STUDY THE EFFECT OF COMPACT PRESSURE OF P/M TOOL ELECTRODE ON ELECTRO DISCHARGE COATING (EDC) PROCESS

A thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of technology (B.Tech)

In

Mechanical engineering

By

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Certificate of Approval

This is to certify that the thesis entitled "**Study the Effect of Compact Pressure of P/M Tool Electrode on Electro Discharge Coating (EDC) Process**" submitted by **Saroj Kumar Naik** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of **Bachelor of Technology** in **Mechanical Engineering** at **National Institute of Technology, NIT Rourkela**, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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ABSTRACT

Electro-discharge machining (EDM) is a widely accepted non-traditional machining process used mostly for machining materials difficult to machine by conventional shearing process. Surface modification by powder metallurgy sintered tools is an uncommon aspect of EDM. In this work, an attempt will be made to deposit tungsten carbide coating on the steel work surface by electro discharge processing, with a view to improve the hardness and wear resistance of the substrate.

In the present investigation, an attempt will be made to improve the surface properties of steel substrate, using tungsten carbide (a hard and wear-resistant ceramic material) compact as tool electrode and reverse polarity setting. A coating layer of tungsten carbide has been formed on the work piece surface. The chemical composition of the surface layer and microstructure has been verified from X-ray diffraction technique and scanning electron microscope (SEM) respectively. The output measures i.e. Deposition rate, tool wear rate, has been correlated with different process parameters.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

INTRODUCTION

At present the available techniques for enhancing the mechanical properties (wear resistance, Hardness) of the surface of an engineering component include carburizing, nitriding chemical/physical vapour deposition (CVD/PVD), ion beam technique and plasma arc spraying etc. Such Processes are secondary operations which either require expensive in-house equipment or the use of sub-contract companies. They add to costs and lead times, significantly in some instances. An alternative approaches deliberate surface alloying/ modification during EDM.

Electro-discharge machining (EDM) is an electro-thermal non-traditional machining process. It is widely used for Machining complicated contours in hard materials. That's why it is used in die and mould-making industries for quite a few decades. There are two major disadvantages of conventional EDM process; one is tool wear and the other is the formation of brittle and cracked white layer on the machined surface. The tool wear can be controlled to some extent in EDM, but to achieve a condition without tool wear is almost impossible. Since EDM is an electro thermal process, so some alteration in surface integrity takes place due to the formation of recast or white layer. Due to the presence of re-solidified alloyed material on the surface and the heat-affected zone, the surface integrity of the work piece changes. The above phenomenon has inspired researchers to explore the possibility of new method of surface modification by EDM. The present work relates to improvement of mechanical properties by employing a suitable hard material de-position. Such a wear-resistant coating enhances the component performance in actual service. Hard-facing by an electric spark in a gaseous dielectric has also been successfully tried by many researchers. Some typical applications include hot forging dies and cutting tools.

In the present work, the surface deposition is achieved by electrical discharge processing with a liquid dielectric using a pre-sintered powder compact tool electrode and a reverse polarity setting. These conditions enhance tool material erosion and hence the deposition on the machined surface. This is also called as **electro-discharge coating (EDC)**.

A substance that is applied to the surface of an object, usually referred to as the substrate. In many cases coatings are applied to improve surface properties of the substrate, such as appearance, adhesion, wettability, corrosion resistance, wear resistance, and scratch resistance.

Electro-discharge coating is a process in which tool material is transfer to the work surface and deposited. These conditions enhance tool material erosion and hence the deposition on the machined surface. The technological feasibility of this modified processing has been already established and published earlier.

An attempt will be made in this work to deposit tungsten carbide on the work surface by electro discharge processing, with a view to improve the wear resistance. However, we are using a mixture of Tungsten carbide (WC) and copper powder in a ratio of 50:50 by their weight to prepare the tool mainly because of its high hardness, strength and wear resistance. Because of its properties, tungsten carbide cannot be processed easily by conventional machining techniques. Tungsten carbide is a type of cemented carbide that is made by a process of powder metallurgy in which the carbide particles are bound to other metals such as in tungsten carbide (WC–Co).

The chemical composition of the surface layer and microstructure can been verified from X-ray diffraction technique and scanning electron microscope (SEM) respectively. The improvement in hardness can be measured by micro-hardness test. The effects of process parameters such as compaction pressure (CP), sintering temperature (ST), peak current (Ip), pulse on time (Ton), pulse off time (Toff) can be observed on material transfer rate (MTR), average layer thickness (LT), surface roughness and hardness value.

CHAPTER 2

BACKGROUND AND LITERATURE SURVEY

BACKGROUND AND LITERATURE SURVEY

❖ 2.1 ELECTRO DISCHARGE MACHINING (EDM)

Electro-discharge machining (EDM) is a well-established non-conventional machining process. In the year 1930s, many attempts were made for the first time to machine metals and diamonds with electrical discharges. Erosion was prominent and mainly caused by intermittent arc discharges occurring in air between the tool electrode and work piece connected. These processes were not very precise due to overheating of the machining area and may be defined as “arc machining” instead of “spark machining”. EDM is widely used for machining complicated contours of hard materials where conventional machining cannot be used. It is a well-accepted practice in die and mold-making industries for quite a few decades.

