UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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PARAMETRIC OPTIMIZATION OF ABRASIVE WATERJET MACHINING (AWJM) ON ALUMINIUM USING TAGUCHI'S METHOD

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Process and Technology) (Hons.)

by

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TAJUK: **PARAMETRIC OPTIMIZATION OF ABRASIVE WATERJET MACHINING (AWJM) ON ALUMINIUM USING TAGUCHI'S METHOD**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Process and Technology) (Hons.). The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

ABSTRACT

Abrasive water jet machining (AWJM) is a non-conventional machining process in which removal of material takes place by impact erosion of high pressure, high velocity of water and entrained high velocity of grit abrasives on a work piece. The purpose of the investigation is to find out the interaction between parameters of AWJM towards the surface roughness during cutting process on aluminium work piece. The experimental approach was based on Taguchi"s method; a design of experiment to select the best combination of control parameters so that the product or process is most robust with respect to noise factors for effective machining process. The focused AWJM parameters in this experiment are Material Thickness and Nozzle distance. The method of orthogonal array in Taguchi"s method will be used to vary the parameter respectively and for each combination, experiments will be conduct. With the help of Minitab 17, the result of surface roughness was organized and analyzed using Taguchi DOE features. The optimum parameter combination was identified by the help of graphical method and the confirmation experiments were carried out using 1-sample T-test statistical method. From the experiment, combination parameter of 5mm nozzle height and 15mm material thickness give the smoothest surface roughness for Mach 2 1313b AWJM.

ABSTRAK

Pemesinan Jet Air Pelelas (AWJM) adalah satu proses pemesinan bukan konvensional di mana penyingkiran bahan berlaku dengan hakisan bahan kesan tekanan tinggi, air berkelajuan tinggi dan pelelas berkelajuan tinggi menghakis di atas bahan kerja. Tujuan kajian adalah untuk mengetahui interaksi antara parameter AWJM terhadap kekasaran permukaan semasa proses pemotongan bahan kerja aluminium. Pendekatan eksperimen berdasarkan kaedah Taguchi itu; reka bentuk eksperimen untuk memilih kombinasi terbaik daripada parameter kawalan supaya produk atau proses yang paling kukuh berkenaan dengan faktor hingar untuk proses pemesinan berkesan. Parameter AWJM yang diberi fokus dalam eksperimen ini adalah ketebalan bahan dan jarak muncung. Kaedah tatasusunan ortogon dalam kaedah Taguchi akan digunakan untuk mengubah parameter masing-masing dan bagi setiap gabungan, eksperimen akan dilakukan. Dengan bantuan Minitab 17, hasil daripada kekasaran permukaan akan disusun dan dianalisis dengan menggunakan ciri-Taguchi DOE. Gabungan parameter optimum telah dikenal pasti dengan bantuan kaedah graf dan eksperimen pengesahan telah dilakukan dengan menggunakan kaedah statistik 1-sampel ujian T kaedah statistik. Daripada eksperimen, jarak muncung 15mm dan ketebalan bahan 5mm memberikan kekasaran permukaan yang terbaik untuk Mach 2 1313b AWJM

DEDICATIONS

To my parents loved that never cease to teach me how to stand with their feet but never tired to stand behind me and prayed that I managed to spend learning the bachelor's degree level. Thanks also to my colleagues where you are constantly helping me and encouraging me when are in distress. I wish a thousand thanks to friends at home I never give up to provide translation and enlightening for me to understand the problems that I have faced. I went through all this is a challenge to myself to be successful in the future. Thanks goes to lecturers who have taught me, Mr. Engr Hanizam bin Hashim, En. Saleh Bin Aboo Hasan, En Mohd Razali bin Md Yunus and other lecturers who were not my call. Do not forget also to assistant engineer who helped me during the workshop. In addition I also say thousands of thanks to the people who helped me and I regard you all as a family on my own. We are all one big family.

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Finally, I would like to thank to any other individual or group that I no longer had also played an important role in doing my final year project and report.

