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RESEARCH ARTICLE

A REVIEW ON EFFECT OF PROCESS PARAMETERS IN WIRE ELECTRICAL DISCHARGE MACHINE

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ABSTRACT

Wire Electrical Discharge Machining is a controlled machining process that produces geometrically complex shapes with high precision and good surface quality that are difficult to machine using conventional machining processes. WEDM is growing today as an important process in several areas; Work has been done to use the technology to make microcomponents. This article provides an overview of the latest work. Some properties and parameters that affect the machining performance of WEDM are also discussed.

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INTRODUCTION

Wire EDM (Electric Discharge Machining) is an electrothermal process in which the material is eroded by a series of sparks between the workpiece and the wire electrode (tool). The part and the cable are immersed in a dielectric liquid (electrically non-conductive), which also acts as a coolant and removes dirt (Kuriakose and Shunmugam, 2004). The movement of the wire is numerically controlled to achieve the desired shape and high precision of the workpiece (Mahapatra and Amar Patnaik, 2006a). Wire EDM is not a new technology in machining. It was introduced in the late 1960s and revolutionized the tool and die, mold, and metallurgy industries. It is probably the most interesting and versatile machine tool that has been developed for this industry in the last fifty years and offers numerous advantages. In this process, there is no contact between the workpiece and the electrode, so materials of any hardness can be cut as long as they can conduct electricity (Kuriakose and Shunmugam, 2004). While the wire does not strike the workpiece, there is no physical pressure on the workpiece and the clamping Although electrical conductivityis an important element in this type of machining, sometechniques can be use to increase the efficiency inmachining of low electrical conductive materials (Kozak *et al*. (2004)). The Spark Theory on a wire EDM isbasically the same as that of the vertical EDM process. Many sparks can be observed at one time. This is because actual discharges can do more than one hundredthousand times per second. The heat of each electricalspark, likely at around 15,000° to 21,000°Fahrenheit. This process is widely used in the aerospace, nuclear and automotive industries to machine precise, complex and irregular shapes in various difficult-to-machine electrically conductive materials (Jain, VK, (2005),CunShanX., (2012), Benedict, GF (1987)). Recently, the WEDM process has also been used to machine a wide variety of miniature and micro-fabricated parts made from metals, alloys, sintered materials, hard metals,ceramics, and silicon (Mukherjee, R., *et al*. (2012)) . These properties makeWEDM a process thatremains a competitive and cost-effective processing option that meets the demanding processing requirements caused by short product development cycles and increasing cost pressures (Ho, K.H. *et al*. (2004), Jameson, E.C. (2001).

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DISCUSSION

Wire EDM Parameters

Pulse on time and Pulse off time: EDM machining must take place (ON time) and stop (OFF time) alternately during machining. During the ON time, voltage is applied to the space between the workpiece and the electrode (wire), while no voltage is applied during the OFF time. As a result, the electrical discharge occurs only for the duration of the ON time. In order to have a long electric discharge duration, it is possible to select a large value for the ON time; however, a short circuit may occur, resulting in a break in the cable. To avoid this inconvenience it is necessary to enter the OFF time as shown in Figure 1.

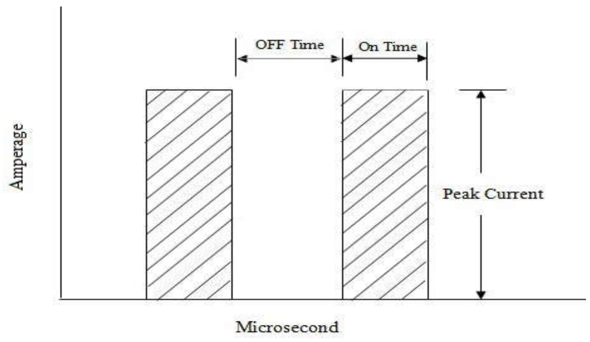

Fig.1. Pulse on time and off time

Peak current and gap voltage: Peak current is basically one of the most important processing parameters in WEDM. It is the power consumed in WEDM and is measured in units of amps. With each ignition pulse, the current increases until it reaches a preset value, which is expressed as the peak current. In both die sinking and wire erosion, the maximum current intensity is determined by the cutting surface. Higher amperages are used in roughing and in cavities or details with large surfaces. The space voltage or open circuit voltage indicates the supply voltage that will be applied to the space. The higher this value, the higher the electrical discharge energy. Nevertheless; these factors are generally not independent. In other words, as the standoff voltage increases, the peak current also increases automatically. On some WEDM machines, both factors indicate the machining voltage.

Servo voltage and Servo feed rate: The Servo Voltage (SV) parameter is used to control how the wire moves back and forth. During machining, the average machining voltage varies between the workpiece and the electrode, depending on the machining state. SV set the reference voltage to control lead advance andretract. When the mean machining stress is higherthan the set voltagelevel, the wire advances, and if it is lower, the wire retracts (more precisely, the worktable moves forward or backward instead of the wire). Therefore, the higher the SV value, the greater the gap between the workpiece and the electrode. Higher SV values also reduce the number of electrical sparks, thus stabilizing the electrical discharge while slowing down the machining speed. If SV is set to a lower value, the middle space becomes narrower, which leads to an increase in the number of electrical sparks. It can speed up the processing speed; however, the machining state in space can become unstable, resulting in wire breakage. Servo feed (SF) also indicates table feed during processing. Usually WEDM machines choose this factor automatically in relation to SV, but this factor can also be set manually. In this case, the machining table has a constant speed regardless of the SV. Both servo voltage and servo feed speed can affect feed speed, as shown in Figure 2.

