A LITERATURE REVIEW ON OPTIMIZATION OF MACHINING PARAMETERS IN WIRE EDM

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Abstract— The recent developments in the materials have become a challenging task for WEDM process to be used for machining alternative in future. So it is essential to make continuous improvement in the current WEDM process to increase their productivity and efficiency. Manufacturing advances 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—brass wire electrodes, optimization, coated wires, ANOVA, DOE

INTRODUCTION

Wire electrical discharge machining (WEDM) is an indispensable machining technique for producing complicated cutouts through difficult to machine metals without using high cost grinding or expensive formed tools [9]. 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.

WEDM has been widely adopted as a machining tool for die materials which require high strength and hardness as well as good wear resistance, while the traditional manufacturing process needs a special tool or technique with a longer process time. In WEDM, a continuously moving conductive wire acts as an electrode and material is eroded from the work piece by series of discrete sparks between the work piece and wire electrode separated by a thin film of dielectric fluid. The dielectric is continuously fed to the spark zone to flush away the eroded material and it acts as a coolant. A literature survey based on some important research papers shows different trends on WEDM.

Working Principle of WEDM

A model of WEDM is shown in fig.1. The electric discharge is caused to occur erratically in a pulse-like manner between an electrode wire and a work piece through a processing liquid so as to fuse-cutting the work piece in a desired configuration. A pulse voltage is applied between the wire electrode and workpiece in the processing fluid to melt the surface of the workpiece by the thermal energy of an arc discharge, while at the same time removing machining dust through a vaporizing explosion and recirculation of the processing fluid. The residue resulting from the melting of a small volume of the surface of both the workpiece and the EDM wire electrode is contained in gaseous envelope. The plasma eventually collapses under the pressure of the dielectric fluid. The liquid and the vapor phases created by the melting are quenched by the dielectric fluid to form solid debris. This process is repeated at nanosecond interval along the length of the wire in cutting zone.

Figure I: Wire electric discharge machining (WEDM) model [10]

The most important performance measures in WEDM are metal removal rate, surface finish, and cutting width. They depend on machining parameters like discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate. Among other performance measures, the kerf, which determines the dimensional accuracy of the
finishing part, is of extreme importance. The internal corner radius to be produced in WEDM operations is also limited by the kerf. The gap between the wire and work piece usually ranges from 0.025 to 0.075 mm and is constantly maintained by a computer controlled positioning system.

**Literature Works**

Mustafa Ilhan Gokler and Alp Mithat Ozanozu [1] present the experimental study to select the most suitable cutting and offset parameter combination for the wire electrical discharge machining process in order to get the desired surface roughness value for the machined workpieces. A series of experiments have been performed on 1040 steel material of thicknesses 30, 60 and 80 mm, and on 2379 and 2738 steel materials of thicknesses 30 and 60 mm.

M.T. Antar, S.L. Soo, D.K. Aspinwall, D. Jones and R. Perez [2] made a brief review of recent minimum damage EDM pulse generator developments, experimental data is presented for workpiece productivity & integrity when WEDM Udiment 720 nickel based super alloy and Ti-6Al-2Sn-4Zr-6Mo titanium alloy, using Cu core coated wires (ZnCu50 and Zn rich brass). Up to a 70% increase in productivity was possible compared to when using uncoated brass wires with the same operating parameters. Surfaces measuring □ 0.6 μm Ra, with near neutral residual stresses and almost zero recast were produced following two trim passes. Cross-sectional micrographs of specimens following rough machining (□180mm²/min) showed the recast to be < 7 μm thick (up to 11 μm for uncoated wire), with comparable results for both alloys. Surface cracking, when evident, was restricted to within the recast layer.

Fuzhu Han, Jun Jiang and Dingwen Yu [3] gives the journal on Influence of machining parameters on surface roughness in finish cut of WEDM, according to them Surface roughness is significant to the finish cut of wire electrical discharge machining (WEDM). This paper describes the influence of the machining parameters (including pulse duration, discharge current, sustained pulse time, pulse interval time, polarity effect, material and dielectric) on surface roughness in the finish cut of WEDM. Experiments proved that the surface roughness can be improved by decreasing both pulse duration and discharge current. When the pulse energy per discharge is constant, short pulses and long pulses will result in the same surface roughness but dissimilar surface morphology and different material removal rates. The removal rate when a short pulse duration is used is much higher than when the pulse duration is long.

