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A Review on Electrical Discharge Machining

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ABSTRACT

Electrical discharge machining is one of the widely used non contact-type advanced machining processes in which material removal takes place due to melting and vaporization by thermal energy of electric sparks. Electrical discharge machining has the capability of machining difficult-to-cut materials such as super alloys, advanced ceramics, and composites with complex shapes at both macro- and micro-levels. This report presents the surface characteristics of CFRP composites machined by depositing tungsten and copper powder on its surface.Surface modification trends in biomaterials, green compact powder metallurgy Inconel-aluminum tool and die steel materials using electrical-discharge machining (EDM) process. The review begins with an introduction to the conventional electrical discharge machining and a brief discussion about the Surface modification techniques in recent years follow.

The EDM process carried out in a distilled water medium resulting in lower surface modification with less diffusion depth than kerosene fluid medium .the contribution of pulse off-time is more than pulse on-time. It means that pulse off-time is more significant and sufficient idle time is essential for the work surface to cool down and absorb the products of spark.we also observe that smaller in the tool erosion ,lesser is the material deposition .for metallic implants maximum corrosion resistance was achieved at 500◦C, where corrosion potential decreased from ~-100 mV to ~ -500 mV.

1. Introduction

Electric discharge machine :-

Electrical Discharge Machining (EDM) is a non-conventional and non-contact machining operation, It was evolved six decades ago by Doctors B. R. Lazarenko and

N. I. Lazarenko as die-sinking suitable for removing stock material. Later, the importance of EDM is increased and it is been used In industry for high precision products and It is used to achieve a stable, accurate and Efficient machining , used in biomedical and aerospace. in which material removal takes place due to melting and vaporization by thermal energy of electric spark. Among the non- conventional machining processes, it is a widely used technique due to their ability to machine any kind of conductive materials irrespective of their mechanical properties. The main process parameters in the EDM process are material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR).

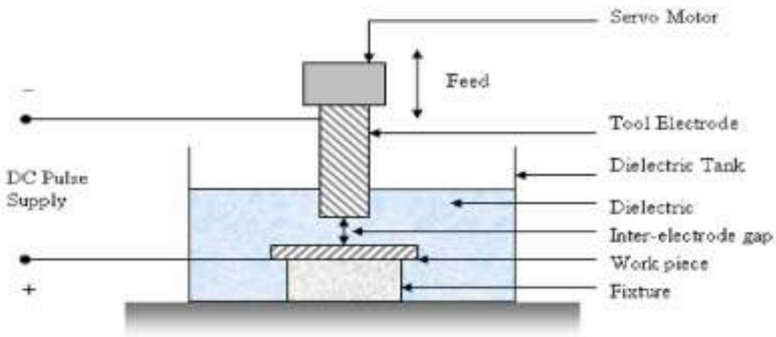

Fig.1.Basic Layout of EDM

The present work investigates the surface modification of die steel materials, CFRP composites by depositing tungsten and copper powder on its surface, Surface modification trends in biomaterials, green compact powder metallurgy Inconel-aluminum tool and die steel materials by EDM .

Applications:-

1. Drilling for micro holes in nozzles.
2. Thread cutting
3. Wire cutting e.t .c……

Surface modification:-

The surface modification is an act of modifying the surface of a material by physical, chemical or biological characteristics different from the ones originally found on the surface of a material. In this process, by the erosion work material during machining removal of some tool material also occurs, this can reduces the tool life , for this reason we have used some surface modification techniques for the modification of the surface.

Thereby, as a method of removing the surface defects generated by EDM, a surface modification method using oxidation is proposed. The proposed method involves the high-temperature oxidation of the surface of cemented carbide, thus softening the layers with many pores so that they can be easily removed by rubbing with a wire brush.

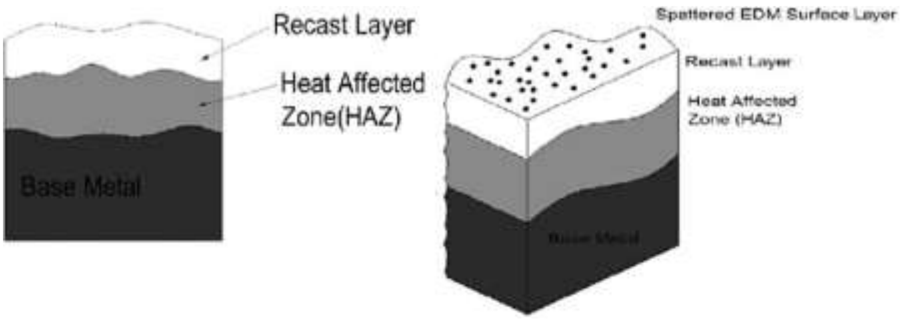

Fig.2. Surface layer formation in EDM

2. Literature Review

S. Suresh Kumar et al.,[1] gives a detailed discussion about the surface modification carried out on the materials during the EDM process. During the machining process, a particle from the compacted electrodes is migrated to the work-piece and reduces the formation of microcracks, voids, recast layer on the surface of the material. Electrical based parameters can be controlled through a power supply system and the parameters are namely pulsed on time, pulse off time, discharge current, discharge voltage and polarity.

