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Single/Multiple Objective Optimization of Machining Parameter in Wire Cut Electrical Discharge Machining: An Overview

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Abstract

Electro Discharge Machining (EDM) is an emerging technology in the field of machining to fabricate very complex micro products. Wire EDM is a very complex process involving the different process parameters. The experiments are often time consuming and costly. It is used to manufacture geometrically intricate shapes with great accuracy and good surface finish that are difficult to machine with the help of conventional machining processes,but recent development in material have become a difficult task for WEDM process to be used for machining alternative in future,so there is need to make continuous improvement in current WEDM process to increase their productivity and efficiency in WEDM have directly contributed to increased cutting speed and dimensional accuracy. This paper reviews the various notable works in the field of WEDM and emphasis is made on optimization of machining parameters.

Keywords: Wire Cut EDM, Principle, Surface finish , Dimentional accuracy ,Cutting Speed.

Introduction

Electrical Discharge Wire Cutting is commonly known as Wire EDM which is generally use to produce complex two and three dimensional shapes through electrically conductive work pieces. Wire EDM comparatively new in manufacturing and there was first use of it in 1968.By 1975, its popularity was rapidly increasing because the process and its capabilities were becoming better understood by industry. This process is similar to counter cutting with a band saw, a slowly moving wire travels along a prescribed path, cutting the work piece, with the discharge sparks acting like cutting tooth. This is used to cut plates as thick as 300mm, and for marking punches, tools, and dies from hard metals. It can also cut intricate components for the electronics industry. The wire is usually made of brass, copper or tungsten; zinc or brass- coated and multi- coated wires are also used. The wire diameter a typically about 0.3mm for rough cutting and 0.2mm for finish cutting. The wire should have sufficient tensile strength and fracture toughness as well as high electrical conductivity [1]. In wire EDM, the conductive materials are machined with a series of electrical discharges that are produced between an accurately positioned moving wire (the electrode) and the work piece. High frequency pulses of alternating or direct current is discharged from the wire to the work piece with a very small spark gap through an insulated dielectric fluid (water). Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required. The heat of each electrical spark, estimated at around 15,000° to 21,000° Fahrenheit, erodes away a tiny bit of material that is vaporized and melted from the work piece. (Some of the wire material is also eroded away) These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the work piece. Without this cooling, thermal expansion of the part would affect size and positional accuracy. Keep in mind that it is the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current [1].

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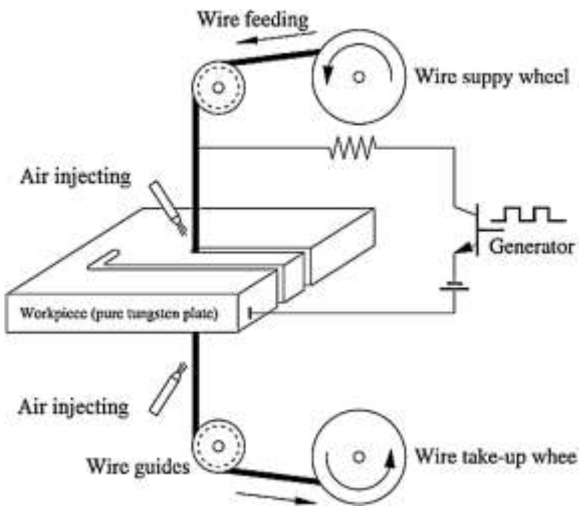

Figure 1: Principle of Wire cut EDM[1]

Key benefits of WEDM

- Electrode wear is negligible.
- Forming electrode to produce shape is not required.
- Machined surface are very smooth.
- Dimensional and Geometrical Tolerances are very tight.
- Straight hole production is possible with higher precision.
- Relative tolerance between punch and die is much higher and die life is extended.
- The machine can be operated unattended for long time at high rate.
- No special skills are required to run the machine.
- Any electrically conductive material can be machined irrespective of its hardness.

