Effect of Difference Electrode Materials in Electrical Discharge Machining of Tungsten Carbide – A Review

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Abstract- **EDM process has become one of the most important and widely accepted production technologies in manufacturing. The principle of Electrical Discharge Machining (EDM) also called electro discharge spark erosion machining, is based on the erosion of metals by sparks discharges. Tungsten Carbide is an important tool and die material mainly because of its high hardness, strength, wear resistance and high melting point. Due to its high hardness and strength tungsten carbide is difficult to machining by conventional machining process. EDM has proved specially valuable in the machining of super-tough, complex-shaped materials.**

Index Terms- **EDM, performance electrode, tungsten carbide, MRR, EWR.**

1. INTRODUCTION

Electrical discharge machining, commonly known as EDM, is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece.This machining process is continually finding applications in the metal machining industry. It is being used extensively in the plastics industry to produce cavities of almost any shape in the metal moulds. Although, the application of EDM is limited to the machining of electri- cally conductive workpiece materials, the process has the capability of cutting these materials regardless of their hardness or toughness.

Tungsten carbide (WC-Co) is an important tool and die material mainly because of its high hardness, strength and wear resistance. The melting point of tungsten carbide is 2,860°C. Due to its properties, it cannot be processed easily by conventional machining technique.So EDM process will open up an opportunity for the machining of tungsten carbide [9].

The first EDM application was carried out by Mr. and Mrs. Lazarenko in the Technical Institute of Moscow during the Second World War [1]. The first of the two important improvements, also carried out by these Soviet scientists, which make it feasible to elevate this electrical technique to the category of manufacturing process was the RC relaxation circuit (Fig. 1), which provided the first consistent depend-able control of pulse times. The second innovation consisted of adding a simple servo control circuit in order to find and hold a given gap automatically.

industrial marketing mainly in the USA. Some of the causes that eased a much more widespread use of the EDM process were the vacuum tubes, its combination with the basic RC relaxation circuit and finally, the development of the transistor.These solid state devices were able to pro-vide high currents and a really much faster switch on and off than the previous vacuum tubes [7].

Therefore, EDM is the technique used in industry for high-precision machining of all types of conductive materi-als such as metals, metallic alloys, graphite, ceramics, etc., of any hardness.

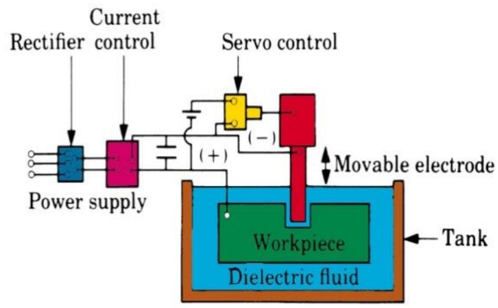
1.1 Principle of EDM

In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system. Both tool and work piece are submerged in a dielectric fluid Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases [3]. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed temperature is reached and at such high pressure and temperature that some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal.Material removal occurs due to instant vaporization of the material as well as due to melting.

2. MATERIALS AND METHOD

2.1 Workpiece material

The workpiece material is tungsten carbide material, having the properties shown in Table 1.This material has wide range of applications due to their high hardness [10].



Process Capability

EDM has numerous applications such as production of die cavities for large automotive body components (die sinking machining centres) deeps small dia. holes with tungsten wire as electrode, narrow slots in parts, turbine blade and various intricate shapes .

Advantages

- MRR is very high as compared to other unconventional machining .
- Surface finish is very good.
- Complex cavities can also be cut by this process

Disadvantages

- Only good conductors material can be machined with this process
- Tool wear limit the accuracy
- Tool wear rate is very high

2.2 Electrode material

The electrode materials investigated in this research were copper, graphite and brass,their properties being shown in Table 2.

Table 1: Physical properties of tungsten carbide

Properties	Tungsten carbide (WC)
Melting point	2,860°C
Density	15.7 g cm^{-3}
Thermal expansion	5×10^{-6}°C
Hardness	87.4 (HRA)
Elastic modulus	648 GPa

Table 2: Physical properties of materials electrode

Properties	Cu	Graphite	Brass
Melting point (°C)	1085	3350	940
Density (g cm^{-3})	8.9	1.81	8.60

1.Brass:

Brass was one of the first EDM electrode materials.It is in expensive and easy tomachine. Today, however, brass is seldom used as an electrode material in modern EDMs, due to its high wear rate . Incertain applications or in older machines with RC power supplies for which wear is not a primary concern, brass still has limited use , since it exhibits a higher degree of stiffness and is easier to machine than copper. Brass, however , is one of the most commonly used materials for High Speed Small Hole Machines.

