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Coating on MS With Reversable Experimental Technique on EDM

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ABSTRACT

Electro discharge machining (EDM) is a non- conventional machining process, which is widely used for machining of very hard materials used for engineering purposes. In Electrical Discharge Coating (EDC) process tool electrode which is manufactured by powder Metallurgy (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). 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 describes an advanced method of surface modification by Electrical Discharge Coating (EDC). In this work 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. Effect of compact pressure, proportions of powder of materials (during tool preparation) and peak current (during EDC) on deposition rate of the coating and brinell. Micro hardness testing has been performed on the coating to measure the hardness values of coated surface.

1. INTRODUCTION

Basically EDM is use for marching and to form cavity by spark erosionbetween tool and work piece but in my project these EDM machine is used to coating surface of works piece by spark erosion and increase the hardness of coated surface inthese process will required to change the electrode and polarity of the machine these coating by EDM is known age electrical discharge coating (EDC)

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.

Surface modification by material transfer during EDM has emerged asa 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 machiningprocess, 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 alloyingmaterials) 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.

There are many surface modification methods through which a ceramiclayer coating is created on the surface of material and these coating techniquesexisting in the present manufacturing world such as Physical vapors deposition (PVD), Chemical vapors deposition (CVD), Electroplating, LASER coating, Electron- Beam Irradiation and Sputtering etc. depending on their requirements.

These processes are carried out in high vacuum and at temperatures inthe range of 473-773 K. The particles to be deposited are transported physically to the work-piece, rather than by chemical reactions, as in chemical vapors deposition. In vacuum deposition, the metal to be deposited is evaporated at high temperatures in a vacuum and deposited on the substrate, which is usually at room temperature or slightly 2 higher. Uniform coatings can be obtained on complex shapeswith this method. In this method of deposition a vacuum apparatus is required and maintaining complete vacuum is not a easy deed.

2. LITERATURE REVIEW

Several research papers have been studied and analyzed for the understanding of EDC Technique. Some of them are reviewed and described in the following paragraphs.

Gangadhar *et al.* [4] observed that during electro-discharge machining (EDM) the topography, metallurgical and physicochemical properties of the surface layer change significantly. Under certain circumstances, the metal transfer from the tool electrode to the machined surface is also appreciable. It has been found that, using suitable process parameters, surface alteration for desired functional behavior is feasible by EDM. The authors performed some experimentation using bronze compacts having 90% copper and 10% tin as tool electrode and mild steel as work- piece. It has also been found that, the metal transfer from the tool electrode to thework surface can be enhanced using powder compact tools with reverse polarity. The experiment was carried for 3 minutes with peak current range of 2.3 to 18.0 amp and frequencies in the range 5- 80 kHz. The authors studied the metal transfer from the tool electrode by cross-sectional examination, electron spectroscopy and X-ray diffraction analysis of the work surface. The associated changes in the surface topography are analyzed by SEM. Surface modification for desired functional behavior during electro-discharge machining (EDM) was correlated by suitable selection of process parameters.

Shunmugan *et al.* [5] uses tungsten carbide compact as tool electrode and experimented on HSS by EDM with reverse polarity. The tool used was of 10mm diameter and 20 mm length prepared with 40%WC and 60% iron at a compaction pressure of 700 MPa. During EDM, the duty factor and peak voltage were 70% and 120-130 V respectively. It has been found that WC-coated HSS tools exhibit improved wear resistance even under the extreme pressure and temperature conditionsencountered in metal cutting. 25%-60% improvement in abrasive wear resistance and 20%-50% reduction in cutting forces are observed with WC-coated HSS tools. This investigation opens up the possibility of EDC for wear-resistant coating.

Samuel *et al.* [6] has been studied the performance of P/M electrodes on various aspects of EDM operation. It has been found that, materials with high thermal and electrical 13 conductivity coupled with considerable mechanical strength can function as good electrodes. The study revealed that P/M electrodes are technologically viable in EDM and that EDM properties of these electrodes can be controlled by varying compaction and sintering parameters. P/M electrodes are found to be more sensitive to pulse current and pulse duration than conventional solid electrodes. Under certain processing conditions P/M electrodes can cause material addition rather than removal.

