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Major Developments in EDM Surface Alloying using Composite Material Tool Electrode

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Abstract: ***Electric Discharge alloying/Coating (EDC) is an emerging field for the surface modification of advanced engineering materials like tool steel, high heat resistance alloy, titanium alloy etc. The advanced engineering materials have good mechanical properties and are used for the engineering applications like dies, aerospace, and automotives. To treat these difficult-to-machine advanced engineering materials with new challenges, numerous advancements in electrical discharge machining (EDM) processes have been carried out. Electrode materials for EDM are usually made up of copper, and its alloys. Proper selection with composition of electrode materials are required to avoid cracks, residual stresses etc during or after Electrical Discharge Machining and at the same time to have better surface finish and material removal rate and lower tool wear rate of the electrode. Further electrodes can be prepared by different methods like powder metallurgy, stir casting technique etc. This paper presents the brief details of effect of different electrodes on the surface and machining characteristics.***

Keywords: ***Alloying, Composite, EDM, Electrode.***

I. INTRODUCTION

EDM is a material removal process which involves melting and vaporization of the electrically conductive workpiece materials by very short duration electrical discharges. The basic process of metal removal is due to discharge of electric current between a thin gap across the tool and the work piece [1-3]. The tool (cathode) as well as the workpiece (anode) remains immersed in a hydrocarbon dielectric medium throughout the machining processes as shown in figure 1.

The temperature of each discharge ranges between 10,000-20,000°C. This technique is widely used in aerospace, mould making, press tools and dies, biomedical and automotive industries [4-5]. The efficiency of the process and quality of the machined surface depends on various input factors like spark gap, voltage, pulse on time, Polarity, peak current, tool material, work piece material and dielectric medium.

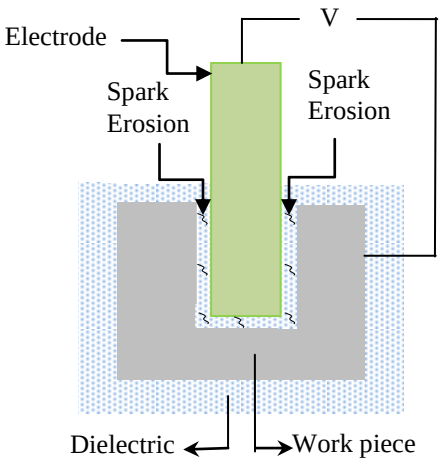

Fig. 1.Schematics of EDM Process

Different theories are there to describe the spark erosion process between tool and workpiece. Electromechanical theories suggest that abrasion of the material is due to the concentrated electric fields and this theory neglects any thermal effect.

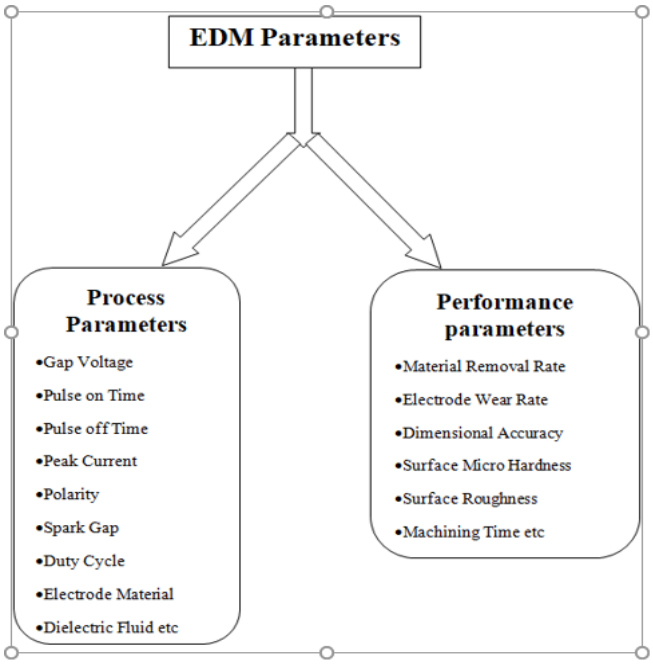

Fig. 2.EDM input process parameters and performance parameters

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Thermo mechanical theory suggests that material is melted due to electrical effects of the discharge. While thermoelectric theory suggests that very high temperature due to high intensity of the discharge current is responsible for the material removal in EDM and this theory is well supported by experimental data. The performance output parameters and the process parameters for EDM process are shown in figure 2.

