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ENHANCEMENT OF SURFACE HARDNESS OF MILD STEEL BY USING EDC

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Abstract—

Electro discharge machining (EDM) is a typical machining process, which is widely used for machining of very hard materials used for engineering purposes for different field. In Electrical Discharge Coating (EDC) process tool electrode which is manufactured by powder Metallurgy and connected to anode with sample work-piece is selected as cathode in electro discharge machine. In presence of dielectric, tool electrode is worn out during EDM and the material removed from the surface of electrode deposited over the work-piece surface. This paper is expressing an advanced method of surface modification by EDC and work carried on Titanium Carbide and Copper (TiC- Cu) composite Coating deposited on mild steel substrate. Titanium (Ti) and Copper (Cu) powder in different weight percentages has been used for preparation of tool electrode by P/M process. Micro hardness testing has been performed on the coating to measure the hardness values of coated surface.

Keywords—Electric Discharge Machine (EDM), Electro Discharge Coating (EDC), Mild Steel (MS)

I. INTRODUCTION

Basically EDM is use for marching and to form cavity by spark erosion between tool and work piece [1]. EDM machine is used to coating surface of works piece by spark erosion and increase the hardness of coated surface in these process will required to change the electrode and polarity of the machine these coating by EDM is known as electrical discharge coating (EDC) [2].

Surface coating is a process to alter the surface of engineering components to achieve improvement properties such as high hardness, wear resistance, high-temperature resistance and corrosion resistance, without making any significant change to bulk characteristics of the structure [3].

Surface modification by material transfer during EDM has emerged as a key research area in the last decade. Electric Discharge Coating (EDC) is one of the emerging coatings processes due to its ease, simplicity, reliability and cost effectiveness. Electric Discharge Machining (EDM) is a non- conventional machining process, which is widely used for machining various engineering materials. EDC is a coating process, which is reverse of the EDM process. In the EDC a tool electrode made up of different materials (materials used for electrode are the coating or alloying materials) and method of manufacturing the electrode is powder metallurgy. Surface modification by EDM is one of the many methods to improve a material work- piece's surface [4].

EDC is the reverse method of EDM. In EDM metal is removed from the material of work-piece or substrate and washed away by dielectric fluid‟s flushing, however in EDC the material of tool electrode is decomposed from the tool and deposited over the substrate. The electrodes employed are generally produced by powder metallurgy (P/M) route, in order to achieve the necessary combination of operating characteristics. In general, material like Ti, W, Ta with some binder materials like Co, Cu, etc. are used as tool compact. The tool electrode compacts made from the powder compaction method uses as tool electrode because it enables the forming of loose metal powders into required shapes with sufficient strength. However during electro discharge loose powder can easily come out from tool electrode and deposit on the work piece. In general, compaction is done without the application of heat. Specific type hydrocarbon i.e. transformer oil or kerosene are used as dielectric during the process [5].

The tool electrode which is manufactured by P/M technique connected to anode and work-piece (on which coating is to be done) is selected as cathode in electro discharge machine (polarity opposite to the electrical discharge machining).

During EDC process a spark is generated between work piece and tool and due to negative polarity, evaporation of the anode is higher than the cathode. This evaporated tool material after the melting rushes towards the cathode (work-piece/substrate) and deposited over the surface. By setting the different parameters of coating thickness of the layer with some more characteristics can be altered. During EDC process Ti, W or other metallic materials used as electrode form a kind of hard carbide such as TiC or WC through chemical reaction between worn electrode material and the carbon particles decomposed from the hydrocarbon fluid under high temperature. The carbide is piled up on the work-piece and produces a hard layer in specified time. The parameters should be controlled in such way that the cutting rate of the work-piece must be lower than the wear rate of electrode [6].

EXPERIMENTATION

Electrode preparation:

In this set of experiment three tool electrodes of composition 70:30,50;50 and 30:70 (Cu:Ti by weight percentage) at two different pressures 150 MPa ,200 and 250 MPa prepared by the powder metallurgy process. The diameter of the tool electrode is kept 15 mm and height as 5 mm. Details of the electrode preparation parameters are given in Table 1.

Table 1: Detailed parameters for P/M tool electrode preparation for final experiments

Proportions of powders (Ti:Cu)	30:70, 50:50 and 70:30 wt.%
Compaction pressures	150, 200 and 250 MPa
Dimensions of compact	15 mm diameter & 5 mm height
Holding / Stand- up time	2 min

As in the process of powder compaction the powder is mixed with desired additives to make bonding between the particles, but in the present study copper itself works as a binding material for tungsten powder. No blending is used and sintering of compact is not done due to the fact that sintered compact is somewhat strengthen the compact and restrict decomposition of powder during electro discharge coating process.

Green powder compact electrode prepared with Ti: Cu=30:70 wt % and compact pressure 150 MPa (T1), Ti:Cu=50:50 wt % and 200 MPa pressure (T2). Another compact prepared with Ti:Cu=70:30 wt % and 250 MPa compact pressure is not shown in the figure. Extensions of tool electrodes have been prepared from mild steel rod with required dimension to accommodate in the EDM machine and P/M green compacted electrodes are brazed and mechanical fastener on the tip of the extensions.

