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Parametric Study and Optimization Along With Selection of Optimal Solution in Die Sinking Electrical Discharge Machining of Tungsten Carbide with Taguchi Hybrid Approach: A Review

[1] Aman Deep [2] Mr. Raj Kumar

[1][2]School of Civil and Mechanical Engineering, Shoolini University, Solan, 173212, India

Abstract: **Electrical discharge machining (EDM) is a process for shaping hard metals and forming deep and complex-shaped holes by arc erosion in all kinds of electro-conductive materials. The objective of this research is to study the influence of operating parameters of EDM of tungsten carbide on the machining characteristics. The effectiveness of the EDM process with tungsten carbide is evaluated in terms of the material removal rate, the relative wear ratio and the surface finish quality of the work piece produced. It is observed that copper tungsten is most suitable for use as the tool electrode in EDM of tungsten carbide. Better machining performance is obtained generally with the electrode as the cathode and the work piece as the anode. Tools with negative polarity give higher material removal rate, lower tool wear and better surface finish. High open-circuit voltage is necessary for tungsten carbide due to its high melting point and high hardness value. Dielectric using pressure is found to be optimal at 50 kPa. High material removal rate, low relative wear ratio and good surface finish are convicting goals, which cannot be achieved simultaneously with a particular combination of control settings. To achieve the best machining results, the goals have to be taken separately in different phases of work with different emphasis. In rough EDM of tungsten carbide, material removal rate is of primary importance. Thus, the higher the discharge current, the faster is the machining time. Material removal rate and the surface rough ness of the work piece are directly proportional to the discharge current intensity. When approaching the finishing stage, an optimum control setting is required for attaining the best surface finish and precision machining. For precision machining of tungsten carbide, the optimum condition of relative wear ratio and surface roughness takes place at a gap voltage of 120 V, discharge current of 24 A, pulse duration of 12.8 ms, pulse interval of 100 ms, dielectric ¯using pressure of 50 kPa and copper tungsten (CuW) as the tool electrode materials with negative polarity. This study confirm that there exists an optimum condition for precision machining of tungsten carbide although the condition may vary with the composition of the material, the accuracy of the machine and other external factors.**

Keywords— **Electrical discharge machining; Tungsten carbide; EDM parameters; Material removal rate; Surface roughness; Machining characteristics.**

I. INTRODUCTION

Electrical discharge machining (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 work piece. There are no physical cutting forces between the tool and the work piece. It has been recognized especially valuable in the machining of super-tough, electrically conductive materials such as the new space-age alloys (Shayan et al., 2013; Zhong et al., 2016). These metals would have been difficult to machine by conventional methods, but EDM has made it relatively simple to machine intricate shapes that would be impossible to produce with conventional cutting tools. This machining process is continually finding further applications in the metal machining industry. It is being used extensively in the plastic industry to produce cavities of almost any shape in metal molds. Although the application of EDM is limited to the machining of electrically conductive work piece materials, the process has the capability of cutting these materials regardless of their hardness or toughness (Kumar and Batra, 2011).

Tungsten carbide is an important tool and die material mostly because of its high hardness, strength and wear resistance over a wide range of temperature. It has high specific strength and cannot be processed easily by conventional machining techniques. EDM has shown to be a versatile method for machining difficult-to-work materials it is believed that the EDM process will open up an opportunity for the machining parameter on the machining characteristics in EDM of tungsten carbide (Zhao et al., 2016; Vikas et al., 2014).

During the EDM process, both the work piece and the tool undergo surface modification. Many researchers (Nakamoto et al., 2012; Nath et al., 2008; Lin et al., 2007) have looked at the modification of a steel work piece, but few have examined the modification of a tungsten carbide work piece. EDM material removal is caused by violent expulsion of the super-heated electrode melts from the melt cavities at the end of the machine pulse. In the present study, EDM experiments have been conducted to investigate the machined work piece surface integrity, including the microstructures, surface topography, micro-cracks, composition and hardness, under a wide range of machining conditions (Lee and Xiaoping, 2003 Lin and Chang, 2009)