Dielectric flow rate: An electric shock can occur in the air; however, it is not stable and cannot be used for rough machining. To obtain a stable electrical discharge, dielectric fluid is required.

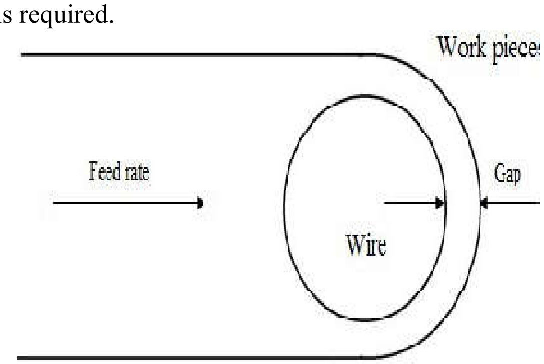

Fig. 2. Feed rate and gap size (Roger Kern, 2008)

Within the dielectric, electrical discharge machining can be stabilized by efficient cooling and chip evacuation. Deionized water is commonly used as a dielectric in wire EDM due to its environmental properties. Due to the low thermal conductivity of titanium alloys, for example, a high wash pressure is absolutely necessary for rough machining, otherwise the short-circuit phenomenon leads to cable breakage. Figure 3 shows the cut line when machining a titanium alloy (Ti6Al4V) at normal discharge pressure. This figure shows that the cut line cannot be more than 1mm without high overpressure.

Fig. 3. Wire broken and small cutting line in Titanium machining due to low flushing pressure

Wire speed or wire feed: Wire speed is another important parameter in WEDM that indicates the wire speed in WEDM. If the wire speed increases the wire consumption and consequently the machining costs increase, while a low wire speed at a high cutting speed can lead to wire breakage.

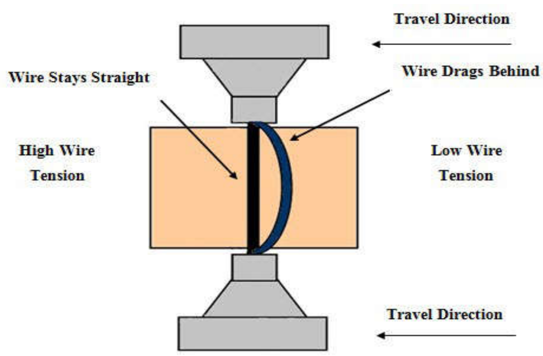

Fig.4. Relation between wire drag and wiretension

Wire tension: Wire tension is the factor that can control wire tension in WEDM. If the cable tension is high enough, the cable will stay straight; otherwise the cable will drag as shown in Figure 4.

Wire Type: When wire EDM was first introduced, the main problem was the material of the wire, as this material was supposed to have many properties. The most important physical properties of EDM cables include: Conductivity. High conductivity is important because it means, in theory at least, that the wire can carry more current, which corresponds to a "hotter" spark and faster cutting speed. Tensile strength, which is the ability of the wire to withstand the tension of the wire placed on the wire during cutting to make a vertically straight cut. Elongation, which describes how much the wire "buckles" or plastically deforms just before breaking. Melting point, we would prefer our wire electrode to be somewhat resistant to melting too quickly from electrical sparks. Straightness - This can help keep the cable straight. Wash ability, the better the wash ability, the faster the cable will be cut and the likelihood of cable breakage will be reduced. Cleaning, the wire can be “dirty” due to contamination from metal dust residues from the drawing process, drawing lubricant or paraffin that some manufacturers add to the wire before they are wound. (Roger Kern, 2007).

Different wire materials

Copper: It was the original material that was first used in wire EDM. Although its conductivity index is excellent, its low tensile strength, high melting point, and low vapor pressure index severely limit its potential. Today, practical use is limited to older machines with copper wire power supplies.

Brass: Was it the first logical alternative to copper when early EDMs were looking for better performance? Brass erosion wire is a combination of copper and zinc that is generally alloyed in the range of 63-65% Cu and 35-37% Zn. The addition of zinc ensures significantly higher tensile strength, a lower melting point and a higher vapor pressure, which more than compensates for the relative loss of conductivity. Brass quickly became the most widely used electrode material for universal wire erosion. It is currently commercially available in a variety of tensile strengths and hardnesses.

