EFFECTS OF WEDM ON THE PERFORMANCE CHARACTERISTICS IN VARIOUS CLASSES OF WORK MATERIAL: A REVIEW

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Abstract

This paper contains introduction to WEDM process along with detailed literature review on the research work reported in the past by various researchers in the field of WEDM. From the review it is evident that, WEDM is widely used to manufacture components with intricate shapes and profiles. It has been commonly used in the automotive, aerospace, mould tool and die making industries. WEDM can machine any complicated profile in electrically conductive materials. Physical and metallurgical properties of the work material, such as strength, hardness, toughness, microstructure, etc. are no barriers to its application. Complicated contours in hard materials can be produced to a high degree of accuracy and surface finish. It eliminates the geometrical changes occurring in the machining of heat-treated steels. Thus wire edm process can pave a way for improvement in existing machining processes.

Keywords: Wire EDM, plasma, surface roughness, Material removal rate, current, pulse

1.0 Introduction to Wire EDM (WEDM)

WEDM is a process which erodes and removes material by using the channel of plasma generated by electric sparks between two conductive materials (i.e. electrode and the work piece), this channel of plasma converted into thermal energy at a temperature range of 8000 to 12000º C at a pulsating direct current supply of 20000 to 30000 Hz. The electrode and work piece are separated by a small gap being immersed in dielectric fluid, an electric spark is produced in between this small gap and the work piece material is eroded, as the pulsating current is turned off, the plasma breaks down which leads to sudden reduction in the temperature and the eroded material is flushed away with the help of dielectric fluid in the form of microscopic debris. With each electric spark discharge a small crater is formed on both the work piece and the electrode which is a prime decider in the final surface quality. The taper can ranging from 15º for a 100 mm thick to 30º for a 400 mm thick work piece can be obtained on the cut surface material. A WEDM schematic is shown in figure 1.2.

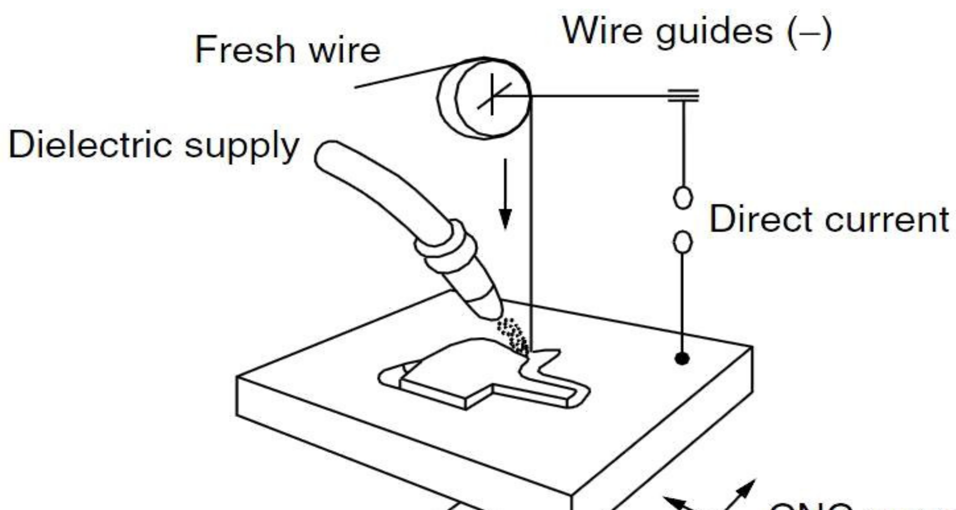

Figure 1.2 WEDM schematic

Deionized water is used as the dielectric as it is the purest form of water and it acts as an insulator. Normal tap water contains minerals which may be too conductive for Wire EDM, in order to control the water conductivity; water is deionized by passing it through a resin tank which eliminates the conductive elements of water. This deionized water is circulated with the help of a pump. As the machining operation is performed, conductivity of water rises and it is again re-circulated through the resin tank. The purpose of deionized water is to stabilize the spark erosion path and to act as the dielectric medium which is forced into the cutting gap to flush out the eroded metal. There is virtually no cutting force on the part of the machine because the wire electrode and work piece never make contact. WEDM process is usually used in conjunction with CNC and will only work when a part is to be cut completely through. The melting temperature of the parts to be machined is an important parameter for this process rather than strength or hardness. The surface quality and material removal rate (MRR) of the machined surface by wire EDM will depend on different machining parameters such as applied peak current, and wire materials. WEDM process is commonly conducted on submerged condition in a tank fully filled with dielectric fluid, nevertheless it also can be conducted in dry condition. This method is used due to temperature stabilization and efficient flushing in cases where the work piece has varying thickness.

