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Effect of Cryo-treated Ni-Ti Alloy and Copper Electrode on Electric Discharge Machining Performance Measures

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Abstract

This study aims at understanding the effect of cryogenic treatment of workpiece and tool electrode on electrical discharge machining (EDM) performance measures viz., material removal rate (MRR) and tool wear rate (TWR) during producing meso-scale holes on NiTi alloys in-conjunction with electrical parameters namely gap current, pulse on time and pulse off time. Based on experimental results it was observed that MRR is high when treated NiTi alloy and untreated copper tool was used. MRR is low when both NiTi and copper are cryo-treated for all electrical parameter. With increase in gap current tool wear increase but tool wear is low when both NiTi and copper are treated. Both MRR and TWR increases with regards to the gap current and pulse on time. And increase in pulse off reduces the MRR and TWR.

Keyword: Ni-Ti alloy, Material removal rate, Tool wear rate, Cryo-treated copper electrode.

1. INTRODUCTION

In today's manufacturing scenario demand for smart material is increasing day by day. NiTi alloy is one of the smart materials. NiTi has properties such as high corrosion resistance, high wear resistance, biocompatibility, superelasticity, high specific strength. It can also have recoverable strain of 7%.This alloy is available in two different phases. The higher temperature phase is known as austenite state, in this state material is hard and strong where as the lower temperature phase is called as martensite phase in this phase material is ductile and soft. In austenite phase crystal structure is simple body centered cubic where as in martensite it is crystal structure is complex rhombic. This alloy also shows a significant property i.e shape memory effect hence it has various applications such as aerospace, defence, medical etc. these application requires high accuracy and precision while machining hence conventional machining cannot be used to machine such alloy hence Electric discharge machining is one of the non-conventional machining processes to machined NiTi alloy. Electric discharge machine and Wire electric discharge machining shows excessive compatibility to machine shape memory alloy. Electric discharge machining is the thermal processes in which material is removed by the heat. Heat is introduced by the flow of electricity between workpiece and tool. It is one of the erosion processes in which material is removed by the erosive action of workpiece by means of flushing fluid. This section discuses the study of various input parameters on performance measure of electric discharge machine such as material removal rate (MRR), tool wear rate (TWR). Ram et al. conducted a research on effect of cryogenic treatment on the workpiece material of EDM process with commercially available EDM oil. Cryogenic is the heat treatment process which helps in enhancing the material property. This research mainly deals with the effect of EDM process parameter on cryogenically treated and non-treated work piece (EN31).The values of these EDM process parameter is being decided by Taguchi's method. MINITAB software is being used for developing the empirical relation of MRR, TWR, Surface Roughness and analysis of the data. From this they concluded that MRR increase in vast amount and surface finish has been improved for most of the level. Todkar et al. conducted a research on effect of vibration on EDM processes for this research a separate vibrating unit is being designed to create the low frequency oscillation to the work piece. Electromagnet is used as actuator in this setup. Work piece and tool used for this research study is WC of grade MG18 and tungsten respectively with commercially available Total FINA ELF EDM 3 oil. From this they come to know that there is continuous suction and pumping action of fluid which leads to improve the flushing condition and results in removing the debris from the machined surface which improves the MRR. Vibration Assist micro EDM also leads to improve the surface finish of micro hole and reduction in the tool wear. On the other hand very high amplitude and frequency found to be unsuitable for surface quality and accuracy of micro holes. Khan et al. conducted a research on effect of tool polarity on the machining characteristics of EDM ,in general tool is at the negative pole and work piece is at positive pole this is called direct polarity, but in this research tool is kept at positive pole and work piece is at the negative pole this is called reverse polarity. In this research copper is being used as tool material and steel of grade 28 is used as a work piece with spark erosion oil as a flushing fluid. A 3^2 factorial design is being used for conduction of the experiments. The study states that direct polarity is suitable for higher Material Removal Rate and less electrode wear rate but on the other hand reverse polarity give better surface finish as compared to direct polarity. Direct polarity gives 10 times more MRR and 5 times less TWR as compared with the reverse polarity. Gil et al. conducted a research on wear reduction of aluminium electrode by cryogenic treatment in electro discharge machine, deep cryogenic treatment is the process of enhancing the material properties in which material is subjected to -185 ^{0}C.Cryogenic treatment improve the crystal structure, relieves the residual stresses and improves the electrical property. Taguchi's design L_9 orthogonal array is being used to conduct the experiment and experiments are carried out on hot die steel (AISI H11) and aluminium as a tool material. The result of experiments suggested that electrode wear is significantly reduces by deep cryogenic treatment as compared with the untreated electrode. Jatti and Singh studied the effects of cryogenic treatments on the machiniability of NiTi shape memory alloys work pieces in electro discharge machining. Due to cryo-treatment the electrical conductivity of work piece exceptionally improved. Experimental results showed about 19% increase in material removal rate of cryogenic treated work pieces. Variations in tool wear rate were found to be marginal. Walkar et al. investigated the effect of magnetic field on the material removal rate and surface roughness, in conjunction with the variation of electrical parameters like pulse on-off times and gap current, while keeping other electrical parameters and work piece/ tool material constant. An experimental result showed that the magnetic field assisted EDM improves the process stability. Payal et al. conducted a research on electro discharge machined surface of EN-31 tool steel. Experiments were performed on EN-31 tool steel as work piece material and copper, brass and graphite as electrode with kerosene as flushing fluid. Scanning Electron Microscope and optical microscope is being used for the surface analysis of machined surface and to understand the effect of heat affected zone respectively. They found that heat affected zone in case of graphite electrode is deeper than copper and brass. And Brass gives good surface finish and normal MRR. Prihandana et al. investigated the effect of vibration on electric discharge machine. Material used for conducting these experiments is stainless steel (SS-304) with low frequency vibration. This research study shows that use of low frequency vibration improves the material removal rate and diminishes tool wear rate and surface finish. From this literature survey it is observed that very few research are carried on NiTi and not as such work is carried on effect of cryogenic treatment of electrode and workpiece. This research work deals with the comparative study of cryogenic treated and untreated NiTi when machined by copper electrode on performance measure of EDM such as material removal rate, tool wear rate by varying input parameters such as gap current, pulse on time and pulse off time.