Electrode material must exhibit desirable properties i.e. should be able to efficiently remove material from the workpiece. The available literature works in this field reveals that there is a need to find cost effective and efficient EDM electrode. The materials for electrode are generally copper and their alloys, aluminum and graphite due to their excellent electrical and thermal conductivity.

II. NEED FOR SURFACE MODIFICATION

To improve the mechanical, thermal and tribological behavior of the machined surface, surface modification is required, the surface of the machined components may be modified by diffusion of various elements therefore forming a layer on the machined surface with desired microstructure and properties [6].

As machined components have to be used in severe practical conditions like high temperature, cyclic and continues loading, therefore premature failures of the casted components may occur resulting in thermal cracks, stress corrosion , fatigue etc. Therefore to avoid these failures, materials are required to be surface treated. The surface treatment results in modified grain structure and composition of the machined surface.

The layer formed on the surface of the machined component has different structure and composition. This surface layer with desirable composition and properties can be obtained with controlled process while on the other hand there can be cracks and other negative effects in case of uncontrolled process [7]. Another way to achieve desirable surface modification is through additions of powder in dielectric fluid.

Surface alloying is required to make the component robust in adverse condition like the desirable elements e.g. Cr can diffuse to the Die steel work piece to improve its corrosion resistance.

III. ACHIEVEMENTS IN THE FIELD OF SURFACE ALLOYING

The significant achievements in the field of EDM surface alloying or modification have been presented in table 1.

Table- I: Key achievements in surface alloying using EDM

Sr No.	Authors	Work material	Tool material	Achievements
1.	Gill et al, 2015 [8]	EN31	Cu-Cr-Ni	Electrodes fabricated by powder metallurgy process were used to investigate the surface modified by electric discharge machining.
2	Klocke F. et al, 2004 [9]	Inconal 718	Tungsten	In the presence of Al and Silicon powder mixed in dielectric, a grey zone was formed.
3	Mohri et al. 1993 [10]	Carbon steel , aluminium	Cu, Al, WC, Ti	Composite structured electrode was used for surface modification. Modified surfaces were having higher wear and corrosion resistance and less cracks.
4	Sidhu et al, 2013 [11]	Al/SiC-MMCs	copper electrode graphite electrode	Higher metal transfer was observed with the copper electrode as compared to graphite electrode.
6	Tsunekawa et al, 1994 [12]	Al	Ti-Al (64%-36 %)	Composite layer of Ti-Al with thickness of 100µm were found. The machined surface was found to be having fine dendritic precipitates of titanium carbide.
5	Samuel M. P. Et al , 1997 (1997) [13]	Many	Copper tungsten	Metal transport from the copper tungsten electrode were observed using electron spectroscopy (for chemical analysis)
8	Kruth et al, 1998 [14]	Mild steel	Many types	Electrodes fabricated by powder metallurgy have high tendency of surface alloying as compared to conventional metallic electrodes.
7	Hwang et al, 2010 [15]	Ni	Ti-Gr (Graphite) Multi layered electrodes	Enhancement in the Surface was observed with better surface finish, the cracks were also fund to be reduced.
8	Stambekova et al, 2012 [16]	5083 Al	Si-Fe alloy	Micro hardness of 5083 Al enhanced and same happended to corrosion resistance also.
9	M M Sari et.al, 2012 [17]	AISI H13 tool steel	Cu	The surface modification of AISI H13 tool steel, was studied, It was observed that EDM process become more efficient by mixing multi walled carbon nanotubes in the dielectric fluid.
10	Furutani et al, 2003 [18]	carbon steel	copper electrode	Titanium carbide layer was observed when EDM machining of carbon steel with copper electrode (negatively polarized) with titanium powder mixed dielectric, titanium was observed to be present in the surface

IV. CONCLUSION

For good consistence performance, EDM machined parts should be able be withstand adverse conditions like High temperature, wear friction, corrosion etc. Surface modification with suitable and controlled alloying elements can provide high surface hardness with better resistance to wear and corrosions. The technique has been found to be more useful where electrodes are fabricated by powder metallurgy process.

Also desired alloying elements with varying concentration can be made by this technique. Surface alloying is very useful in aerospace industries where wear resistance of Al alloys can be improved with this process. It has been observed that addition of different powders like Cr, Al, Si, Cu, Ni, Ti etc resulted in increase in wear and corrosion resistance, micro hardness and decrease in surface roughness, cracks. There is a great scope of research work in important alloying elements/materials like manganese, vanadium, carbon nanotubes etc as very little work for the same has been reported and this can be further extended to super alloys and composite materials. Also hardly any work has been reported for the surface allying using electrode tool fabricated by stir casting technique.

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