Coated Wires: Since brass wire with a higher concentration of zinc cannot be manufactured efficiently, the next logical step was to develop coated wire, sometimes referred to as coated or "layered" wire. They typically have a brass or copper core for higherconductivity and tensile strength and are galvanized with a layer of pure or diffuse zinc to improve spark and discharge properties. Originally called "Speedwire" because it can cut with significantly higher metal removal rates, coated wires are now available in a variety of core materials, coating materials, coating depths, and tensile strengths to meet different applications and machine requirements. Although more expensive than brass, coated wires are currently the optimal choice for superior performance in all respectsAntar, M. T., *et al*. (2011) presented work piece productivity and integrity in WED Ming nickel-based super alloys and titanium alloys, and found that a productivity increase of approximately 40% was possible for nickel-based super alloys and approximately 70% for titanium alloys replacing the uncoated standard. Cu-core coated brass wires, diffusion annealed under the same operating parameters. Regarding the thickness of the encapsulation layer, better results were obtained with the coated wire for both roughing and roughing. In fact, coated wire machining produced new castings approximately 25% thinner for nickel-based super alloys and approximately 40% thinner for titanium alloys. In another study by Poro and Zaborski (2009) they found that an increase in discharge time can significantly influence the cutting speed and the material removal rate by 62% for brass wire electrodes and 138% for wire. made of galvanized brass. Therefore, according to various investigations, the cutting speed of galvanized wire is almost twice that of brass wire, since the outer zinc layer of the electrode has a lower melting temperature than the core material (brass). Therefore, in the presence of an impulse, the zinc overheats and vaporizes. Evaporation acts as a heat sink, reducing the temperature of the wire and improving the effectiveness of the WEDM process. As a result, the cutting speed increases by up to 50% if stronger heat fluxes are enabled (Prohaszka *et al*., 1997). In addition, evaporation of the coating increases the size of the gap and results in better dirt removal, which can reduce surface roughness and spark gap (Dauw and Albert, 1992). However, the higher cutting speed of galvanized wire also worsens spark gap and surface roughness. Composite wires are an advance over galvanized wire as the preferred wire for work pieces. Composite wires have a single carbon steel core surrounded by a layer of pure copper and coated on the outside with zinc-enriched brass. However, for tall workpieces, copper clad steel wires work best. (Kapoor, J., *et al*., 2010). Furthermore,Kruth, J.P.*et al*. (2004) found that composite wires with a high tensile strength core can significantly increase precision, especially when cutting corners. In terms of breaking strength, diffusion annealedwires have significant improvement over plainwires.

Fine Wires: Typically, wire diameters will be in the 0.006-0.012 inch range. High precision work on wire EDM machines requiring small inside radii and wire diameters in the 0.001-0.004 inch range. Since brass and coated wires are impractical in these sizes due to their low load capacity, molybdenum and tungsten wires are used. However, due to limited conductivity, high melting points, and low vapor pressures, they are not suitable for very thick jobs and tend to cut slowly. So far only a few scientists’ works have been dealing with cutting by WEDM Use of wires with a diameter less than 50 µm. The materials of the wires are tungsten with high tensile strength and melting temperature and steel wire with brass coating. Typical ultra-thin wire diameters are 20, 25, 30, and 50 µm. These cablescan be used to fabricate micro parts with wire EDM (Klocke, F. *et al*. (2004)).

Different process responses

Material removal rate and cutting speed: Much research has attempted to maximize the material removal rate and cutting speed through various approaches. Because these factors can help significantly increase the bottom line of WEDM. Almost both factors (removal rate and cutting speed) determine the same phenomenon, that is, the machining rate.

MRR value normally obtained by the following equation: MRR = (W W) / (T × p) (mm3 / sec) (1) b a m Rajurkar and Wang (1993) analyzed cable break phenomena with a thermal model and experimental investigations. The material removal rate with WEDM was found to initially increase with decreasing pulse off time. However, if the pulse deactivation time is very short, the gap becomes unstable, which leads to a reduction in machining speed. Singh and Garg (2009) presented the effects of the process parameters on the material removal rate in WEDM, and it was found that as the pulse activation time and maximum current increase, the material removal rate also increased. increases, but with increasing pulse frequency. -off time and servo voltage, MRR decreases. These results agree with those of PoHuaiYu *et al*. (2011). Poros and Zaborski. (2009) investigate the effects of wire and workpiece material on WEDM efficiency. It has been found that a higher value of thermal conduction and the specific heat capacity of the processed material cause the decrease in the efficiency of WEDM. Furthermore, they found that thermal conductivity and specific heat were the most important factors in the workpiece that can determine the MRR and the volume of the heat affected zone. In another work (Mahapatra S. S. and Amar Patnaik, 2006a) an attempt was made to determine the important processing parameters for performance measures such as MRR, surface quality and cut width in the WEDM process. Factors such as discharge current, pulse duration, and dielectric flux rate and their interactions have been found to play an important role in roughing operations to maximize MRR. Shah, A. *et al*. (2011), examined the influence of the thickness of the workpiece on the material removal rate, this factor was expected to be a significant factor, while according to this study the thickness of the workpiece is not a significant factor for the material removal rate. Konda *et al*. (1999) classified the various potential factors influencing WEDM performance measures into five main categories. Where W and W are weights of the workpiece material before quantities, that is, the different properties of the workpiece material or after processing (g). T is machining time (s) and dielectric, machine properties, adjustable machine, and ð is the material density of the workpiece.