2. MATERIAL AND METHODS

The work material selected for the study is NiTi alloy of dimension ϕ20 mm x 20 mm and cryo-treated and untreated electrolytic copper is used as tool electrode with dimension of □3 x 25 mm. Workpieces and tool were cryo-treatment at -185 ^{0}C at Kryoscape, Pune, India. Experiments were conducted at die sink type electrical discharge machine of C 400 x 250 model and Electronic make. Table 1 and 2 show the properties of electrolytic copper and NiTi alloy respectively. Gap voltage is kept constant at 55 V and flushing pressure is set at 0.5 Kg/cm^2. Gap current, pulse on time, pulse off time were varied and experimental conditions are mentioned in Table 3. The change in weight of workpiece and tool electrode is being measured by digital weighing balance of model GR-300 with accuracy of 0.0001 gm. Material removal rate and tool wear rate is calculated using equation 1 and 2.Figure 1 shows the experimental set up and figure 2 shows NiTi alloy and copper electrode.

$$\text{MRR}= \frac{(W_1 - W_2)*1000}{\rho * t} \quad (1)$$

$$\text{TWR} = \frac{(T_1 - T_2)*1000}{\rho * t} \quad (2)$$

Where, W_1= weight of workpiece before machining (gm), W_2= wieght of workpiece after machining (gm) T_1= weight of tool before machining (gm), T_2= weight of tool after machining (gm), t= machining time (mins), ρ = density of material (gm/cc).