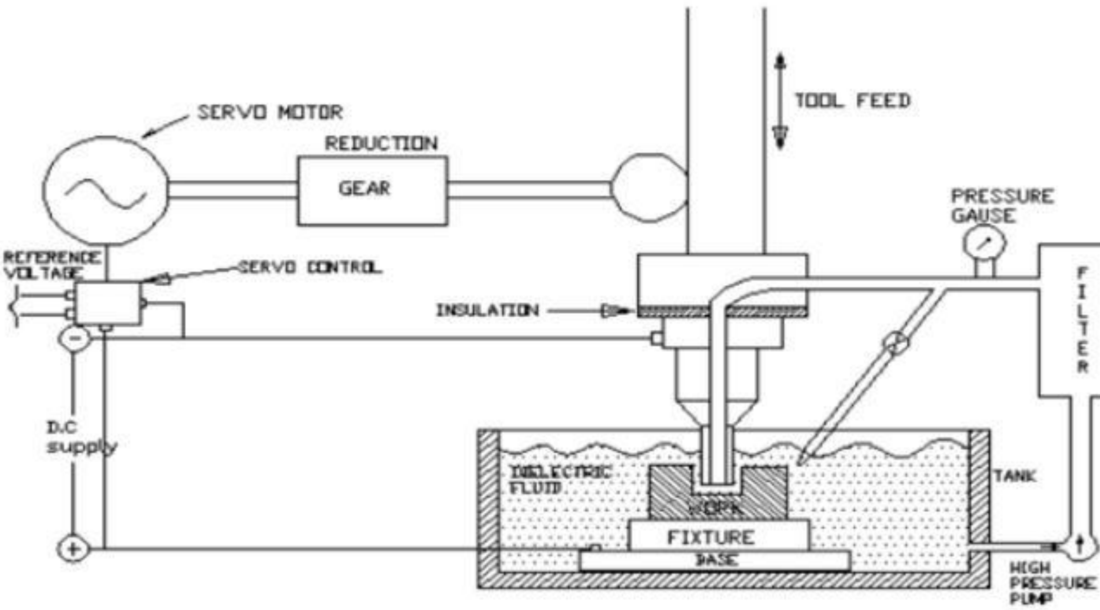

Fig. 1 Schematic Diagram of Set up of EDM

In EDM, a potential difference is applied between the tool and work piece. Both the tool and the work piece are to be conductors of electricity. The tool and the work piece are immersed in a dielectric medium. Generally kerosene or deionised water is used as the dielectric medium. A gap is maintained between the tool and the work piece. Depending upon the applied potential difference and the gap between the tool and work piece, an electric field would be established. Generally the tool is connected to the negative terminal of the generator and the work piece is connected to positive terminal. As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces. The emitted electrons are then accelerated towards the job through the dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionisation of the dielectric molecule depending upon the ionisation energy of the dielectric molecule and the energy of the electron. This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux. Such intense localised heat flux leads to rise in temperature which would be in excess of around 10000^{o}C. This localised rise in temperature leads to material removal. Material removal occurs due to instant vaporisation of the material as well as due to melting.

Generally the work piece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal. Similarly, the positive ions impinge on the tool leading to tool wear. There are two major disadvantages of conventional EDM process and they are as: one is tool wear and the other is the formation of brittle and cracked white layer on the machined surface. The tool wear can be controlled to some extent in EDM, but to achieve a condition without tool wear is almost impossible. Due to the presence of re-solidified alloyed material on the surface and the heat-affected zone, the surface integrity of the work piece changes. The above phenomenon has inspired researchers to explore the possibility of new method of surface modification by EDM.

2.1.1 PROCESS PARAMETERS

In EDM, the process parameters are as follows:

- The open circuit voltage - V_o
- The polarity – straight polarity – tool (-ve)
- The gap between the work piece and the tool – spark gap - δ
- The maximum current - I_o
- The pulse off time - t_{off}
- The working voltage - V_w
- The pulse on time – the duration for which the voltage pulse is applied - t_{on}

2.2 SURFACE COATING

A substance applied to other materials to change the surface properties, such as color, gloss, resistance to wear or chemical attack, or permeability, without changing the bulk properties. Surface coatings include such materials as paints, varnishes, enamels, oils, greases, waxes, concrete, lacquers, powder coatings, metal coatings, and fire-retardant formulations.. In many cases coatings are applied to improve surface properties of the substrate, such as appearance, adhesion, wettability, corrosion resistance, wear resistance, and scratch resistance. In other cases, in particular in printing processes and semiconductor device fabrication (where the substrate is a wafer), the coating forms an essential part of the finished product.

Coatings may be applied as liquids, gases or solids. Coatings can be measured and tested for proper opacity and film thickness by using a drawdown card.

2.2.1 COATING PROCESSES

Various types of coating processes are:

(a) PHYSICAL VAPOR DEPOSITION (PVD)

PVD is a type of vacuum deposition method. In this process deposition is done by vaporizing the desired coating material on the work piece surface. This involves processes such as evaporation and condensation, involving plasma bombardment at the surface to be coated. The particles follow a straight path, deposition by physical means are generally directional.

(b) CHEMICAL VAPOUR DEPOSITION (CVD)

In this process, reactant gases are used which undergoes a chemical change at the solid surface, forming a solid layer.

(c) ELECTROPLATING

In this work-piece is plated with a different metal while both are suspended in a bath containing a water-base electrolyte solution. The anode (metal to be deposited) metal ions are discharged under the potential from the external source of electricity and then combine with the electrolyte ions and are deposited on the cathode (work-piece).

2.2.2 ELECTRO DISCHARGE COATING (EDC)

An electrical discharge coating method comprising the steps of generating pulsed discharge between a green compact electrode and a treatment target surface in a working fluid; thereby, depositing the component of the green compact electrode onto the treatment target surface so as to form a coating. It is possible to form a thick coating mainly containing a high hardness metal even on a low melting point metal such as an aluminium material, without depending on a carbide that reduces conductivity.

Among these coating processes EDC has some specific advantages which make an emerging coating technology. In this method of coating, no need of vacuum chamber or any special apparatus. Using simple EDM set-up and by selecting appropriate parameters coating of different materials can be done on different substrate materials.

2.2.2.1 HISTORY & DEVELOPMENT

Electric discharge coating technology has been introduced into actual use for surface treatment of molds and tools. The cost for the conventional cladding by welding process was too high. So to reduce the cost it has been determined to develop a new technology. In the beginning, a proposal was made to the department in charge of engine parts development, for the adoption of thin ceramic coating. But the development of thick metal cladding similar to that by welding was requested, and a technology to clad metal rather thickly has been developed.

2.2.2.2 PROCESS

The process of surface modification by which a layer is formed on the work piece on reversing the polarity improves several properties of work piece is known as **Electro-discharge coating (EDC)**. It leads to improvement in abrasive wear resistance and hardness of the original material .EDC electrode material must have basic properties such as electrical and thermal conductivity, a high melting temperature, low wear rate, and resistance to deformation during machining. P/M compact, either green or semi sintered, can play a vital role as EDM tool, which can supply required materials to the work piece surface. By using an ordinary EDM machine tool and hydrocarbon oil as dielectric fluid, a hard layer can be created on the work piece with a powder metallurgy (P/M) tool with certain parametric combinations. This novel method is also called as electro-discharge coating (EDC).

