PERFORMANCE EVALUATION OF WIRE ELECTRODE DISCHARGE MACHINING (WEDM) ON INCONEL 718

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To my beloved mother and father
Ali bin Mohd Jos
Badariah bt. Md. Noh

My beloved wife and son
Roslina bt. Mamat
Muhammad Ali Imran bin Mohd Nizam

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In the Name Of Allah, the most Gracious and most Compassionate

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ABSTRACT

Superalloys are known as unique materials ever produced in manufacturing industries. It's capable to withstand in high temperature and the excellent resistance in mechanical and chemical degradations. Inconel 718 is one of the superalloy material whichs is which is widely used in aeronautical and aerospace industries. This nickel-based superalloy is a high strength, thermal resistance with extreme toughness and work hardening characteristics materials. It is also noted for its excellent corrosion resistance in many conditions of engineering applications. Due to it extremely tough nature, the machinability studies of this material had been carried out by many researchers for the past few years. This master project presents the machining of Inconel 718 using wire electro-discharge machining with zinc coated brass electrode wire diameter of 0.25mm. The objective of this master project is mainly to investigate the performance of wire electro-discharge machining on Inconel 718. This is done by observing the influence of the various WEDM machining characteristics namely, surface roughness (Ra), sparking gap (Gap), material removal rate (MRR) and cutting speed (CS). A full factorial design of experiment (DOE) approach with two-level was employed to conduct this experiment. Design expert software was used to perform the ANOVA analysis and confirmation test was also conducted to verify and compare the results from the theoretical prediction using software. Overall result showed that pulse duration (ON) was the most significant factor that appeared to influence on all machining characteristics that had been investigated. The experimental results also acceptable due to the results obtain fall in acceptable values with less than 15% of margin error.

ABSTRAK

Superaloi telah diketahui umum sebagai bahan yang unik yang pernah dihasilkan di dalam industri pembuatan. Ianya mampu untuk bertahan pada suhu yang tinggi dan mempunyai ketahanan yang lasak di dalam pelbagai applikasi kejuruteraan. *Inconel 718* adalah salah satu bahan superaloi yang digunakan secara meluas terutamanya di dalam industri aeronatikal dan angkasa lepas. Superaloi berasaskan bahan *nickel* ini mempunyai kekuatan, rintangan haba dan ketahanan karat yang tinggi serta dicirikan juga dengan pengerasan kerja yang baik. Berdasarkan kepada sifat *Inconel 718* yang tahan lasak, kajian kebolehmesinan bahan ini telah menjadi minat pengkaji sejak beberapa tahun kebelakangan ini. Projek sarjana ini bertujuan untuk menyiasat prestasi kebolehmesinan *Inconel 718* menggunakan proses pemotongan nyahcas-elekrik menggunakan wayar elektrod tembaga bersalut zink berdiameter 0.25mm. Ianya melibatkan ujikaji serta pemerhatian terhadap ciri-ciri pemesinan *Inconel 718* seperti kekasaran permukaan (Ra), jarak percikan api (Gap), kadar pemotongan bahan (MRR) dan kelajuan pemotongan (CS). Rekabentuk ujikaji dengan pendekatan *full factorial* dua tahap telah digunakan di dalam ujikaji ini. Perisian *Design Expert* juga telah digunakan untuk tujuan analisa varian (ANOVA) bagi setiap keputusan ujikaji. Bagi tujuan penentuan ralat, ujikaji pengesahan dilaksanakan untuk menguji kesahihan dan perbandingan diantara keputusan yang dihasilkan oleh ujikaji dan juga secara teori. Secara keseluruhannya, keputusan ujikaji menunjukkan tempoh masa denyutan (ON) adalah faktor yang paling signifikan mempengaruhi semua ciri pemesinan yang dikaji. Data ujikaji juga menunjukkan perbezaan margin di bawah nilai 15% dan ianya adalah didalam julat yang boleh diterima pakai di dalam analisa ini.

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CHAPTER ONE

INTRODUCTION

1.1 Project Background and Rationale

Electrical discharge machining (EDM) is a non-traditional concept of machining which has been widely used to produce dies and molds. This technique has been developed in the late 1940s and has been one of the fast growing methods in manufacturing during 1980s and 1990s [1].

