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Research Article

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Electric discharge machining of cryo-treated NiTi alloy by cryo-treated and untreated copper electrode

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ABSTRACT

NiTi alloy is one of the advanced materials which have properties such as high specific strength, high corrosion resistance, biocompatibility etc. Due to such superior properties it is used in the field of aerospace, medical and defence. These field required high machining accuracy and precision. So machining of these alloys is not possible with conventional machining hence non-conventional machining processes i.e. electric discharge machining (EDM) is implemented to machined these alloy. In the present study effect of cryogenic treatment on NiTi workpiece and copper electrode is investigated. EDM performance measures viz. Material removal rate and tool wear rate are evaluated against the variation of gap current, pulse on time, pulse off time for different combinations of workpiece and tool. It is concluded that cryogenic treatment of NiTi workpiece improves the material removal rate. Also MRR and TWR increases with regards to gap current and pulse on time and declines with regard to pulse off time.

Keywords: NiTi alloy, material removal rate, tool wear rate, cryogenic treatment.

INTRODUCTION

NiTi alloy is a shape memory alloy. This alloy exhibits in two different phases. High temperature phase is called as austenite and low temperature phase is called as martensite. This alloy has properties such as high specific strength, high corrosion resistance, biocompatibility etc. These alloys are mainly having application in field of medical, defense, space. Due to such wide application machining of these alloy required high accuracy and precision for these application. Such high accuracy can't be obtained by conventional machining hence non-conventional machining such as electric discharge machining is used for these alloy. Gil et al. conducted a research on wear reduction of aluminum 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 improves the crystal structure, relieves the residual stresses and improves the electrical property. Taguchi's design L_9 orthogonal array is being used to conduction of the experiment and they 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 [1]. Khan et al. conducted a research on machining characteristics of EDM with the effect of tool polarity, 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 lower tool wear and higher material removal but on the other hand reverse polarity give better surface finish as compared to direct polarity. As that of reverse polarity, direct polarity gives 5 times less TWR and 10 times more MRR [2]. Gharg et al. studied about optimization of EDM process with triangular shaped electrode on EN-19 steel. They have considered control parameters as concentration of micro nickel powder, peak current, angle of triangular electrode, duty cycle. Response surface method is being implemented for the optimization of data. On doing experiments they have found that peak current and concentration of powder are found to be most significant parameters. They have also found that performance of PMEDM has found to be better than conventional EDM and also they have found that the maximum MRR and minimum TWR are found at 4.34A current, 72% duty cycle, 3.60gms/l powder concentration, 130 degree tool angle [3]. Ram et al. conducted a research on effect of cryogenic treatment on the work piece 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 come to know that MRR increase in vast amount and surface finish has been improved for most of the level [4]. Jatti and Singh studied the effect of cryogenic treatment on NiTi. Experimentally they found that there is increase in electrical conductivity of workpiece. They also noted that material removal rate increased by cryogenic treatment [5]. Guu et al. studied the effect of rotating workpiece on electric discharge machine performance measure. In this work workpiece material used was AISI D2 tool steel with copper as tool electrode. It is concluded from this research work that MRR improves twice as that of conventional EDM. The rotation of tool improves the flow of dielectric hence it results in improved MRR and surface finish [6]. Todkar et al. conducted a research on effect of vibration on EDM processes for this research a separate vibrating unit is being designed for giving low frequency oscillation on workpiece. Electromagnet is used as actuator in this setup. Workpiece and tool used for this research study is WC of grade MG18 and tungsten respectively with 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 for improving the surface finish of micro hole and reduction in the wear rate of tool. Form other side it was noted that very high frequency, amplitude are unsuitable for accuracy and surface quality of micro holes [7]. Manjaiah et al. made a review on non-conventional machining of SMA. According to this material removal rate improves with increasing the current and depends on melting temperature and thermal conductivity of material, if thermal conductivity of a material is more than the energy transferred to nearby matrix will be increased which leads to the decreased MRR. MRR increase with pulse on but start decreasing when pulse on crosses the certain limit this happens because longer pulse on leads to expansion of plasma channel hence molten material will not able to flow away from machined surface effectively due to lesser amount of plasma energy to explode the dielectric fluid, also longer pulse on reduce the energy density. Material removal rate is found to be more in case of rotary electrode due to centrifugal action and positive polarity electrode shows the higher values of both MRR as well as TWR [8]. From the literature review it was found that not much research carried out on NiTi alloys. This study deals with the study of effect of cryogenic treatment on machining of NiTi and copper electrode. This study aims at to study the performance measure of EDM viz. material removal rate and tool wear rate by varying the processes parameter on cryo treated NiTi and untreated NiTi by untreated and cryo treated copper electrode.