Electrical discharge machining (EDM), otherwise known as thermal erosion process, is one of the non-conventional machining processes, where tool and workpiece do not come into contact with each other during the machining process. The progression of events constituting the process of material erosion from the work surfaces by an electrical discharge machining can be explained in the following way. If an appropriate voltage is developed across the tool electrode (normally cathode) and the workpiece (normally anode), the breakdown of dielectric medium between them happens due to the growth of a strong electrostatic field (Martineau et al., 2003 Nath et al., 2009). Owing to the electric field, electrons are emitted from the cathode toward the anode on the electrode surfaces having the shortest distance between them. These electrons impinge on the dielectric molecules of the insulating medium, breaking these dielectric fluid mole- clues into positive ions and electrons. These secondary electrons travel along on the same ionization path. This event causes an increase in the electric field strength across the work surfaces and liberates a large number of electrons. It creates an ionized column in the shortest spark gap between the tool electrode and the work piece, thereby decreasing the resistance of the fluid column and causing an electrical discharge in the shortest distance point between the tool and the work piece (Polini, 2006 Muthuramalingam and Mohan, 2014)
The enormous thermal energy melts and vaporizes the material from the work piece, which creates a small crater over the work surface. There happened a collapse of the ionized column with the termination of the electrical energy by means of the switching circuit and then surrounding dielectric fluid occupies its place. The melted debris is removed by the flushing process. The conduction of dielectric medium can be determined by the current, duration and pulse energy (Lee and Li, 1997;Das et at., 2014; Lin, 2005).

III. EDM PROCESS

The EDM system consists of electrode and work piece, which are electrically conductive and immersed in dielectric fluid. It is a controlled metal removal process in which the metal is removed by means of electric spark erosion. In this method an electrical spark is used as a cutting tool to disintegrate the work piece and create a desired shape. Once a voltage is supplied to the tool the suspended particles in the dielectric fluid concentrate between the electrode and work piece due to the magnetic field and generating a bridge for a current to flow to the work piece. Then the electrical intensive arc is produced, creating sufficient heat to melt a part of work piece and some of the tooling material. The high concentration of electrons and ions among the tool and work piece make a plasma channel. The large amount of electrons will flow from tool to job and ions from job to tool due to the less electrical resistance of plasma channel as shown in (Figure 1.1). At a temperature of about (10,000 ºC – 12000 ºC) the material removal occurs due the melting of work piece (Patel NK).

IV. DIELECTRIC FLUID

The mineral oils, kerosene or de-ionized water is used as dielectric fluid and act as a flushing medium to carry away the debris in the gap. Dielectric fluid provides a cooling medium. The work piece is placed within the tank containing dielectric fluid. Dielectric medium is spread around the spark zone and supplied through tool to get high removal of molten metal. The dielectric fluid provides an oxygen free machining environment.
The volume of material removal rate (MRR) per discharge is ranges from 10-6 to 10-4mm3. The surface roughness (SR) and material removal rate increases with increase in current density and decreasing the sparks frequency. The capacitor discharge is reoccurred with a range of 50-500 kHz, with voltage between 50 to 380 V and current ranges from 0.1-500 A.

IV.ELECTRODES

Electrodes used in electrical discharge machining (EDM) are made of graphite, brass, copper, Tellurium copper (99% Cu and 0.5% tellurium) and copper tungsten alloy. The electrodes having 0.1mm diameter are used for operation. Tool wear is an essential factor because it

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affects the accuracy and shape produced. It can be reduced by reversing polarity and using copper tool.

V. CLASSIFICATION OF EDM

There are two types of EDM:

A. Die-sinking EDM
B. Wire-cut EDM

A. Die–sinking EDM

In the Sinker EDM Machining process, two metal parts submerged in an insulating liquidate connected to a source of current which is switched on and off automatically depending on the parameters set on the controller. When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together to within a fraction of an inch, the electrical tension is discharged and a spark jumps across. Where it strikes, the metal is heated up so much that it melts. Sinker EDM, also called cavity type EDM or volume EDM consists of an electrode and work piece submerged in an insulating liquid such as, more typically, oil or, less frequently, other dielectric fluids. The electrode and work piece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the work piece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps.
These sparks usually strike one at a time because it is very unlikely that different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur simultaneously in all such locations. These sparks happen in huge numbers at seemingly random locations between the electrode and the work piece. As the base metal is eroded, and the spark gap subsequently increased, the electrode is lowered automatically by the machine so that the process can continue uninterrupted. Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters.

B. Wire–cut EDM

The wire cutting EDM is generally used for the manufacturing of two or three dimensional complex shapes with electro thermal mechanism for eroding material. De-ionized water is used as a dielectric fluid. Any material used for machining should be electrically conductive. The electrode is mainly made of brass or copper having a diameter of 0.5-0.25 mm and the movement speed of wire is 3 m/min (Patel NK). The material is removed when a spark is generated between electrode wire and work piece. A fully CNC machine set up is used to perform the operation.
Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. If the energy/power per pulse is relatively low (as in finishing operations), little change in the mechanical properties of a material is expected due to these low residual stresses, although material that hasn't been stress- relieved can distort in the machining process. Due to the inherent properties of the process, wire EDM can easily machine complex parts and precision components out of hard conductive materials.