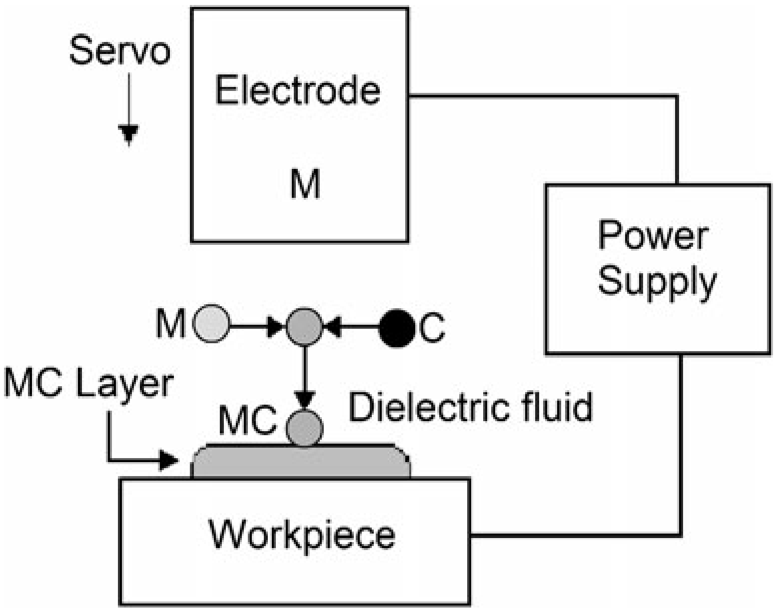

Fig. 2: Schematic Diagram of EDC

A schematic diagram of the principle of EDC is shown in **Fig. 2**. The process of EDC begins with erosion of the tool during EDM, followed by creation of hard carbides through the chemical reaction between the worn electrode material (M) and the carbon particles (C) decomposed from hydrocarbon fluid under high temperature. The carbide (MC) is gradually piled up on the work surface and becomes a thick hard layer in a few minutes. Electro-discharge coating is basically a process of mass transfer to the work surface. So, the tool materials should erode sufficiently to get transferred to the work surface in this type of treatment. P/M compact, either green or semi sintered, can play a vital role as EDM tool, which can supply required materials to the work piece surface. The weak bonding among the powder particles helps in this regard. The other advantages of P/M tools lie in the facts that they can be fabricated easily by mixing powders of any composition and can be given various shapes with less effort. The properties of P/M tools can be controlled by varying compaction pressure and sintering temperature. Thus, the P/M tools help in modifying the surface integrity of a work surface.

EDM is a complex phenomenon which is very stochastic in nature and depends upon a number of variables such as compaction pressure (CP), sintering temperature (ST), peak current (Ip), pulse on time (Ton), pulse off time (Toff) with output measures like material transfer rate (MTR), and average layer thickness (LT). Thus, it would help in predicting the MTR and LT with various input parameter combinations.

❖ 2.3 LITERATURE SURVEY

Toshio Moro et al.(5) studied application of electrical discharge coating (EDC) to improve cutting tool life by electrical discharge machining (EDM) instead of Physical Vapour Deposition (PVD) or Chemical Vapour Deposition (CVD). He investigated the relation between a wear rate of an electrode and maximum thickness. The maximum thickness responds to the increasing wear rate, as increased linearly.

Jorge Simao et al.(24) conclude from the tests and research on surface modification/alloying and combined electrical discharge texturing (EDT) that, variables such as compacting pressure and sintering conditions are vital in determining EDT-related properties of tool electrodes in powder metallurgy process.

H.M.Zaw (23) showed that the **c**ompounds of ZrB2 and TiSi with Cu at various compositions are investigated for EDM electrodes by either solid-state sintering or liquid phase sintering and also compared with the conventional electrode materials such as Cu, Graphite, CuW. Due to its high electrode wear rate resulting in damage at the work piece surface, TiSi/Cu compound could not use as an EDM electrode, although its sintered structure is good.

M.P.Samuel et al (20) preferred powder metallurgy method for the fabrication of tool electrodes. He justified that the P/M electrodes affect the micro- and macro variables in EDM and there is a way to control the properties of P/M electrode by adjusting the parameters like compacting pressure and sintering temperature. It has been found that for electrodes with rough surfaces, subjected to strong electric fields, as in EDM, there is an apparent reduction in the surface work function. Under certain processing and operating conditions P/M electrodes can cause net material addition rather than removal.

Sanjeev Kumar et. al (17) investigated the response of three die steel materials to surface modification by EDM method with tungsten powder mixed in the dielectric medium. From SEM images, he concluded that the presence of discrete craters was formed by the removal of molten material, which is connected with the micro cracks generated during EDM. He also studied that peak current, pulse on-time and pulse off time were taken as variable factors and micro-hardness of the machined surface was taken as the response parameter. Tungsten forms hard, abrasion-resistant particles in tool steels and promotes hardness and strength at elevated temperatures and may be present as independent carbide in the form of WC, W2C, etc. or form intermetallic compounds with iron such as Fe3W2 or Fe2W.

M.S.Shunmugan et al (2) had done the experiment on EDM by using tungsten carbide powder as the compost, to evaluate wear resistance by cutting tests. Also he compared the results with the results obtained when he used bronze P/M electrode. He also investigated that the presence of a white layer on the work piece surface improves the wear resistance. He observed that, in addition to tungsten carbide, there exists iron carbide also on the deposited layer in the form of FeC, (Fe) and (Fe,C) 160 etc. The thin layer of WC attributed to the higher melting point of tungsten carbide compared with bronze, which leads to premature solidification before it has time to reach the cathode surface

A. Gangadhar et al (6) stated that the topography, metallurgical and the physiochemical properties of the surface layer that is formed change considerably during electro discharge machining. Surface modification for some functional behaviour is possible by electro discharge machining (EDM) providing that suitable process parameters are employed. He used Nassovia Krupp electro discharge machine equipped with an Iso-frequent pulse generator. Using powder compact tools with reverse polarity, 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. The processes like X-ray diffraction analysis of the work surface, the metal transfer from the tool electrode by cross-sectional examination and spectroscopy for the chemical analysis, were studied by him.

Promod Kumar Patowari (1) found that surface modification by powder metallurgy sintered tools is an uncommon aspect of EDM. He made attempts to model the surface modification phenomenon by EDM. He used steel as work piece and W-Cu P/M sintered electrode as tool electrode. The ANN (Artificial Neural Network) has been successfully applied for surface modification with W–Cu P/M sintered electrodes in EDM. From the experiment, two output measures, average layer thickness and material transfer rate were determined and correlated with different process parameters. The simulated results from the networks have been presented and discussed. To initiate work piece surface modification during electro discharge machining (EDM), the paper reviews the use of metal powders dispersed in the dielectric fluid and refractory P/M electrodes.

❖ 2.4 OBJECTIVE OF THE PRESENT WORK

Development of tungsten carbide (WC) coating layer on steel substrate (mild steel) by Electro Discharge Coating (EDC) process using a powder compact electrode and reverse polarity setting with the help of Electro discharge machine. Using reverse polarity in electro discharge machine and mild steel as work piece material a composite layer of WC-Cu has been deposited on the work piece.

Detail study of micro-structure and composition of the coating and their variation with process parameters such as compaction pressure (CP) and peak current (Ip) has been investigated. We studied the microstructure of the layers in the coating by SEM (Scanning Electron Microscope) while the compounds present in the coating were analysed by XRD (X-Ray Diffraction) technique.