EXPERIMENTAL SECTION

In present study NiTi alloy is selected as workpiece material and electrolytic copper as tool electrode. NiTi samples were cut into size of ϕ20 mm x 20 mm length and tool electrode of size □3 mm x 90 mm length. Both the workpiece and tool are cryo-treated at -185 ^{0}C at cryospace, Pune. Electrical conductivity of workpiece and tool is obtained from electrical resistivity testing system. In this gap current, pulse on time, pulse off time are varied. Experiments were carried out on die sink type of electric discharge machine of make electronic machine tool limited. Digital weighing balance of model GR 300 with accuracy 0.0001 is being used to measure the weight of workpiece and tool before and after machining also for weighing. Flushing fluid and gap voltage kept constant i.e. 0.5 kg/cm^2 and 55V respectively throughout the experiments. Material removal rate is calculated using equation (1) and tool wear rate by equation (2) for all the experimental conditions. Figure 1 and figure 2 shows the EDM experimental set up and EDM operation respectively.

$$\text{MRR} = \frac{W_1 - W_2}{\rho \times T} \qquad (1)$$

W_1= work piece weight before machining, gm
W_2=work piece weight after machining, gm
ρ = work piece density, gm/cm^3
T = cycle time, minute (using stop watch)

$$\text{TWR} = \frac{T_1 - T_2}{\rho \times T} \qquad (2)$$

T_1= tool weight before machining, gm
T_2= tool weight after machining, gm
ρ = tool electrode density, gm/cm^3
T = cycle time, minute (using stop watch)

Figure 1 EDM experimental set up

Figure 2 EDM operation

RESULTS AND DISCUSSION

This section discuses the effect of EDM processes parameter on performance measure namely material removal rate and tool wear rate. Figure 3 and figure 4 shows the variation of MRR, TWR with regards to gap current respectively.

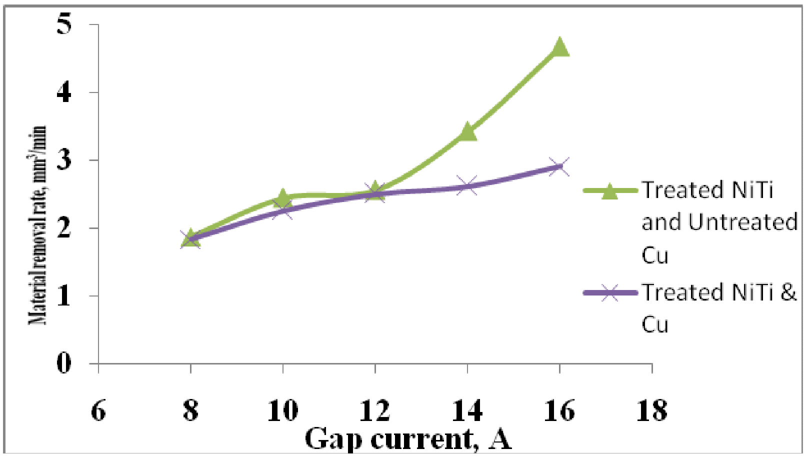

Figure 3 MRR versus gap current

From figure 3 it is noted that as there is increase in gap current MRR also starts increasing. Increase in gap current leads to increase spark energy which is directly proportional to gap current. Spark energy increases the surface temperature of workpiece which results in increased MRR. From this study it is concluded that MRR in case of treated workpiece and untreated copper electrode is more as compared to MRR of treated NiTi and treated copper. MRR is less in case of treated NiTi and treated copper electrode because cryogenic treatment improves the crystal structure and as both are cryo treated hence energy required to remove material is more hence MRR to be observed in this case. Figure 4 shows the variation TWR with regards to gap current. From this study it is noted that with rise in gap current there is rise in TWR.

