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Development of Rotary Axis For Wire Electrical Discharge Machining (WEDM)

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Abstract: ***This paper gives an overview of setting up a rotary axis to the existing WEDM machine to investigate the machining parameters in WEDG of harder materials. There are a number of hybrid machining processes (HMPs) seeking the combined advantage of EDM and other machining techniques. One such combination is wire electrical discharge grinding (WEDG), which is commonly used for micro-machining of fine and hard rods. WEDG employs a single wire guide to confine the wire tension within the discharge area between the rod and the front edge of the wire and also to minimize the wire vibration. Other advantages of WEDG include the ability to machine hard- to- machine materials with large aspect ratio.***

Keywords-WEDM;WEDG;aspect ratio

I INTRODUCTION

The electrical discharge machining (EDM) is a thermoelectric process that erodes workpiece material by a series of discrete electrical sparks between the workpiece and electrode. Unlike traditional cutting and grinding processes which rely on a much harder tool or abrasive material to remove the softer work material, the EDM process utilizes electrical sparks or thermal energy to erode the unwanted workmaterial and generate the desired shape. These sparks generate craters and recast layer on the surface of the EDM workpiece. Wire Electrical Discharge Machining (WEDM) is a widely accepted non- traditional material removal process used to manufacture components with intricate shapes and profiles. However WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or zinc coated brass or copper of diameter 0.05- 0.3mm, which is capable of achieving very small corner radii. During the WEDM process the hardness and strength of the work materials are no longer the dominating factors that affect the tool wear and hinder the machining efficiency. This makes EDM particularly suitable for machining hard, difficult- to- machine materials, such as the metal- matrix composited (MMC), Titanium, Tungsten, Zirconium, Molybdenum which are widely used in aerospace, nuclear, and automotive industries. Without WEDM the fabrication of precision workpieces reqiured many hour of manual grinding and polishing. Grinding with WEDM is one of the emerging areas developed to generate cylindrical form on hard and difficult to machine materials by adding a rotary axis to WEDM.

II CURRENT STATUS ON WEDM

The concept of cylindrical wire electrical discharge turning is developed by adding a rotary axis to a conventional five axis WEDM machine inorder to produce cylindrical forms (Mohammadi et al., 2005; Qu et al., 2002a- Fig 2). The initial shape of the part need not to be a cylindrical form. The electrically charged wire is controlled by the X and Y slides to remove the work material and generation of the desired cylindrical forms.

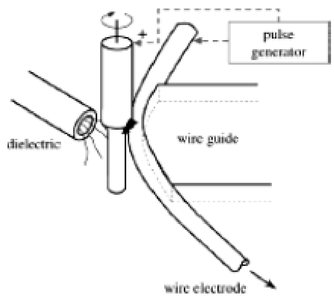


Fig 1 Principle of WEDM (Masuzawa et al., 2004)

Some turning wire EDM works have been reported for manufacturing small pins by Dr. Masuzawa's research group at the University of Tokyo (Masuzawa et al., 1985; Masuzawa et al., 1994; Masuzawa and Tonshoff, 1997). The small diameter pins can be used as tools for 3D micro EDM application (Mohammadi et al., 2005; Qu et al., 2002a). Also the application of a water cooled submerge spindle extends the application of WEDM to WEDT with rotation speeds upto 2800rpm. This enables the production of gear wheels with integrated shafts for easy gear assembly (Masuzawa et al., 2002). The feasibility of using cylindrical WEDM for dressing a rotating metal bond diamond wheel used for the precision form grinding of ceramics has also been studied (Rhoney et al., 2002).

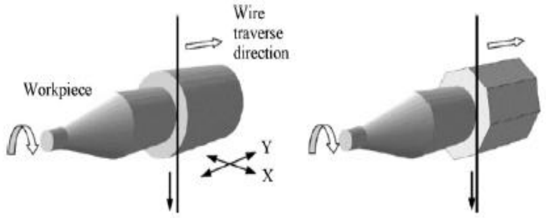


Fig 2 Concept of WEDM process (Qu et al., 2002a)