CHAPTER 3

EXPERIMENTAL DETAILS

EXPERIMENTAL DETAILS

❖ 3.1 EXPERIMENTAL PLANNING

The research work consists of three parts:

3.1.1 Green compact sintered powder metallurgy (P/M) tool preparation
3.1.2 Brazing of the powder metallurgy (P/M) tool with steel pin
3.1.3 Electro Discharge coating (EDC) with P/M tool on mild steel by using EDM

3.1.1 Green compact sintered powder metallurgy (P/M) tool preparation

To fabricate a suitable tool electrode for the application of EDC, the powder metallurgy (P/M) method will be used. Basically the process follows the name green compact because in green compacted tools, no sintering of the compact occurs. Moreover, the particles are loosely compacted using a press and a die so at the time of deposition tool material easily parted from the tool electrode and deposited over the work surface.

Table 1 shows the experimental parameters of the tool making process.

Table 1: Powder compaction, Proportions and Press capacity

Press capacity (in tons)	15- 25 tons
Applied load	2.7 & 3.6 tons (depends on dimensions of compact)
Holding / Stand- up time	2 min
Proportions of powders (Cu:W)	50:50 (by weight)
Compaction pressures	150MPa, 200 MPa

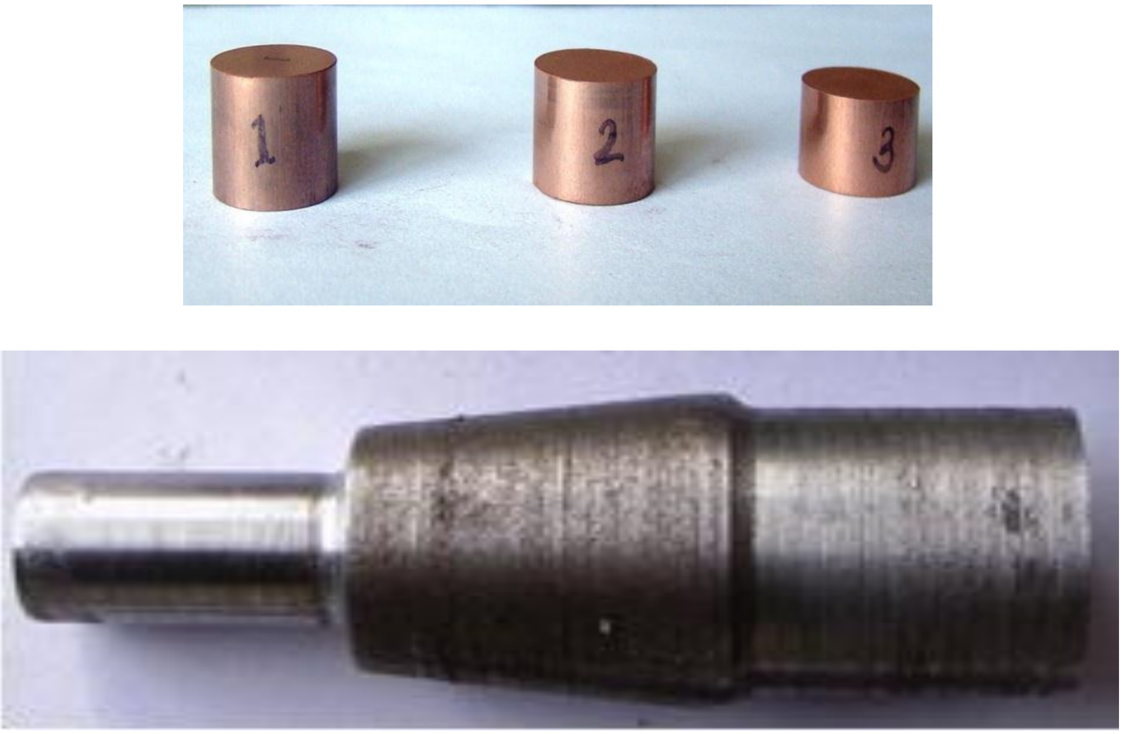

Fig 3: compacted tool & tool electrode extension

Fig 3 shows the top view of the tool electrode prepared and also the steel pin with which the electrode is joined by brazing for the further process.

3.1.2 Brazing of the powder metallurgy (P/M) tool with steel pin

Brazing is a metal-joining process whereby a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action. The filler metal is brought slightly above its melting (liquidus) temperature while protected by a suitable atmosphere, usually a flux. It then flows over the base metal (known as wetting) and is then cooled to join the work pieces together. The tool extension is prepared by machining and tool manufactured in the press are joined by **brazing.**

With the use of EDM machine tool, kerosene (or any hydrocarbon fluid) as dielectric, electrode prepared by the powder metallurgy described above and reverse polarity a hard carbide layer can be created by the chemical reaction between worn electrode material and carbon particle from kerosene fluid.

Fig 4: Tool electrode after brazing

3.1.3 Electro Discharge coating (EDC) with P/M tool on mild steel by using EDM

3.1.3.1 WORKING PRINCIPLE

In EDC, the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in a dielectric fluid. The process of EDC begins with erosion of the tool during EDM, followed by creation of hard carbides through the chemical reaction between the worn electrode material (M) and the carbon particles (C) decomposed from hydrocarbon fluid under high temperature. The carbide (MC) is gradually piled up on the work surface and becomes a thick hard layer.

3.1.3.2 PROCESS PARAMETERS

1. **Pulse Duration and Pulse Interval:** Each cycle has an on-time and off-time that is expressed in units of microseconds. Since all the work is done during on-time, the duration of these pulses and the number of cycles per second (frequency) are important. Metal removal is directly proportional to the amount of energy applied during the on-time. This energy is controlled by the peak amperage and the length of the on-time. Pulse on-time is commonly referred to as pulse duration and pulse off-time is called pulse interval.

2. **Duty Factor:** Duty factor is a percentage of the pulse duration relative to the total cycle time. Generally, a higher duty factor means increased cutting efficiency. It is calculated in percentage by dividing pulse duration by the total cycle time (on-time + off-time).

   Duty Factor (%) = (Pulse duration (μs)/Total cycle time (μs))*100

3. **Discharge Voltage:** Discharge voltage in EDM is related to the spark gap and breakdown strength of the dielectric (Kansal et al., 2005). Before current can flow, the open gap voltage increases until it has created an ionization path through the dielectric. Once the current starts to flow, voltage drops and stabilizes at the working gap level. The preset voltage determines the width of the spark gap between the leading edge of the electrode and work piece. Higher voltage settings increase the gap, which improves the flushing conditions and helps to stabilize the cut. MRR, tool wear rate (TWR) and surface roughness increases, by increasing open circuit voltage, because electric field strength increases.