I hope that the report of this final year project will meet the requirements as requested in the format. Thanks.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Water jet cutting machines started to operate in the early 1970s for cutting wood and plastics material and cutting by abrasive water jet was first commercialized in the late 1980s as a pioneering breakthrough in the area of unconventional processing technologies. In the early 1980s, AWJ machining was considered as an impractical application. Today, state-of the art abrasive jet technology has grown into a full-scale production process with precise, consistent results (Korat & Acharya, 2014).

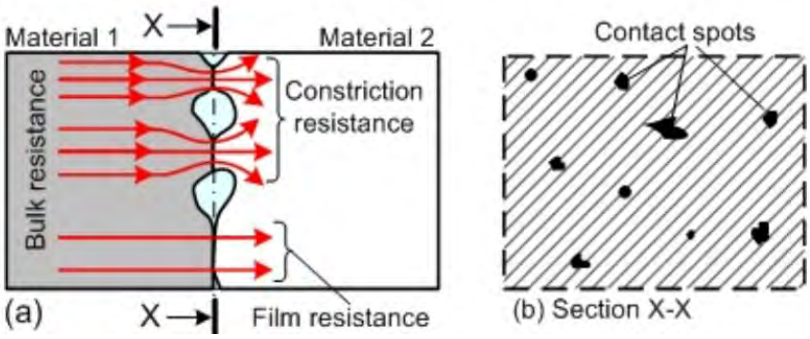
In AWJ machining process, the work piece material is removed by the action of a high-velocity jet of water mixed with abrasive particles based on the principle of erosion of the material upon which the water hits. AWJM is one of the most advanced modern methods used in manufacturing industry for material processing. AWJ has few advantages such as high machining versatility, small cutting forces, high flexibility and no thermal distortion. Comparing with other complementary machining processes, no heat affected zone (HAZ) on the work piece is produced. High speed and multidirectional cutting capability, high cutting efficiency, ability to cut complicated shapes of even non flat surfaces very effectively at close tolerances, minimal heat build-up, low deformation stresses within the machined part, easy accomplishment of changeover of cutting patterns under computer control, etc. are a few of the advantages offered by this process which make it ideal for automation. Due to its versatility, this cutting tool is finding application not only in contour cutting, but also in other machining methods such as drilling, milling, turning, threading, cleaning, and hybrid machining. AWJM is widely used in the processing of materials such as titanium, steel, brass, aluminium, stone, Inconel and any kind of glass and composites. Being a modern manufacturing process, abrasive water jet machining is yet to undergo sufficient superiority so that its fullest potential can be obtained (Korat & Acharya, 2014).

Quality of cutting surface in AWJM is depending on so many process parameters. Process parameter which affect less or more on quality of cutting in AWJM are hydraulic pressure, Standoff distance, types of abrasive, size of abrasives, abrasive flow rate, nozzle diameter, orifice size, and traverse speed. Quality of cutting surface is measured by material removal rate, surface roughness, kerf width, kerf taper ratio (Sreekesh & Dr Govidan, 2014).

AWJM have certain advantageous characteristics, which helped to achieve significant penetration into manufacturing industries. For Example, extremely fast set-up and programming, very small fixture for most parts, machine virtually any 2D shape on any material, very low side forces during the machining, almost no heat generated on the part, and machine thick plates.

1.2 Project Background

Surface roughness is one of the most important criteria which determine the true area of contact with respect to the apparent contact area. It will not only affect the contact resistance but also will affect the mechanical property of the surfaces (Lemu, 2011). Figure 1 shows the representation of the idea.



`Figure 1.0: Apparent contact spots in microscope

This is because contact spots must support the local mechanical pressure that is larger than the yield strength of the materials in contact. The consequence of this high mechanical pressure is that contacting asperities deform permanently, expanding the contact area that allow the contact to take place through shorter and wider peaks (Lemu, 2011). Parts such as gear application require crucial surface roughness for fitting purposes. Though gear parts usually is not thought to be machined using AWJM, a gear tooth is just one particular shape that can be made easily with an AWJM. AWJM has advantages in gear part machining because there is absolutely no mechanical stress, heat distortion or heat-affected zone (HAZ), secondary processing can be eliminated in many cases. Material can be stacked to increase productivity. Setup and fixturing are complete in just minutes (Hasish, 2015).