Zaw *et al.* [7] suggested some electrode materials for electrical- discharge machining i.e. graphite, copper, copper alloys, copper-tungsten, brass, silver-tungsten and steel. Materials having good electrical and thermal conductivity with a high melting point are preferred to be used for fabricating electrodes. Compounds of ZrB2 and TiSi with Cu at various compositions are investigated for EDM electrodes by either solid-state sintering or liquid phase sintering. The performance of this electrode is compared with the conventional electrode materials such as Cu, Graphite, CuW.

Simao *et al*. [8] modify the surface of hardened AISI D2 Sendzimir rolls, by electrical discharge texturing (EDT). It has been revealed that, by using powder metallurgy (PM) green compact and sintered electrodes of TiC/WC/Co and WC/Co, life and performance of rolls have been improved significantly. Analysis shows that Ti and W contained in the PM electrodes, together with C decomposed from the dielectric medium made various compounds which were transferred to the work-piece surface during sparking. An increase in the roll white layer micro hardness was observed (up to 950 HK0.025) on employing sintered TiC/WC/Co tool electrodes. This value was much higher than either that of the heat-treated AISI D2 roll matrix or the measured typical roll white layer hardness by using conventionaltool electrodes.
~24, 20 14 and 19%, respectively. Typically, changes in surface metallurgy were measured up to a depth of ~30 µm and increase in the surface hardness up to ~1350 HK0.025 observed.

Lee H.G. *et al.* [10] studied the surface alloying of titanium alloy i.e. gamma Ti-Al (Ti– 46.5Al–4(Cr, Nb, Ta, B)) and Ti alloy (Ti–6Al–4V) sheet during wire cutting using demonized water as dielectric with nickel and copper wires. The authors further observed that utilization of partially sintered powder metallurgy (PM) electrodes, where the binding energy between grains is reduced as compared to fully dense products, can encourage surface alloying. some textured and alloyed layers on the roll material were over 900HK0.025 when using WC/Co electrodes as comparedto surfaces produced with standard Cu/graphite tools of 500–740HK0.025.

3. COATING WITH EDM (EDC)

EDC is a coating technique in which tool electrode manufactured by powder of materials, such as Ti, W, Ta, Cr etc. The tool electrode is made by powder compaction in power press at certain pressures. Maintaining the tool as anode and work-piece as cathode, in the presence of dielectric fluid, material is decomposed from the tool electrode and compiled over the work piece surface in several minutes. In this method of coating, there is no need of vacuum apparatus, or any special apparatus with complicated set-up. Simple EDM set-up could be used to deposit coating and by selecting coating parameters carefully and appropriately, thickness and coating characteristics can be controlled.

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. Fig. 1 shows the principle of EDC. 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 isdone without the application of heat. Specific type hydrocarbon i.e. transformer oil or kerosene are

used as dielectric during the process.
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 rateof the work-piece must be lower than the wear rate of electrode.