Table 1 Physical, mechanical and chemical properties of copper

Copper	99.9 %
Density	8.94 gm/cc
Ultimate Tensile strength	220.632 MPa
Yield Tensile strength	68.947 MPa

Table 2 Physical, mechanical and chemical properties of NiTi alloy

Density	6.45 gm/cc
Ultimate Tensile strength	754-960 MPa
Yield Tensile strength	560 MPa
Elongation at break	15.5%
Modulus of Elasticity	75 GPa
Poisson's ratio	0.300
Shear Modulus	28.8 GPa
Specific Heat capacity	0.320 J/g-^{0}C

Table 3 Experimental conditions

Workpiece	NiTi Shape Memory Alloy(Treated treated)
Tool	Electrolytic Copper(Treated and Untreated)
Flushing fluid	Commercial EDM Oil
Gap current (A)	8,10,12,14,16
Pulse on time (µs)	13,26,38,51,63
Pulse off time (µs)	5,6,7,8,9

Fig. 1 Experimental set up

3. Result and Discussions

This section discuses the effect of cryogenic treatment of NiTi alloy and copper electrode on electric discharge machining performance measures namely MRR and TWR. It was observed from the experimentation that MRR in case of treated NiTi and untreated copper is more as compared with treated NiTi and treated copper because when both workpiece and tool are treated then energy required to remove the material is more due to the bonding of molecules. And TWR is slightly high when untreated copper was used for the experimentation. Figure 2 and 3 shows the variation of MRR and TWR with respect to gap current.

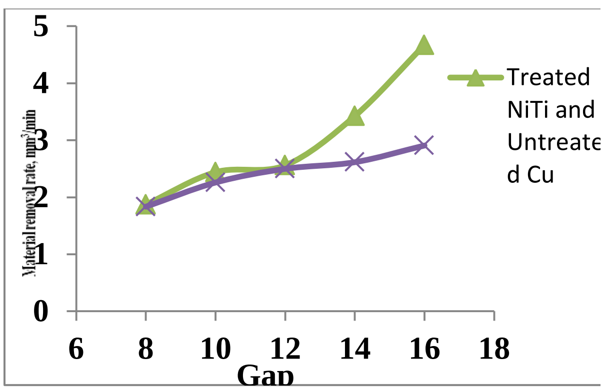

Fig. 2 MRR versus gap current

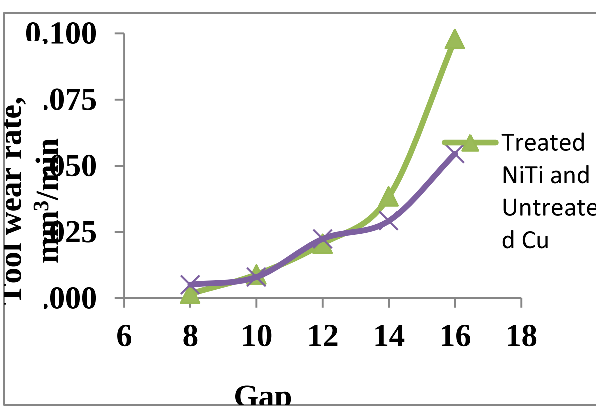

Fig. 3 TWR versus gap current

Figure 4 and 5 shows the variation of MRR and TWR with respect to pulse on time. It is noted that MRR starts increasing as there is increase in the pulse on time. As pulse on time increases plasma channel diameter become wider and causes positive ion to become active which then attacks the workpiece surface and removes the material by evaporation. As pulse on increases the TWR also starts increasing but it declines after 25 µs because when pulse on increases, the plasma channel diameter gradually increase and positive ion become more active. This reduces the movement of electron towards the tool because of this amount of heat and energy transferred to the tool reduces which results in diminishing of TWR. It was noted that MRR is less and TWR is more in case when workpiece as well as copper electrode are treated. Figure 6 and 7 shows the variation of MRR and TWR with respect to pulse off time. It is noted from the experiments that MRR and TWR both decreases as increase in the pulse off time, increased pulse off leads to cool the machining surface of workpiece hence there is decline in MRR and TWR. It is noted that MRR in case when both are cryotreated i.e workpiece and electrode is less as compared with the untreated NiTi and treated copper.