1.3 Problem Statement

Based on previous research, studies on surface roughness using AWJM are available. However, the studies are not focused on to a single brand of the AWJM and created for general purpose. The purpose of the investigation is to find out the interaction between parameters of AWJM towards the surface roughness during cutting process on aluminium work piece and apply the findings to Mach 2 1313b AWJM.

1.4 Objective

In order to complete the Final Year Project, there are some objectives that must be accomplished. The objectives are:

i. To optimize the parameter of nozzle height and thickness of aluminium in AWJM on surface roughness of the alumimium

ii. To analyze the optimized parameters using Taguchi"s method

iii. To propose the best nozzle height and thickness of aluminium to be applied to Mach 2 1313b AWJM.

1.5 Work Scope

In this project, the experiment will be conducted at FTK Manufacturing Process Laboratory.

The scope of the project is to select the best parameter combination that gives the best result for the surface roughness during cutting process of AWJM. Therefore, the response for this experiment is the surface roughness of the material cut. Machine used is FLOW Abrasive Water Jet type MACH 2 1313b. Material that will be used for the cutting test is aluminium and the dimension of the work piece will be specified in Chapter 3, Methodology. The control parameter of the machine that will be used during cutting process is material thickness and the nozzle distance. Constant parameter in this project is jet impact angle on 90°, Garnet Mesh 80 as the type of abrasive material, cutting pressure of 50,000 Psi. The surface roughness of the material cut will be measured using Mitutoyo SJ-410.

CHAPTER 2
LITERATURE REVIEW

In this chapter, the summary of the literature review for this research is presented. The literature review provides background information and thus to determine the objectives of the present project. It will give part in order to get that information. The study on surface roughness of the cutting surface work pieces by using AWJM has been discussed in the previous research findings.

2.1 Abrasive Water Jet Machining

Abrasive water jet machining is a mechanical, non-conventional machining method in which abrasive particles such as Silica sand, Garnet, Aluminium oxide, Silicon carbide are entrained in high speed water jet to erode materials from the surface of material. About 90% of machining is done by using garnet as abrasive particle. In AWJM material removal take place by erosion induced by the impact of solid particles. Material removal occurs by cutting wear and deformation wear, cutting wear defines erosion at smaller impact angle. (Sreekesh & Dr Govidan, 2014)

High velocity of water is used to entrain and accelerate abrasive particles such as garnet or silica sand to achieve the needs for machining of material such as metals, ceramics, composites and others. Figure 2.0 and 2.1 shows the image of Mach 2 1313b AWJM and its controller.

Figure 2.0: Mach 2 1313b AWJM
Source of image:
http://www.flowwaterjet.com/~/media/Images/waterjet/waterjet/product%20detail/mach-2/pop-ups/PopUp_Mach2_1313b.ashx?la=en

Figure 2.1: Controller of Mach 2 1313b AWJM
Source of image: http://www.flowwaterjet.com/en/waterjet-cutting/cutting-systems/mach-2/cutting-systems/Mach%202b%20Models.aspx

2.1.1 Component of Abrasive Water Jet Machine (AWJM)

In Figure 2.2, shows the typical component that is available in abrasive water jet machine. Typically AWJM system includes high pressure pump, nozzle assembly, abrasive delivery system, catcher system, motion system, and control unit.