The cutting speed is also calculated by dividing the cutting length by the corresponding cutting time. According to theory, increasing the peak current can increase the energy of each discharge, creating wider and deeper craters that result in a higher rate of material removal. Also, increasing the pulse timecan lengthen the material removalrate. Lots of Research confirms these theories asTosun, N. *et al*. (2004) presented a study on the optimization and influence of machining parameters on cutting and MRR. In this thesis, the importance of the machining parameters in the MRR was determined by ANOVA. Open circuit voltage and pulse duration were found to be the most effective parameters, while cable speed and dielectric discharge pressure were the least effective factors. According to this research, the open circuit voltage to control the MRR was about six times more important than the secondary factor (pulse duration). Component geometry and parameters. They also applied the Design of Experiments (DOE) technique to study and optimize the possible effects of the variables during the design and development of the process, and validated the experimental results using a signal-to-noise (S / N) relationship analysis method. There are other important studies that deal with the material removal rate, such as (Kozak, J. etal. (1994), Spedding, T.A. and Wang, Z.Q. (1997a), Kuang-Yuan Kung & Ko-Ta Chiang (2008), Parashar *et al*. (2012))

Surface Roughness: Many investigations have attempted to minimize surface roughness using various approaches. According to the theory, surface roughness, which is significantly influenced by pulse activation time and peak current, and cutting speed and surface roughness, have an inverse relationship. Based on Sarkar *et al*. (2008) investigated the decrease in surface roughness with increasing cutting speed. According to various research results, the time pulse is the most important factor influencing surface roughness. As the pulse activation time increases, the surface roughness increases due to the "double spark". In other words, double sparks and localized sparks become more common as the pulse duration increases. Double sparks produce a poor quality surface. These results agree with those of Sarkar *et al*. (2005); Kanlayasiri and Boonmung (2007a and b) and Kumar *et al*. (2012). Sarkar (2005) confirms that the time pulse is the most important parameter influencing surface roughness, followed by the maximum current for zinc-coated wire. Kanlayasiri and Boonmung (2007a and b) found that the pulse in time and the maximum current have a significant impact on the surface roughness and, as these variables increase, the surface roughness increases. Kumar *et al*. (2012) also confirm that a longer pulse duration and a larger current peak lead to a double spark, which increases the surface roughness value. Tosun *et al*. (2003) examined the effects of shear parameters on the size of erosion craters (diameter and depth) in the wire electrode. Examination of wire electrode craters is critical to understanding wire breakage, groove size, and workpiece surface roughness. Larger craters in the wire increase the risk of wire breakage and also lead to poor surface quality and machining precision of the workpiece. Increasing the duration of the pulse, the open circuit voltage, and the speed of the wire have been found to increase the size of the crater, while increasing the dielectric purge pressure decreases the size of the crater. Rao, P., S. *et al*. (2011) described their efforts to optimize surface roughness and found that parameters such as maximum current and pulse time are the most important. Cable tension and servo tension are important and pulse idle time; Discharge pressure and screen speed are less important factors affecting surface roughness. This result is in agreement with Vamsi *et al*. (2010) and Kumar, *et al*., (2012) research.

Hasçalýk, A. and Çaydas, U., (2004) examine the effects of different surface roughness parameters. The surface roughness was found to increase as pulse duration and open circuit voltage increased. It seems that the surface roughness depends mainly on these parameters, without the pressure of the dielectric fluid and the speed of the wire having a great influence. Mahapatra and Patnaik (2006b) examined the effects of six factors including discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flux rate on surface roughness. and the material removal rate, and it was found that factors such as discharge current, pulse duration, dielectric flux rate and their interactions play an important role in surface roughness and material removal rate. Tosun *et al*. (2004) investigated the influence of pulse duration, open circuit voltage, wire speed, and dielectric discharge pressure on the surface roughness of the WED Medworkpiece. Increasing pulse duration, open circuit voltage, and wire speed have been found to increase with surface roughness, while increasing dielectric fluid pressure decreases surface roughness. There are other important studies that deal with surface roughness such as (Spedding, T.A. andWang, Z.Q.(1997b) ,Liao Y.S. *et al*. (2004), Yan, M.T. and Lai, Y. P. (2007), Han,F., *et al*. (2007a and b)Bamberga , E. and Rakwal, D.,(2008), Choi,K. *et al*.

(2008), Aspinwall, D.K. *et al*. (2008), Nishikawa, M.and Kunieda, M.(2009))

Kerf width and Sparking Gap: Kerf width and spark gap investigate the same phenomenon as in Figure 5 and are the measure of material loss during machining. You can determine the dimensional accuracy of the finished part and the radius of the inside corner of the product in WEDM operations is also limited by this factor (Parashar et.al, 2010).