S. S. Mahapatra and Amar Patnaik [4]- studied optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, Wire electrical discharge machining (WEDM) is extensively used in machining of conductive materials when precision is of prime importance. Rough cutting operation in WEDM is treated as a challenging one because improvement of more than one machining performance measures viz. metal removal rate (MRR), surface finish (SF) and cutting width (kerf) are sought to obtain a precision work. Using Taguchi’s parameter design, significant machining parameters affecting the performance measures are identified as discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow. It has been observed that a combination of factors for optimization of each performance measure is different. In this study, the relationship between control factors and responses like MRR, SF and kerf was established by means of nonlinear regression analysis, resulting in a valid mathematical model. Finally, genetic algorithm, a popular evolutionary approach, was employed to optimize the wire electrical discharge machining process with multiple objectives. The study demonstrated that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously.

M.J. Haddad and A. Fadaei Tehrani [5], made material removal rate (MRR) study in the cylindrical wire electrical discharge turning (CWEDT) process- As using wire EDM (WEDM) technology, complicated cuts can made through difficult to machine electrically conductive components, the cylindrical wire electrical discharge turning (CWEDT) process was developed to generate precise cylindrical forms on complicated, hard and difficult to machine materials. The hardness and strength of the work material are no longer the dominating factors that affect the tool wear and hinder the machining process. The right selection of machining conditions is the most important aspect to take into consideration in process related to the WEDM operations. This paper presented an investigation on the effects of machining parameters on material removal rate (MRR) in cylindrical wire electrical discharge turning (CWEDT) process. In this research, CWEDT of AISI D3 (DIN X210Cr12) tool steel was studied by using of statistical design of experiment (DOE) method.

Nihat Tosun and Can Cogun [6], An investigation on wire wear in WEDM- In this study, the effect of cutting parameters on wire electrode wear was investigated experimentally in wire electrical discharge machining (WEDM). The experiments were conducted under different settings of pulse duration, open circuit voltage, wire speed and dielectric fluid pressure. Brass wire of 0.25 mm diameter and AISI 4140 steel of 10 mm thickness were used as tool and workpiece material. It is found experimentally that the increasing pulse duration and open circuit voltage increase the wire wear ratio (WWR) whereas the increasing wire speed decreases it. The variation of workpiece material removal rate and average surface roughness were also investigated in relation to the WWR. The variation of the WWR with machining parameters was modelled statistically by using regression analysis technique. The level of importance of the machining parameters on the WWR was determined by using analysis of variance (ANOVA) method.

Nihat Tosun, Can Cogun and Gul Tosun[7]- A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method, This paper presented an investigation on the effect and optimization of machining parameters on the kerf (cutting width) and material removal rate (MRR) in wire electrical discharge machining (WEDM) operations. The experimental studies were conducted under varying pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. The settings of machining
parameters were determined by using Taguchi experimental design method. The level of importance of the machining parameters on the cutting kerf and MRR is determined by using analysis of variance (ANOVA). The optimum machining parameter combination was obtained by using the analysis of signal-to-noise (S/N) ratio. The variation of kerf and MRR with machining parameters is mathematically modelled by using regression analysis method. The optimal search for machining parameters for the objective of minimum kerf together with maximum MRR is performed by using the established mathematical models.

Aminollah Mohammadi, Alireza Fadaei Tehrani, Ehsan Emanian and Davoud Karimi[8]- Statistical analysis of wire electrical discharge machining on material removal rate was made. The application of wire electrical discharge machining (WEDM) for machining of precise cylindrical forms on hard and difficult-to-machine materials is presented. At first, the design of a precise, flexible and corrosion-resistant rotary spindle submerged is introduced. The spindle has been mounted on a five-axis wire EDM machine to rotate the workpiece in order to generate free form cylindrical geometries. The material removal rate (MRR) is an important indicator of the efficiency and cost-effectiveness of the process. Several experiments are conducted to consider effects of power, time-off, voltage, servo, wire speed, wire tension, and rotational speed (factors) on the MRR (response).

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

1. The surface roughness can be improved by decreasing both pulse duration and discharge current.
2. This indicates that a short pulse duration combined with a high peak value can generate better surface roughness, which cannot be achieved with long pulses.
3. Reversed polarity machining with the appropriate pulse energy can improve the machined surface roughness somewhat better compared with normal polarity in finish machining, but some copper from the wire electrode is accreted on the machined surface.
4. The hardness and strength of the work material are no longer the dominating factors that affect the tool wear and hinder the machining process.
5. The increasing pulse duration and open circuit voltage increase the wire wear ratio whereas the increasing wire speed decreases it.

REFERENCES
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