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Effect of Pulse on / Pulse off on Machining of Steel Using Cryogenic Treated Copper Electrode

Harpreet singh[1], Amandeep singh[2]
[1]Department of Mechanical Engg. YCOE Talwandi Sabbo
[2]Department of Mechanical Engg. FCET Ferozshah, Ferozepur

Abstract:-Electrical discharge machining (EDM) process, at present is still an experience process, wherein selected parameters are often far from the optimum, and at the same time selecting optimization parameters is costly and time consuming. In this paper cryogenic treatment is used for increasing the material removal rate and lowering the tool wear rate. cryogenic treatment is a process of keeping the specimen in cold environment to increase its wear resistance and relieving its residual stresses. In the present paper study conduct on MRR and TWR by using cryogenic and non cryogenic electrode with pulse on/off as parameter.

Keywords:- cryogenic, Current, EDM, Pulse, Wear.

I. INTRODUCTION

Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage in the manufacture of mould, die, automotive, aerospace and surgical components [1]. The exact mechanism of metal erosion during sparking is still debatable. This technique has been developed in the late 1940s [2] where the process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid [3]. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric [4]. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece [5]. EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses, chatter and vibration problems during machining [1]. Materials of any hardness can be cut as long as the material can conduct electricity [6]. Yu et al. have studied the tool wear during the 3D micro ultrasonic machining. They showed that the tool shape remain unchanged and the tool wear has been compensated by applying the uniform wear method developed for micro EDM and its integration with CAD/CAM to micro ultrasonic vibration process for generating accurate three-dimensional (3D) micro cavities[7]. In 1991 Kunieda et al. has revealed a new method to improve EDM efficiency by supplying oxygen gas into gap. They found that the stock removal rate is increased due to the enlarged volume of discharged crater and more frequent occurrence of discharge[8].The following figure1 is showing the systematically process how the material is removed by sparking.

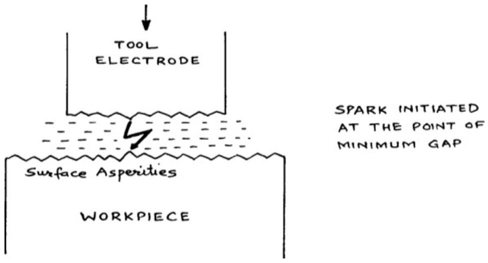

Fig.1: Material removal process in EDM

Then in 1997 Kunieda et al. discovered a 3D shape can be machined very precisely using a special NC tool path which can supply a uniform high-velocity air flow over the working gap and MRR is improved as the concentration of oxygen in air is increased[9]. The mechanism for minute tool electrode wear in dry EDM was studied by Yoshida and Kunieda. The tool electrode wear is almost negligible for any pulse duration because the attached molten work piece material protects the tool electrode surface against wear. From observation of the cross-section of the tool electrode surface, it was found that the tool electrode wore by the depth of only 2 mm during the early stage of successive pulse discharges since the initial surface of the tool electrode was not covered with the steel layer[10]. Jeswani revealed that the addition of about 4 g/l of fine graphite powder in kerosene increases MRR by 60% and tool wear by 15%[11]. Yan and Chen describes the effect of dielectric mixed with electrically conductive powder such as Al powder on the gap distance, surface roughness, material removal rate, relative electrode wear ratio, and voltage waveform. It is shown that the dielectric with suspended electrically conductive powder can enlarge the gap distance and can improve the energy dispersion, surface roughness, and material removal rate[12]. Machining efficiency and surface roughness of rough PMEDM in rough machining was studied by Zhao et al. using Al with 40 g/l and 10 mm granularity and they discovered that machining efficiency was improved from 2.06 to 3.4mm3/min with an increasing rate of 70%. The machining efficiency can be highly increased by selecting proper discharge parameter (increasing peak current and reducing pulse width) with better surface finish in comparison with conventional EDM machining [13]. Tzeng and Lee indicated that the greatest MRR is produced by chromium and 70–80 nm of grain size[14]. Kansal et al. established optimum process conditions for PMEDM in the rough machining phase using the Taguchi method with graphite powder and found out that addition of an appropriate amount of the graphite powder into the dielectric fluid caused discernible improvement in MRR and reduction in tool wear as well as in surface roughness[15].

