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Review of Electrochemical Sparks Machining Process

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ABSTRACT

Electro Chemical Spark Machining (ECSM) is an important process as it can be applied to metal, ceramics, smart material, composites. It can be applied in micro fabrication, heat treatment, welding. Advanced ceramics and composites have high potential for their application in various field of engineering due to their superior properties such as high compressive strength, good thermal shock resistance, high wear resistance, high hardness, high strength, to weight ratio such improved material properties have new challenges in manufacturing. ECSM can become a practical solution for these problems. There is need of research for better control, cracking of material, deep drilling, tool wear etc. The research done until today mainly focused on experimenting the machining of various materials and investigating the effect of different parameter on material removal rates. One main challenge in repeatability application is control of gas film around tool electrode. This paper review history and advancement in ECSM process.

Key words: Electrochemical Spark Machining (ECSM), Non-Traditional Machining, Advanced Machining.

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Introduction

Machining is process of controlled removal of material from workpiece to get desired dimensions required for engineering component. In traditional machining process tool material should be harder than work piece material. This limitation is overcome by many advanced manufacturing techniques, like Ultrasonic machining (USM), Electrochemical machining (ECM), Electro discharge machining (EDM), etc. To get advantage of more than one non-conventional machining there immerged concept of Hybrid machining. Electro chemical spark machining (ECSM) is also a hybrid machining process which is combination of Electrochemical machining (ECM) & Electro discharge machining (EDM) which is also known as, Electrochemical Engraving, Electrochemical Discharge Machining etc.

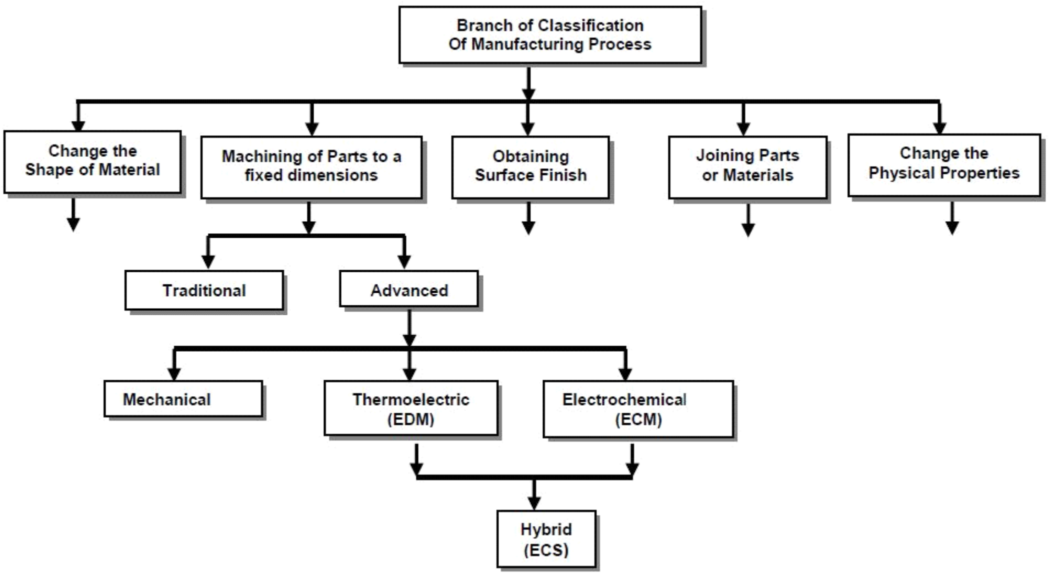

Figure 1: Evolvement of ECS (Branch in the Classification Tree of Manufacturing Process)

Spark and arc formation is not desirable in case of ECM as it damages workpiece and tool. But this phenomenon is useful for machining of non-conductive materials.

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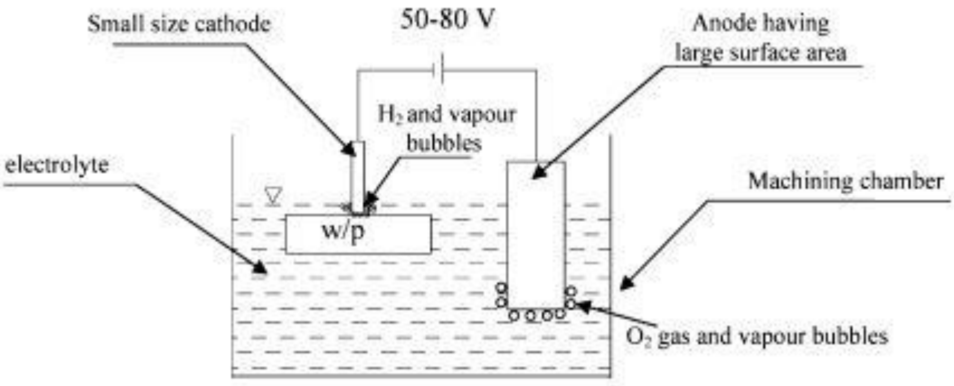

Figure 2: Schematic diagram of basic electrochemical cell in ECSM process.