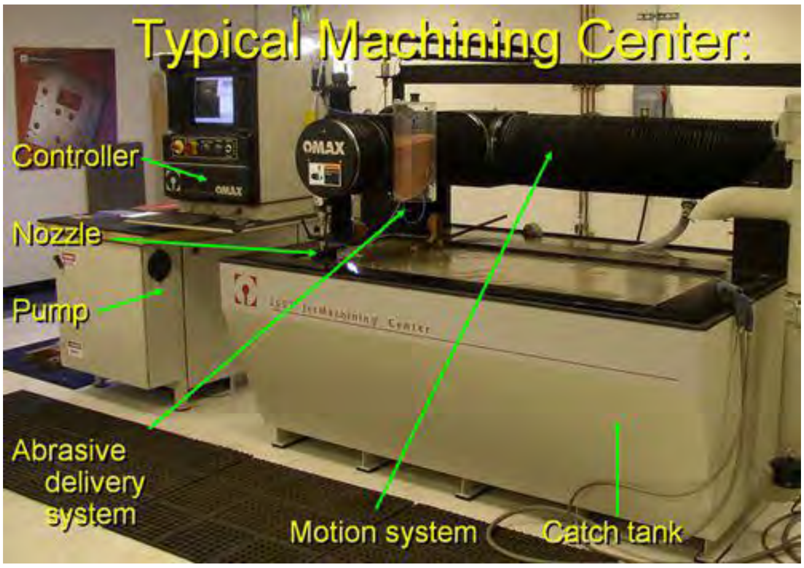


Figure 2.2: Component of Abrasive Water Jet Machine

Source: What goes into a water-jet. Written by Staff of Water Jets.org 2014.Web 6 May 2014<http://waterjets.org/>

Figure 2.3 below shows the cross section view of nozzle assembly. Nozzle assembly houses the water jet orifice and mixing tube that provide coherence and direction to the jet streams. The estimates speed is about 900 m/sec. The diameter of emitted jet is adjusted by using a sapphire jewel assembly. The diameter of sapphire jewel range from 0.076 mm to 0.51 mm. Water and abrasive are mixed and accelerated in tungsten carbine focusing nozzle (Summers, 2011)

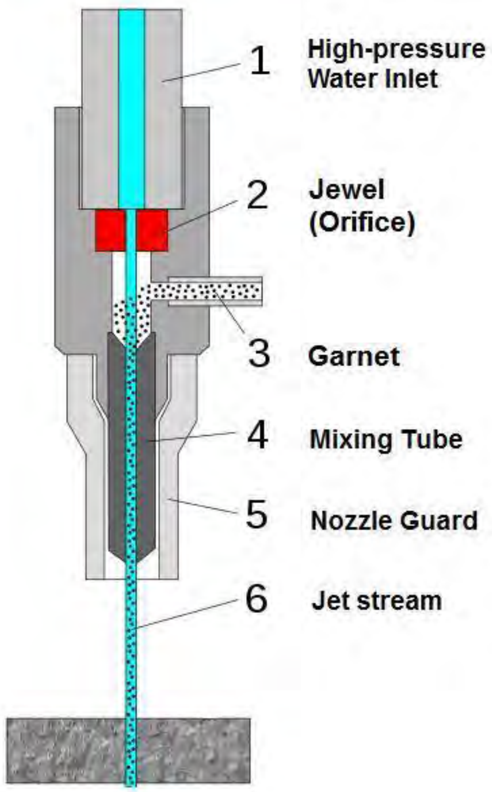


Figure 2.3: Cross section view of abrasive water jet nozzle

Source: https://multicamcanada.files.wordpress.com/2011/11/nozzle_waterjet.jpg

2.1.2 Mechanism of Abrasive Water Jet Machine

The operation of a water jet can be simplistically stated as a pump that pressurizes water up to 410 MPa (60 ksi) and delivers the water through a small orifice, ranging in size from 0.13 mm (0.005 in.) to 1.32 mm (0.052 in.) in diameter, as a continuous stream. This continuous stream of water is traveling at velocities approaching 825 m/s (3000 US) and impacts the target material, causing erosion at a rate dependent on the mass and velocity of the water and the yield strength of the target material. The numbers of components used in a water jet are few and appear deceptively simple. What is difficult to show in this diagram is the stress on the equipment and the precision machining necessary for the system to remain reliable over a long period. For instance, the typical water jet orifice, used in our operations is manufactured from sapphire, and some of them, for ultrahigh-pressure work, must be manufactured from diamond in order to withstand the stress (Miller, 1992).

Figure 2.4 below shows the schematic system of AWJM cutting mechanism. The pressure is generated from the system creates water with high velocity to be used to cut material intended.