II. EDM PROCESS PARAMETERS

2.1 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 [16]. 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. With longer pulse duration, more work piece material will be melted away. The resulting crater will be broader and deeper than a crater produced by a shorter pulse duration. These large craters will create a rougher surface finish. Extended pulse duration also allow more heat to sink into the work piece and spread, which means the recast layer will be larger and the heat affected zone will be deeper. However, excessive pulse duration can be counter-productive. When the optimum pulse duration for each electrode—work material combination is exceeded, material removal rate starts to decrease. A long duration can also put the electrode into a no-wear situation. Once that point is reached, increasing the duration further causes the electrode to grow from plating build-up. The cycle is completed when sufficient pulse interval is allowed before the start of the next cycle. Pulse interval will affect the speed and stability of the cut. In theory, the shorter the interval, the faster will be the machining operation. But if the interval is too short, the ejected work piece material will not be swept away by the flow of the dielectric and the fluid will not be deionized. This will cause the next spark to be unstable. Unstable conditions cause erratic cycling and retraction of the advancing servo. This slows down cutting more than long, stable off-times. At the same time, pulse interval must be greater than the deionization time to prevent continued sparking at one point[17]. Modern power supplies allow independent setting of pulse on-times and off-times. Typical ranges are from2 to 1000_s. In ideal conditions, each pulse creates a spark. However, it has been observed practically that many pulses fail if duration and interval are not properly set, causing a loss of the machining efficiency. Such pulses are known as "open pulses".

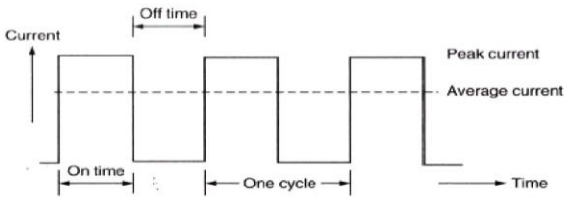

Fig.2: Typical EDM pulse current train for controlled pulse generator [18, 19]

2.2 PEAK CURRENT

This is the amount of power used in discharge machining, measured in units of amperage, and is the most important machining parameter in EDM. During each on-time pulse, the current increases until it reaches a preset level, which is expressed as the peak current. In both die-sinking and wire-EDM applications, 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. New improved electrode materials, especially graphite, can work on high currents without much damage[1].

III. COLD AND CRYOGENIC TREATMENTS

Cryogenics is a branch of low-temperature physics concerned with the effects of very low temperatures less than about 123°K (-150°C) and it extends down to absolute zero -273°C (-459°F). Historically, the development of cryogenic science occurred primarily in the years from 1900 to 1950 with liquefaction technology for cryogens. Applications of cryogenics in industry vary from space research to food handling. The effects of cryogenic. temperatures on properties of materials have been examined extensively in terms of mechanical, thermal and electrical properties. It is reported for several engineering materials that mechanical properties such as the yield strength, tensile strength, fatigue strength, impact strength, hardness and elastic modulus increase as the temperature decrease [20]. Another study reports that the thermal conductivity decreases as the temperature is lowered for certain alloys such as titanium alloy-TC4 and impure metals such as magnesium-AZ31B [21]. Positive effects of low temperatures on mechanical, thermal and electric properties of materials has lead to the cold/sub-zero and cryogenic treatments of wide variety of cutting tools and mechanic parts in manufacturing and automotive industry to increase their strength, hardness and wear resistance and thus substantial savings were recorded. As the name suggests, cold treatment or sub-zero treatment involves temperatures below zero but higher temperatures than the cryogenic temperatures (down to about -80 ºC). Cryogenic treatment can be characterized by its application temperature, below 123°K or at about liquid nitrogen (LN2) temperature (-196ºC). Figure 1: A typical cryogenic treatment cycle [22] In the beginning, cryogenic treatment was tried by immersing of tools into liquid nitrogen; however, it resulted in damaging of tools by thermal shocks. So, more effective and controlled techniques including programmable temperature controllers, a solenoid valve to control liquid nitrogen flow and a thermocouple to monitor the work temperature were used [23]. Generally, cold and cryogenic treatment processes are operated in three main stages, as seen in Figure 1, including slow cooling stage (the cool-down cycle/period) in which the parts are cooled from ambient temperature to cold/cryogenic temperatures during a time period (degrees per hour or minute), soaking stage in which the parts are maintained at cold/cryogenic temperatures for a given duration (hour) and tempering/warming stage (warm-up cycle/period) in which the parts are heated from cold/cryogenic temperatures to tempering temperatures during another time period (degrees per hour or minute). Characteristics of these stages depend on the desired properties, time-cost and the shape and size of the parts .to be treated [24]