4. **Electrode Gap:** voltage. The most important requirements for good performance are gap stability and the reaction speed of the system; the presence of backlash is particularly undesirable.

5. **Peak Current:** The maximum amount of amperage is governed by the surface area of the cut. Higher amperage is used in roughing operations and in cavities or details with large surface areas. Higher currents will improve MRR, but at the cost of surface finish and tool wear. This is all more important in EDM because the machined cavity is a replica of tool electrode and excessive wear will hamper the accuracy of machining.

FIG 5: EDM set up

❖ 3.2 EXPERIMENTAL PROCEDURE

3.2.1 TRIAL EXPERIMENT

To get the approximate parameters for EDC with tools of composition pure copper and 70 :30 Cu/W (v/v), we have done some trial experiments with the tool electrode (70:30 Cu/W) . We get the following results from the trial experiments.

Table 2 shows the results of some trial experiments with the tool electrode having different composition.

Table 2: Trial experimental results

Exp. No.	Tool material	polarity	volt	Ip	Duty factor (Ʈ): 25+5T	Time (min)	Remarks
1	Pure Cu	+Ve	40	4	50%	2 min	No deposition (machining)
2	Pure Cu	-Ve	40	4	50%	2 min	Very less deposition at the edges with machining
3	Pure Cu	-Ve	40	8	50%	2 min	Very less deposition at the edges with higher machining
4	W: Cu (50:50 wt.%)	-Ve	40	4	50%	2 min	Deposition on substrate
5	W:Cu (50:50 wt.%)	-Ve	40	8	50%	2 min	Deposition on substrate as well as very less machining

The advantages of P/M tools lie in the facts that they can be fabricated easily by mixing powders of any composition and can be given various shapes with less effort. So from the above results and using these results, two tool electrodes of composition 50:50 (W: Cu) at two different compaction pressures 150 MPa and 200 MPa are prepared.

Work- pieces of mild steel are cut into the 20*20*5 mm. size. In general tool electrode is maintained as cathode for basic metal cutting process, but in our regards, tool electrode is kept as anode (precisely condition is called reverse polarity).

The diameter of the tool electrode is kept similar for all sample electrodes as 15 mm. and height as 10 mm. Due to the fact that green compacted tool electrode are very sensitive loosely compacted, therefore making heighted tool electrodes and holding them in the EDM machine is not at all justified. Because of these above reasons, extensions of tool electrodes have been prepared and powder green compacted electrodes are brazed on the tip of the extensions.

Table 3 shows different properties of tool and work-piece material as copper and mild steel and, tungsten respectively.

Table 3: Properties of work- piece and tool materials

Material	Density (gm/cm^3)	Melting temp. (K)	Specific heat (J/kg K)	Thermal conductivity (W/m K)	Coefficient of thermal expansion (/ K)	Particle size (microns)	Mesh size
Cu powder	8.97	1355	385	393	16.5	44	325
M.S. substrate	6.92	1644	490	20	12	-	-
W powder	19.29	3683	138	166	4.5	44	325

3.2.2 FINAL EXPERIMENT

The weight of the work-piece and tool before and after the coating is measured and the rate of deposition calculated. **Table 4** shows the parameters, which are common for all experimental setups. The weight of the tools and work- pieces has been taken by electronic weighing machine and the weights taken are correct up to the three decimal places.

Table 4: Fixed EDM parameters

Voltage	40 V
Duty Factor	50%
T_{on}	100 µs
Time of experimentation	20 min
Composition (W:Cu)	50:50 by weight %

Now the experimental condition of the process is shown below in the T**able 5**. We have done experiments on the basis of composition of W and Cu (50:50 wt.%) at different compact pressure (150 & 200 MPa) by varying the current value (2A, 4A, 6A, 8A).

Table 5: Experimental condition of EDC process

Expt. No.	Powder ratio (W:Cu)wt%	Pressure (MPa)	Current (A)
1	50:50	150	2
2	50:50	150	4
3	50:50	150	6
4	50:50	150	8
5	50:50	200	2
6	50:50	200	4
7	50:50	200	6
8	50:50	200	8

CHAPTER 4

RESULT AND DISCUSSION

RESULT AND DISCUSSION

❖ 4.1 EXPERIMENTAL RESULTS

Table 6 shows the experimental results below :

Table 6: Final experimental results

Expt. No.	Powder ratio (W:Cu)wt%	Pressure (MPa)	Current (Amp) (A)	Weight of work-piece (gm)		Deposition (gm) (B-A)	Weight of tool (gm)		Tool Wear (gm) (C-D)
				Before (A)	After (B)		Before (C)	After (D)	
1	50:50	150	2	26.118	26.124	0.006	115.213	115.193	0.020
2	50:50	150	4	23.793	23.807	0.014	115.183	115.113	0.070
3	50:50	150	6	23.328	23.358	0.030	115.103	114.843	0.260
4	50:50	150	8	17.718	17.835	0.117	114.843	112.071	2.772
5	50:50	200	2	19.405	19.408	0.003	114.307	114.298	0.009
6	50:50	200	4	20.801	20.809	0.008	114.298	114.258	0.040
7	50:50	200	6	22.148	22.160	0.012	114.241	114.111	0.130
8	50:50	200	8	18.323	18.353	0.030	114.090	113.102	0.988

From all the experiments we consider eight observations with composition of W and Cu (50:50 wt%) at different compact pressure i.e. 150 MPa and 200 MPa by varying the peak current values in EDM machine.

Fig. 6 shows the coated surface at different currents and surface coated by W and Cu mixed powder compacted tool at 8 A current and, 150 and 200 MPa pressure of compaction.

Fig.6: WC-Cu coated mild steel surface developed by using tool electrode processed with 150 & 200 MPa compaction pressures and EDM parameters of 8 Ampere peak current

4.2 EFFECT OF TOOL COMPACT PRESSURE ON DEPOSITION OF COATING:

From the observations, the weight difference of the work piece, before and after the coating, gives the deposition rate.

Here, below the graphs shows the variation of the deposition rate corresponding to the different current values.

