



UNIVERSITY TECHNICAL MALAYSIA MELAKA

Investigation of surface roughness and accuracy in EDM wire-cut processes

Thesis submitted in accordance with the requirements of the University Technical
Malaysia Melaka for the Bachelor Degree of Manufacturing Engineering in
Manufacturing Process

By

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ABSTRACT

The experimental study presented in this paper aims 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 several types of steel material with desired thicknesses. The test specimens have been cut by using different cutting and offset parameter combinations of the “Mitsubishi RA90” wire electrical discharge machine in the University Technical Malaysia Melaka CNC center lab. The surface roughness of the testpieces has been measured by using a surface roughness measuring device. The related tables and charts have been prepared for material type, wire diameter and wire type. The tables and charts can be practically used for EDM parameter selection for the desired workpiece surface roughness.

DEDICATION

Specially dedicated to my beloved father, Tengku Bahanuddin Bin tengku Sulong and my mother, Meriam Binti Ramli and who are very concerns, understanding patient and supporting, thank you for everything to my supervisors, Mr. Raja Izamshah Bin Raja Abdullah, my sisters, brother and all my friends. The work and success will never be achieved without all of you.

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CHAPTER 1

INTRODUCTION

1.1 Background

In wire electrical discharge machining (WEDM), the cost of machining is rather high due to a high initial investment for the machine and the cost of the wire which is used as a tool in this process. The WEDM process is economical if it is used to cut complex workpieces and difficult to machine materials. In manufacturing die and mold components like sheet metal press dies, extrusion dies, etc., prototype and special form inserts manufacturing, WEDM is commonly used.

As surface roughness is one of the most important parameters in manufacturing, various investigations have been carried out by several researchers for improving the surface roughness of the WEDM process. These investigations show that the surface roughness of the process is closely dependent on the machining parameters. However, the published papers available do not provide any specific information on the selection of machining parameters for various machining conditions and materials.

Since WEDM is a necessary process with a high cost, it is required that the appropriate machining parameters are selected for an economical machining operation. The machining parameters can be set for optimum machining with the knowledge of the effect of the machining parameters on the surface roughness of the process, as a result of the experimental study.

1.2 Objectives

The objectives of this investigation are:

1. To study the relationship between the surfaces roughness values and cutting parameters such as feed rate and voltage.
2. To study about another factor that maybe influences the surface roughness result.

1.3 Scope of project

The scope of this project is to perform the machining operation using CNC WEDM. Next, is to identify the surface roughness value of the work piece that was cut in the different value of cutting parameter. Beside that to look up another factor that maybe happens in the machining operation that influences the surface roughness result.

CHAPTER 2

LITERATURE REVIEW

2.1 WEDM

This section provides the basic principle of the WEDM process and the variations of the process combining other material removal techniques.

2.1.1 WEDM process

The material removal mechanism of WEDM is very similar to the conventional EDM process involving the erosion effect produced by the electrical discharges (sparks). In WEDM, material is eroded from the workpiece by a series of discrete sparks occurring between the workpiece and the wire separated by a stream of dielectric fluid, which is continuously fed to the machining zone. However, today's WEDM process is commonly conducted on workpieces that are totally submerged in a tank filled with dielectric fluid. Such a submerged method of WEDM promotes temperature stabilisation and efficient flushing especially in cases where the workpiece has varying thickness. The WEDM process makes use of electrical energy generating a channel of plasma between the cathode and anode, and turns it into thermal energy at a temperature in the range of 8000–12,000 °C or as high as 20,000 °C initializing a substantial amount of heating and melting of material on the surface of each pole. When the pulsating direct current power supply occurring between 20,000 and 30,000 Hz is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulating

dielectric fluid to implore the plasma channel and flush the molten particles from the pole surfaces in the form of microscopic debris.

While the material removal mechanisms of EDM and WEDM are similar, their functional characteristics are not identical. WEDM uses a thin wire continuously feeding through the workpiece by a microprocessor, which enable parts of complex shapes to be machined with exceptional high accuracy. A varying degree of taper ranging from 15° for a 100 mm thick to 30° for a 400 mm thick workpiece can also be obtained on the cut surface. The microprocessor also constantly maintains the gap between the wire and the workpiece, which varies from 0.025 to 0.05 mm. WEDM, eliminates the need for elaborate pre-shaped electrodes, which are commonly required in EDM to perform the roughing and finishing operations. In the case of WEDM, the wire has to make several machining passes along the profile to be machined to attain the required dimensional accuracy and surface finish (SF) quality. Kunieda and Furudate tested the feasibility of conducting dry WEDM to improve the accuracy of the finishing operations, which was conducted in a gas atmosphere without using dielectric fluid. The typical WEDM cutting rates (CRs) are 300 mm²/min for a 50 mm thick D2 tool steel and 750 mm²/min for a 150 mm thick aluminium, and SF quality is as fine as 0.04–0.25 μ Ra. In addition, WEDM uses deionised water instead of hydrocarbon oil as the dielectric fluid and contains it within the sparking zone. The deionised water is not suitable for conventional EDM as it causes rapid electrode wear, but its low viscosity and rapid cooling rate make it ideal for WEDM.

2.1.2 Hybrid machining processes

There are a number of hybrid machining processes (HMPs) seeking the combined advantage of WEDM with other machining techniques. One such combination is wire electrical discharge grinding (WEDG), which is commonly used for the micro-machining of fine rods utilized in the electronic circuitry. 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 to minimize the wire vibration. Therefore, it is possible to grind a rod that is as small as 5 μm in diameter with high accuracy, good repeatability and satisfactory straightness. Other advantages of WEDG include the ability to machine a rod with a large aspect ratio, maintaining the concentricity of the rod and providing a wider choice of complex shapes such as tapered and stepped shapes at various sections. Several authors have employed the WEDG process in the micro-machining of fine electrodes or pins with a large aspect-ratio, which are difficult to be machined by traditional precision micro-machining methods such as Micro-EDM, LIGA and excimer laser drilling.