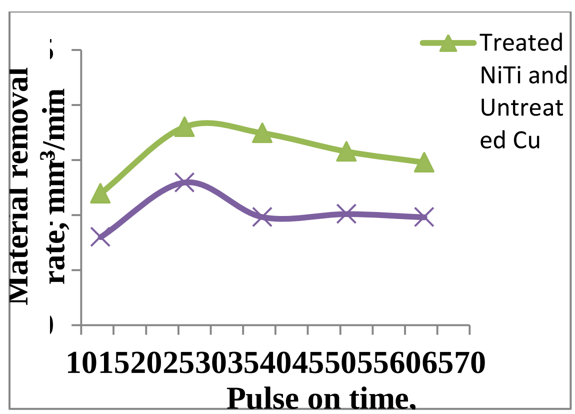

Fig. 4 MRR versus pulse on time

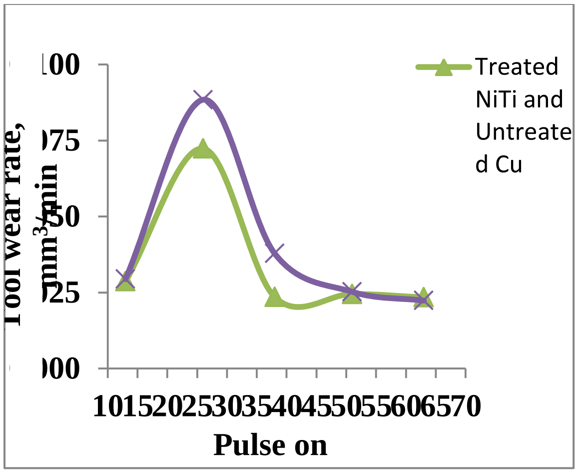

Fig. 5 TWR versus pulse on time

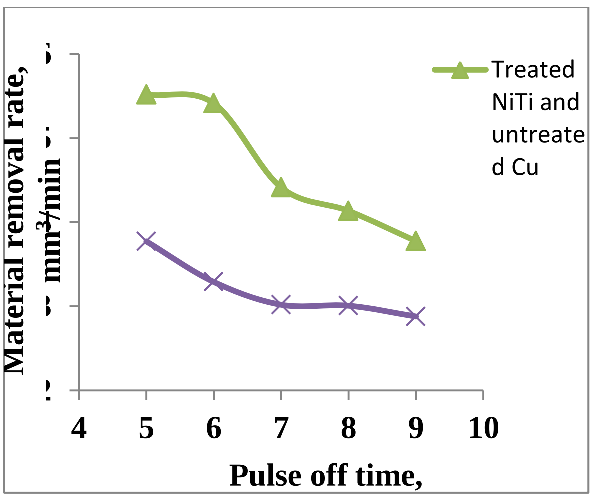

Fig. 6 MRR versus pulse off time

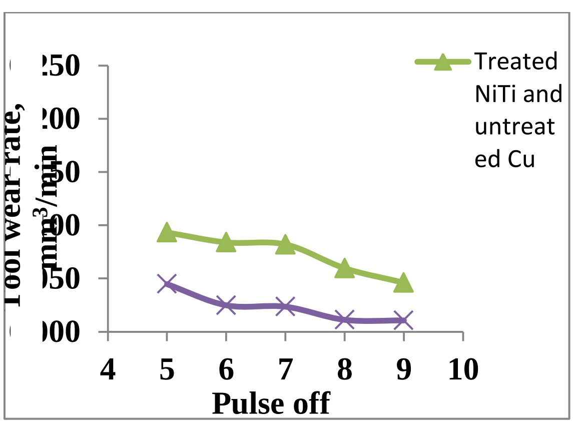

Fig. 7 TWR versus pulse off time

4. CONCLUSIONS

In this research study mesoscale square hole of 3 mm x 3 mm were drilled on the cryo-treated NiTi alloy using cryo-treated and untreated copper electrode in electric discharge machining. It was observed that cryo-treatment of electrode improves the tool life. Both MRR and TWR increases with regards to the gap current and pulse on time. And increase in pulse off reduces the MRR and TWR. From this study it can be concluded that MRR is always less in case when both the workpieces and tool are cryo-treated.

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