2. Copper:

Copper has properties, such as its high electrical conductivity, tensile strength, ductility, creep (deformation) resistance, corrosion resistance, low thermal expansion, high thermal conductivity, solder ability, and ease of installation. Copper is a chemical element with symbol Cu and atomic number. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable.

3. Graphite:

It is flexible but not elastic, has a high thermal andelectrical conductivity, and is highly refractory and chemically inert. Graphite has a low adsorption of X-rays and neutrons making it a particularly useful material in nuclear applications. The unusual combination of properties is due its crystal structure.

3. LITERATURE SURVEY

I. Puertas , C.J. Luis, L. Álvarez

Analysis of the influence of EDM parameters on surface quality, MRR and EW of WC–Co.

There are a large number of design factors to be consid- ered within the EDM process, but in this work we have only considered the level of the generator intensity (I), pulse time (t_i) and duty cycle (η). surface roughness parameter selected as response variable, defined in accordance with UNE-EN-ISO 4287: 1999, was the arithmetic average roughness of the roughness profile, that is to say, the R_a parameter.When carrying out the roughness measurements over the ceramic sheets, a phase corrected 2CR filter for the ru- gosimeter, along with a length of measurement or evaluation of 6.4 mm (8 mm 0.8 mm), were selected. The values of the surface roughness parameter for each

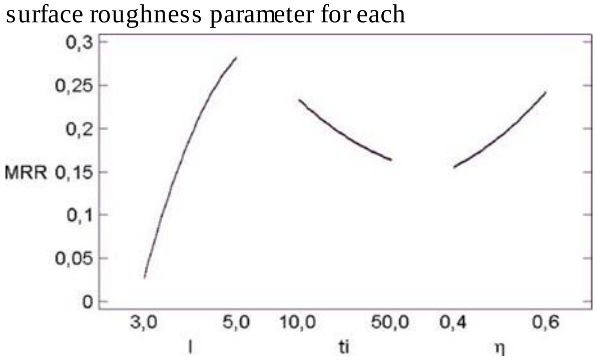


Fig. Graph of the main effects of MRR

experiment were obtained from the arithmetic mean of the values of the mea- surements taken following three parallel directions and in an equidistant distribution over the total area subjected to the EDM process.

In addition to surface roughness, other very important response variables which are of interest when studying EDM processes, are material removal rate (MRR) and electrode wear.

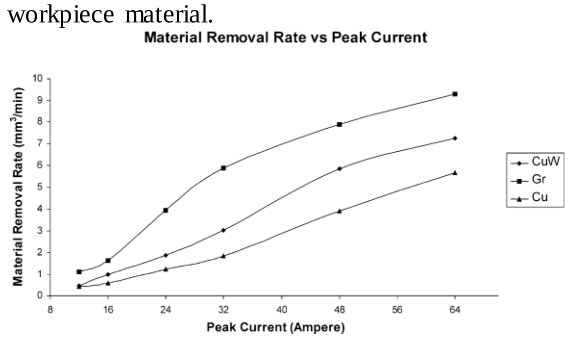
- The technique of design of factorial experiments, combined with techniques of multiple linear regression, can be successfully applied to modelling the functions which depend on various variables. This has been carried out in an efficient way, as a great number of experiments have not been necessay.
- In the case of the R_a parameter the most influential factors were intensity, followed by the pulse time factor, while the duty cycle factor was not significant at the considered confidence level. When either intensity or pulse time were increased, the roughness value also increased. Furthermore, a significant interaction effect was observed between the intensity and pulse time factors.
- To obtain a good surface finish in the case of tungsten carbide, low values should be used for both intensity and pulse time. Another way of obtaining low roughness values, although higher than in the previous cases, is to combine the use of high values of intensity and low values of pulse time, within the considered work interval.
- Intensity factor was the most influential, followed by its own pure quadratic effect and the interaction effect of intensityand pulse time. In order to be able to obtain low values of electrode wear, values of the intensity factor close to its central value (that is to say, I 4) or slightly higher should be used along with low values for pulse time, within the considered work interval.

2. S.H. Lee, X.P. Li

Study of the effect of machining parameters on the machining characteristics in electrical discharge machining of tungsten carbide.