Following equation normally use to determine the Sparkinggap value:

Sparking gap (mm) = (average of kerf width-diameter ofwire)/2 (2)

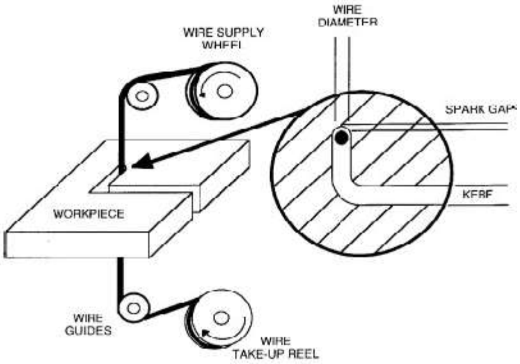

Fig. 5. Details of Sparking Gap(Scott, 1991)

There have been some reports of conflicts over pulse off time, peak current, and dielectric bleed pressure due to their impact on cut width. Parashar et.al (2010) examine the effects of WEDM parameters on cutting width when machining stainless steel. Pulse on time and dielectric wash pressure have been found to be the most important factors, while standoff voltage, pulse off time, and wire feed are the most important and least significant factors in the cutting width. Tosun, N. *et al*. (2004) presented an investigation on the importance of the machining parameters in the cutting width using ANOVA. Open circuit voltage and pulse duration were found to be the most effective parameters, while cable speed and dielectric discharge pressure were the least effective factors. According to this study, open circuit voltage was about three times more important in controlling cut-off width than the second ranking list. factor (pulse duration). Swain, *et al.* (2012) also studied the kerf width and it was foundthat just gap voltage is the significant factor that affectkerf width and pulse on time and pulse off time are insignificant.

Wire Wear Ratio: Some research has attempted to minimize the cable wear ratio using various approaches. Because this factor can help to considerably reduce the phenomena of yarn breakage.

Wire wears ratio (WWR) value normally obtained bythefollowing equation

WWR= WWL/IWW (3)

Where WWL is the weight loss of the wire after machining and IWW is the initial weight of the wire.Tosun and Cogun, C., (2003) examined the effects of various parameters of wire EDM on the wire wear ratio and it was found experimentally that increasing pulse duration and open circuit voltage increase WWR, while that the increase in wire speed and the pressure of the dielectric fluid decrease it. Also, high WWR was found to be everything. In the case of orthogonal corners, the solution to this problem is quite simple and straightforward, which is a transverse method, but things get tricky when it comes to cutting along a curve. (Sinha, p. K., (2010)) Puri, A.B. and Bhattacharyya, B. (2003) investigated the influence of various WEDM parameters on wire drag during rough cutting and trim cutting. It was found that pulse in time, pulse out of time and peak current pulse when grinding; and the peak pulse voltage, cable tension, servo spark gap set voltage during clipping are the essential factors. There are other important studies that address the inaccuracy of WEDM such as (Hsue, W. J. (1999), Yan, M.T. y Huang, P.H. (2004), Han, F. *et al.* (2007) y Zhang, X. Y. *et al*. (2012))

Surface Integrity: To improve the surface integrity of the WEDM process, factors such as surface roughness, white coat thickness, and surface cracking must be considered. High-quality surface roughness can be accompanied by a high MRR and a high R-value. This regret, fatigue resistance, corrosion and wear resistance of the results are in agreement with other research results such as Ramakrishnan, R. and Karunamoorthy, L. (2006).

Dry and Near-Dry Wire Cut: There is a process in wire EDM that is carried out in a gas atmosphere without the use of a dielectric liquid, this process is called DryWEDM. Recently, a new method called NearDryWireCut was introduced in WEDM. In this process, the liquid dielectric fluid is replaced by the minimum amount of liquid with the gas mixture. (Boopathi, S. (2012)) Kunieda and Furudate (2001) conducted studies in dry WEDM. It was found that with dryWEDM the vibration of the wire electrode is minimal due to the negligibly small process reaction force. In addition, a closer gap distance and the absence of corrosion of the workpiece during machining are the additional advantages of dry erosion. These properties can improve the precision and quality of the workpiece surface during finish cutting. The main disadvantages are less material removal compared to conventional WEDM and the likelihood of streaking with this process. The disadvantages can be overcome by increasing the wire winding speed and decreasing the actual depth of cut. These results are in line with other reports. Wang, T. *et al.* (2006 and 2008) Studied the finish with cut with Dry-WEDM and it was found thatdry-WEDM has some advantages, such as better straightness, lower surface roughness and shorter parting length, and the main disadvantage of this process was a lower material removal rate compared to conventional processes. In contrast to this study,Abdulkareem, S., (2011) examined the effects of machining parameters on surface roughness in wet and dry wire EDM machining and found that normal machining was examined in this study (without finishing process). In addition, Wang, T. (2006) investigated high-speed WEDM (HSWEDM) in emulsion gases and liquids and experimental results have shown that WEDM in atmosphere offers a number of advantages, such as better straightness accuracy and higher rate. removal of material. Figure 7 shows (HSWEDM) in gas. There are other important studies that address dry WEDM such as (Furu date C. and Kunieda, M., (2001)), Wang, T., *et al*. (2004), Wang, T., *et al*. (2008), Wang, T., *et al*. (2009), Wang, T., *et al*. (2012) and Lu, Y. *et al*. (2012))

Recent Developments in Wire EDM: In the field of wire erosion technology, enormous research has been carried out in recent years to increase metal removal rate, tool life, surface quality and minimize the time required for metal removal. process, etc.