Electro-discharge coating process:

In second step EDC process performed using EDM machine. The tool electrode and work piece are immersed in a dielectric medium. In order to deposit the material over the work surface by erosion of the tool electrode, tool electrode is kept as anode and work piece as cathode (reverse polarity). By using different type of tool electrode prepared with different composition and compact pressure experimentation have been performed.

Electro discharge machine has been used for the present experimentation. The prepared electrode after brazing with tool extension is mounted on the EDM"s servo control unit and substrate on the work table with the fixture of suitable height. To study the effect of peak current on deposition rate experimentation have been done with 2 different current setting i.e. 2 and 4 amp, by keeping the other EDM parameters like TON, TOFF, duty factor, gap voltage constant.

Independent variable:

1. Material Composition of tool electrode (MC)

MC1=70:30(Cu:Ti)

MC2=50:50(Cu:Ti)

MC3=30:70(Cu:Ti)

MC4=100:00((Cu:Ti)

2. Compaction pressure of green compact electrode (CP)

CP1=150 MPa

CP2=200 MPa

CP3=250 MPa

3. Current given to electrode (I)

I1=2 AMP

I2=4 AMP

Dependent variable:

1. Weight (Wt) of material deposition coating Wt in gm
2. Coating hardness (in BHN)

Table 2: Detailed experimental parameters.

Tool No.	(Cu:Ti) wt %	Pressure (MPa)	Exp. No.	Ip (Amp)
MC1	70:30	150	1	2
			2	4
MC2	50:50	200	3	2
			4	4
MC3	30:70	250	5	2
			6	4
MC4	100% Cu	200	7	2
			8	4

Measurement of deposition rate:

After preparing the EDM and making all necessary arrangements, initial weight of work piece is measured. After the experiment final weight of work piece and tool is measured. Difference between the weights of workpiece after and before experiment represents the amount of material deposited on the substrate surface. Deposition rate has been calculated by dividing the deposition with total experimental time.

Preparation of sample for micro hardness analysis:

After the experiments substrate has to be prepared for further analysis such as Micro Hardness Test (Brinell‟ Hardness Test). For micro hardness testing, top surface of the coating are polished with fine grade polishing paper so that indentation could be visible under Brinell‟ micro-hardness tester.

RESULT AND DISCUSSION

Experimental results:

The developed coating of TiC-Cu on mild steel are analyzed by Microscopy for study the microstructure of the coated surface and Brinell" Micro hardness Tester for knowing the hardness value of the coated surface respectively. The effects of composition (Ti and Cu ratio) and compaction pressure of the tool electrode and peak current during electro discharge process were observed and analyzed specifically for deposition rate, micro-structure of the coating and different phases formed on the coating surface in EDC.

Figures 1 shows the TiC-Cu coated steel substrate EDC coating. Suffix Ex-number on the sample represents the experiment number. The effect of compaction pressures and composition can be understood by comparing the experiments of 70:30, 50:50 and 30:70 composition and 150, 200 and 250 MPa .

The effect of compaction pressure on the surface layer is such that higher the compact pressure lower will be the deposition over the substrate surface. But from the experimental results, it is evident that pressure of compaction is not only factor to affect the coating phenomenon but also composition participates significantly. Composition of powder compact with greater titanium amount causes coarser coating surface.

When amount of copper is greater in composition, it gives a cutting action but at higher currents this amount of copper also deposits on the substrate surface. Even at higher pressures greater amount of titanium causes coarse deposition than at lower pressures. From the Figure 1, it is evident that increase in current causes increasing deposition rate, but at very high currents as 4amp. A coating layer becomes rough and coarse.

Trial-1 Trial- 3 Trial- 5

Trial- 8

Figure 1: Substrates' surfaces at the same current (2 and 4 ampere), but at different compositions and different compaction pressures (Ti:Cu=50:50 wt%, 200 MPa; Ti:Cu=30:70 wt%, 150 MPa; Ti:Cu=70:30 wt%, 250 MPa; Cu=100 wt%, 200 MPa).

Effects of different parameters on material deposition rate (MDR)

The weight of the work-pieces before and after the coating was measured and the deposition rate has been calculated for unit time (gm/min). The weight of the work- pieces has been measured with an electronic weighing machine with accuracy up to 1 mg.

Effect of electrode composition

Effect of composition on the EDC process were analyzed and observed shows, the variation of deposition rate against applied current during electro discharge coating process using tool electrode prepared with different composition ration of Ti and Cu Ti:Cu= 50:50 and 70:30 weight ration) for compaction pressure of 200 MPa and 250 MPa respectively.

It is observed from the graphs, the deposition rate increases almost gradually with the increase of applied current for Ti:Cu=70:30 Wt%. However, for the composition of Ti:Cu=50:50 Wt% deposition rate increase with increase in current, but compared to 70:30 proportion it is very less. Using a tool electrode with higher percentage of Cu Content may enhance the machining rate instead of deposition which may reduce the deposition rate.