The results show that the WEDM process is capable of generating precise and intricate profiles with small corner radii. Qu et al. (Qu et al., 2002b) investigated through a mathematical model the surface integrity of CWEDT parts. The same authors derived a mathematical model for the material removal rate (MRR) of a CWEDT process (Qu et al., 2002a). Mohammadi et al. (Mohammadi et al., 2006) investigated turning by wire electrical discharge machining to evaluate the effects of machining Parameters on Ra and roundness. Also, they investigated turning by wire electrical discharge machining to evaluate the effects of machining parameters on MRR by using the Taguchi approach in design of experiments (DOE) (Mohammadi et al., 2005). There are also a number of published works that solely study the effects of the machining parameters on the WEDMed surface. Gokler and Ozanozgu (Gokler and Ozanozgu, 2000) studied the selection of the most suitable cutting and offset parameter combination to get a desired Ra for a constant wire speed and dielectric flushing pressure. Tosun et al. (Tosun et al., 2003) investigated the effect of the pulse duration, open circuit voltage, wire speed and dielectric flushing pressure on the WEDMed workpiece surface roughness. It was found that increasing the pulse duration, open circuit voltage and wire speed increases with the surface roughness, whereas increasing the dielectric fluid pressure decreases the surface roughness. Anand (Anand, 1996) used a fractional factorial experiment with an orthogonal array layout to obtain the most desirable process specification for improving the WEDM dimensional accuracy and Ra. Spedding and Wang (Spedding and Wang, 1997) optimized the process parameter settings by using artificial neural network modeling to characterize the WEDMed workpiece surfaces, whilst Williams and Rajurkar (Williams and Rajurkar, 1991) presented the results of the current investigations into the characteristics of WEDM generated surfaces. According to Trezise (Trezise, 1982), the fundamental limits on machining accuracy are dimensional consistency of the wire and the positional accuracy of the worktable. Most of the uncertainties arise because the working region is an unsupported section of the wire, remote from the guides. Rajurkar and Wang analyzed the wire rupture phenomena with a thermal model. An extensive experimental investigation has been carried out to determine the variation of machining performance outputs viz., MRR and SF with machining parameters in the study. Tarng (Tarng et al., 1995) used a neural network system to determine settings of pulse duration, pulse interval, peak current, open circuit voltage, servo reference voltage, electric capacitance, and table speed for the estimation of cutting speed and surface finish. Scott (Scott et al., 1991) used a factorial design method to determine the optimal combination of control parameters in WEDM, the measures of machining performance being the metal removal rate and the surface finish.

In our country this WEDG is an emerging field and even though some studies are going on still there is much scope to do the experimental study and analysis. With the help of the existing experimental setup and results done by V. Janardhan et al, an improved setup can be built for WEDG to incorporate mainly for micro machining with wire diameter of 0.10mm for machining harder materials and the results can be analyzed.

III DEVELOPMENT OF ROTARY AXIS FOR WEDM

The rotating work piece is driven by a spindle, which is submerged in a tank of deionized water or dielectric fluid. Two jets of high-pressure water are used to flush the work piece to improve the material removal rate and maintain a uniform thermo-environment. A precision underwater spindle is the key subsystem of the experiment. This spindle must meet the following design criteria:

Accuracy: The spindle error needs to be small to machine accurate parts and maintain the consistent gap condition.

Flexibility: The spindle has to accommodate different sizes of work piece.

High Current Electrical Connection: Wire EDM requires high-current, high-voltage electrical connections between the rotating work piece and the ground.

Corrosion Resistance: Because the spindle is underwater, components of the spindle need to be sealed.

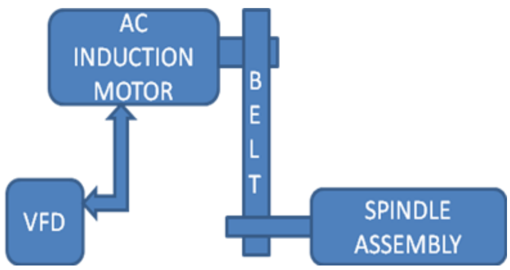


Fig 3 Rotary Axis- Set up

IV CURRENT SET UP

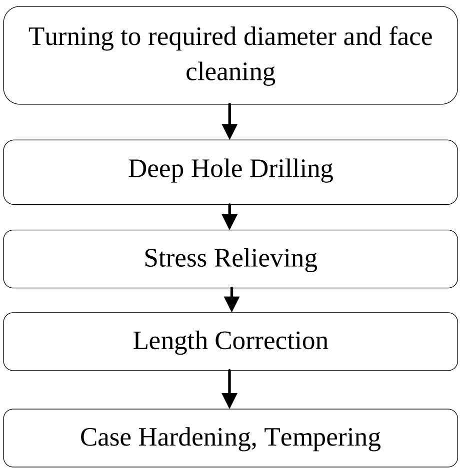
The purpose of spindle is to give rotary motion to the work piece during discharge. Precision spindle is the key sub- system for wire electrical discharge grinding process. Since this spindle is going to be used in submerged environment the parts of this spindle needs to be sealed properly. So the oil seal was used. Ball bearing has been selected in order to avoid the run out errors. Both the spindle shaft and the motor shaft are connected using timing belt and pulley. Motor has been isolated from the spindle unit by placing the nylon sleeve in between the motor shaft and the pulley to avoid the back current from the spindle and to avoid damage of the motor.