Some of the HMPs seek to improve the WEDM performance measures such as the surface integrity and the CR. For example, the ultrasonic vibration is applied to the wire electrode to improve the SF quality together with the CR and to reduce the residual stress on the machined surface. On the other hand, the wire electrochemical grinding (WECG) process replaces the electrical discharge used in WEDG with an electrochemical solution to produce high SF quality part for a wide range of machining condition. Masuzawa et al. compared the SF quality obtained from the WECG with WEDG, which is suitable for finishing micro-parts. A rotary axis is also added to WEDM to achieve higher material removal rate (MRR) and to enable the generation of free-form cylindrical geometries. The effects of the various process parameters such as part rotational speed, wire feed rate and pulse on-time on the surface integrity and roundness of the part produced have been investigated in the same feasibility study.

2.2 WEDM applications

This section discusses the viability of the WEDM process in the machining of the various materials used particularly in tooling applications.

2.2.1 Modern tooling applications

WEDM has been gaining wide acceptance in the machining of the various materials used in modern tooling applications. Several authors have investigated the machining performance of WEDM in the wafering of silicon and machining of compacting dies made of sintered carbide. 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. The results show that the WEDM process is capable of generating precise and intricate profiles with small corner radii but a high wear rate is observed on the diamond wheel during the first grinding pass. Such an initial high wheel wear rate is due to the over-protruding diamond grains, which do not bond strongly to the wheel after the WEDM process. The WEDM of permanent NdFeB and 'soft' MnZn ferrite magnetic materials used in miniature systems, which requires small magnetic parts, was studied by comparing it with the laser-cutting process. It was found that the WEDM process yields better dimensional accuracy and SF quality but has a slow CR, 5.5 mm/min for NdFeB and 0.17 mm/min for MnZn ferrite. A study was also done to investigate the machining performance of micro-WEDM used to machine a high aspect ratio meso-scale part using a variety of metals including stainless steel, nitronic austenitic stainless, beryllium copper and titanium.

2.2.2 Advanced ceramic materials

The WEDM process has also evolved as one of the most promising alternatives for the machining of the advanced ceramics. Sanchez et al. provided a literature survey on the EDM of advanced ceramics, which have been commonly machined by diamond grinding and lapping. In the same paper, they studied the feasibility of machining boron carbide (B₄C) and silicon infiltrated silicon carbide (SiSiC) using EDM and WEDM. Cheng et al. also evaluated the possibility of machining ZrB₂ based materials using EDM and WEDM, whereas Matsuo and Oshima examined the effects of conductive carbide content, namely niobium carbide (NbC) and titanium carbide (TiC), on the CR and

surface roughness of zirconia ceramics (ZrO_2) during WEDM. Lok and Lee have successfully WEDMed sialon 501 and aluminium oxide–titanium carbide (Al_2O_3 –TiC). However, they realized that the MRR is very low as compared to the cutting of metals such as alloy steel SKD-11 and the surface roughness is generally inferior to the one obtained with the EDM process. Dauw et al. explained that the MRR and surface roughness are not only dependent on the machining parameters but also on the material of the part.

An innovative method of overcoming the technological limitation of the EDM and WEDM processes requiring the electrical resistivity of the material with threshold values of approximately $100 \Omega/cm$ or $300 \Omega/cm$ has recently been explored. There are different grades of engineering ceramics, which König et al. classified as non-conductor, natural-conductor and conductor, which is a result of doping non-conductors with conductive elements. Mohri et al. brought a new perspective to the traditional EDM phenomenon by using an assisting electrode to facilitate the sparking of highly electrical-resistive ceramics. Both the EDM and WEDM processes have been successfully tested diffusing conductive particles from assisting electrodes onto the surface of sialon ceramics assisting the feeding the electrode through the insulating material. The same technique has also been experimented on other types of insulating ceramic materials including oxide ceramics such as ZrO_2 and Al_2O_3 , which have very limiting electrical conductive properties.

2.2.3 Modern composite materials

Among the different material removal processes, WEDM is considered as an effective and economical tool in the machining of modern composite materials. Several comparative studies have been made between WEDM and laser cutting in the processing of metal matrix composites (MMC), carbon fiber and reinforced liquid crystal polymer composites. These studies showed that WEDM yields better cutting edge quality and has better control of the process parameters with fewer workpiece surface damages.

However, it has a slower MRR for all the tested composite materials. Gadalla and Tsai compared WEDM with conventional diamond sawing and discovered that it produces a roughness and hardness that is comparable to a low speed diamond saw but with a higher MRR. Yan et al. surveyed the various machining processes performed on the MMC and experimented with the machining of Al₂O₃/6061Al composite using rotary EDM coupled with a disk-like electrode. Other studies have been conducted on the WEDM of Al₂O₃ particulate reinforced composites investigating the effect of the process parameters on the WEDM performance measures. It was found that the process parameters have little influence on the surface roughness but have an adverse effect on CR.

2.3 Major areas of WEDM research

The authors have organized the various WEDM research into two major areas namely WEDM process optimization together with WEDM process monitoring and control.

2.3.1 WEDM process optimization

Today, the most effective machining strategy is determined by identifying the different factors affecting the WEDM process and seeking the different ways of obtaining the optimal machining condition and performance. This section provides a study on the numerous machining strategies involving the design of the process parameter and the modeling of the process.

2.3.1.1 Process parameters design

The settings for the various process parameters required in the WEDM process play a crucial role in producing an optimal machining performance. This section shows