2.0 Literature review

Over the years, the WEDM process has remained as a competitive and economical machining option fulfilling the demanding machining requirements imposed by the short product development cycles and the growing cost pressures. However, the risk of wire breakage and bending has undermined the full potential of the process drastically reducing the efficiency and accuracy of the WEDM operation. A significant amount of research has explored the different methodologies of achieving the ultimate WEDM goals of optimizing the numerous process parameters analytically with the total elimination of the wire breakages thereby also improving the overall machining reliability.For better understanding, a detailed literature survey has been carried out by considering the effects of WEDM and µWEDM parameters on the performance characteristics such as MRR, surface roughness, Kerf width etc. in various classes of work material. The detailed literature review is presented below:

2.1 LITERATURE REVIEW: BASED ON WEDM and µWEDM

Dongre et al. [2015] used Wire EDM process for slicing Si ingots to Si wafers. They used Molybdenum wire of diameter 40-120µmDuring the experiments wafers of various heights ranging from 50 to 150 mm were fabricated and capability of the process was assessed in minimizing the kerf width. It was evident that the kerf width reduces from 250µm to 50µm, when sliced by a 40µm diameter wire, which amounts to a reduction in kerf loss by 300. **Bobbili et al. [2015]** developed equations for material removal rate and surface roughness using Buckingham pi theorem with pulse on time pulse off time flushing pressure, input power, thermal diffusivity and latent heat of vaporization as input variables. **Sivaprakasam [2014]** investigates the influence of three different input parameters such as voltage, capacitance and feed rate of micro-wire electrical discharge machining (micro-WEDM) performances of material removal rate (MRR), Kerf width (KW) and surface roughness (SR) using response surface methodology with central composite design (CCD). The experiments are carried out on titanium alloy (Ti-6Al-4V). The machining characteristics are significantly influenced by the electrical and non-electrical parameters in micro-WEDM process. Analysis of variance (ANOVA) was performed to find out the significant influence of each factor. The model developed can use a genetic algorithm (GA) to determine the optimal machining conditions using multi-objective optimization technique. The optimal machining performance of material removal rate, Kerf width and surface roughness are 0.01802 mm^3/min, 101.5 mm and 0.789 mm, respectively, using this optimal machining conditions viz. voltage 100 V, capacitance 10 pf and feed rate 15 mm/s. **Islam et al. [2010]** investigated the WEDM process for its dimensional accuracy. Mild steel 1040 is used as work piece material for the investigations and the wire material used is brass of 0.25 mm diameter. Process parameters for WEDM were varied to have obtained different results. **Kumar et al. [2010]** investigated on WEDM parameters on machining Inconel 800 super alloy. The process parameters considered in this research work were gap voltage, pulse on time, pulse off time and wire feed. Taguchi's 9 Orthogonal Array was used to conduct experiments. Optimal levels of process parameters were identified using Grey Relational Analysis and the relatively significant parameters were determined by Analysis of Variance. The variation of output responses with process parameters was mathematically modeled by using non-linear regression analysis method and the models were checked for their adequacy results. **Rakwal and Bamberg [2009]** performed experiments for machining of Germanium wafers using WEDM process. Molybdenum wire of two different diameters was used as electrode used during the process. The process parameters that have been varied were wire speed, voltage and capacitance, the response parameters that have been observed during the experiments were kerf and etch rates. Surface profiler and Scanning Electron microscopy is used to