VI. LITERATURE REVIEW

(Kumar and Batra, 2010) evaluates the surface modification of three die steel material by EDM. In this study work on tungsten is selected due to important alloying element and its three levels of machining parameter such as; peak current (Ip), pulse on time (Pon) and pulse off time (Poff). In this investigation they obtained low peak current, pulse off time, negative polarity of tool, minimum pulse off time and optimal machining condition of material transfer was achieved by EDM. With the optimal machining conditions considerable amount of MRR take place from the work material. At high temperatures of plasma channel the powder particles postponed in dielectric fluid can combined with the carbon and increased the percentage of carbon content in the presence of tungsten carbide on machined surface.
(Shabgard and Najafabadi, 2014)examined the synthesis of nano-structured tungsten carbide(wc) powder using electrical discharge between graphite and tungsten electrode in medium of deionized water and kerosene with various parameter Viz. structure , phases, morphological properties and size distribution of particles. Author found that the tungsten and graphite electrode produced the nano-structured tungsten carbide powder in medium of kerosene and deionized dielectrics fluids. At negative polarity large amount of powder is produced than the positive polarity of the dielectrics and the size of particles in kerosene dielectrics is small as compared with the particles of deionized water.

(Shayan et al., 2013) work on the parametric study of dry wire EDM (WEDM) process of cemented tungsten carbide. This experiment presented the effect of control parameter i.e. pulse on time, pulse off time, gap set voltage, discharge current and wire tension on response parameters like cutting velocity(CV) surface roughness (SR) and oversize (OS) using air as dielectric to improve its environmentally friendly performance during the machining of cemented tungsten carbide (WC-Co).

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Author found that the surface analysis of CV, SR and OS can inferred the variation of response which was similar to result of preliminary experiment using the mathematical model which analysis of variances (ANOVA) confirmed the adequacy of each model. Moreover the result shows that the BPNN-PSO has superiority in finding optimal solution than mathematical model. The main reasons are accuracy of neural network to finding the desirability function in both case of single and multi-objectives optimization problem. (Shunmugam et al. 1993) investigated the electro discharge machining properties with pulsing relaxation generator, powder compact electrode and reverse polarity in kerosene dielectric fluid. Moreover tungsten carbide powder is used as compact and deposit on work surface of EDM with kerosene dielectric medium. X-ray is used to shows the chemical composition of surface layer. They revealed that at the extreme temperature and pressure conditions WC-coated HSS tools improved 25%-60% wear resistance in metal cutting and 20%-50% reduction in cutting forces respectively. (Singh and Shukla, 2012) studied about the energy distribution in the EDM which effect the material removal rate, and other parameter viz. crater geometry, relative wear ratio and surface roughness. This investigation show that energy transferred to work piece during EDM process is small percentage of total energy, it varies with current and pulse duration from 6.5% to 17.7%, against the 50% energy used in EDM model. The maximum fraction of energy is transferred to the work piece by using the optimum parameter and the values of current and pulse duration. Due to increase in pulse duration at high current of 24A a significant energy distribution takes place on work piece. At a value of high pulse-on time an optimal surface finish of work piece was achieved. (Zhong et al., 2016) investigate that the high wear-resistance of the composite was due to the formation of dense and hard WC particulates that acted as reinforcement phase with parameter of, thermodynamics, phase composition, microstructure, micro hardness, and wear resistance of Fe-W- C ternary system were examined by X-ray diffraction, scanning electron microscopy, Vickery hardness test, and wear test respectably. In this experiment the services life of tungsten carbide tools, the grinding parameter optimization in the cutting edge preparation process, and how to eliminate the tensile stress in the surface layer of the cutting edges after grinding. Author found that the thermodynamically favored product were W2C, WC, and Fe3C according to Fe-W-C thermodynamics calculation. W had a stronger carbide- forming tendency then Fe. W2C and WC were stable carbide with Gibbs free-energies that decrease significantly with increased in temperature. (Zhao et al., 2016) studied about the potential failure cause of tungsten carbide tools with a comprehensive consideration of cutting edges preparation process. The present study focuses on the preparation of tungsten carbide end mills, an experimental study was conducted which includes the microstructure comparative analysis of the material surface layer in the different positions of tungsten carbide end mills, and the grinding effect comparison of tungsten carbide materials between different grinding parameters. The main findings include: (1) The internal micro cracks already exist in surface layer of cutting edge even these tungsten carbide end mills have not been involved in machining process; (2) In the surface layer of tungsten carbide tools, different types and levels of residual stress will be generated by different grinding process parameters. It can provide an important basis for the preventive measures to eliminate the potential factors that affect the service life of the cutting tool in the fabrication stages. (Vikas et al., 2014) deals with the comparison of the MRR for EN19 and EN41 material in die sinking EDM machine. Various parameters are taken like Pulse ON time, Pulse OFF time, Discharge current, Voltage and Taguchi method was performed to find the best combination of inputs toward maximum output. From investigation it was found that the EN41 material and EN19 material had a large impact as compare to other processing parameter on MRR. It was also observed form experimental data for both EN19 and EN41 that the MRR values for input parameter was higher for EN41 than in case of EN19. (Nakamoto et al., 2012) study about the quality of micro- machined surfaces on tungsten carbide generated by PCD micro end –milling. This study described the result of research conducted to reveal the systematic understanding on the surface quality in relation to machining conditions and tool wear behavior when super-micro grain WC is mechanically micro-machined by a small diameter PCD micro end mill.