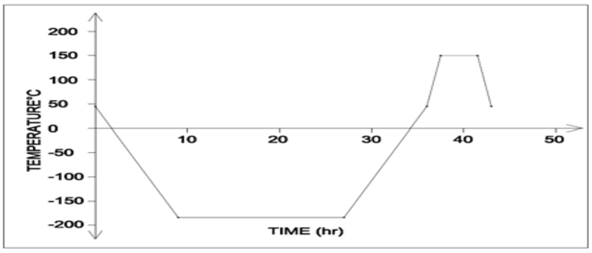

Fig.3: A typical cryogenic treatment cycle [22].

IV. EXPERIMENTAL DETAIL

Machining was performed on the electronics CNC EDM machine available at central tool room, Ludhiana. Machining test was carried out for 20 min at two different pulse on/off setting. The mass lost was measured after every 20 min. The mass lost from the electrode and work material laws weighed using a digital weighing scale and recorded. Machining procedures were repeated for copper and cryogenic treated copper electrodes with diameter of 16 mm.The following tables shows the design of experiment in two levels

Level 1, the following settings (as shown in Table no1) are used for conducting the machining test

S.no	Current	Supply voltage	Electrode	Pulse/on time	Machining time(min)
1	4	110	Copper	50	20
2	4	110	Cryo treated copper	50	20
3	4	110	Copper	100	20
4	4	110	Cryo treated copper	100	20

Level 2, the following settings (as shown in Table no2) are used for conducting the machining test

s.no	Current	Supply voltage	Electrode	Pulse/off time	Machining time(min)
1	4	110	Copper	15	20
2	4	110	Cryo treated copper	15	20
3	4	110	copper	20	20
4	4	110	Cryo treated copper	20	20

The Table 3 is showing the properties of dielectric used

Name- kerosene oil
Surface tension(N/m)- 0.028
Density(Kg/m^3)- 820
Dynamic viscosity(N/m^2-S)- 2400

The **Table** 4 is showing the chemical composition of electrode used

Name- copper
Cu-99.8%
Zn- 0.05%
Al- 0.15%
Bi- 0.0011%
Thermal conductivity(W/mK)- 380.7
Melting point(°C)- 1083

Table 5 is showing the chemical composition of work piece used

Name-	Aisi D3 die steel
C-	1.88%
Si-	0.5%
Mn-	0.38%
Cr -	11.5%
Cu-	0.16%

V. OBSERVATIONS AND DISCUSSION

5.1 INFLUENCE OF PULSE-ON TIME ON TWR

The Fig. 4 shows that with increase in pulse-on time from 50-100µs, the tool wear rate decreases. This may be due to reason that at high value of pulse on time, high heat energy is generated at the electrode and work piece interface. Due to high heat energy the volume of the molten material at tool work piece interface increases, which require proper flushing but as the value of pulse off time is too short so proper flushing does not take place which result in decrease in TWR[25]

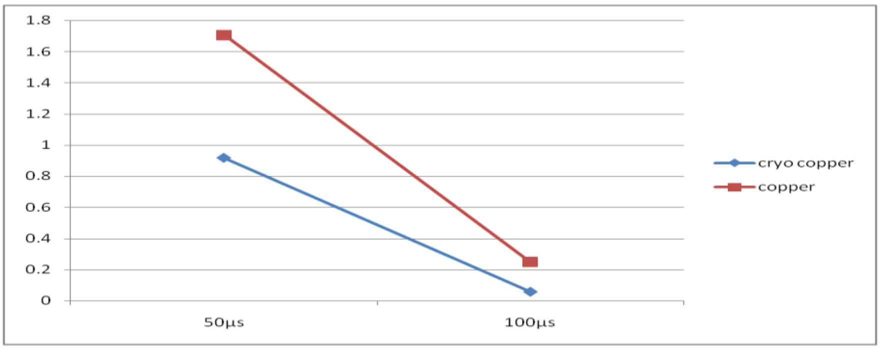

Fig.4: Shows the percent of mass loss of electrode with two different pulse on time at current of 4A

5.2 Influence of pulse-off time on TWR

The influence of the pulse off time on the TWR is shown in the Fig. 5. The results show that with increase in the pulse off time the TWR increases. This may be reason that for very short pulse-off time (15µs) the probability of arcing is high because the dielectric in the gap may not have completely recovered its dielectric strength and also debris particles may still remain in the discharge gap, which lead to lower TWR.