The major functions of the dielectric medium are

(a) it enables more to concentrates the spark energy on a very slender region in the spark gap

(b) it helps to reduce the work piece and tool electrode temperature

(c) it is also used to flush away the removed material.

Sandeep Devgan et al.,[2] experimented with the electrical discharge machining process, a possible futuristic surface modification method that is known by its versatile characteristics of high precision and ability for altering the surface topography. the Biomaterials improve the quality of life by contributing their applications in vast field of joint and limb replacements, ocular implants, dental implants, artificial arteries and skin surgery.in this paper author explains the chronology of surface modification trends which includes various types of bio-coating and different coating techniques used for fabrication of bio materials.

Rashed Mustafa Mazarbhuiya et al.,[2]experimented with the surface characteristics of CFRP composites by depositing tungsten and copper powder on its surface using electrical-discharge machining (EDM) process. An attempt is made to study the size of crystallite, dislocation density, and micro strain at the surface level of the deposited material. The presence of tool material and the carbides such as WC and W2C of tool constituents are detected on the surface of the CFRP composites. Dispersion of tungsten and copper particles improves the surface characteristics of the CFRP composite by altering the crystallographic structure at the surface level.

Deepak Rajendra Unune[4] experimented For successful implantation, biomaterials need excellent corrosion and wear resistance in the body environment.in this paper the author Commonly used metallic biomaterials are Stainless steel, Cobalt Alloys, Titanium and titanium alloys. peak current of 9.98 A, pulse-on time of 259.88 μs, 200.174 MPa compaction. Maximum deposit layer thickness of 69.42 μm. Titanium and Titanium alloys, continue to be the most popular option for biomedical applications because it has outstanding mechanical properties, bio compatibility and corrosion resistance.

Mahajan et al.,[5] experimented with the Surface modifications of biomaterials play a vital role in matching the complexities of the biological system and improving the performance of bioimplants. This review article has the surface modification techniques of several essential metallic biomaterials, viz. stainless steel, magnesium, titanium and chromium–cobalt. The plasma consisting of spark channel is highly conductive and capable of sustaining large current (104 A) and generating temperature of around 0·7 eV (8100 K).

Ankita Sarmah et al.,[6] experimented with the present work attempts to modify the surface characteristics of Al-7075 alloy using powder metallurgy (PM) green compact tool in electric discharge machining (EDM). Al-7075 alloy has high strength but possesses poor tribological properties due to its lower hardness, Inconel 718 powder having high hardness and corrosion resistance. The deposited layer exhibits an increase in micro-hardness by 1.5–2.5 times as compared to the base material. This confirms the effectiveness of depositing Inconel on the surface of Al workpiece using EDM. The surface of Al-7075 alloy has been successfully modified by depositing 50% Inconel 718 and 50% Al using EDC process.

Ndaliman et al.,[7] This paper presents investigation on the alloying capability of Cu-TaC electrode during electrical discharge machining (EDM). The electrode produced through powder metallurgy technique was used in machining alpha-beta titanium alloy (Ti-6Al-4V) under different machining conditions. EDM experiments were conducted with distilled water as dielectric fluid. The peak current range of 3.5-5.5A and pulse duration of 3.3 - 5.3µsec were the machining conditions used as variables, while other conditions remained constant.

Sanjeev Kumar et al.,[8] experimented Material may be provided to the machined surface of the workpiece by the eroding tool electrode or by using powder-mixed dielectric. Breakdown of the hydrocarbon dielectric contributes carbon to the plasma channel which may also cause surface modification. The present work has investigated the response of three die steel materials to surface modification by EDM method with tungsten powder mixed in the dielectric medium.

Tyau-Song Huang et al.,[9] experimented with This study attempts to decrease the martensite transformation temperature of Ti50Ni50 shape memory alloy (SMA) for its use in biomedical applications by Cr addition. In addition, surface modification of Ti50Ni50 and Ti50Ni49.5Cr0.5 SMAs using electrical discharge machining (EDM) is Studied. TiO and TiC were formed on the surface when Ti–6Al–4V alloys were EDMed in kerosene and distilled water, respectively.

