WIRE ELECTRICAL DISCHARGE MACHINING OF Ti-48Al INTERMETALIC ALLOYS USING TAGUCHI APPROACH

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To my beloved mother, wife and my kids

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In the name of Allah, the most Gracious and most Compassionate

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ABSTRAK

Kajian ini telah dijalankan dengan menggunakan proses pemesinan dawai nyah cas elektrik ke atas sebatian antara logam Ti-48Al. Sebatian antara logam Ti-48Al boleh dikategorikan sebagai bahan ringan yang mempunyai kekuatan dan ketahanan yang tinggi diketahui menimbulkan cabaran yang besar semasa pemesinan konvensional atau pun bukan konvensional. Pemesinan dawai nyah cas electric (WEDM) agak dominan diantara proses pemesinan bukan konvensional dijangkakan penggunaannya akan lebih meluas disebabkan sifat-sifat dan kelebihan ke atas bendakerja. Projek ini dilakukan untuk mengkaji prestasi pemotongan dawai nyah cas elektrik dengan menggunakan dawai tembaga bergaris pusat 0.2 mm. Parameter pemesinan yang diuji ialah tempoh denyutan (On Time), tempoh denyutan (Off Time), arus puncak, kadar suapan mesin dan voltan rujukan mesin. Kesan perubahan parameter yang diuji terhadap respon seperti kelajuan pemotongan, kadar pembuangan bahan (MRR), kemasan permukaan dan keluasan lurah pemotongan (kerf) juga dikaji. Kajian ini juga dijalankan untuk menentukan kombinasi parameter yang optimum untuk memesin sebatian antara logam dengan menggunakan kaedah Taguchi sebagai alat rekabentuk ujikaji. Aturan ortogan L_8 digunakan dalam kaedah Taguchi dan keputusan ujikaji dinilai menggunakan analisa variasi (ANOVA). Keputusan ujikaji mendapati kadar suapan mesin merupakan parameter yang paling signifikan terhadap keempat-empat respon yang diuji.

ABSTRACT

This study investigates the wire electrical discharge machining (WEDM) of Ti-48Al intermetallic alloys. Ti-48Al is intermetallic alloys which are categorized as lightweight material, posses greater strength and toughness are usually known to create major challenges during conventional and non-conventional machining. Wire electrical discharge machining (WEDM) which is very prominent amongst the non-conventional machining methods is expected to be used quite extensively in machining titanium aluminides (Ti-Al) alloys due to favorable features and advantages that it can offer. This project was under taken to study the machining performance of WEDM on Ti-48Al by using 0.2mm brass wire. The machining parameter was be studied including pulse on time, pulse off time, peak current, servo reference voltage and servo feed rate. The effect of those varying parameters on the machining responses such as cutting speed, material removal rate (MRR), surface finish and width of kerf was investigated. This study presents an attempt to determine the optimum combinations of WEDM process parameters in machining Ti-48Al intermetallic by using the Taguchi Methodology as parametric design tool. An L_8 orthogonal array was employed in this study and the results were statistically evaluated using analysis of variance (ANOVA). Result showed that servo feed rate was the most significant parameter that influence the machining responses of Ti-48Al.

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LIST OF SYMBOLS / NOMANCLATURES

A	-	ampere
ANOVA	-	Analysis of variance
CS	-	Cutting Speed
DOE	-	Design of Experiment
DOF	-	Degree of Freedom
EDM	-	Electrical Discharge Machining
EDX/EDS	-	Energy Dispersive Spectroscopy Microanalysis
FESEM	-	Field Emission Scanning Electron Microscope
gm	-	gram
HAZ	-	Heat affected zone
in.	-	inch
IP	-	Peak current
Min	-	minutes
Mm	-	millimeter
MRR	-	Material Removal Rate
MSD	-	Mean Square deviation
OA	-	Orthogonal array
OFF	-	Off time
ON	-	On time
QC	-	Quality characteristic
Ra	-	Surface roughness mean deviation
S/N	-	Signal to noise ratio

SEM	-	Scanning Electron Microscope
SF	-	Servo Feed Rate
SV	-	Servo Reference Voltage
TiAl	-	Titanium aluminide
V	-	Voltage
WEDM	-	Wire Electrical Discharge Machining
WK	-	Flushing rate
WS	-	Wire speed
WT	-	Wire Tension
α	-	Alpha
γ	-	Gamma
μm	-	Micrometer
μs	-	Microsecond