Litreture works

S.r.nithin aravind et al (2012)[14] presents the experimental stydy to select best suitable value of voltage, current, speed, pulse on/off time in order to get maximum metal removal rate (MRR) and minimum surface roughness (SR) on wire EDM (electrical discharge machining) by employing Taguchi's experimental design (Ll8 orthogonal array) and concluded that the factors like the pulse duration and the feed rate plays a significant role**.**

Ali vazini shayan et al (2013)[1] have conducted parametric study along with selection of optimal solutions in dry wire cut machining of cemented tungsten carbide (WC-Co),using an air as dielectric medium to investigate effect of pulse on time, pulse off time, gap set voltage, discharge current and wire tension on cutting velocity (CV) surface roughness (SR) and oversize (OS).they have concluded that the use of air at inlet pressure of 1.5 bar leads to higher material removal rate and lower surface roughness and oversize, also a cutting velocity and surface roughness increase by increasing in discharge current and pulse on time. But increasing in pulse on time leads to lower oversize while increasing discharge current firstly increases oversize then decreases it, and also stated that the cutting velocity and surface roughness decrease by increasing pulse off time and gap set voltage, from result of preliminary experiment. The level of importance of the machining parameters on the response parameter was determined by using analysis of variance (ANOVA) method.

M. Durairaj et al (2013)[5]- presents the study to optimize process parameters in wire EDM with stainless steel using single objective taguchi method and multi objective grey relational grade for ss304 as a work piece material. They have studied the parametric effect of gap voltage, wire feed, pulse on time, and pulse off time with a tool of brass wire of 0.25 mm diameter. They have concluded based on taguchi’s optimization that the minimum surface roughness are at 40v gap voltage, 2mm/min wire feed, 6 µs pulse on time, 10 µs pulse off time and similarly optimized conditions to get the minimum kerf width are 50v gap voltage, 2mm/min wire feed, 4 µs pulse on time, 6 µs pulse off time.

K. Kanlayasiri and s. Boonmung (2007)[4]- Authors have done an investigation on effects of wire-EDM machining parameters on surface roughness of newly developed DC53 die steel. They have investigated machining parameters like pulse-on time, pulse-off time, pulse-peak current, and wire tension using ANOVA technique to find out the parameters affecting the surface roughness. They have concluded that the pulse-on time and pulse-peak current are significant variables to surface roughness of wire-EDMed DC53 die steel. The surface roughness of the test specimen became larger when these two parameters are increased.

Farnaz nourbakhsh et al (2013)[3]- Authors have done work on wire electro-discharge machining of titanium alloy. They have studied parametric effect of pulse width, servo reference voltage, pulse current, and wire tension on process performance parameters (such as cutting speed, wire rupture and surface integrity) employing taguchi L18 DOE. They have concluded that the cutting speed increases with peak current and pulse interval and surface roughness

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increase with pulse width and decrease with pulse interval, also the *analysis of variance (ANOVA*) indicates that voltage, injection pressure, wire feed rate and wire tension have non-significant effect on the cutting speed.

Aniza alias et al (2012)[2]- Authors have done work on influence of machine feed rate in machining Titanium Ti-6AL-4V using brass wire and constant Current (4A).they have investigated influence of feed rate on kerf width, material removal rate And surface roughness. they optimized machine feed rate at (4 mm/min), wire Speed at (8 m/min), wire tension at (1.4kg) and voltage at (60v).they have concluded that feed rate plays an important role.

P. Sivaprakasam et al (2014)[9]- Authors have done modeling and analysis of micro-WEDM process of titanium alloy (Ti-6AL-4V) using response surface approach. They have investigated 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).they have concluded that the optimal machining performance of material removal rate, kerf width and surface roughness are 0.01802 mm3/min, 101.5 mm and 0.789 mm, respectively, using this optimal machining conditions viz. Voltage 100 v, capacitance 10 nf and feed rate 15 µm/s.

Reza kashiry farda, et al (2013)[13]- Authors have done experimental investigation, intelligent modeling and multi-characteristics optimization of dry WEDM process of Al–Sic metal matrix composite. they have carried out experiment based on L27 taguchi's orthogonal array to study the effect of pulse on time, pulse off time, gap voltage, discharge current, wire tension and wire feed on cutting velocity (CV) and surface roughness (SR),and performed ANOVA to identify significant factor and concluded that according to ANOVA, pulse on time and discharge current are found to have significant effect on CV and SR and Also, wire tension appears the most insignificant factor. Based on obtained ANFIS surfaces, they have concluded that combination of high pulse on time, low pulse off time, low gap voltage, high current resulting higher cutting velocity regardless wire feed and wire tension. Moreover, combination of low pulse on time, high pulse off time, high gap voltage, low discharge current, low wire feed and low wire tension leads to lower surface roughness.