T. TAMURA [10] experimented a method of processing cemented carbide, sinking electrical discharge machining (EDM) is generally used. However, typical surface defects, such as cracks, micro craters and recast layer, lead to a decreased surface integrity, probably resulting in a short tool life. Cemented carbide, which is about two times harder than high-speed steel, exhibits superior wear- and heat resistance properties. As methods of processing cemented carbide, electrical discharge machining (EDM) and grinding are generally used.

3. Observations from Literature Review

PAPER[1]

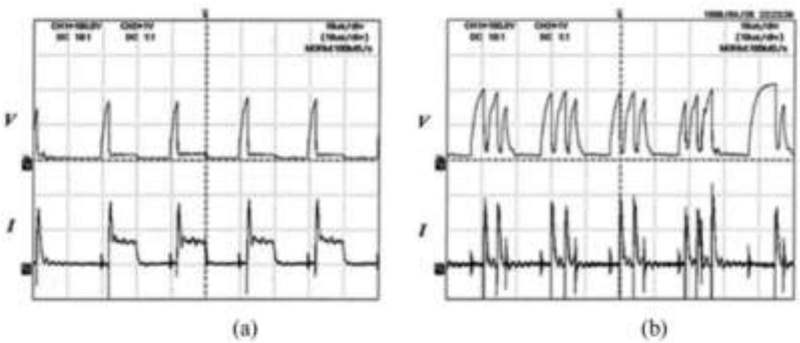

Fig.3. Voltage and current wave pattern (a) kerosene and (b) kerosene with Al powder

An increase in the frequency utilized to overcome the lower material removal obtained from a single spark. Thus, multiple discharge paths lead to the dispersion of discharge energy in contrast with ordinary or pure fluid which will produce a steady waveform which is presented in Fig. 3.

PAPER[2]

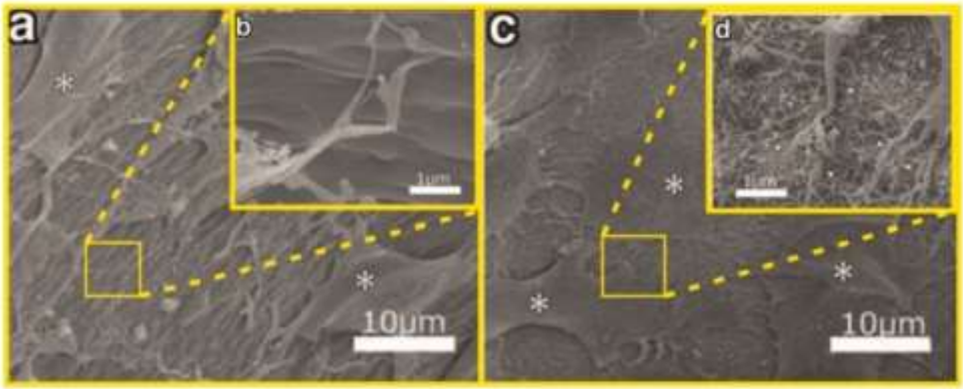

Fig.4. SEM of incubating cells on surfaces after 1 week (a) collagen sponge and (c) MWCNT-coated sponge, (b) and (c) represents the images at higher magnification

obtained a MWCNTs-coated collagen by employed soaking methods that conclude that MWCNTs coatings improve the cell attachment and proliferation as shown in Fig. 8.