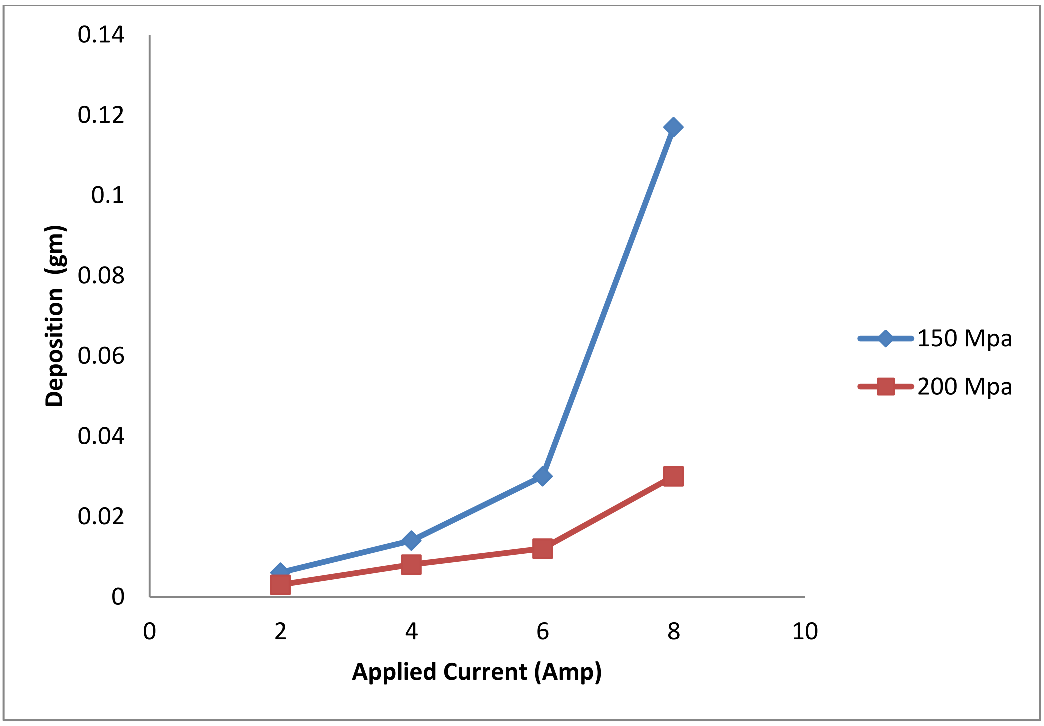

Fig.7: Effect of compact pressures (150 MPa & 200 MPa) on deposition

From the above graph, we conclude that for a constant compaction pressure (150 MPa or 200MPa), as current increases, deposition rate increases. On lower current (upto 6 amp), deposition rate is gradually increased but at higher currents (6 to 8 amp), the deposition rate suddenly increased.

4.3 EFFECT OF TOOL COMPACT PRESSURE ON TOOL WEAR

From the observations, the weight difference of the tool, before and after the coating, gives the tool wear rate. Here, below the graph shows the variation of the tool wear rate corresponding to the different current values.

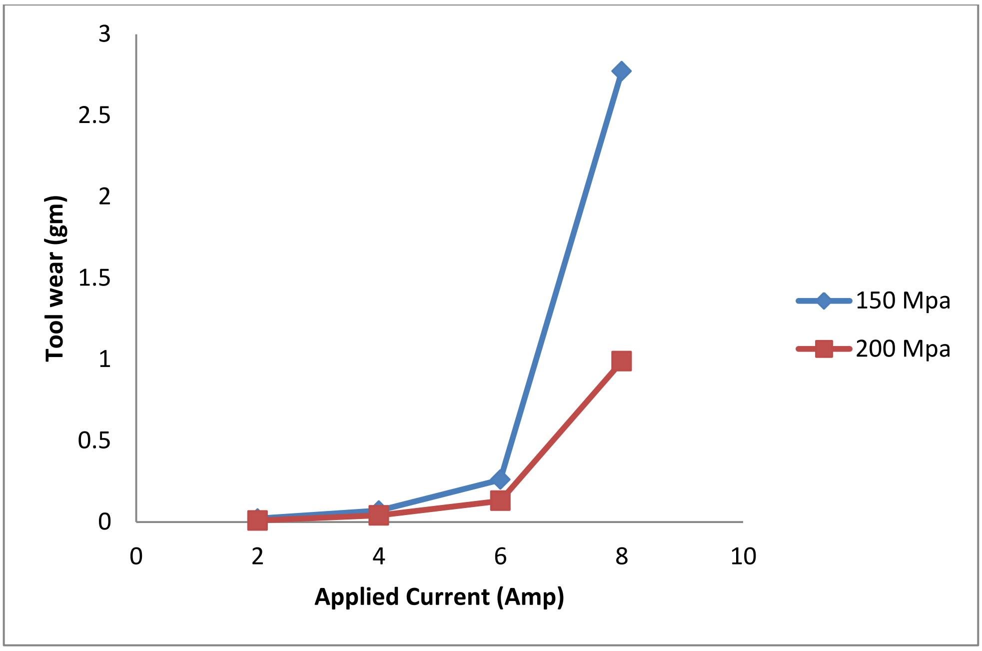

Fig.8: Effect of composition for constant pressures (150 MPa & 200 MPa) on tool wear

The above graph represents effect of current corresponding to tool wear rate. It is evident that increase in current causes high tool wear rate. Therefore it can be concluded that for a constant compaction pressure (150 MPa or 200MPa), as current increases, tool wear rate increases. On lower current (upto 6 amp), tool wear rate is gradually increased but thereafter further increase in current causes rigorous wear of tool and higher deposition but at the same time due to higher wear tool becomes coarser and coarser.

4.4. SCANNING ELECTRON MICROSCOPY (SEM)

A scanning electron microscope (SEM) is an electron microscope that used focused beam of electrons to produce image of the samples. The interaction of the electrons with electrons in the sample produces various signals that can be detected and studied to get information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve a resolution better than 1 nanometre.

Fig 9: JEOL JSM-6480LV scanning electron microscope

Scanning electron microscope of Model JEOL JSM-6480LV **(Figure 9)** was used for the morphological characterization of the composite surface.

Fig 10 and **Fig 11** shows the microstructure of the samples used in experiment 3 and experiment 7 respectively.