PCD tool does not affect the quality of machined surface, allowing long WC micromachining cutting lengths to be used while maintaining an excellent surface quality. (Nath et al., 2008) experimental study on ultrasonic elliptical vibration cutting (UEVC) of sintered WC(~15%Co) using polycrystalline diamond (PCD) tools. This experiment carried out to investigate the effect of cutting parameter in the UEVC method in terms of cutting force, flank wear, surface finish while cutting sintered WC. In the UEVC method, the PCD tools used in cutting of sintered WC are able to achieve better result at 4um depth of cut (DOC) as compared to both a lower DOC of 2um and higher DOCs of 6 and 8um. The tests showed that the PCD tools can be applied on the sintered WC using the UEVC method at low feed rate and low cutting speed to produced high quality surface. (Lee and Li, 2003) investigated the EDM experiment have been conducted the machined work piece surface integrity, including the microstructures, surface topography, micro- cracks, composition and hardness. From experiment, it is observed that the depth of the damaged layer and the average length, width and number of micro-cracks increase with the peak current and pulse duration. When peak current and pulse duration were low at that time damaged layer and micro- cracks seem to be disappear. It has been found that there is no significant difference between hardness of the EDM surface and the original hardness of the work piece for cases under all EDM condition.

(Ming-Hong Lin, 2005) studied about the synthesis of nano phase tungsten carbide by EDM. The study purposes an attractive technique for preparing nanocrystalline powders of cubic WC1-x and hexagonal WC by EDM and annealing processes. Powders produced were characterized by XRD, SEM, and TEM. The investigation show that WC1-x transformed to hexagonal W2C phase under N2 atmosphere, then it became nanoparticular hexagonal WC at 1200 . (Lin et al., 2007) work elucidates the effect of electrical discharge energy on surface crack and bending strength of cemented tungsten carbide by EDM. The surface cracks and large discharge craters on the machined surface markedly reduced the bending strength. During experiment the surface roughness increased with peak current and MRR of cemented tungsten carbide increased with the peak current and also bending strength of cemented tungsten carbide decrease as increased in peak current.

A. Discussion on the literature and research gaps

The above literature shows that EDM invent lots of application to get the better surface finish, material removal rate, tool wear rate but very small work is revealed on the use of EDM in case of rough machining phase, tool wear rate and material removal rate for tungsten carbide alloy. Moreover the EDM includes a large amount of machining parameters and that upset the quality of product. Due to their complex nature and large amount of parameters it becomes complicated to state them in a single analytical model. Large amount of experimental work is since required to optimize and analyze the process parameters to know their impact on product quality. Taguchi method is one of the welling techniques, which helps in carrying out the analysis of experiments along with minimum experimental work.

VII. OBJECT OF PRESENT RESEARCH

In view of above, the present investigation will be carried out with following objectives:

1. To study the effect of variant machining parameters i.e. duty cycle, pulse on time, pulse off time and gap voltage, discharge current on response parameters such as MRR, TWR and SF in die sinking EDM process.
2. To investigate the enhancement in the performance of different input parameter on different specimen with tungsten carbide cylindrical tool electrodes.

XI. METHODOLOGY

In this study Taguchi method is used to establish the relationship between some of the process parameter and machining standards. Taguchi designs give an efficient and powerful approach for designing products which work optimally and consistently over a variety of conditions. Dr. Genichi Taguchi is reputed as the first supporter of robust parameter design, which is an engineering system for process design and product that concentrate on minimizing variation and sensitivity to noise. Taguchi projected some method to experimental design which is known as "Taguchi Method". These methods are two, three, four, five and mixed level partial factorial designs. Taguchi point out to experimental design as "off-line quality control" because it is a process of providing better behavior in the design stage of product or process.