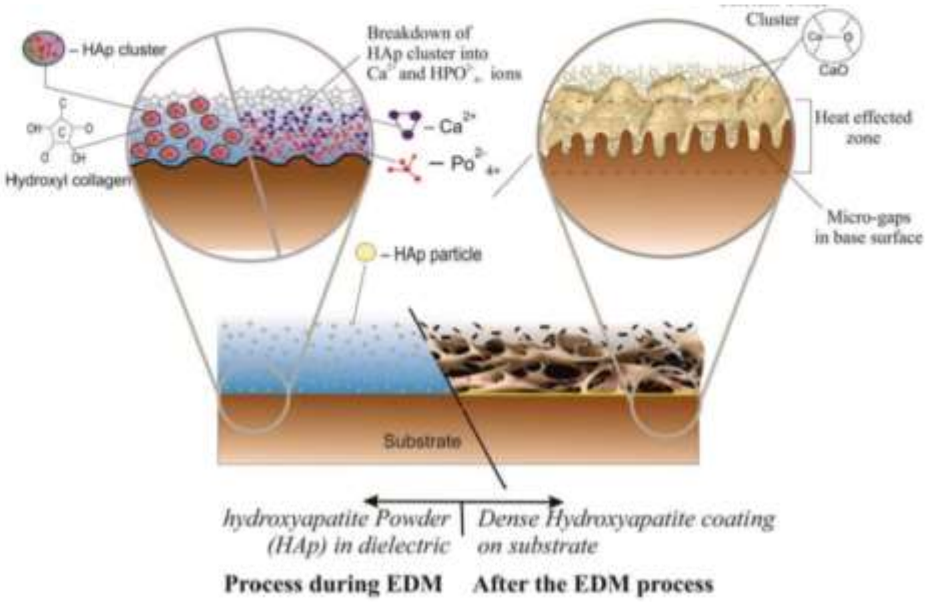

Fig.5. Schematic diagram of EDM process incorporating Hap powder in dielectric medium.

This phenomenon leads to change in chemical composition and metallurgy of recast layer. For example EDMing process incorporating HAp powder in dielectric medium (deionized water) was schematized in Fig. 5.

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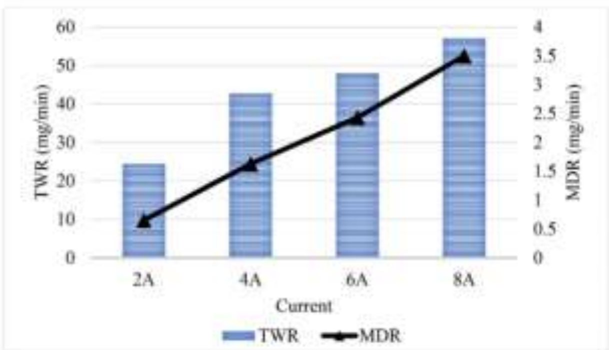

Fig. 6. Variation of TWR and MDR.

The rate of tool wear and consequent rate of deposition increases with the increased current during the EDM operation as shown in Fig. 6.

PAPER[4]

Table.3. Mechanical properties of metallic biomaterials and bone

material	Young's Modulus (GPa)	Elongation to failure (%)	Ultimate tensile stress (MPa)	Density (kg/m^3)
Bone	20	1–2	90–140	1900
Stainless steel	200	45	465–950	7800
colbalt alloys	275–1585	5–30	600–1795	8500
titanium	105	15–24	785	4200
ti-6al-4v	110	10–15	960–970	4500

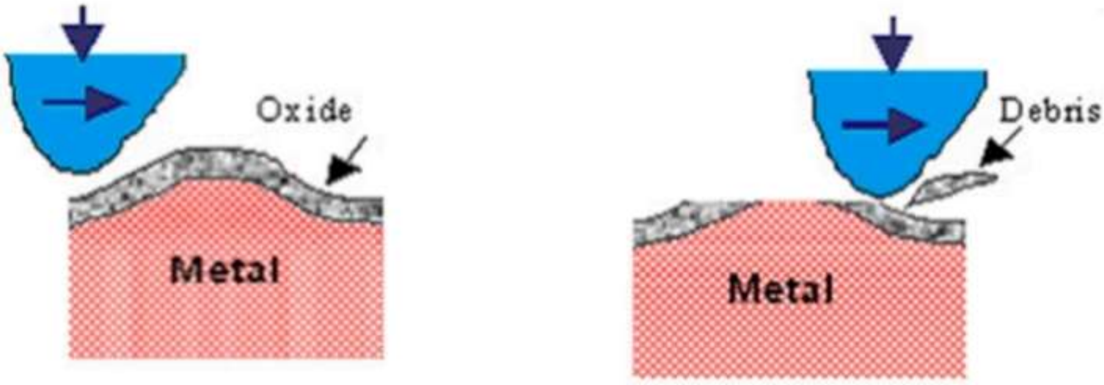

Fig.7. A schematic diagram to show the creation of wear debris during oxidational wear

wear mechanism creates wear debris, as shown in Fig. 7. Such wear debris can initiate an immune response in which macrophages phagocytose the foreign matter.