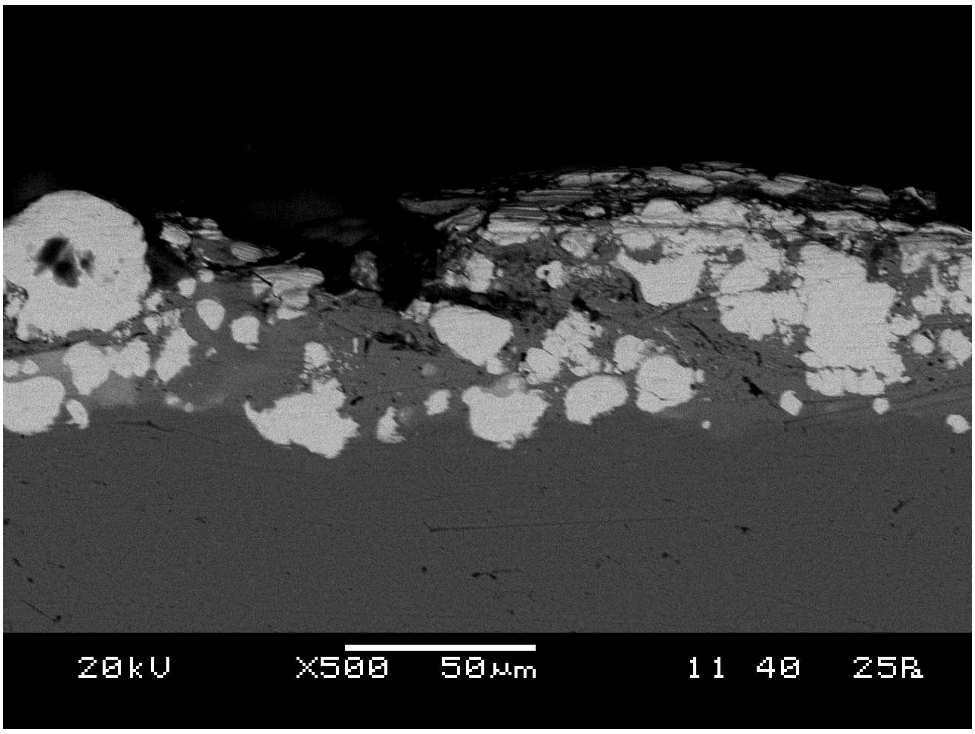

Fig 10: SEM analysis (150 MPa, 6 Amp)

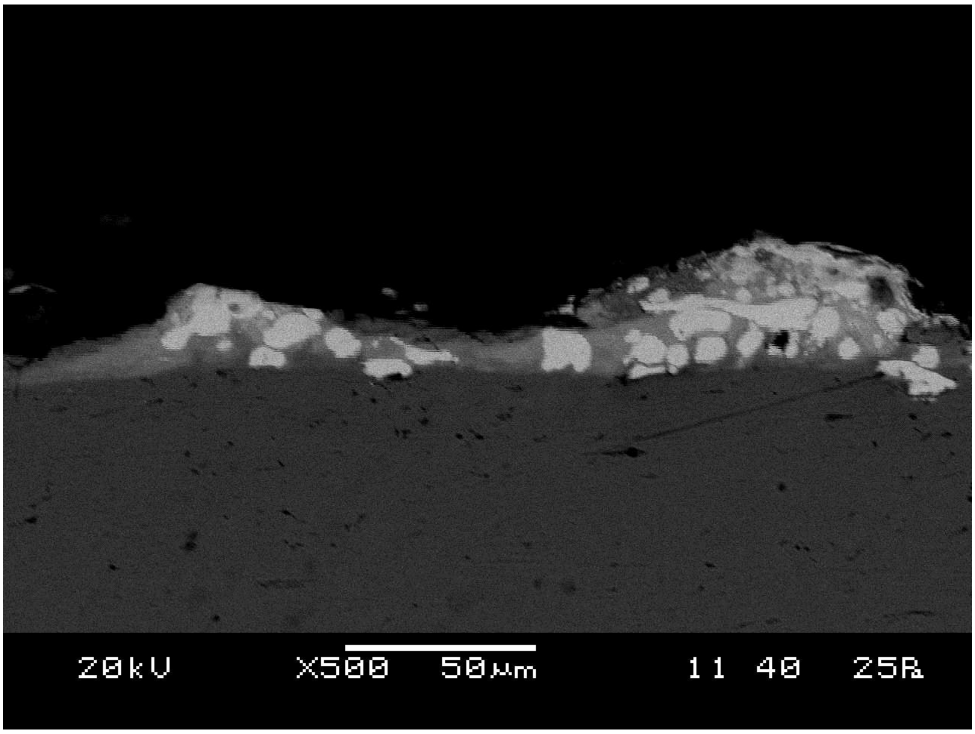

Fig 11: SEM analysis (200 MPa, 6 Amp)

From the above figures that are taken by SEM and by amalyzing them, we get following conclusions :

1. When the compaction pressure is more, the thickness of average layer over the surface of the substrate is less.
2. The compaction pressure is the only factor that affects the layer thickness, rest factors are current and composition.
3. The rate of deposition is much higher, when the compact pressure is less.

4.5. X-RAY DIFFRACTION TECHNIQUE (XRD)

X-ray diffraction (XRD) is a versatile, non-destructive analytical technique that is usually used to study crystalline materials. It determined the detailed information about the chemical composition and type of molecular bond of crystalline phase. When a focused X-ray beam interacts with these planes of atoms, part of the beam is transmitted, part is absorbed by the sample, part is refracted and scattered, and part is diffracted. XRD is an efficient technique to expose the crystallographic structure of natural and manufactured materials.

The X-ray source was operated at a voltage of 40 kV and current of 35 mA. The diffraction angle was varied in the range of 20-100 degrees while the scanning rate was 0.05degree/s. The XRD data diffraction patterns were analysed with the help of Phillip's X'pert software.

Fig. 12: Philips X-pert MPD X-ray diffractometer

Fig 13 shows the XRD characteristics of the sample used for the experiment no 4 (Compact pressure-150 MPa, Peak current-8 Amp, W:Cu-50:50)

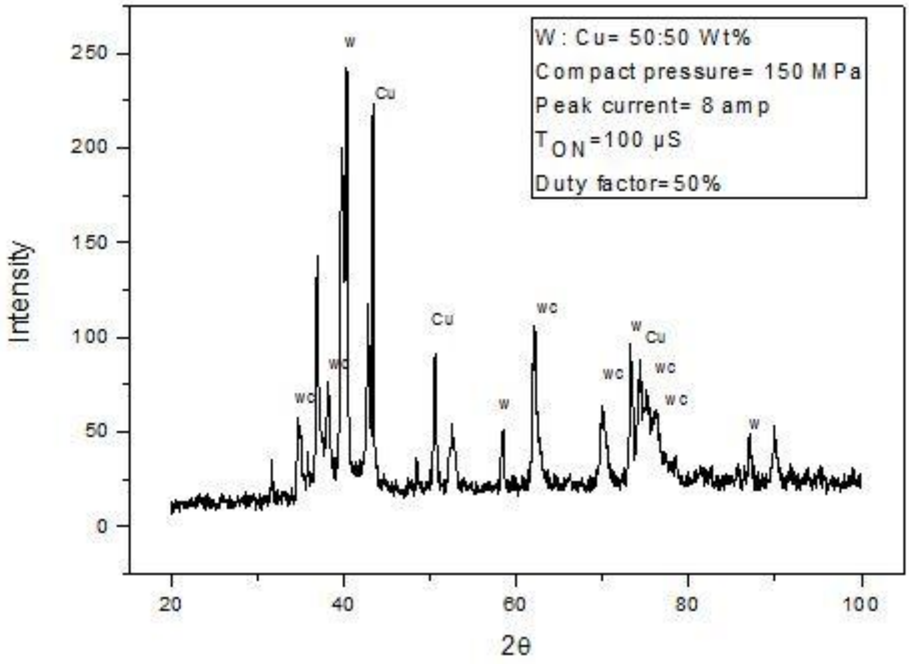

Fig 13: XRD analysis of the sample

From the XRD analysis of the above graph (Fig 13), it shows that the diffraction apex of W,C, and WC, which implies the presence of these elements in coating.