Experimental Set up

Machine used	: Mitsubishi Advance FA10S
Motor	: AC Induction Motor
Motor Rating	: 150 W, 0- 1350 rpm
Drive	: Variable Frequency Drive
Spindle Material	: EN 8
Maximum Stress	: 700- 850 N/mm^2
Yield Stress	: 465 N/mm^2
Young's Modulus	: $2.1*10^5$ N/mm^2
Hardness	201- 255Brinell

The ER16 type Collet was chosen in order to hold the cylindrical component of size from Ø2 to Ø6 mm and it was attached to the spindle.

V FABRICATION OF SPINDLE



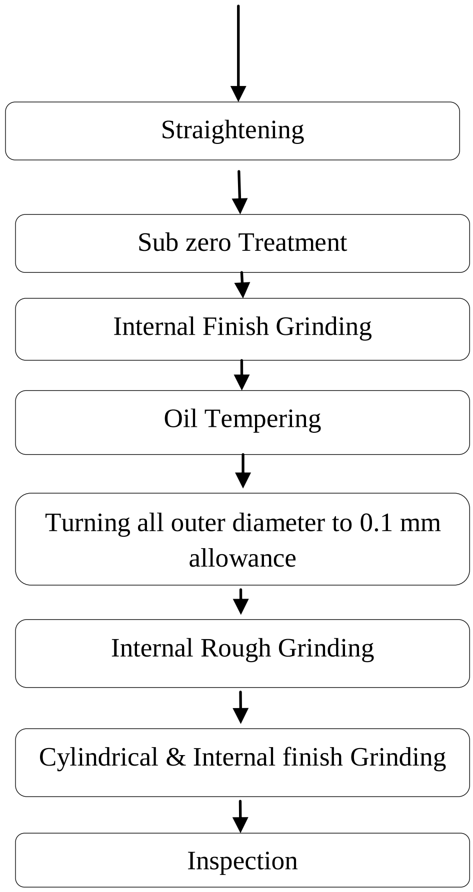


Fig 4 Process Sequence for Spindle fabrication

VI SPINDLE ERRORS

Spindle runout error is an important parameter that can affect the maximum material removal rate, roundness, diametral accuracy, surface finish and other characteristics of turning wire EDM parts. The maximum spindle error is defined as the average peak to valley value on the error trace. The spindle error determines the bearing error, and the shaft error describes the runout error of workpiece. An electronic indicator with 0.1µm resolution was used to measure the runout of spindle bar.

The existing set up has run out error upto 35 microns. This is due to bearing failure and assembly errors. So the existing set up is developed by changing the spindle material from EN 24 to EN 8 and Ball bearings to angular contact bearings. Because EN 8 is readily machinable in any condition which makes it suitable for the manufacture of general purpose axles and shafts. This steel is able to endure higher level of stress, particularly on smaller diameters. And angular contact bearings have the ability to take both axial as well as radial loads. The spindle runout error affects the consistency of the spark gap condition. During the inspection 6 microns run out has been identified in the spindle after the assembly the run out has been identified as 8 microns.

Fig 5 Fabricated Spindle- EN 24

Fig 6 Fabricated Spindle- EN 8

Fig 7 Developed rotary axis set up for the existing WEDM- Installed in the WEDM Machine

VII FURTHER WORK

The experimental trials will be taken based on Taguchi's method- L_{27} orthogonal array by changing various parameters like changing the spindle speed, Peak current(I_p), Pulse off time (T_{off}), wire speed(WS) and the results will be taken. Based on the results, analyses of Variance [ANOVA] will be carried out and the significance of each parameter has to be analyzed. Regression models for MRR and Diametral accuracy have to be developed.

VIII CONCLUSION

In the present work a precise and simple spindle for WEDG process is fabricated. It was observed that the spindle runout is the key parameter affecting consistent machining in WEDG. By doing rework to the spindle, runout was minimized. Then finally the spindle shaft was connected to the motor shaft through pulley and timing belt. Based on the requirement spindle was assembled and installed to the WEDM machine. Initially a Tungsten rod was machined and found that the set up is ready inorder to take more experimental trials for the investigation purpose.

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