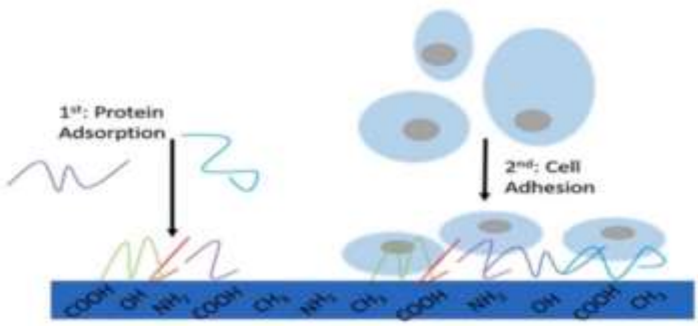

Fig. 8. Protein adsorption to a biomaterial surface depends on the exposed chemical groups.

The initial stages of biomaterials being introduced into the body, proteins adsorb to their surface ; the type of protein that adsorbs in a particular area depends on the metal's surface chemistry and topology.

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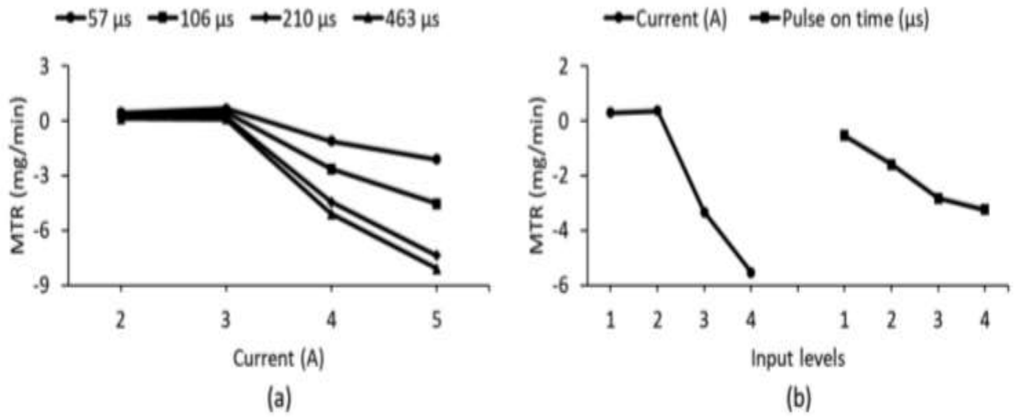

Fig.9. Effect of process parameters on MTR (a) Parametric effect and (b) Mean effect

Parametric effect and mean effect plots of MTR are shown in Fig.14a,b, respectively. Positive value of MTR indicates net material addition, whereas negative MTR indicates net material removal

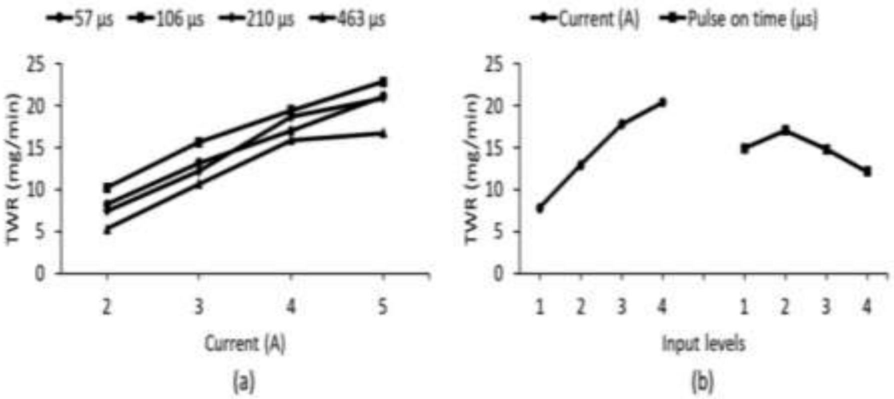

Fig.10. Effect of process parameters on TWR (a) Parametric effect and (b) Mean effect

Parametric effect and mean effect plots of TWR are shown in Fig.15a,b, respectively. Both the plots reveal that TWR increases with an increase in Ip from 2 to 5 A.

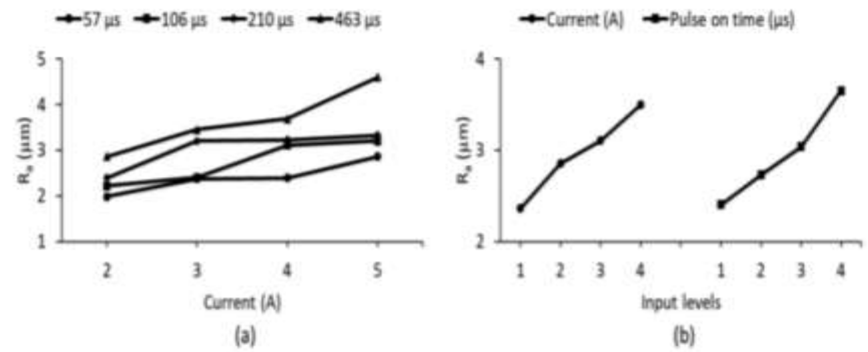

Fig.11. Effect of process parameters on Ra (a) Parametric effect and (b) Mean effect

Parametric effect of process parameters on Ra and its mean effect plots are shown in Fig. 5a,b, respectively. Ra increases with the enhancement in both Ip from 2 to 5 A and Ton from 57 to 463 µs.

