]. the sparking occurs due to arc discharges when small hydrogen bubble transforms into large bubble.

4. Occurrence of sparking was produced due to percolation effect of small bubbles as proposed by Wuthrich and Bleuler [8]. They opine that sparks pass through (or percolate) in the shortest available path.

5. Main challenge is in the controlling of gas film, its stability and its dynamics. MRR increases with the applied D.C. voltage and electrolyte temperature, as reported by Wuthrich[8].

VIII. STUDIES ON GAS FILM AND VCR IN ECDM

1. Some researchers (Cheng et.al.[9]) have shown that the quality of the gas film is the dominant factor that determines the:

- Geometric accuracy
- Surface finish and
- Repeatability in the ECDM

Bhattacharya et. al.[6] reported that the critical voltage depends on:

- The concentration of the electrolyte
- The conductivity of the electrolyte and
- The tool geometry.

IX. VARIANTS IN PROCESS OF ECDM

Some of the vaiants of ECDM process as discussed by researchers are mentioned below:

1 Basak and Ghosh added extra inductance in the circuit and found that there was a substantial increase in MRR on normal glass slides.[1,2]

2 Yang et.al [11] added SiC abrasives in the electrolyte and found increased performance in terms of improvement in overcut quality.
3 Some experiments on ceramics using gas filled process reported savings in amount of electrochemical energy and increase in MRR.
4 Jain et al [10] have used alumina glass composite ceramic material and found that MRR is greatly affected by porosity of the samples.
5 Liu [7] has reported that the craters formed in the ECDM process are almost same as those formed in EDM, along with same recast layer, which is mainly due to sparking action and Spalling is the major material removal mechanism

X. ECDM APPLICATIONS

Specific applications may include:

- Miniature feature for turbine blades
- Filters for food and textile industries,
- Micro-fluidic channels in non-conducting materials (quartz, glass and ceramics)
- Micro-electro-seam welding of copper platesand foils
- Turning and dressing of metal bonded grindingtools
- The ECDM has been used to fabricate electrodes for pressure micro-sensors and resonance detection micro-sensors, etc
- The process can be effectively used for micro-fabrication of an array of holes in micro-filters.

XI. POTENTIAL BENEFITS/POSSIBLE OUTCOMES (SCOPE)

After analysis of presented work on developments in variants of electrochemical discharge machining (ECDM)the major scope is found is as per following:

- To meet the growing demand of micro components made of non-conductive materials, there is a need to develop micro machining techniques. Micromachining of Brittle materials is possible with micro- ECDM. The process is helpful to industry for manufacturing of extremely difficult to machine materials with usual methods.
- Improvement in process repeatability and accuracy can increase industrial applicability in case of electrochemical discharge grinding.
- Investigations can be conducted on electrochemical discharge milling for fabrication of complex micro features with high aspect ratios.
- Modifications in tool design can further enhance the dimensional accuracy of the process.

CONCLUSION

After analysis of work on developments in variants of electrochemical discharge machining (ECDM) the major conclusions of the Process are summarized as below:

The process (ECDM) is efficient than other conventional methods. ECDM is a novel hybrid micromachining technology for production of through and blind micro-holes, Micro-grooves, Micro-slots, Micro-channels and Complex shaped micro-contours in electrically non-conductive materials.

Proper gas film formation with controlled input parameters like current and voltage, tool electrode shape, use of appropriate electrolyte with or without abrasives and motions of tool electrode and work piece will result in improved machining efficacy.

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