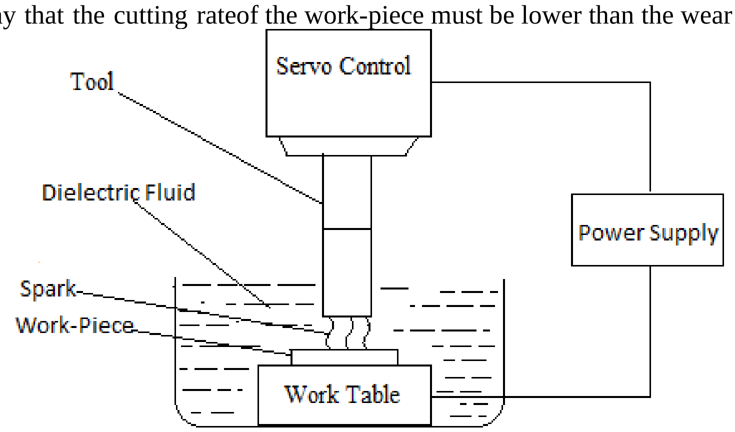

Figure 3.1 : Basic mechanism of Electro-discharge processing

A wide range of powders with alternative compositions can be used forthe manufacture of tool electrodes. These tend to be materials which can form / transfer hard particles such as carbides and may incorporate a secondary binder phase, e.g. WC/Co, TiC/WC/Co, W/Cr C/Cu, etc. By using electrodes made from different materials, the possibility exists to „engineer" one or more alloyed layers (which may be functionally graded) with different mechanical properties. The compacting and sintering conditions under which the P/M electrodes are produced greatly affect their performance. In this technique of EDC, there are mainly two parts of process; firstly we have to make a powder compact tool electrode and this electrode is used as anode in EDM machine tool. Figure 1 shows this type of arrangement of coating. Basic mechanism of this type EDC described in previous section. Green compacted tool electrode EDC can be of two types; In first type, tool electrode material disintegrated and reacted with carbons (which is the result of decomposition of hydrocarbon/dielectric fluid) and deposited over the surface of the substrate. First type of green compacted tool electrode EDC mechanism is shown in Figure 2.

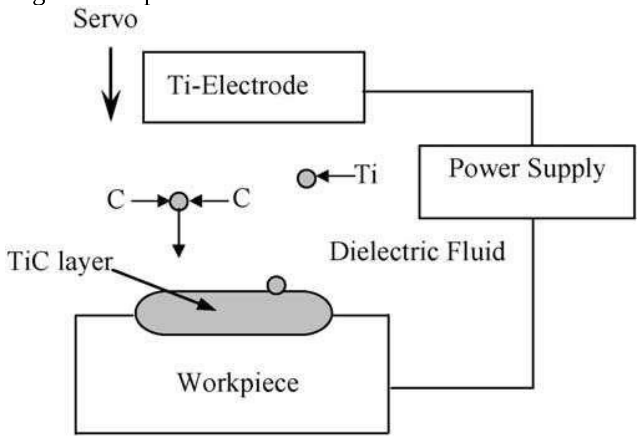

Figure 3.2: Electrode and dielectric reaction kind EDC (Ref. : Wang *et al.* [2])

4. EXPERIMENTATION

This part of project work includes properties of materials used in experiment such as properties of work-piece, tool electrode powders, preparation of powder compactedgreen electrode, preliminary experiment and final experimentation. When experiments were performed by the prepared green compacted electrode of pure Cu Deposition of the electrode material on the substrate surface did not take place, instead machining on the substrate surface observed. In the case of mixed powder tool electrode (Ti: Cu =50:50 wt %) very small amount of coating has been observed and there also cutting of work-piece took place. The above results are evident by visual inspection of the sample and measured weight of the work piece and tool before and after experiments.

Following are the outcomes of preliminary experiments, which bound us for further changes in process parameters;

- The compaction pressure (250 MPa) selected for powder compaction is too high and this restricts the disintegration of powder from the tool at the time of coating.
- Higher amount of copper in powder compact causes the properties of cutting the material as Cu is one of the best cutting tool material in EDM process. So Cu impairs the coating phenomenon significantly.
- Only higher current settings and larger pulse on time help to coat the substrate to some extent, but if compaction pressure is high or amount of Cu is more, cutting of substrate surface will also be rigorous.
- Brazing temperature at the time of joining the extension rod with powder compact was a worrying factor, because the highest temperature of brazing by silver and its alloys goes typically up to 895 K-1425 K (average temperature of 1160 K), which is almost same as the sintering temperature of Cu powder (even though the sintering temperature of Ti is 2675 K). Due to this fact partial sintering of compact takes place and it becomes harder and difficult to disintegrate.

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 kept15 mm and height as 5 mm. Method is similar as described in 3.2. Details of the electrode preparation parameters are given in Table 5.3.

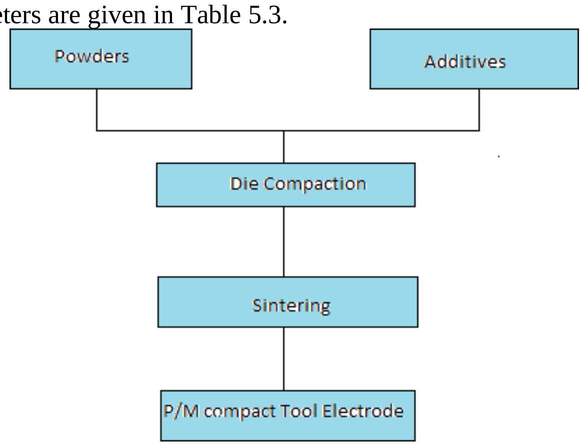

Figure 5.6: Flow chart of manufacturing P/M product

Table 5.3: 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.