Mechanism of generation of spark in electrolyte

Electrochemical reaction at anode:-

Generally copper is used as electrode & NaOH as electrolyte. Oxygen gas is generated at anode due to following electrochemical reaction.

$$\mathbf{Cu \rightarrow Cu^{2+} + 2e^{-}}$$
$$\mathbf{2H_2O \rightarrow O_2\uparrow + 4H^{+} + 4e^{-}}$$

Electrochemical reaction at cathode:-

Due to following reaction hydrogen gas is generated at cathode.

$$\mathbf{Cu^{2+} + 2e^{-} \rightarrow Cu}$$
$$\mathbf{2H^{+} + 2e^{-} \rightarrow H_2\uparrow}$$
$$\mathbf{Na^{+} + e^{-} \rightarrow Na}$$
$$\mathbf{2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow}$$
$$\mathbf{2H_2O + 2e^{-} \rightarrow H_2\uparrow + 2OH^{-}}$$

In ECSM process generally two electrodes are largely different in size. Machining may takes place at cathode and anode. The electrode which is used as tool is called active electrode and which is small in size compared to another electrode, which is called as auxiliary electrode. Work piece is kept near to active electrode. Here, voltage applied is also large. Due to small shape at active electrode there is large current density so large amount of gas is generated there. This gas is nonconductive in nature. So this gas film acts as high resistance for electric current so ohmic heating also takes place & more number of gas bubbles are generated this gas is passivate active electrode. As applied voltage is above break down voltage of gas film there is occurrence of spark. Due to this spark gas layer break down takes place & again electrochemical reaction starts. This process continues. Generally power applied in pulsed form of micro second range. This process is shown by operation flow of ECSM.

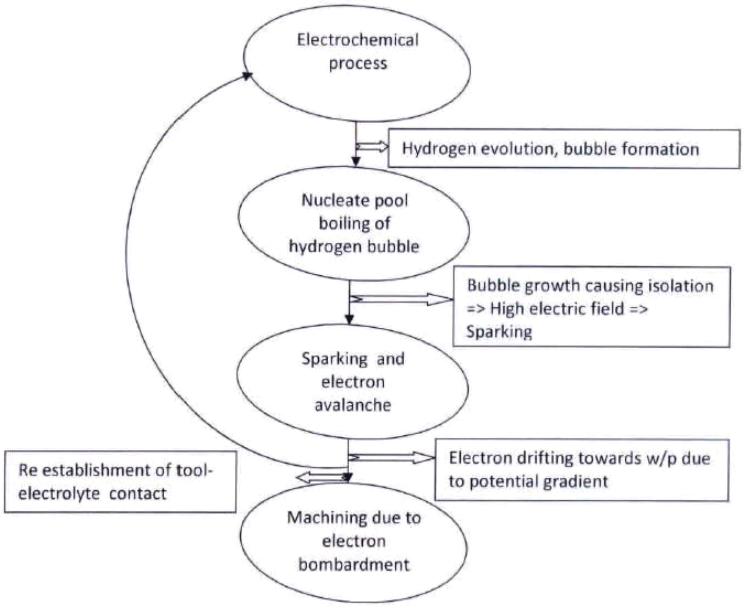

Figure 3: **Operational flow of ECSM process showing intermediate processes**

So, material removal takes place by combined effect of Melting, Vaporisation, Chemical reaction, Cavitation Erosion.

In ECSM we can perform machining at cathode as well as anode. When cathode is used as active electrode then it is called as ECSM direct polarity and when anode is used as tool then it is called as ECSM reversed polarity. In both case workpiece to be machined is kept near active electrode. Following table compare ECDP & ECRP.