Fig.7. Photo of dry HS-WEDM (Wang,T.,(2011))

Some of the more recent developments are discussed here. For high speed cutting and high precision machining, a wire electrode must have physical properties such as high conductivity, tensile strength, elongation, etc. An EDM cable breaks when a discharge introduces a fault in the cable. Each spark creates a crater in both the wire and the workpiece. This crater is called a fault in WEDM. If wash conditions deteriorate, the tendency for cable breakage increases. Zinc in the electrode improves performance, but more than 40% zinc causes wire drawing problems. These changes make the cable too brittle. To avoid this difficulty, zinc is added to the surface of the wire, which helps the wire slide through the wire guide. These coated wires offer the highest cutting speeds. The authors found that zinc coatings improved wire electrode speed and performance. The addition of zinc to copper wire has been found to improve wire performance in many ways. The wire gives more energy to the work zone because the zinc present in the wire evaporates during cutting and cools the wire, and some zinc particles help to ionize the space and the cutting process.

Wire EDM with Coated Electrodes: In 1979, researchers discovered that wire electrodes coated with a metal or alloy with a low evaporation temperature were better able to protect the core of the wire from thermal shock. US Patent No. 496886790 discusses the use of a 'wire electrode comprising a wire core with high thermal conductivity, then a layer made of a metal or an alloy with a low boiling point and an outermost layer made of a metal / an alloy with high mechanical strength, ultimately leading to aincrease in machining speed. In recent years, high-performance coated wires with high conductivity and better washability have been developed and used for machining, leading to better surface quality and improved cutting speeds. However, these cables are expensive and cause a lot of dielectric pollution and some environmental hazards as well.

Wire EDM With Multi- Layered Electrodes: Korean patent number 1019850009194 reported on a wire electrode comprising a steel core clad with copper or some other material. A great deal of work has been reported on various patents for multilayer steel core wire electrodes, and most of these multilayer wire electrodes have problems of accuracy and precision with longer tool life. From this it can be concluded that the steel wires are coated to achieve high strength and rigidity. Kruth, et. Alabama. from the University of Katholieke, Belgium, examined and experimentally tested various wire compositions with a high-strength core and various coatings. They have found that when cutting with prototype wires, a significant increase in precision is achieved, especially when cutting corners, while the cutting speed is at a level comparable to commercial reference wire.

Wire EDM with Advance Power Supply: MuTian Yan and YiPeng Lai of Huafan University, Taiwan, have developed a new fine-tuning power supply for WEDM. The supply is transistor controlled and consists of a full bridge circuit, two snubber circuits and a pulse control circuit to provide the anti-electrolysis, high frequency and very low energy pulse control functions. The test results showed that adjusting the capacitance in parallel to the spark gap leads to a shortening of the pulse duration of the discharge current. Experimental results show that the developed fine power supply is very useful in eliminating the bluish and oxidative effects of titanium and also in reducing microcracks in tungsten carbide through electrolysis and oxidation. It is also useful for achieving a fine surface finish on the order of 0.22 µm Ra. D. Model for WEDM mixed in powder with FEM Kansala et. Alabama. (2008) proposed a simple and easily reasonable model for an axially symmetric two-dimensional model for mixed powder discharge machining (PMEDM) using FEM. The model uses many important functions, such as the properties of the temperature sensitive material, the shape and size of the heat source (Gaussian heat flux distribution), the% heat distribution between the tool, the workpiece and dielectric, pulse on / off time, material dispensing efficiency, and phase shift. etc. thermal prediction behavior and material removal mechanism in the PMEDM process. The developed model first calculated the temperature distribution in the workpiece material with ANSYS software and then the material removal rate (MRR) was predictable from the temperature profiles. The influence of various process parameters on the temperature circulation along the radius and depth of the workpiece was investigated. Finally, the validation was carried out by relating the theoretical MRR with the experimental MRR obtained from a anewly designed experimental setup.

New Control System to Improve Machining Accuracy: MuTian Yan and Pin-Hsum Huang introduced a closed-loop wire tension control system for WEDM to improve machining precision. The dynamic performance of the closed-loop cable tension system was investigated using a proportional integration (P.I.) controller and a one-step forward controller. Dynamic dampers have also been used to reduce the vibration of the wire electrode. From a series of experiments, they concluded that this system can achieve a faster transient response and a smaller stationary error than an open control system. They also concluded that corner cutting can reduce geometric contour errors by up to 50%. F. New Guide to Eliminate Wire Bending Defects University of Tokyo

Research Fellows have developed a new guide for wire electrodes. The guide does not cause a locally sharp bend in the cable and the cable passes smoothly through the guide. Therefore, it helps to reduce defects caused by sharp bending of the wire. G. New materials for WEDM electrodesProhaszka *et al*. (1996) suggested the requirements for the materials that can be used as WEDM electrodes and will lead to an improvement in the performance of WEDM. Discussed the material requirements for making WEDM electrodes to improve the performance of WEDM. Tests were carried out to select suitable materials for wire electrodes and the effects of material properties on the machinability of WEDM. He evaluated the influence of the various materials used to make wire electrodes on the machinability of WEDM. A series of experiments were performed on a standard EDM unit. Rods with negative polarity made of pure magnesium, tin and zinc with a diameter of 5.0 mm were used as tool electrodes. The workpiece (anode) was low carbon annealed carbon steel. The operational parameters werekept constant duringall the experiments performed.