- Effect of type of electrode material

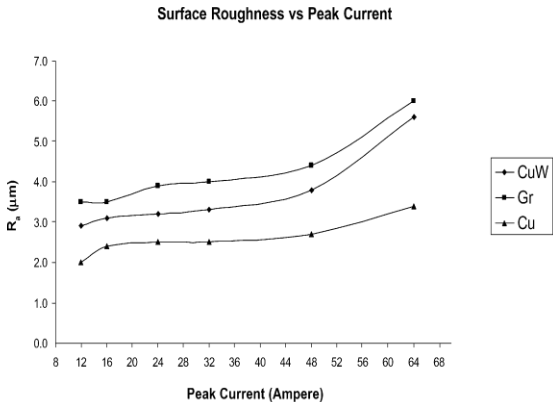
The effect of type of electrode materials on EDM characteristics , respectively, for varying peak currents at a voltage of 80 V, pulse duration of 23 µs, pulse interval of 200 µs, dielectric flushing pressure of 30 kPa, and copper (Cu), graphite (Gr) and copper tungsten (CuW) as the tool electrode materials with negative polarity, and tungsten carbide as the workpiece material.



- Effect Of Peak Current

The effect of peak current on the workpiece material removal rate for copper, graphite and copper tung- sten material. The trend shows that as the peak current increases, the material removal rate also increases. The relationship is almost directly proportional for all the three workpiece materials. The graphite electrode gives the high- est material removal rate followed by copper tungsten and then copper.

The effect of peak current on the relative wear ratio



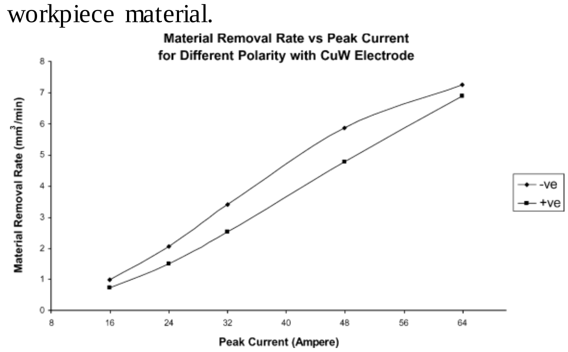
for copper, graphite and copper tungsten material is illustrated.The result shows that in EDM with copper tungsten electrode, the relative wear ratio is maintained at a level below 21% for the whole range of current settings under investigation (between 12 and 64 A). It is the least among the three electrode materials. The relative wear ratio pro- duced by using copper tool increases from about 44% at 12 A to about 140% at 32 A and thereafter remains almost constant up to 64 A. The graphite electrode takes a some- what middle position as compared to copper and copper tungsten. It produces relative wear ratios of roughly between 60 and 100%. The minimum relative wear ratio of 60% occurs from about 32 to 48 A.

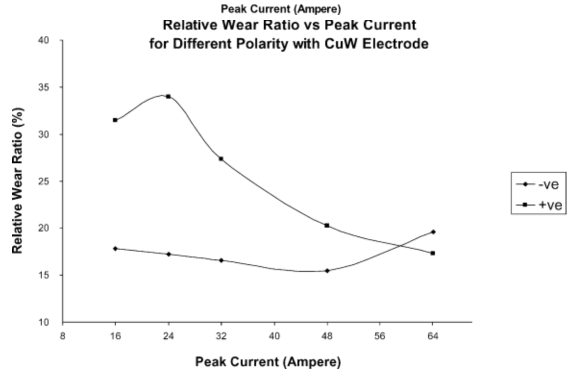
For all of the three electrode materials, it seems that the trend of the relative wear ratio graph remains relatively constant after about 32 A. It is interesting to note that the graph of copper shows a trend opposite to that displayed by graphite and copper tungsten. This abnormality of the shape of the graph of copper could be due to the electrode polarity used in this experiment. Copper is normally used as positive electrode polarity, but in this experiment it is used as negative polarity for standardisation and comparison purpose.

The prime requirements of any electrode material are that it must be electrically conductive and maintain a good tool- to-workpiece wear ratio (relative wear ratio). In principle, the materials best suited have a very high melting point and a very low resistance to electricity. Electrode tool materials perform with varying degrees of success on different work- piece materials.

- Effect of electrode polarity

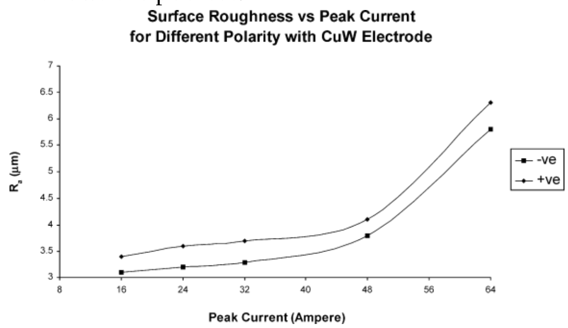
In EDM, the choice of electrode polarity is an important factor. The effect of polarity on the material removal rate, relative wear ratio and surface roughness is illustrated respectively, for varying peak currents at a voltageof 80 V, a pulse duration of 23 µs, a pulse interval of 200 µs, a dielectric flushing pressure of 30 kPa, a copper tungsten (CuW) as the tool electrode materials with both negative and positive polarity, and tungsten carbide as the workpiece material.