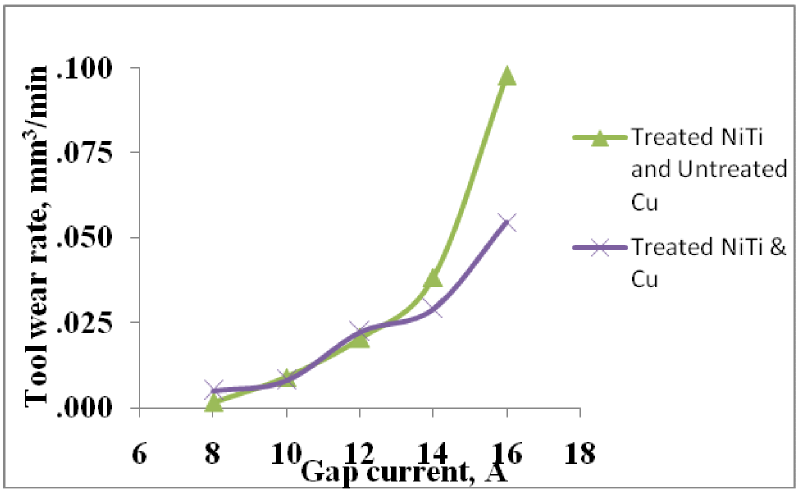

Figure 4 TWR versus gap current

Increase in gap current raises the TWR. This happens because increased current leads to increase spark energy which result in increased TWR. It is noted form figure that TWR is less in case of treated NiTi and treated copper electrode as compared with the treated NiTi and copper.