CHAPTER 5

CONCLUSION

CONCLUSIONS

The experimental investigation on the development of tungsten carbide (WC) coating layer on the steel substrate (mild steel) by electro discharge coating (EDC) process, were conducted. Properties such as deposition rate, tool wear rate has been measured and effect of compact pressure and peak current on these have been evaluated from various experiments. Study of microstructure and composition of the coating were analysed by SEM and XRD techniques respectively. The experiments lead us to the following conclusions on this study:

1. The rate of deposition is much higher, when the compact pressure is less.
2. Deposition rate of the coating increased on increasing current at constant compacting pressure.
3. XRD analysis shows the presence of W, Cu and WC in the coating.
4. At higher compaction pressure, both tool wear rate and deposition rate are more gradual than at lower pressure. The compaction pressure should be in such a range, quality of deposition does not impair by it.
5. The coating was analysed by SEM which shows that the coating was almost uniform
6. For a constant compaction pressure, as current increases, tool wear rate also increases.
7. When the compaction pressure is more, the thickness of average layer over the surface of the substrate is less.

REFERENCES

1. Patowari, P. K., Saha, P., and Mishra P. K. , 2010, "Artificial neural network model in surface modification by EDM using tungsten–copper powder metallurgy sintered electrodes", Int J AdvManuf. Technol, 51, pp. 627–638
2. Shunmugam M.S., Philip P.K. and Gangadhar A., 1994, "Improvement of wear resistance by EDM with tungsten carbide P/M electrode", Wear, 171, pp. l-5
3. Pawar R. S., Sharma S. B. and Kajale S. R., 2011, "Surface Modification by Electro Discharge Coating-A Review", International J. of Engg. Research &Indu. Appls. (IJERIA).ISSN 0974-1518, 4, pp. 121-140
4. Peng Q.F., 1989 , "Improving abrasion wear by surface treatment", Wear, 129, pp. 195-203.
5. Moro T., Mohri N., Otsubo H., Goto A. and Saito N., 2004 , "Study on the surface modification system with electrical discharge machine in the practical usage", Journal of Materials Processing Technology, 149,pp. 65–70
6. Gangadhar A., 1994, "Improvement of wear resistance by EDM with tungsten carbide P/M electrode", Journal of Materials Processing Technology, 173, pp. 45-52
7. Kumar S., Batra U., 2012 , "Surface modification of die steel materials by EDM method using tungsten powder-mixed dielectric", Journal of Manufacturing Processes, 14,pp. 35–40
8. Erden A.,1983, "Effect of materials on the mechanism of electric discharge machining (E.D.M.)", Trans ASME J Eng Mater Technol, 105, pp.132–138
9. Kahlon C.S., Baker H.J., Noble C.F. and Koenigsberger F., 1969, "Electric spark toughening of cutting and steel component", Int. MTDR Con&, 10, pp. 95-121.
10. Kramer B.M., 1983, "Requirements of wear resistance coatings", ht. J. Sci., 8,pp. 117-125.
11. Vaidyanathan S. and Venkatesh V.C., 1974 , "Improving wear resistance of HSS tools by carbide coating", Tribol. Int.,156, pp. 54-58
12. Samsonov G.V. , 1974, "Carbide coatings applied by spark alloying method increase abrasive wear resistance of carbon steel", Russ. Eng. J., 54, pp. 38-39

13. Ho S.K., Aspinwall D.K. , Voice W., 2007, "Use of powder metallurgy (PM) compacted electrodes for electrical discharge surface alloying/modification of Ti–6Al–4V alloy", Journal of Materials Processing Technology, 191, pp. 123–126
14. Kruth J.P., Froyen L., Dejonghe P., 1998 , "In-process alloying of the white layer of a workpiece machined by die-sink EDM", Int. J. Electr. Machining ,3, pp. 33–38
15. Wang Z.L., Fang Y., Wu P.N., Zhao W.S., Cheng K., 2002 , "Surface modification process by electrical discharge machining with a Ti powder green compact electrode", J. Mater. Process. Technol., 129, pp. 139–142.
16. Lee H.G., Dewes R.C., Aspinwall D.K., 2000 ,"Electrical discharge surface alloying of Ti–6Al–4V using partially sintered tool electrode", Advances in Manufacturing Technology, XVII, pp. 55–60
17. Kumar S., Singh R., Singh T.P., Sethi B.L., 2009 , "Surface modification by electrical discharge machining", A review, Journal of Materials Processing Technology, 209, pp. 3675–3687
18. Kruth, J.P., Stevens, L., Froyen, L., Lauwers, B., 1995, "Study on the white layer of a surfacemachined by die sinking electro-dischargemachining", Annals of the CIRP44, 1, pp. 169–172
19. Miyake H., Imai A., Goto A., Saito N., Mohri N., 1998, "Improvement of tool life through surface modification by electrical discharge machining", Proceedings of the ISEM,12, pp. 261–270
20. SAMUEL M. P. and PHILIP P. K., 1997, "Power metallurgy tool electrodes for electrical discharge machining", Int. J. Mach. Tools Manufact., 37, pp. 1625-1633
21. Janmanee P., Muttamara A., 2012 , "Surface modification of tungsten carbide by electrical discharge coating (EDC) using a titanium powder suspension", Applied Surface Science, 258, pp. 7255– 7265
22. Mohri N., Saito N., Tsunekawa Y., 1993 , "Metal surface modification by electrical discharge machining with composite electrodes", CIRP Annals, 42, pp. 219–222
23. Zaw H.M., Fuh J.Y.H., Nee A.Y.C., Lu L., 1999, "Formation of a new EDM electrode material using sintering techniques", Journal of Materials Processing Technology, 89-90, pp. 182-186.
24. Simao J., Lee H.G., Asplnwll D.K., Dews R.C., Asplnwall EM., 2003**, "**Workplace Surface Modmcatlon Uslng Eledrlcal Dlscharge Machlnlng", Int. J. Mach. Tools Manul., 43.2, pp. 121-128