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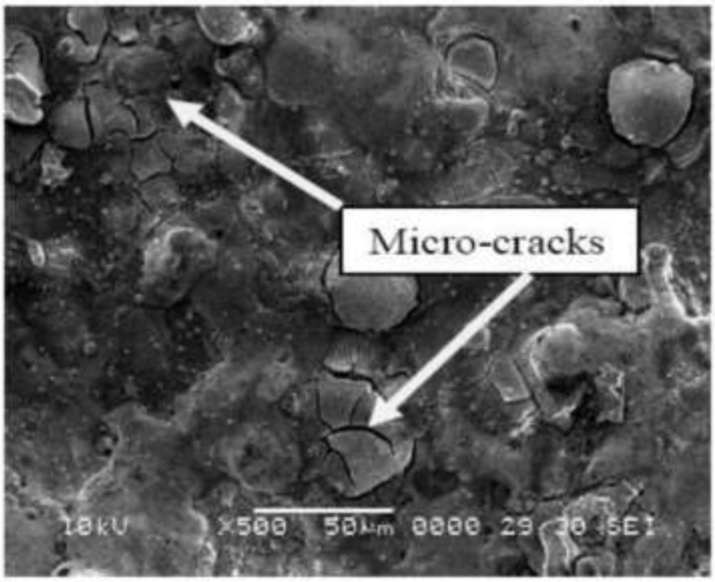

Fig.12. Topography of the surface machined with Ip3.5A, to -3.3µsec.

The scanned images of the EDMed surface under different machining conditions are presented in figures 3-5. Theses surfaces are characterized by various degrees of micro-cracks and craters depending on their machining conditions. At lower peak currents and pulse durations, the surfaces generally exhibit some small size cracks with little or no craters (Figure 12).

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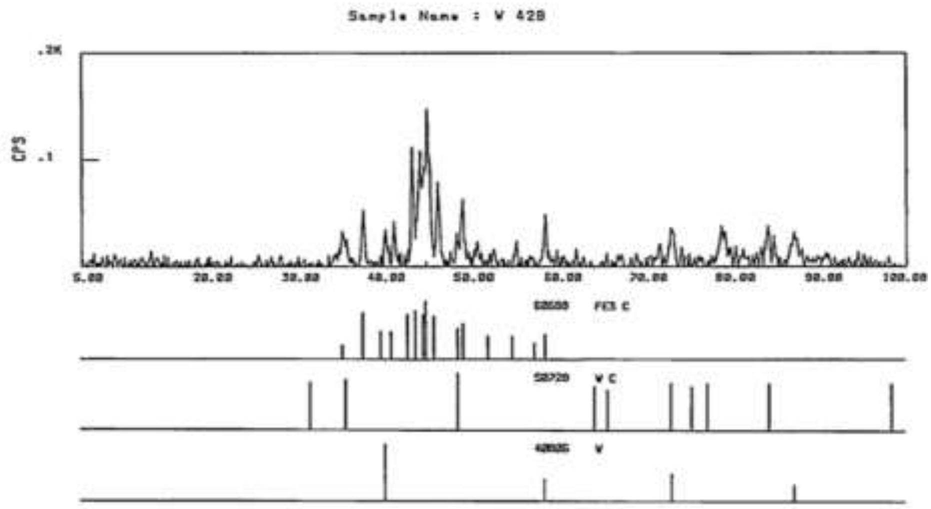

Fig.13. XRD pattern of OHNS die steel after machining with tungsten powder-mixed dielectric.

An XRD pattern obtained from the machined surface given in Fig. 4 shows the presence of WC, Fe3C and elemental W. This indicates the transfer of W from the tungsten powder suspended in dielectric and of carbon from the dielectric itself on its dissociation to the die material surface.