Wire Electrodes with Cryogenic Treatment: In the electronics industry, aluminum, brass, copper, tin, and lead show better wear resistance after cryogenic treatment. When processed with cryogenically treated brass wire with three process parameters, namely wire electrode type, pulse width, and wire tension, EN 31 steel shows a significant improvement in surface roughness than the electrode of raw wire. A strong interaction is observed between the type of wire and the tension of the wire; Pulse width and wire tension.

Process Modelling and Multi Optimization: WEDM process modeling using various approaches, such as mathematical techniques, has also been used to effectively relate the large number of process variables to variable process performance.

Response surface methodology: The Response Surface Methodology, or RSM, is a collection of mathematical and statistical techniques useful for modeling and analyzing problems where the responses of interest are influenced by various variables and the goal is to optimize those responses. This property makes RSM a useful method for modeling and optimizing wire EDM. In this method, if the response is well modeled by a linear function of the independent variable, then the approximate function is the first-order model.

$$Y_U = b_0 + b_1X_1 + b_2X_2 + \cdots + b_iX_i + e \quad (4)$$

If the system has a curvature, a polynomial of higher degree should be used, Such as a second order model

$$Y_U = b_0 + \sum_{i=1}^{K} b_i X_i + \sum_{i=1}^{K} b_{ii} X_i^2 \quad (5)$$

$$+ \sum_{j>i}^{K} b_{ij} X_i X_j + \cdots + e$$

Herei is the linear coefficient, j the quadratic coefficient and β the regression coefficient, k the number of factors examined and optimized in the experiment, and e the random error. Analysis of variance (ANOVA) was used to assess the adequacy of regression model (Montgomery, 2009, Noordin *et al*. (2004)). In this method, the effects of noise factors were taken into account. Furthermore, the statistical optimization model can overcome the limitation of classical methods to obtain optimal process conditions. In addition, the interactions between the process variables are demonstrated. The main disadvantage of this method is that the optimal value obtained can be a local optimal value, as shown in Figure 7. In Figure 7, the goal is to minimize the response. Furthermore, this method is quite expensive due to the large number of experiments that must be performed. For example, if eight factors have taken into account that two must be raised to the power of eight experiments in a full factorial design (= 256), the number of experiments even in a semifactorial design becomes 128, which is still high . Many authors have tried to model this process using the Taguchi method and the response surface method. ComoHewidy, M.S. *et al*. (2005), Puri, A. B., Bhattacharyya, B., (2005), Kung, K. Y. y Chiang, K. T. (2008), Sarkar, S., *et al*. (2008). Ghodsiyehy col. (2012a, b, cyd), Kumar, A., *et al*. (2012) y Datta, S., Mahapatra S. S., (2010) using the response surface methodology together with the grey-Taguchitechnique.

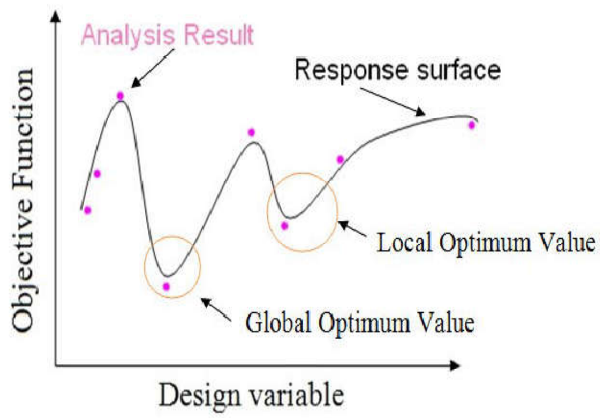

Fig. 8. Response surface methodology optimization

Orthogonal array (OA): This Taguchi method is very useful for modeling and understanding the WEDM process. This Taguchi method allows the analysis of many different parameters without much experimentation. This property makes OA a useful approach to wire EDM modeling due to the large number of parameters in this process. The main disadvantage of this method is that the results obtained are only relative and do not indicate exactly which parameter has the greatest influence on the performance indicator. Since orthogonal matrices do not test for all combinations of variables, they also cannot indicate the importance of the interaction of various factors, which is quite important in WEDM. Many authors have tried to model this process using this method. As Anand, K.N., (1996), Huang, J.T. *et al*. (1999),Puri, A. B.,Bhattacharyya, B.,(2003), Kuriakose, S. and Shunmugam, M.S.,(2004),Tosun, N. *et al.*(2004), Wang,C.C., *et al*. (2009),Vamsi K. P. *et al.*(2010), Parashar, *et al.*(2010) ,Rao,P.S., *et al.* (2011), Kuruvila, N. and Ravindra, H. V.(2011), Satishkumar, D. *et al.*(2011).