XI CONCLUSION

An extensive experimental study has been conducted to investigate the effect of the machining parameters on machining characteristics in EDM of tungsten carbide. The machining parameters are the electrode material, electrode polarity, open-circuit voltage, peak current, pulse-duration, pulse interval and flushing. The machining characteristics are the material removal rate, relative wear ratio and surface roughness.

REFERENCES

1. Chandra Nath, Mustafizur Rahman, Ken Soon Neo. Machinability study of tungsten carbide using PCD tool under ultrasonic elliptical vibration cutting. International Journal of Machine Tool & Manufacture. 2009; 49; 1089- 1095.

2. Gangaram Mandaloi, Subash Singh, Pradeep Kumar, Kaushik Pal. Effect of crystalline of AISI M2 steel using tungsten-thorium electrode through MRR, EWR, and surface finish. Measurement. 2016; 90; 74-84.

3. Harminder Singh, D.K. Shukla. Optimization EDM parameters for tungsten-carbide utilization thermo-mathematical modeling. International Journal of Thermal

Science. 2012; 59; 161-175.

4. Kazuo Nakamoto, Kazutoshi Katahira, Hitoshi Ohmori, Kazuo Yamazaki, Tojiro Aoyama. A study on the quality of micro-machined surface on tungsten carbide generated by PCD micro end-milling. CIRP Annals-Manufacturing Technology. 2012; 61; 567-570.

5. Lisheng Zhong, Xi Zhang, Shili Chen, Yunhua Xu, Hong Wu, Juan Wang. Fe-W-C thermodynamic and in situ preparation of tungsten carbide-reinforced iron-based surface composites by solid-phase diffusion. International Journal of Refractory Metals and Hard Material. 2016; 57; 42-49

6. Ming-Hong Lin. Synthesis of nano phase tungsten carbide by electrical discharge machining. Ceramics International. 2005; 31; 1109-1115.

7. Mohammad Reza Shabgard, Amir Forouzan Najafabadi. The influence of dielectric media on nano-structured tungsten carbide (WC) powder synthesized by electro- discharge process. Advanced Powder Technology. 2014; 25; 937-945.

8. Riccardo Polinio. Chemically vapour deposited diamond coatings tungsten carbide: Substrate pretreatments, adhesion and cutting performance. Thin Solid Films. 2006; 515; 4-13.

9. Rick L. Martineau, Michael B. Prime, Thomas Duffey. Penetration of HSLA-100 steel with tungsten carbide spheres at striking velocities between 0.8 and 2.5 km/s. International Journal of Impact Engineering. 2004; 30; 505- 520.

10. S.H. Lee, X.P. Li. Study of the machining parameters on the machining characteristics electrical discharge machining of tungsten carbide. Journal of Material Processing Technology. 2001; 115; 344-358.

11. Sanjeev Kumar, Uma Batra. Surface modification of die steel material by EDM method using tungsten powder-mixed dielectric. Journal of Manufacturing Process. 2012; 14; 35-40.

12. Soo Hiong Lee, Xiaoping Li. Study of the surface integrity of the machined work piece in the EDM of tungsten carbide. Journal of Material Processing Technology. 2003; 139; 315-321.

13. T. Muthuramalingam, B. Mohan. A review on influence of electrical process parameters in EDM process. 2014; 1644- 9665

14. Vikas, Shashikant, A.K.Roy, Kaushik Kumar. Effect of optimization of machine process parameter on MRR for EN19 &EN41 material using Taguchi. 2nd International Conference on Innovation in Automation and Mechatronics Engineering, ICIAME 2014. 2014; 14; 204-210.

15. Xiuxu Zhao, Wei Ke, Shuanshuan Zhang, Wenhan Zheng. Potential failure cause analysis of tungsten carbide end mills for titanium alloy machining. Engineering Failure Analysis. 2016; 66;321-327

16. Y.C. Lin, K.Y. Chang. Elucidating the microstructure and wear behavior of tungsten carbide multi-pass cladding on AISI steel. Journal of Material Processing Technology. 2010; 210; 219-225.

17. Yan-Cherng Lin, Lih-Ren Hwang, Chao-Hsu Cheng, Pao- Lin Su. Effect of electrical discharge energy on machining performance and bending strength of cemented tungsten carbides. Journal of Material Processing Technology. 2008; 206; 491-499.