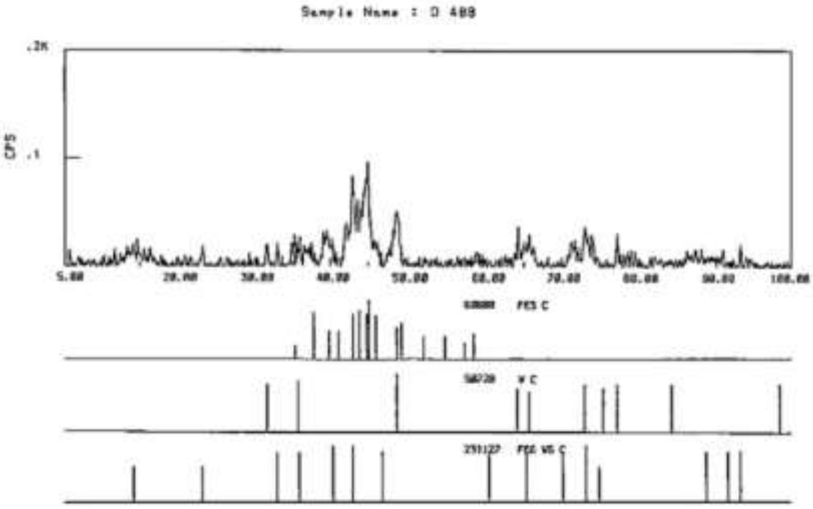

Fig.14. XRD pattern of D2 die steel after machining with tungsten powder-mixed dielectric

The corresponding XRD pattern from the D2 die steel EDMed surface shows the formation of Fe6W6C, Fe3C and WC (Fig. 14) which is responsible for the improvement in micro-hardness. The carbon and W pick up by the machined surface is confirmed and quantified by spectroscopic analysis carried out at the machined surface of D2.

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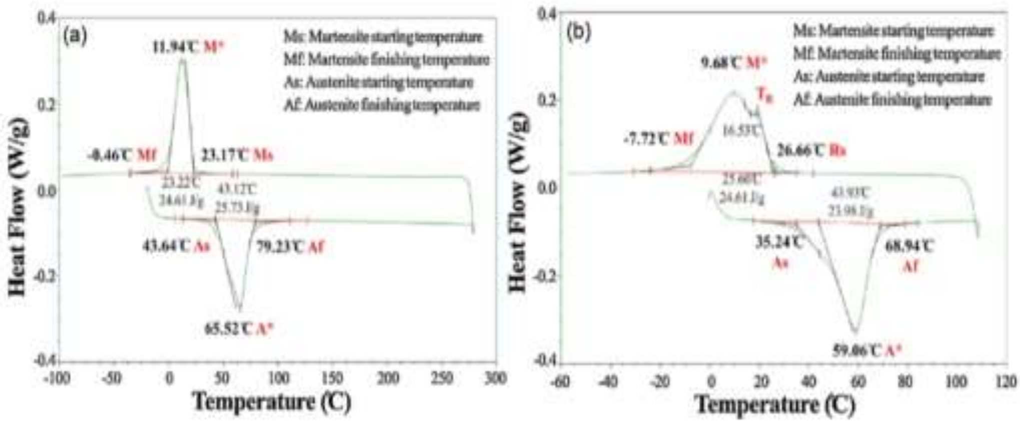
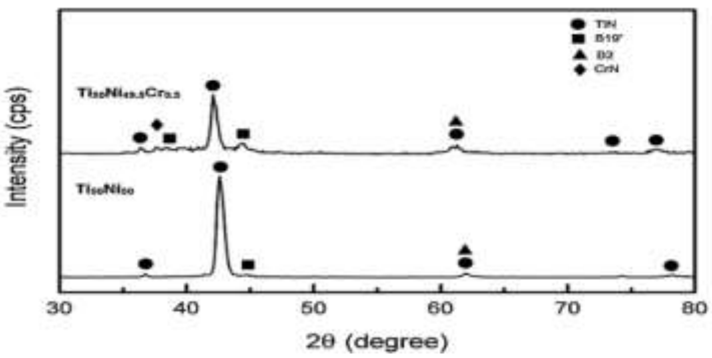


Fig.15. DSC curves of (a) Ti50Ni50 and (b) Ti50Ni49.5Cr0.5 SMA

Fig. 15(a) and (b) show the DSC curve of Ti50Ni50 and Ti50Ni49.5Cr0.5 in both forward and reverse transformation, respectively. It is indicated that decreased martensite transformation temperatures (M* and A*) can be achieved by adding a small amount of Cr.