Non-Traditional Optimization Algorithms: Since the early 1960s, various mathematical techniques were developed that copy various phenomena from nature. The mentality of engineers is that they can learn and know from nature. Engineers follow natural rules, such as artificial neural networks, the study of neurons is involved, and genetic algorithms transform the laws of genetics to use as an optimization tool. These algorithms are very useful to optimize the process that includes many parameters like WEDM. Sometimes the result suggested by these algorithms cannot be achieved in reality; Due to the lack of the optimal combination of parameters in the machine, this could be the main disadvantage of this method. (Mahapatra and Patnaik (2006a)). The reason for using these algorithms is the ability of these algorithms to find the global optimal parameters, whereas traditional optimization techniques tend to be trapped in local optimum (Mahapatra, S.S., Amar Patnaik, (2006c)). Some authors tried to optimize WEDM using this method, such as Kuriakose, S., Shunmugam, (2005),Jeyapaul, R. *et al*. (2006), Mahapatra and Patnaik (2006c), Debabrata *et al*. (2007), Kuruvila, N. and Ravindra, H. V. (2011). Mukherjee, R. (2012), compared the performance of different optimization algorithms to optimize the WEDM process. This article compared six non-traditional optimization algorithms, including; Genetic algorithm, particle swarm optimization, sheep flock algorithm, ant colony optimization, artificial bee colony and biogeography-based optimization for optimization of one or more targets of the WEDM process. It turned out that although all these six algorithms have high potential to achieve optimal parameter settings, the biogeography-based algorithm outperforms the others in terms of optimization performance, fast convergence, and dispersion of optimal solutions from their value. half. There are some investigations that have used a traditional approach to modeling WEDM, such asTarng, YS, (1995) that uses a feedback neural network to model and then a simulated annealing (SA) algorithm is applied in the neural network to solve the optimal cutting parameters problem. Another is Lin, J. L. *et al*. (2000), who used the Taguchi method with fuzzy logic for modeling and optimization. In addition, Huang, J. T., and Liao Y. S. (2003) examined WireEDM based on statistical and relational Gray analyzes. Furthermore, Kuriakose *et al*. (2003) used the data mining approach and the C4.5 algorithm to model this process. Furthermore, Yuan *et al*. (2009) uses Incorporating Prior Model into Gaussian Process Regression for the modeling of WEDMprocesses. Çaydas, U. *et al*. (2009) used the neurofuzzy& # 40; inference system; ANFIS & # 41; to model this process.Also Çaydas, U., *et al.* (2009) used neuro-fuzzyinference system (ANFIS) to model this process.Besides Chen, H.C. (2007) utilized a neural networkintegrated simulated annealing approach for optimizingWEDM.

Temperature and Thermal Stress Analysis: Due to the high temperature gradients that are generated during electrical discharge machining (EDM) in a small heat-affected zone in space, high residual thermal stresses arise on the surfaces of electrical discharge machining parts. These thermal loads can lead to micro cracks, reduced wear life and fatigue strength, and potentially catastrophic failure. The results of the analysis show areas with high temperature gradients and areas with high stresses, in which they sometimes exceed the elastic limit of the material. A transient thermal analysis assuming a Gaussian heat source with temperature-dependent material properties can be used to investigate the temperature distribution. This article presents a basic description based on various parameters and various methods used by others to estimate temperature distribution and heat stress analysis.

Concluding remarks: (WEDM) is an advanced thermal machining process capable of precision machining intricately shaped parts, especially for parts that are very difficult to machine using conventional machining methods. It is widely used for machining and micromachining of parts with intricate shapes and varying degrees of hardness that require high profile accuracy and tight dimensional tolerances. Optimizing the WEDM process parameters is essential because WEDM is an expensive and widely used process. The ultimate goal of the WEDM process is to achieve an accurate and efficient machining process. Several researchers have investigated methods to improve surface quality and increase material removal from the WEDM process. However, the problem of selecting the cutting parameters in the WEDM process has not been completely solved, although the most modern CNCWEDM machines are currently available. Information on various types of WEDM cables is still lacking. Therefore, more research needs to be done to compare different types of cables in different responses. Also, there is not enough information about WEDM inaccuracies. More research can improve the precision of WEDM machining, especially contour cutting. Also, there still appears to be a lack of information on dry and near-dry WEDM. Furthermore, the use of optimization algorithms can significantly further develop the optimization process, whereas only genetic algorithms that have been widely used so far to optimize this process and the use of other algorithms could improve optimization. The WEDM process must be continually improved to survive as a competitive and economical machining process in the modern tool-making industry. Finally, it appears that further research can greatly enhance the capabilities of the WEDM process to improve machining productivity, precision and efficiency. Conclusion From the bibliographic search it can be concluded that wires with higher tensile strength can be produced, but that they have adverse effects in terms of increased resistance to breakage. Coated wires may perform best in today's scenario, where surface finish and tool life are most preferred. Galvanized brass wires perform better than plain brass wires because of their low rate of wear and tear at high currents. Due to the high precision and good surface quality, WEDM is a potentially important process. The development of the WEDM as a Micro WEDM is being investigated where it can beused more efficiently and effectively on an industrial scale for the production of micro components. Some work with cryogenic treatment has been carried out on the different types of workpieces; This area can play a crucial role in the development of WEDM.More compositions can beadvanced and used for the brand new multilayered electrodes; high-qualityendenergydeliver can discoverextra zones to attainsuitablepleasant of floorendin addition tostrongerdevice life. To sum up we are able to say extensive studies has been finished with inside the beyond and hugequantity of labor can nonetheless be finished with inside the destinyat the topic, in order that WEDM can serve the cause of excessivevelocitymachining with suitablepleasantmerchandise in quickterm and at decreased costs.

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