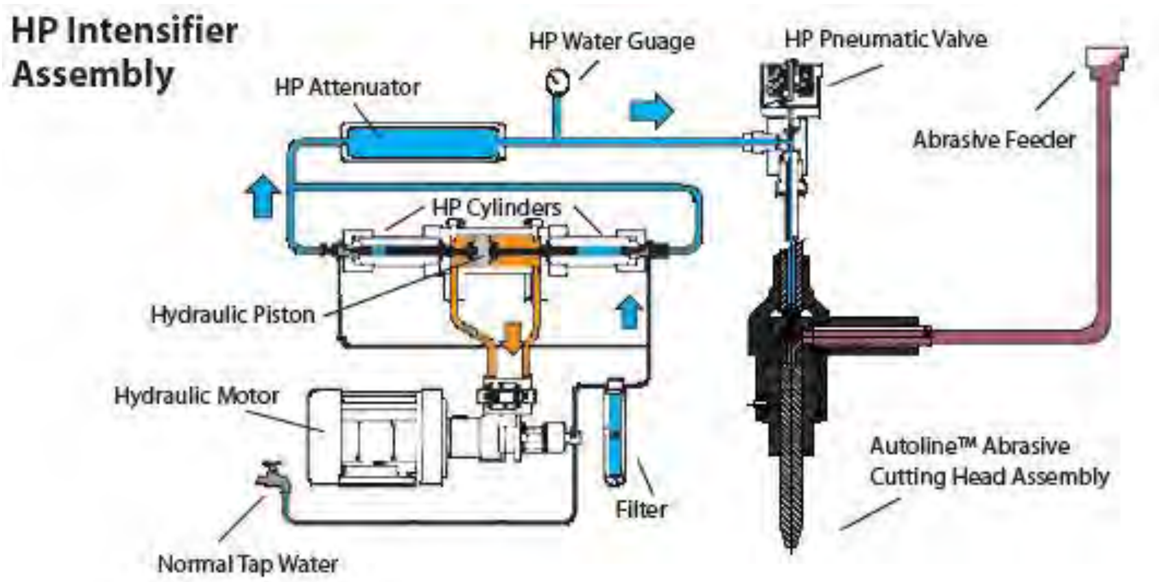


Figure 2.4: schematic figure of AWJM cutting mechanism

The abrasive water jet utilizes the basic water jet concept and augments it with the introduction of abrasives aspirated through a venturi section. The abrasives and water are mixed in a short mixing tube, typically made of carbide or some ceramic, and the mixture discharged toward the target. The abrasive grains act as individual single-point cutting tools similar in action to that of a sandblaster. In the case of an abrasive water jet, the grains of abrasive are accelerated by water instead of air to a high velocity (although significantly less than the jet velocity) and impacted upon the target material. The target is both cut and worn away by the abrasives and the machining debris is flushed away by the water stream (Miller, 1992)

2.1.3 Abrasive

The size, shape and work piece material also the desired finish are the factors that influence the choice of the abrasive. The hardness or roughness of the abrasive cause the high value of surface roughness. Moreover, large size of abrasive removes too much material and leave undesired scratch marks. Meanwhile, finer and soft abrasive leave much finer scratch marks even invisible to naked eye. This means that the surface roughness of cutting material is low. However, finer abrasive will take longer to cut and will cut less deeper than rough abrasive (Ahsan, Noraziaty, & Harnisah, 2005).

Other important to consider when choosing abrasive are the price and availability. Abrasive that used must be able to cut specific materials in short time without neglected the cost of machining as well the surface roughness of cutting surface. From Figure 2.5, the abrasive with size of 80 mesh is use because this micro grain of garnet are perfectly suitable for the water jet cutting in the industrial purpose. Consistency in grain size, hardness and sturdiness give quality for cutting-edge, optimum efficiency as well low in economics (Kovacevic, 1991)

Figure 2.5: Abrasive Grain 80 Mesh

Source:

http://g04.s.alicdn.com/kf/HTB1U6SDHFXXXXXsaXXXq6xXFXXXu/High-purity-80-mesh-garnet-sand-for.jpg_220x220.jpg