This non-traditional machining method is commonly used for very hard metals that would be impossible to machine with traditional techniques. It has been extensively used, especially for cutting intricate contours or delicate cavities that also would be difficult to produce with a conventional machining methods or tools. However, one critical limitation is that EDM only works with electrically conductive materials. Metal that can be machined by using EDM include nickel-based alloy (such as inconel), hardened tool steels and carbides.

Wire electrical discharge machining (WEDM**)** is introduced in the late 60's. The process was fairly simple, not complicated and wire choices were limited to copper and brass only. WEDM is a thermo-electrical process in which material is

eroded from the workpiece by a series of discrete sparks between the workpiece and the wire electrode (tool) separated by a thin film of dielectric fluid (deionized water) that is continuously fed to the machining zone to flush away the eroded particles. The movement of wire is controlled numerically to achieve the desired three-dimensional shape and accuracy of the workpiece [2]. 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 [3].

In recent years, the technology of wire electrical discharge machining (WEDM) has been improved significantly to meet the requirements in various manufacturing needs, especially in the precision mold and die industry. WEDM is being used to machine a wide variety of miniature and micro-parts from metals, alloys, sintered materials, cemented carbides, ceramics and silicon. This tremendous achievement in WEDM technology has been achieved by many researchers from some of the world leading institution and research centre, but still cannot coped with the new materials introduced to the market.

The selection of cutting parameters for obtaining higher cutting efficiency or accuracy in WEDM is still not fully solved, even with the most up-to-date CNC WEDM machine. This is mainly due to the nature of the complicated stochastic process mechanisms in wire-EDM. As a result, the relationships between the cutting parameters and the process performance are hard to achieve accurately [4]. There is still lack of research on WEDming of material such as nickel based super alloy which include Inconel 718. It is widely used; mostly in aerospace and marine applications which are classified as difficult to machine material by conventional method due to high cutting temperature and rapid tool wear [5].

1.2 Research Statement

Studies on WEDM using coated wire somehow is limited and manufactures claimed that the outstanding performance is achieved through their lab test. But the results are not disclosed to the public and researcher for further study and understanding. As such the machine materials information and the WEDM parameters setting for the subjected wire are somehow limited. The only information given/set by manufactures is commonly applicable to the common steel grades [6].

Inconel 718 is a high strength and thermal resistance (HSTR) [7] known to play increasingly important in the aviation, space navigation and shipping industries because of its outstanding multi-properties [8]. Broad bases of Inconel 718 knowledge are now exist due to its great acceptance in industries. However, the parameter setting on WEDM of Inconel 718 is still lacking. The available technological data which is based on manufacturers for in house experimentation is helpful but insufficient.

Inconel 718 is assigned to be machined with WEDM in this project with the attention to study the parameters setting for an optimum machining. A comparative study will be carried out between previous study using brass wire and the proposed study using coated wire electrode.

1.3 Research Objectives

The objectives of the research are:

a. To determine the significant parameters that influences the machining responses during Wire Electro-Discharge Machining (WEDM) of Inconel 718.
b. To evaluate the performance of Electro-Discharge Machining (WEDM) on Inconel 718 with respect to various responses such as spark gap, material removal rate, cutting speed and surface finish.
c. To establish mathematical model for spark gap, surface finish, cutting speed and material removal rate during WEDM of Inconel 718 alloy.

1.4 Scope of Study

The scope of the research consists of:

a. Wire Electro-Discharge Machining, (WEDM) linear motor 5-axis – Sodick series AQ537L will be employed.
b. Nickel based superalloy, Inconel 718 will be used as the workpiece material.
c. Zinc coated brass wire of diameter 0.25mm will be used as electrode.
d. Parameters to be studied include voltage, peak current, pulse duration and interval time.
e. Response variable to be study are surface finish, spark gap, material removal rate and cutting speed.
f. The DOE and analysis of variance (ANOVA) will be processed using Design Expert software version 7.0.0.

1.5 Expected Results

The expected outcomes of this study are as follows:

a. To obtain the optimum condition for WEDM on Inconel 718 in various parameters setting using zinc coated brass wire.
b. Establishment of mathematical models for various responses during WEDM on Inconel 718
c. The outcome of the study can be used to assist the industrial practitioners that involved in machining of superalloy materials such as nickel alloys and to select the most suitable cutting parameters for machining nickel alloys application.
d. This will help in improving the quality of Inconel products as well as minimizing the machining cost to realize the economical potential to the fullest.