	ECDP	**ECRP**
Cathode	Active Electrode (small in size)	Auxiliary Electrode (Large in size)
Anode	Auxiliary Electrode(large in size)	Active Electrode (small in size)

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Surface finish	Better than ECRP	Good
Passivating gas	Hydrogen	Oxygen
Material removal rate	Good	Better than ECDP

ECSM at both electrodes

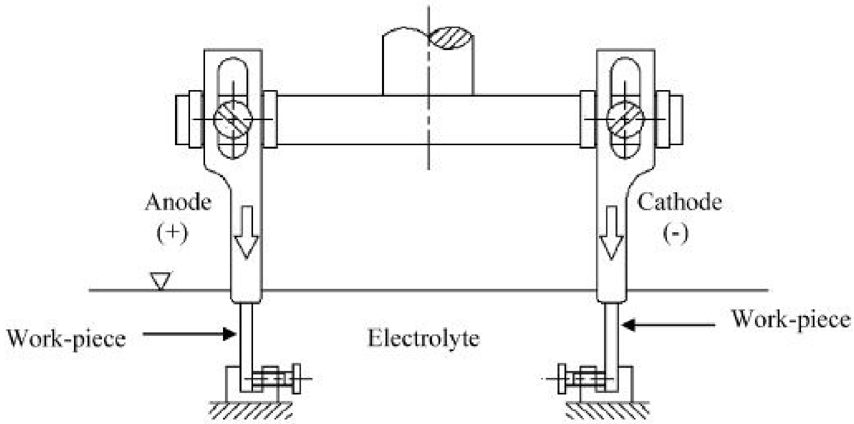

Figure4: Machining at both the electrodes

If active and auxiliary electrode is small size then machining can be done at both electrodes. Sparking is not constantly occurring at both electrode, it keep shifting from one electrode to another electrode. There is resistance to electric current at both electrodes due to generation of gas. Spark is occurred at one electrode then there is shielding takes place at another electrode. So we can perform machining at both electrodes. Diagram shows schematic diagram.

Kulkarni Anjali concluded that ECSM is potential candidate for micro fabrication. Discharge phenomenon in ECSM is discrete phenomenon. In another paper author found that ECSM is good for production of micro-channel on glass pallets. Author found that machined surface is found by melting & evaporation. Also found need to reduce energy of spark for good surface finish. Kulkarni et al try to investigate mechanism of ECSM by experimental observation.

Jain and Adhikary successfully applied ECSM process for cutting of quartz using controlling tool & wedge edged tool by using cathode & anode as tool.

Jain et al electrochemical spark abrasive drilling (ECSAD) experiments were performed to enhanced capabilities of process. Author found use of abrasive improved the process performance. The work piece used was Alumina & Borosilicate glass.

Bhatt charyya et al developed micro-tool vibration system which consist of tool holding unit, micro-tool vibrant unit etc. Author also performed experiments to found out effective values of process parameters such as micro tool vibration frequency, amplitude &electrolyte concentration. Author found lower electrolyte concentration (15-20 gm/lit) decreases stray effect. 50-200Hz range of frequency is good for machining of narrow gap.

Panda &Yadava developed 3D finite element transient model to estimate temperature field & material removal rate due to Gaussian distributed input heat flux of spark. Author found that MRR increases with ejection efficiency duty factor, energy partition. Increase in spark radius reduces MRR.

Bhondwe et al attempted to develop model for MRR by use of finite element method. Author found that model predict experimental result in range of accuracy. Also parametric study of electrolyte concentration, duty factor & energy partition was carried out.

Fascio et al analysed ECSM by electrochemical approach author also proposed two models of ECSM phenomenon based on percolation theory and another to estimate the spark characteristics with the help of experimental data.In another paper *Fascio et al* done 3D-micropattering with electro discharge assisted etching at tool tip.

Wathrich& Hof presented method for measuring the gas film thickness using current voltage characteristics. They demonstrated reducing wettability of tool electrode cause reduction of gas film thickness which is better for machining repeatability.

Peng & Liao studied travelling wire electrochemical discharge machining (TWECDM) to slicing nonconductive brittle materials (optical glass & quartz bars) of size 10 to 30mm diameter.

Conclusion

ECSM is very good process that can be applied to metal, ceramic, composite and non conductive material. It has less MRR but that is advantage during micromachining. Main obstacle to apply ECSM to miniature component is crack near machining. MRR is also dependent on many parameters. To increase reproducibility of ECSM, there is need of research to control over gas film during dynamic conditions of machining. This process has potential to heat treatment also. Comparing to another non conventional process it has less setup cast, so by proper modification it can become practical machining process.

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