AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
DESIGN AND PRODUCTION ENGINEERING DEPARTMENT

Investigation into effect of CNC-EDM wire cutting parameters for turning operation

A Thesis Submitted in Partial Fulfillment for the Requirements of the
M. Sc. in Mechanical Engineering

by

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B.Sc. In Production Engineering, 2008

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ABSTRACT

In this investigation, an experimental study in cylindrical wire EDM machining parameters is presented for both longitudinal and cross-feed turning processes. At first, the design of a precise, flexible and corrosion resistant rotary spindle is introduced. The spindle has been mounted on a conventional four axis wire EDM machine to provide the workpiece rotation in order to generate free form cylindrical geometries. Several experiments are conducted to investigate the influence of six input variables: the depth of cut, gap, workpiece rotational speed, pulse time-on, wire speed and interval time (factors) on the material removal rate (MRR) and the average surface roughness (R_a) (responses) as indicators of the efficiency and cost-effectiveness of the process. In this investigation, two techniques for design of experiments (DOE) were used. Stainless steel k316 is one of the difficult-to-machine material, was used in this study. The experimental work was done for longitudinal turning operation by changing one variable and keeping the others constant to point out the effect of each of these variables on the six control factors. In the pre-experiment, regression equations interpreting the relationship between the six input variables and the material removal rate, surface roughness have been deduced.

An L18 ($2^1 \times 3^5$) Taguchi standard orthogonal array is chosen for the design of experiments (DOE) for cross-feed turning process due to the number of factors and their levels in the investigation. Mini tab Software version 16 was used to determine the main effects of the process parameters. Analysis of variance (ANOVA) was performed to find the dependent variables that affect the machining characteristics. Regression analysis is performed to find out the relationship between the different factors and responses. Signal to noise (S/N) ratio analysis is used to establish the optimum condition.

Key words

WEDM, CWEDM, MRR, Ra, Taguchi's L-18 Orthogonal array

SUMMARY

Chapter one of this thesis provides an introduction to the investigation and processes involved as well as their significance in the industry also the introduction of the industrial workpiece demanding such process.

Chapter two presents an overview of the up to date research topics in this area and this includes a definition of the electrical discharge machining process, the mechanism of material removal, process capabilities and limitations, the dielectric fluid types, and the factors affecting the process of material removal. Also the definition of the wire cut EDM process, with its advantages and point of strength over other machining processes, a part of this chapter deals with the concept of WEDM turning process and factors affecting the rate of metal removal of the process, the last section in this chapter represents the scope of the investigation.

Chapter three illustrates the research design variables, the workpiece material, electrode material, the machine and equipment used to measure the response (MRR, Ra) and the design and features of the underwater rotating spindle that was used in this investigation. Also two techniques for design of experiments (DOE) that was used in this investigation were explained in detail in this chapter.

Chapter four is the chapter which reports the outcomes or results and discussion from the investigation

Chapter five presents the recommendation and conclusion.

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1. Introduction

Among the non-traditional methods of material removal processes, electrical discharge machining (EDM) has drawn a great a deal of researchers' attention because of its broad industrial applications. This process is well studied for machining of casting and forging dies, powder metallurgy, injection molds and aerospace parts.

One of the branches of the EDM process is wire electrical discharge machining. Electrical discharge wire cutting, more commonly known as wire electrical discharge machining (WEDM), is a spark erosion process used to produce complex two- and three-dimensional shapes through electrically conductive workpieces by using wire electrode. The sparks is generated between the workpiece and a wire electrode which flushed with or submerged in a dielectric fluid. The degree of accuracy of workpiece dimensions obtainable and the fine surface finishes make WEDM particularly valuable for applications involving manufacture of stamping dies, extrusion dies and prototype parts. Without WEDM the fabrication of precision workpieces requires many hours of manual grinding and polishing. The most important performance measures in WEDM are material removal rate (or cutting speed), workpiece surface finish and kerf (cutting width). Discharge current, pulse duration, pulse frequency, wire speed, wire tension, average working voltage and dielectric flushing conditions are the machining parameters which affect the performance measures.