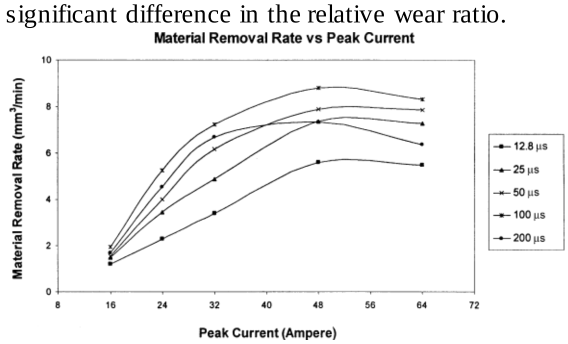


1. For all electrode materials, the material removal rate increases with increasing peak current. Graphite elec- trodes give the highest material removal rate, followed by copper tungsten and then copper. At the low range of peak current, the relative wear ratio decreases with the peak current for graphite electrodes, but increase with the peak current for copper electrodes. At the range of high peak current, copper electrodes have the highest relative wear ratio. Copper tungsten exhibits the lowest relative wear ratio at all ranges of peak current. For all the three electrode materials, the machined workpiece surface roughness increases with increasing peak current. Copper exhibits the best performance with regard to surface finish,

followed by copper tungsten, while graphite shows the poorest.



2. With the electrode as cathode and the workpiece as anode in EDM of tungsten carbide, better machining performance can be obtained. The negative tool polarity gives higher material removal rate, lower relative wear ratio and better surface roughness. The negative tool polarity produces a fairly constant relative wear ratio over a wide range of peak current, whereas the positive polarity gives a decreasing trend over a range of low peak current. However, at high current settings, negative or positive polarity make no significant difference in the relative wear ratio.

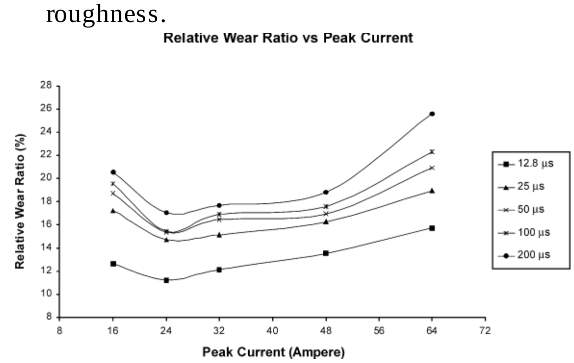


3. The material removal rate generally decreases with the increase of open-circuit voltage, whereas the relative wear ratio and machined workpiece surface roughness increase with the increase of open-circuit voltage.

4. For the effect of the peak current, it is observed that for all values of pulse duration, the material removal rate increases with the increase of the peak current in the range of low current settings, and becomes constant when machining at higher values of peak current. The relative wear ratio first decreases slightly with the peak current and then increases with further increase of the peak current. There is an optimum peak current, at which the relative wear ratio is minimum for all settings of pulse duration. The surface roughness of the work- piece increases steadily with increasing peak current.

5. There is a maximum material removal rate with pulse duration at all current settings. The relative wear ratio increases with increase in pulse duration for all peak current settings. The increase is very pronounced at low pulse duration. The machined workpiece surface rough- ness increases steadily with increasing pulse duration.

6. The material removal rate decreases when the pulse interval is increased. Both the relative wear ratio and the surface roughness have minimum values when varying the pulse interval, the minimum values occurring at the same value of pulse interval.
7. The material removal rate decreases gradually with the flushing pressure, and becomes constant at high values of flushing pressure. The relative wear ratio decreases with the flushing pressure at low flushing pressure and increases with the flushing pressure at high flushing pressure. There is an optimal flushing pressure for the relative wear ratio, which gives the minimum relative wear ratio. There is also an optimal flushing pressure for the machined workpiece surface roughness.



3. P. Janmanee and A. Muttamara

Performance of Difference Electrode Materials in Electrical DischargeMachining of Tungsten Carbide.

- Effect Of Process Parameters

1. Effect of duty factor (off time):

Duty factor with variation of off-time, show that the lower duty factor have a higher material removal rate too and when they are compared with values of on-time condition can be represented that their material removal rate have a higher value significantly. Negative polarity graphite electrode has the most MRR 11%.