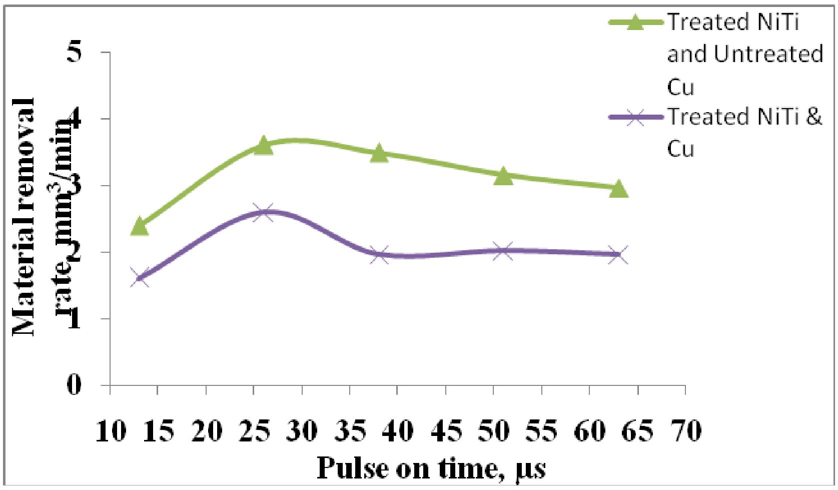

Figure 5 MRR versus pulse on time

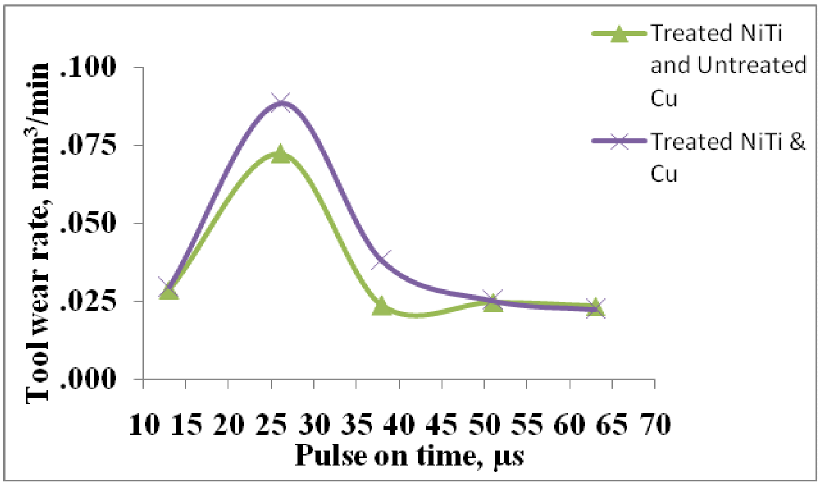

Figure 6 TWR versus pulse on time

Figure 5 and figure 6 shows the variation of MRR and TWR with regards to the pulse on time. It is noted from the experimentation that increases in pulse on duration increase the MRR as well as TWR. This happens because spark energy is function of pulse on time, as increase in pulse on time leads to increase spark energy which results in increased surface temperature of material and consequently the MRR and TWR. It is also observed that when cryo-treated workpiece is machined with the treated copper electrode then MRR is improved as compared to the cryo-treated NiTi and copper. It is also significantly noted that TWR rises with regards to pulse on time and TWR is more in case of cryo-treated NiTi and copper. It is also significantly noted that after 25 µs both MRR and TWR declines this happens because increased pulse on results in dispersion of energy hence there is fall in MRR and TWR.

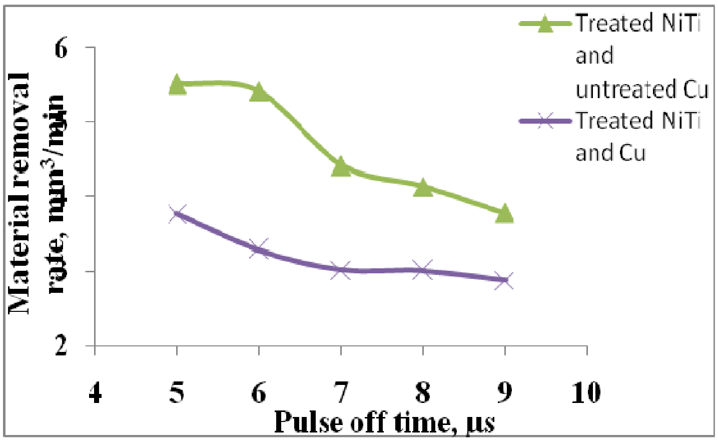

Figure 7 MRR versus pulse off time

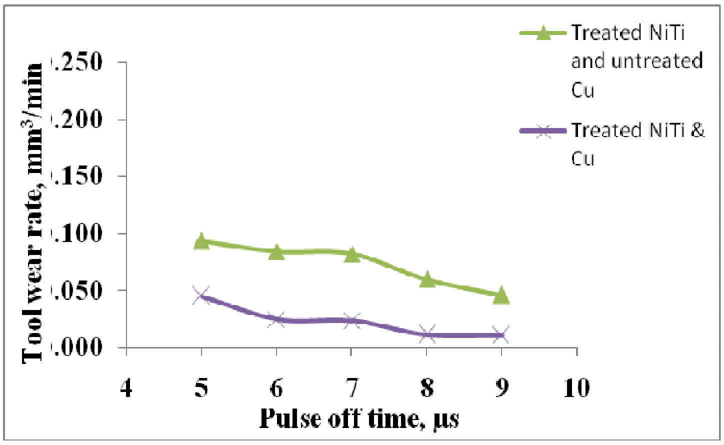

Figure 8 TWR versus pulse off time

Figure 7 and figure 8 shows the variation of MRR and TWR with regards to pulse off time respectively. It is observed from the experiment that as pulse off time increases the MRR and TWR both start declining. It is noted that MRR in case of cryo-treated NiTi and untreated copper is more as compared to cryo-treated NiTi and cooper. It is also noted that TWR in case of cryo-treated NiTi and cooper is less. The reason behind decreasing of MRR and TWR with regards to the pulse off time is increased pulse off causes the cooling of the surface of workpiece which results in reduced MRR and TWR.

CONCLUSION

In the present study meso-scale square holes were produced on the NiTi workpiece to measure the performance parameter of EDM viz. MRR and TWR. From this study it is concluded that MRR and TWR both increases with the respect to pulse on time and gap current but declines with respect to the pulse off time. It is also noted that cryogenic treatment of workpiece improves the MRR of NiTi alloy. It is also noted that MRR and TWR shows declining trend after 25 µs.

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