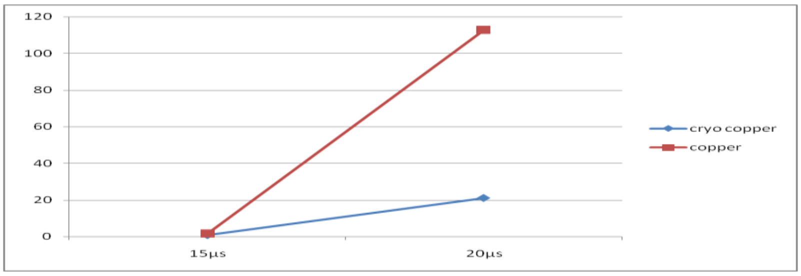

Fig.5: Shows the percent of mass loss of electrode with two different pulse off time at current of 4A

5.3Influence of pulse-on time on MRR

The Fig.6 shows that maximum MRR is obtained by using a copper electrode for value of pulse on =50µs. With the increase in pulse on-time from 50 -100 µs, the MRR decreased in case of cryogenic treated and non cryogenic treated copper electrode. This may be due to reason that with high pulse on time i.e. 100µs more material gets melted at the tool work piece interface, which require proper flushing time but as the value of pulse off time is too shot (15µs), so there is not enough time for the flushing to clear the debris from the inter-electrode gap between the tool and work piece, so arcing take place which result in decreasing the MRR [26]

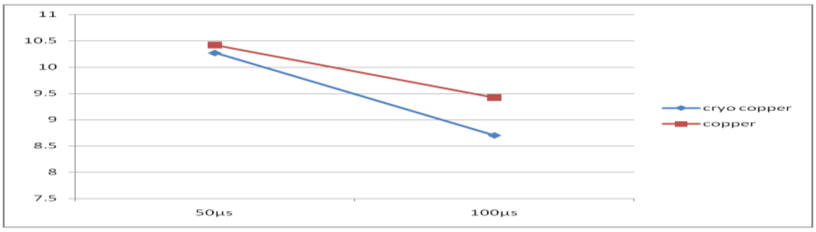

Fig.6: Shows the percent of mass loss of workpiece using two different electrode with pulse on as variable at current of 4A

5.4 Influence of pulse-off time on MRR

Experiments shows that with the increase in pulse off time from 15µs to 20µs the MRR increased for both electrodes used

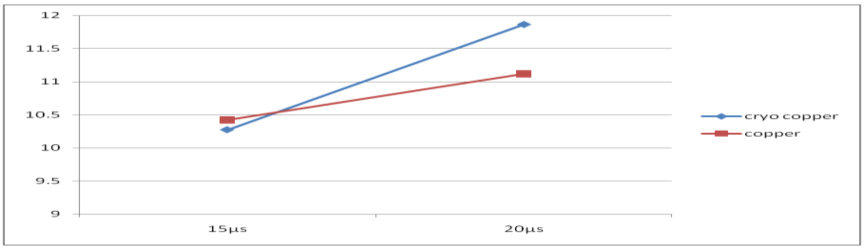

Fig.7: Shows the percent of mass loss of work piece using two different electrode with pulse off as variable at current of 4A

VI. CONCLUSION

- With increase in pulse on time tool wear rate is decreased in both electrode cryogenic treated and non cryogenic copper electrode.
- Tool wear rate is increased with increase in pulse off time.
- Material removal rate is decreased with increased in pulse on time from 50 µs to 100µs.
- Material removal rate is increased with increased in pulse off time from 15 µs to 20µs.
- Tool wear rate is very less in cryogenic treated copper electrode as compared to non cryogenic treated electrode.

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