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CHAPTER 1

INTRODUCTION

1.1 General Review

Wire electrical discharge machining (WEDM) has been found to be an extremely potential electro-thermal process in the field of conductive material machining. Owing to high process capability it is widely used in manufacturing of cam wheels, special gears, stators for stepper motors, various press tools, dies and similar intricate parts. Selection of optimum machining parameter combinations for obtaining higher cutting efficiency and other dimensional accuracy characteristics is a challenging task in WEDM due to presence of large number of process variables and complicated stochastic process mechanism. Hence, there is a demand for research studies which should establish a systematic approach to find out the optimum parametric setting to achieve the maximum process criteria yield for different classes of engineering materials. An effective way to solve this state of problem is to focus on establishing the relationship between machining input parameters and machining criteria performances. A number of research works has been carried out on different materials to study the influence of different process parameters on EDM and WEDM [1].

In the present research study wire electrical discharge machining of γ-titanium aluminide alloy (Ti-48 Al-4Cr (at. %)) has been considered. The material is attracting considerable interest now a day due to their high temperature strength retention, low-density, excellent resistance to ignition and good creep and oxidation resistance. TiAl-based alloys are potential candidates for replacing Ti-based and Ni-based superalloys for structural applications in the range of 400 ^{o}C–800 ^{o} C [2]. This alloy is of great interest in aerospace and automobile industries. Most of these components have performed well in laboratory tests as well as in the field. Engine valves, turbine blades, airframes, seal supports and cases are some examples [3]. But like other intermatallics these alloys are not ductile and have low fracture toughness at room temperature which makes them difficult to fabricate [4]. Further it is found that it is extremely difficult to machine by conventional method due to its excellent strength property.

Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. This practical technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non-contact technique of material removal. Since the introduction of the process, WEDM has evolved from a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish quality. Over the years, the WEDM process has remained as a competitive and economical machining option fulfilling the demanding machining requirements imposed by the short product development cycles and the growing cost pressures. However, the risk of wire breakage and bending has undermined the full potential of the process drastically reducing the efficiency and accuracy of the WEDM operation. A significant amount of research has explored the different methodologies of achieving the ultimate WEDM goals of optimizing the numerous process parameters analytically with the total elimination of the wire breakages thereby also improving the overall machining reliability.

The purpose of the research project is to investigate the machinability of Titanium Aluminides intermetallic alloys (Ti-Al) using wire-cut EDM process. By using the selected parameters WEDM such as pulse on-time, pulse off-time, peak current, servo reference voltage, servo speed, wire speed and dielectric pressure flushing as a factor to get the good performance machining of the Ti-48Al-4Cr ternary alloys. The resulting surface roughness of the Wire EDM surface and material removal rate (MRR) will be investigated to determined the optimum wire EDM conditions for obtaining Taguchi techniques of experimental design process were developed to predict the effect of wire EDM parameters on surface roughness, cutting speed and material removal rates.

1.2 Objective

To establish the optimum combinations of WEDM process parameters which are able to provide high material removal rate, fastest cutting speed, finest surface finish and smaller width of slit (kerf) in machining of Ti-48Al and investigate the surface characteristic due to the WEDM process of Ti-48Al.

1.3 Scope

The scope of this project is as follow:

1. Ternary alloys Ti-48Al will be studied using 0.2 mm brass wire

2. To investigate quality attributes of wire EDM machining including surface roughness, material removal rates, cutting speed, kerf , recast layer and microcracks.
3. The machining variables to be investigate include on time, off time, peak current, servo feed rate and servo reference voltage
4. To apply the Taguchi method in the designation of experiment.

1.4 Background of the problem

WEDM process is used to achieve high accuracy, fine surface finish, high removal rate and increased productivity. However there are some problems that might occur when we do WEDM process such as bad surface finish, wire breakage, microcracks and others. The problem still happened even the skilled operator is used. It is difficult to achieve the optimal performance machining. These problems made the product have bad surface finish, low mechanical strength and other problems.

In Present, most of the WEDM machine manufacturers are able to provide machining condition guidelines, but it is found that these guidelines are only applicable to common material such as steel, copper and aluminium. Advance material like titanium intermetallic is still new and rare in the industry; therefore it is difficult to obtain suitable guidelines which will result in good accuracy and fine surface finish.

It is useful to understand the parameter optimization clearly when machining intermetallic titanium aluminides alloys by using brass wire diameter 0.2 mm. The Taguchi method is used as a tool for experimental design and analysis the result to find optimum condition for observed value of machining characteristics.