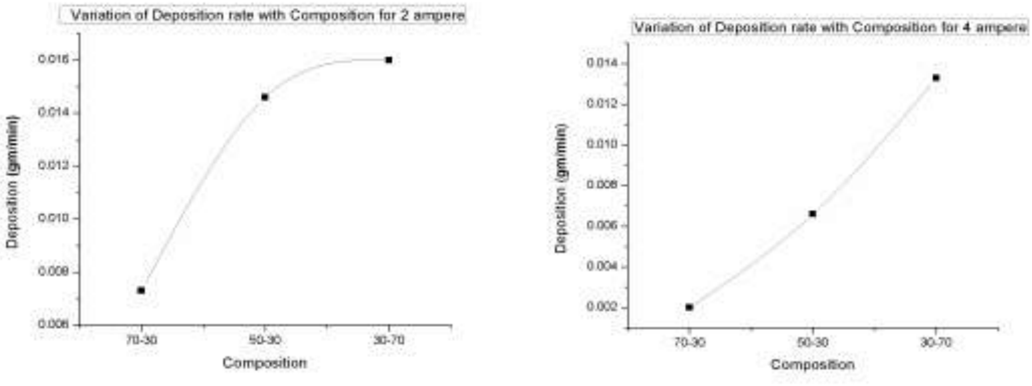

Figure 2 A & 2 B: Deposition rate against composition for different current

Micro hardness (Brinell)

The brinell hardness test is commonly used to determine the hardness of materials like metals and alloys. The test is achieved by applying a known load to the surface of the tested material through a hardened steel ball of known diameter. The diameter of the resulting permanent impression in the tested metal is measured and the Brinell hardness is calculated .Micro-hardness of the coating surfaces were measured by brinell hardness tester.

Due to presence of pores on the coated surface micro hardness value for all the samples could not be measured. Here in Table 6.2, micro hardness values of some specific samples.

Table- 3 Reading of coated MS surface hardness

Exp. No.	Before Coating	After Coating
1	128 BHN	164 BHN
2	132 BHN	172 BHN
3	128 BHN	168 BHN
4	134 BHN	165 BHN
5	132 BHN	190 BHN
6	136 BHN	188 BHN

From the above value it can be observed that with increase in current (Experiments 3 & 4 i.e. 50:50 composition and at 150 MPa compaction pressure) when other parameters are fixed, deposition rate increases and with that average micro hardness also increases. Further from Exp- 5 to Exp-6 (Experiments of 30:70 composition and at 200 MPa compaction pressure) when current increases from 2 ampere to 4 ampere for tool compact prepared with 200 MPa compaction pressure average micro hardness increases. It may be due to the fact that at higher compaction pressures surface layer created is of great strength and hardness increases rapidly.

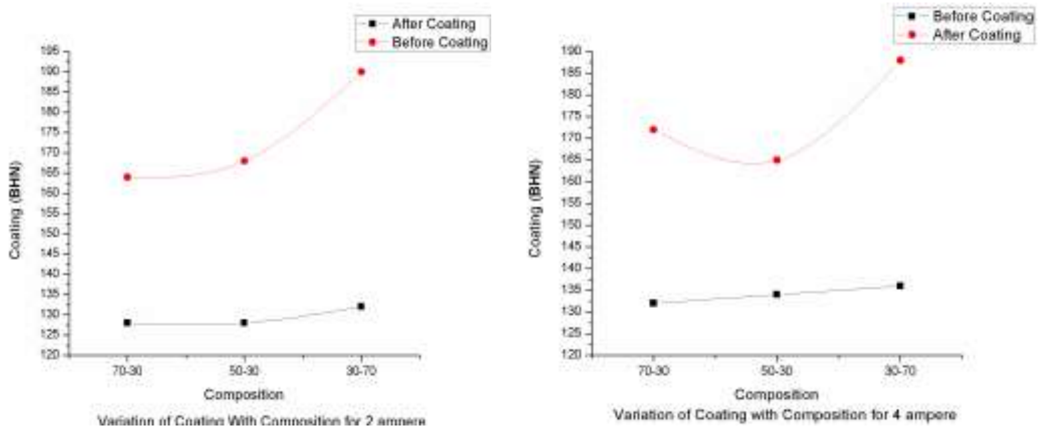

Figure. 3 A, 3 B hardness against composition for different rate of current

CONCLUSION

From the current experiments it has been found that TiC-Cu composite coating deposited on mild steel substrate. It has been found that, during electro-discharge processing in a liquid dielectric medium, the metal transfer from the tool electrode to the work surface can be enhanced using powder compact tools with reverse polarity. The green compact tool electrode with lower compaction pressures gives higher amount of coating over the surface. With increase of Titanium percentage in the tool electrode, deposition rate increases when other parameters are kept constant.

EDC method gives improvement in hardness up to 3 to 4 times (up to 190 BHN) compared to substrate material. Applied current during EDC process is a significant parameter for good compilation of the ceramic layer on the work- piece surface. Deposition rate of the coating material on substrate increases with the increase of peak current. However quality of surface becomes poor.

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