In the WEDM process there is no relative contact between the tool and workpiece material, therefore the workpiece material hardness is not a limiting factor for machining materials by this process. In this process the material removal occurs from any electrically conductive material by the initiation of rapid and repetitive spark discharges between the gap of the workpiece and tool electrode connected in an electrical circuit. The liquid dielectric medium is continuously flushed to deliver the eroded particles and to provide the cooling effect. A small diameter wire ranging from 0.05 mm to 0.3 mm is applied as the tool electrode. The wire is continuously supplied from the supply spool through the workpiece, which is clamped on the table by the wire traction rollers. A gap of 0.025–0.07 mm is maintained constantly between the wire and workpiece. Brass and copper wires which are coated by zinc are widely applied as the tool electrodes. The wires once used cannot be reused again due to the variation in dimensional accuracy. The dielectric fluid (deionized water) is continuously flashed through the gap along the wire, to push the molten metal away from the sparking area during the erosion. Since WEDM in some industries is an essential operation in several manufacturing processes, precision and accuracy are of great importance. In order to improve the performance namely the surface roughness, cutting speed, dimensional accuracy, and material removal rate (MRR) of the WEDM process, several researchers have attempted previously. However, the full potential utilization of this process is not completely solved because of its stochastic nature and plenty of variables that are involved in this operation.

Machining of axisymmetric shapes by WEDM (cylindrical wire electrical discharge turning or (CWEDT) using a rotating workpiece system. A rotary axis is added to a conventional four-axis CNC wire EDM machine in order to produce cylindrical forms. When the workpiece was rotated, the wire was scanned in arbitrary paths, so the axisymmetric shape was machined on the workpiece. The initial shape of the part doesn't needs to be in a cylindrical form. The electrically charged wire is controlled by the X and Y slides to remove the work material and generate desired cylindrical form. Examples of the machined parts using the CWEDT method are discussed in detail in the next chapter. Taguchi's robust design is a simple, systematic and more efficient method to determine optimum or near optimum settings of design parameters. Many researchers have attempted to analyze and optimize a single performance characteristic of a manufacturing process using Taguchi methodology.

1.1 Problem statement

The wire EDM turning is one of the most accurate manufacturing processes. But there are a few problems that need to be highlighted. The selection of cutting parameters for obtaining higher cutting efficiency or accuracy in wire-EDM turning process is still not fully solved. This is due to the complicated stochastic process mechanisms in wire-EDM turning process. Stainless steel k316 is used in this investigation as one of the materials that is hard to be machined using traditional machining processes, so the suitable value of parameters need to study to get high material removal rate or high quality in surface finish.

1.2 Objectives:

1. To investigate the effect of CNC-EDM wire cutting parameters for turning operation on material removal rate and surface roughness of stainless steel k316 using longitudinal and cross feed.
2. To find the dependent parameters that affects the material removal rate and surface roughness.
3. To deduce equations interpreting the relationship between the different variables and the material removal rate and surface roughness.
4. To find the optimum cutting condition to obtain maximum material removal rate or better surface quality.

2. Literature review

2.1 Introduction to nontraditional manufacturing processes

Nontraditional machining processes, such as Electrical Discharge Machining (EDM), Electrochemical Machining (ECM), Laser Beam Machining (LBM), Abrasive Water Jet Machining (AWJM), Abrasive Flow Machining (AFM), and hybrid machining processes provide one of the best alternatives, and sometimes the only alternative for machining a growing number of high-strength, corrosion resistant, and wear resistant materials. Many advanced materials such as super alloys, engineering ceramics and metal matrix composites cannot be machined by traditional methods, or at best they are machined with excessive tool wear and at high cost. The complexity and required surface quality of machined parts, tools and geometries, such as deep internal cavities, may only be produced by these advanced or nontraditional manufacturing processes. These processes are rapidly gaining importance in producing complex parts from a variety of material such as super alloys, ceramics, plastics, fiber reinforced composites, wood and textiles in diverse applications throughout the aerospace, automotive, electronics and medical industries, i.e. essentially all competitive manufacturers of durable goods, [1].

This research deals mainly with Electrical Discharge Machining (EDM) processes and related machine tools. A brief introduction of each process is followed by the summary of recent research and development reported worldwide.

2.2 Electric discharge machining process

2.2.1 Introduction to the process

EDM is a non-traditional process that is used to remove metal through the action of an electrical discharge of short duration and high current intensity between the tool (electrode) and the workpiece. There are no physical cutting forces between the tool and the workpiece. This process is finding an increasing demand owing to its ability to produce geometrical complex shapes as well as its ability to machine hard materials that are extremely difficult to machine when using conventional