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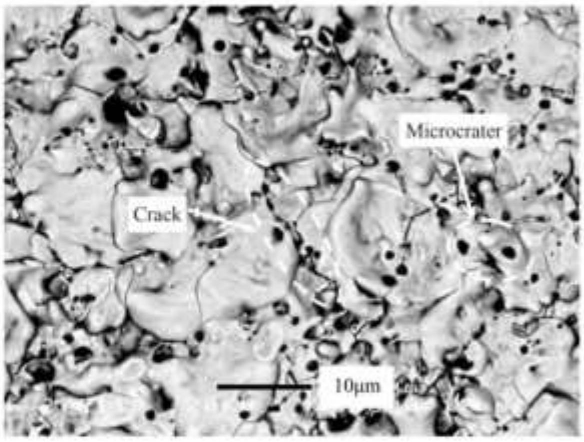

Fig.1. Surface subjected to EDM

Figure 16 shows a surface subjected to EDM observed by a scanning electron microscope (SEM) as a COMPO image. This surface is machined under the finishing conditions. A large number of cracks can be clearly recognized around the circumference of the discharge craters on the machined surface. Moreover, many microcraters, which are visible as dark spots, are also distributed throughout the machined surface.

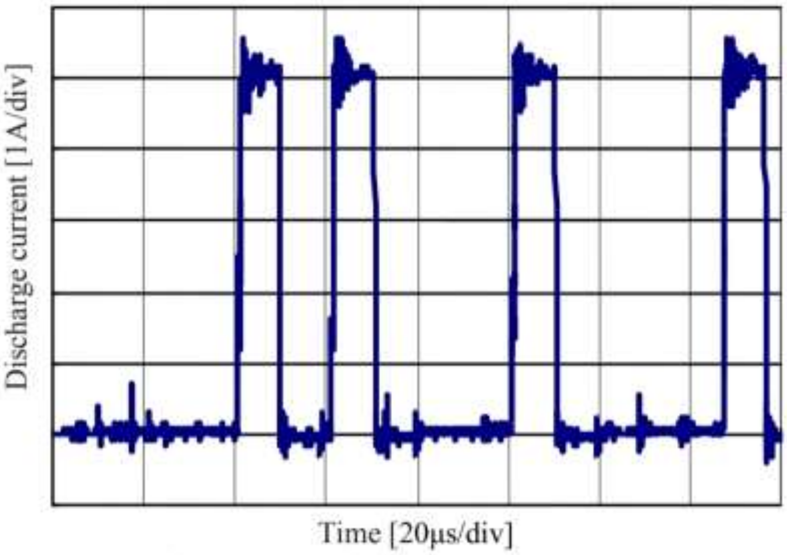

Fig.16. Current waveform obtained during EDM

the current waveform was measured to ensure that only the electrolysis phenomenon occurs during SIME. A Rogowski-type current sensor is used in this experiment. The current waveform obtained during EDM is shown in Fig.16.

4. Conclusions

A detailed study was done on the surface modifications made on the various materials using the EDM process. The surface-level changes attained through powder mixed dielectric medium, various electrode materials, and a composite electrode formed through powder metallurgy route and EDC process are included. The machined surface made by EDM is having comparatively fewer defects. The powder mixed EDM process and also composite electrodes help to form the defect-free surface. The HAp is bone grafting material which exhibited excellent bonding strength and can be easily coated on substrate by retaining its bulk materials properties. Carbon nanotubes (CNT's) show remarkable potential in a wide variety of applications and are still in sprouting stages. CNTs can be coated uniformly on the metals with excellent packing density without any macroscopic irregularities.

CFRP composite material under reverse EDM process possible to perform the alteration of surface properties using W-Cu P/M green compact tool electrode. Metallic biomaterials, especially, Titanium and Titanium alloys, continue to be the most popular option for biomedical applications. Surface modification route via EDM process enables the depositions of minerals. The presence of tungsten carbide and increase in the percentage of carbon on the machined surface indicate that suspended powder particles can react with carbon (from the breakdown of the hydrocarbon dielectric) at high temperatures of the plasma channel to form carbides . Moreover, the microhardness, surface finish, wear resistance and corrosion behavior of the material are enhanced by these surface modification techniques.

5. Scope for Future work

The formation of the thick coating through the EDC process still needs to be explored further as it is an alternative for the coating process. The automobile parts specially, mating components that must have better wear and corrosion resistance are processed by using any of the surface modification techniques towards improving its surface characteristics. Nowadays, The antibacterial coating on materials being used in biomedical applications is the scope for researchers. Surface modification of biomaterials is an extensive subject with a broad range of contemplation for improving the implant performance and its service life in a human body. Stainless steel, titanium, magnesium and the chromium-cobalt are the leading implant materials in orthopedic applications.

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