5. RESULT AND DISCUSSION

This chapter contains all the results and their relevant discussions ofthe experimentation conducted by EDM machine tool on M.S. work-piece with powder compact electrode of Titanium and copper.

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 6.1 shows the TiC-Cu coated steel substrate EDC coating. Suffix Ex-number on the sample represent the experiment number as per Table 6.1. InFigure 12, 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 onlyfactor 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 6.1, 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. For further results all experimental values are shown in Table-7

Trial-1 Trial- 3 Trial- 5 Trial- 8

Figure 6.1 : 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 were 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. Deposition rate and tool wear rate for different samples are shown in Table 6.1. Table 6.1: Experimental data for deposition rate of EDC.

Exp.No.	(Cu:Ti) Wt%.	Pressure (MPa)	Current (amp)	Work piece weight		Deposition(gm)	Deposition rate (gm/min)
				Before Coating(Bw)	After Coating (Aw)	(Aw-Bw)	(Bw- Aw)/15
3	50:50	200	2	78.20	78.42	0.22	0.0146
4	50:50	200	4	85.06	85.19	0.13	0.0066
5	30:70	250	2	84.05	84.29	0.24	0.016
6	30:70	250	4	82.02	82.22	0.20	0.0133

Effect of electrode composition

Effect of composition on the EDC process were analyzed and observedin Figures 14 and 15 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 can be observed from the Figure 14, 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.

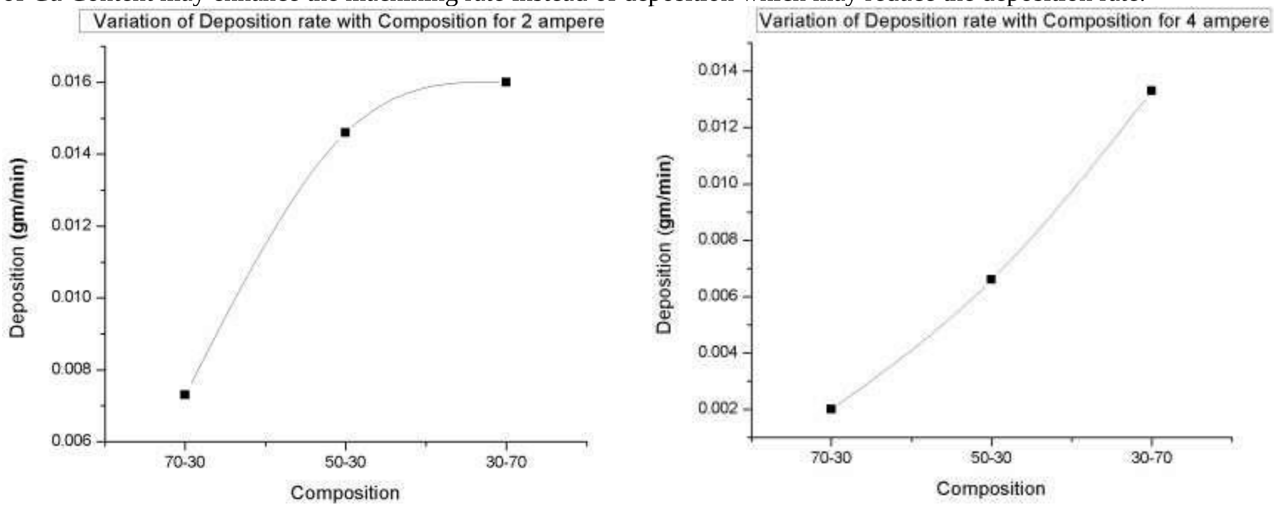

Figure 6.2 A & B deposition rate against composition for different current

6. 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 forgood 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. Howeverquality of surface becomes poor.

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