2. Effect of open circuit voltage:

Variation of on-time and off-time condition show that negative polarity and graphite electrode are appropriate parameters to sparking carbide tungsten material. variation of open circuit voltage, MRR and electrode wear rate have insignificantly different values, graphite electrode has a maximum MRR and maximum electrode wear rate.

3. Effect of discharge current:

An increased current have influence to increasing of MRR, graphite electrode has the most MRR.An increased current have influence to deceasing of electrode wear rate.

- The duty factor value decreased give the less material removal rate and the effectiveness of the process is evaluated of MRR increases with the discharge current intensity
- The graphite electrode gives the most material removal rate and gives the better than surface roughness but it gives high electrode wear ratio.
- The results show that the electrode negative polarity performs very well, Poco EDM-3 gives significantly higher Material Removal Rate (MRR) and lower surface micro-crack density than the Poco EDM-C3 and copper-tungsten
- The material powder electrode (EDM-3 and EDMC3) give the better MRR and less micro-cracks than solid electrode.

The results show optimum of all electrodes same parameters with negative polarity, open-circuit voltage of 90 V, current is 25 A, on time is 25 μ sec and off time is 200 μ sec.

4. CONCLUSION

Tungsten Carbide is an important tool and die material because of its high hardness, strength, wear resistance and high melting point. Due to its properties it cannot be processed easily by conventional machine technique. So, EDM process with different electrode material like copper, brass and graphite open up an opportunity for the machining of tungsten carbide.

REFERENCES

[1] Lee, S.H. and X.P. Li, 2001. Study of the effect of machining parameters on the machining characteristics in electrical discharge machining of tungsten carbide. J. Mater. Process. Technol., 115: 344-358. DOI: 10.1016/S0924-0136(01)00992-X.

[2] V.S.R. Murti, P.K. Philip, A comparative analysis of machining char-acteristics in ultrasonic assisted EDM by the response surface method-ology, Int. J. Prod. Res. 25 (2) (1987) 259–272.

[3] J.H. Zhang, T.C. Lee, W.S. Lau, Study on the electro-discharge ma- chining of a hot pressed aluminum oxide based ceramic, J. Mater. Process. Technol. 63 (1997) 908–912.

[4] Puertas, I., C.J. Luis and L. Alvarez, 2004. Analysis of the influence of EDM parameters on surface quality, MRR and EW of WC-Co. J. Mater. Process. Technol., 153: 1026-1032. DOI: 10.1016/j.jmatprotec.2004.04.346

[5] Sajjad Amirkhanlou, Mostafa Ketabchi, Nader Parvin, Shohreh Khorsand, Fernando Carreno, Effect of processing cycles on aluminum/tungsten carbide composites prepared by continual annealing and press bonding process, IOP Conf. Series: Mater. Sci. Eng. 63 (2014) 1–4.

[6] Lee, S.H. and X.P. Li, 2003. Study of the surface integrity of the machined workpiece in the EDM of tungsten carbide. J. Mater. Process. Technol., 139: 315-321. DOI: 10.1016/S0924-0136(03)00547-8

[7] I. Puertas, C.J. Luis, A study on the machining parameters optimisation of electrical discharge machining, in: J.M. Torralba (Ed.), Proceedings of the International Conference on Advanced Materials and Processing Technologies (AMPT), Leganés, Spain, 2001, pp. 1173–1180.

[8] W.S. Lau, M. Wang, W.B. Lee, Electrical discharge machining of carbon fibre composite materials, Int. J. Mach. Tools Manuf. 30 (2) (1990) 297–308.

[9] P. Janmanee and A. Muttamara, Performance of Difference Electrode Materials in Electrical DischargeMachining of Tungsten Carbide.

[10] K.Revikumar and V.S. Sreebalaji "characterization of mechanical properties of aluminium /TC composites."

[11] U.P. Singh, P.P. Miller, W. Urquhart, The influence of electrical- discharge machining parameters on machining characteristics, in: Proceedings of the 23th International Machine

Tool Design and Research Conference, 1983, pp. 337–343.
[12] W.S. Lau, T.M. Yue, T.C. Lee, W.B. Lee, Unconventional machining of composite materials, J. Mater. Process. Technol. 48 (1993) 199–203.
[13] T.T. Chin, T.S. Leong, Optimisation of EDM Machining Condition, Academic Exercises, National University of Singapore, Singapore, 1983.
[14] N.S. Ricci, W.R. Blumenthal, H.A. Skeele, Electrical Discharge Machinability of Ceramics, Vol. 34, American Society of Mechanical Engineers, New York, 1988, pp. 281–296.
[15] EDM Technical Manual, Poco Graphite Inc..1993.