Nihat Tosun et al (2004)[7]- Authors have done A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method. they have investigated effect of pulse duration, open circuit voltage, wire speed and dielectric flushing pressure on the kerf (cutting width) and material removal rate (MRR). The level of importance of the machining parameters on the cutting kerf and MRR was determined by using analysis of variance (ANOVA).they have found that the highly effective parameters on both the kerf and the MRR are open circuit voltage and pulse duration, whereas wire speed and dielectric flushing pressure less effective factors. They have concluded that the open circuit voltage is about three times more important than the second ranking factor (pulse duration) for controlling the kerf, whereas open circuit voltage for controlling the MRR is about six times more important than the second ranking factor (pulse duration).

R. Ramakrishnan and L. Karunamoorthy (2008)[12]- Authors have done Modeling and multi-response optimization of Inconel 718 on machining of CNC WEDM process. they have performed Experiment on Inconel 718 under different cutting conditions of pulse on time, delay time, wire feed speed, and ignition current in order To predict the performance characteristics namely material removal rate and surface roughness using artificial neural network models. they have concluded that that the pulse on time, delay time and ignition current is influenced more than wire feed speed, But wire feed speed plays a very significant role for allotting equal importance to both responses and by an increase of pulse on time and ignition current, the effect of MRR is improved. But at higher rates of pulse on time and ignition current the surface quality of the work specimen is affected.

Pragya Shandilya et al (2013)[10]- Authors have done RSM and ANN Modeling Approaches for Predicting Average Cutting Speed during WEDM of SiCp/6061 Al MMC. They have investigated four parameters namely servo voltage (*SV*), pulse-on time (*TON*), pulse-off time (*TOFF*) and wire feed rate. They have concluded that the Combined effect of input process parameters on average cutting speed shows that voltage is more significant parameter on average cutting speed than pulse-off time and wire feed rate (*WF*) are chosen as machining process parameters, also voltage is more significant parameter on average cutting speed than pulse-off time and wire feed rate for 10% SiCp/6061 Al MMC.

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Nixon kuruvila and ravindra h. V (2011)[8]- Authors have done work on parametric influence and optimization of wire EDM of hot die steel. They designed experiment as per taguchi's L16 orthogonal array (OA) wherein pulse-on duration, current, pulse-off duration, bed-speed and flushing rate have been considered as the important input parameters and dimensional error (DE), surface roughness (SR) and volumetric material removal rate (VMRR) are considered as the output parameter on material of hot die steel (HDS) having the thickness of 40 mm.they have concluded that it is preferable to go for smaller pulse-off duration for achieving overall good performance. Regarding pulse-on duration, higher values are recommended for error constrained machining with higher MRR and constrained/limited values for attaining good surface texture. Smaller current is suggested for better surface finish/texture control, medium range for error control and high value for MRR.

Pujari Srinivasa Rao et al (2011)[11]- Authors have done work on effect of WEDM conditions on surface roughness: a parametric optimisation using taguchi method on Aluminum-24345 work piece material. They have carried out experiment by using taguchi L18 OA.they have studied the parametric effect of Pulse On time ,pulse off time, peak current, flushing pressure of dielectric fluid, wire feed rate, wire tension ,spark gap voltage, servo feed setting on surface roughness. They have concluded that the SR tends to decrease significantly with decrease in peak current (IP) and TON and the minimum SR is obtained at low IP (10 A) and low TON (105 μsec).they also have stated that The parameters wire tension and spark gap voltage are observed as significant parameters in obtaining better surface finish and The minimum SR is obtained at high wire tension (10 kg-f) and low spark gap voltage (8 V).

Conclusion

From the papers referred above many conclusions can be drawn. These are summarized below:

1. Good surface roughness can be generated with a short pulse duration and with a high peak value, which cannot be achieved with long pulses.
2. Decrement in both pulse duration and discharge current can improve surface roughness.
3. Increment in wire speed decreses wire wear ratio and same phenomenon in pulse duration and open circuit voltage increase it.
4. Hardness and strength of material are least significant factor that affect tool wear.

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