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propose surface material characteristics for the wafers. It has been observed by performing experiments that use of thin wires offer advantage in terms of less material wastage. WEDM can slice germanium wafers at a much quicker rate than Wire Saws and WEDM do not create any damage in the form of micro cracks. **Mohammadi et al. [2008]** investigated the effect of various process parameters for Turning WEDM such as power, time-off, voltage, servo, wire tension, wire speed along with rotational speed on surface roughness and roundness. 1.731 cemented steel was chosen as work piece material. Taguchi standard orthogonal array was chosen for the design of experiments and ANOVA was used for determining level of importance of machining parameters on surface roughness and roundness. **Saha et al. [2008]** developed a second order multi-variable regression model and back-propagation neural network (BPNN) model for WEDM process. The process parameters chosen for the experimentation were pulse on-time, pulse off time, peak current, and capacitance with the performance measures namely cutting speed and surface roughness. The effect of input parameters have been studied and correlated with that of results obtained from the above said models. Also SEM analysis has been performed for the same. It has been observed that increase in both peak current and capacitance lead to the increment of cutting speed and surface roughness. **Chiang and Chang [2006]** optimized machining parameters namely cutting radius of work piece, on time of discharging, off time of discharging, arc on time of discharging, arc off time of discharging, servo voltage and wire feed with consideration of multiple performance characteristics such as surface removal rate and maximum surface roughness. **Lin and Lin [2005]** reported the use of an orthogonal array, grey relational generating, grey relational coefficient, grey-fuzzy reasoning grade and analysis of variance to study the performance characteristics of the WEDM machining process. The machining parameters (pulse on time, duty factor and discharge current) with considerations of multiple responses (electrode wear ratio, material removal rate and surface roughness) were effective. The grey-fuzzy logic approach helped to optimize the electrical discharge machining process with multiple process responses. The process responses such as the electrode wear ratio, material removal rate and surface roughness in the electrical discharge machining process could be greatly improved **Huang et al. [1999]** performed WEDM operation on SKD11 alloy steel with Brass wire as electrode (0.25 mm diameter). Influence of various machining parameter such as pulse-on time, pulse-off time, table feed-rate, flushing pressure, distance between wire periphery and work piece surface, and machining history has been observed on the machining performance of WEDM in finish cutting operations.

2.2 LITERATURE REVIEW: BASED ON OPTIMIZATION TECHNIQUES

Julong [1987] tells us how to apply Grey Relational analysis. Applications of Grey system like in agriculture, economy, ecology, medicine, geography etc. He tells us about Grey relational space, Grey modeling, Grey forecasting, Grey generating space and Grey theory. This is first ever research paper published on Grey Relational Analysis. **Saedon et al. [2014]** investigated on the effect and optimization of machining parameters on the kerf (cutting width) and material removal rate (MRR) of titanium alloy (TI-6AL-4V) using wire electrical discharge machining WEDM with a brass wire diameter of 0.5mm. The experimental studies were conducted under varying pulse-off time, peak current, wire feed and wire tension. The settings of machining parameters were determined by using Taguchi experimental design method. The multiple performance characteristics based on the statistical based analysis of variance (ANOVA) and grey relational analysis (GRA) was attempted. **Raguraman et al. [2013]** investigated the optimal set of process parameters such as current, pulse ON and OFF time in Electrical Discharge Machining (EDM) process to identify the variations in three performance characteristics such as rate of material removal, wear rate on tool, and surface roughness value on the work material for machining Mild Steel IS 2026 using copper electrode. **Ranganathan at al. [2012]** envisages multi-response optimization of machining parameters in hot turning of stainless steel (type 316) based on Taguchi technique. The effect of cutting speed, feed rate, depth of cut, and work piece temperature on surface roughness, tool life, and metal removal rate have been optimized by conducting multi-response analysis. From the grey analysis, a grey relational grade is obtained and based on this value an optimum level of cutting parameters has been identified. **Datta and Mahapatra [2010]** derived the quadratic mathematical models to represent the process behavior of wire electrical discharge machining (WEDM) operation. Experiments were conducted taking into account six process parameters: discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate; to be varied at three different levels. Data related to the process responses viz. material removal rate (MRR), surface roughness and kerf were measured for each of the experimental run. Grey relational analysis was adopted to convert this multi-objective criterion into an equivalent single objective function

3.0 Conclusions

This paper contains introduction to WEDM process along with detailed literature review on the research work reported in the past by various researchers in the field of WEDM. From the review it is evident that, WEDM is widely used to manufacture components with intricate shapes and profiles. It has been commonly used in the automotive, aerospace, mould tool and die making industries. Applications can also be found in the field of medical, optical, jewellery and dental parts processing. Owing to high process capability, it is widely used in manufacturing of cam wheels, special gears, bearing cage, various press tools, dies, and similar intricate parts. WEDM can machine any complicated profile in electrically conductive materials. Physical and metallurgical properties of the work material, such as strength, hardness, toughness, microstructure, etc. are no barriers to its application. Complicated contours in hard materials can be produced to a high degree of accuracy and surface finish. It eliminates the geometrical changes occurring in the machining of heat-treated steels. Thus wire edm process can pave a way for improvement in existing machining processes.

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