UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# SURFACE INTEGRITY OF AISI D2 WHEN MACHINED WITH PLASMA ASSISTED MACHINING

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

by

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TAJUK: **Surface Integrity of AISI D2 when Machined with Plasma Assisted Machining**

SESI PENGAJIAN: **2014/15 Semester 2**

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2015

# APPROVAL

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

………………………………

(Dr. Mohd Hadzley bin Abu Bakar)

# DECLARATION

I hereby, declared this report entitled “Surface Integrity of AISI D2 when Machined with Plasma Assisted Machining” is the results of my own research except as cited in references.

| | | |
|---|---|---|
| Signature | : | ……………………………………………. |
| Author’s Name | : | SHAHRAIN BINTI AHMAD ROZI |
| Date | : | 30 JUNE 2015 |

# ABSTRAK

Kajian ini melaporkan mengenai keutuhan permukaan AISI D2 apabila dimesin menggunakan *"plasma assisted machining"*.Tujuan kajian ini adalah untuk menganalisis mikrostruktur Zon Terjejas Habe (HAZ) dan mikrokekerasan AISI D2 selepas dipanaskan oleh mesin pemotongan plasma. Walaupun ciri-ciri hebat yang dihasilkan oleh kaedah pemotongan plasma, kelemahan dari operasi ini ialah suhu yang tinggi pemotongan plasma mengubah suai keutuhan permukaan bahan. Apabila AISI D2 terdedah kepada suhu tinggi daripada kaedah pemotongan plasma, terdapat perubahan berlaku di bawah permukaan. Disebabkan oleh perubahan mikrostruktur, sifat-sifat di zon sub-permukaan juga berbeza daripada bahan pukal. Perubahan sifat-sifat menjejaskan keutuhan permukaan. Perubahan keutuhan permukaan memberi kesan kepada prestasi bahan Dalam kajian ini, AISI D2 telah dimesin pada keadaan pemotongan yang berbeza seperti tekanan udara, kadar aliran semasa, kadar suapan dan jarak antara *"plasma torch"*dengan bahan kerja .Mesin dan peralatan yang digunakan dalam kajian ini ialah ,mesin "CNC milling" yang dipasang *"plasma torch"*, "*EDM wire cut ","Automatic Buehler Simplimet 3000"* dan mikroskop imbasan elektron (SEM). Dari eksperimen ini, penemuan berikut telah terhasil Kesan daripada suhu operasi yang tinggi oleh pemotongan plasma menghasilkan dua kawasan iaitu Zon Terjejas Haba (HAZ) dan Zon tidak Terjejas(non – HAZ) Haba. Dari kajian ini, didapati bahawa parameter yang paling penting dalam mempengaruhi Zon Terjejas Haba adalah kadar aliran elektrik, diikuti oleh kadar suapan manakala parameter lain kurang memberikan kesan kepada ketebalan HAZ. Selain itu, nilai mikrokekerasan pada kawasan HAZ berbeza dari mikrokekerasan di bahan pukal dimana mikrokekerasan pada kawasan HAZ adalah lebih tinggi daripada mikrokekerasan pada bahan pukal.

# ABSTRACT

This study reports on the surface integrity of AISI D2 when machined using plasma assisted machining. The purpose of this study were to analyse the microstructure, Heat Affected Zone ( HAZ) and microhardness of AISI D2 after heated by plasma cutting. Despite the great qualities produced by plasma cutting, the drawback from this operation was that the high temperature of plasma cutting modify the surface integrity of the material.When AISI D2 was exposed to the hight temperature of plasma cutting operation, there were changes occur at subsurface layer. Due to the alteration of the microstructure, the properties in the sub-surface zone are also different from those of the bulk material. The changes of the properties affects on the surface integrity. The changes of surface integrity affects to the performance of material In this study,AISI D2 was machined at different cutting condition which were current flow rate, feed rates, air pressure and standoff distance.The machine and equipment used in this study were CNC milling machine with plasma torch attach on it, EDM wire cut, Buehler Simplimet 3000 automatic mounting press machine and Scanning Electron Microscopes (SEM). From this experiment, the following findings have been discovered, the effect from the high operating temperature of plasma cutting produced two regions which are Heat Affected Zone and non -Heat Affected Zone. HAZ). The most significant parameter that influence on the HAZ were current flow rate, followed by feed rates. Meanwhile air pressure and stand off distance gave less effect on the thickness of HAZ. Apart from that, the microhardness value at HAZ region varied from the microhardness at the bulk material in which the microhardness HAZ region was much more higher than the microhardness at bulk material.

# DEDICATION

Especially for my beloved father, lovely mother, sister, considerate brother and last but not least my lovely friend as well as housemate for supporting me endlessly in term of courage, motivation and caring until now.

# ACKNOWLEDGMENT

Alhamdulilah, grateful to Allah S.W.T for good health and well being that were necessary to complete this Final Project.

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I take this opportunity to express gratitude to all of the friend for their help and support. I also thank my parents for the unceasin encouragement, support and attention. I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture

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| | | |
|---|---|---|
| AISI D2 | - | Cold Work Tool Steel |
| AMZ | - | Altered Material Zone |
| CNC | - | Computer Numerical Control |
| HAZ | - | Heat Affected Zone |
| Non HAZ | - | Non Heat Affected Zone |
| SEM | - | Scanning Electron Microscope |

# CHAPTER 1
# INTRODUCTION

This chapter presents the background of the project, problem statement, objectives and scopes of this project.

## 1.1 Background of the Project

The trend in manufacturing industry has evolved from using a material that is commonly used in industry into hard to machine advanced material. The rapid growth of advanced materials is due to factor such as it is widely used in various applications due to its excellent properties. Some applications require materials with a certain properties such as high strength, toughness and wear resistant, thus making advanced materials the most desirable materials in industry.

Plasma arc cutting is favorable processes for machining hard to machine materials Sun (2010) states that thermally assisted machined such as plasma arc cutting is the process that uses heat energy for material removal. The material removal is done by means of consuming heat source to heat and soften the workpiece. The yield strength, hardness and strain hardening of the work piece lowered the deformation behavior of the materials that is hard to machine from brittle to ductile**.** Hence, it improves the machinability of hard materials with low machine power consumption, which leads to increase in material removal rate and productivity

It is crucial to satisfy the component performance and reliability. While machining components, it is necessary to satisfy surface integrity requirements. Surface integrity can be classified into two divisions. The first part is surface texture, which is mainly about surface roughness. Another class of surface integrity is called surface metallurgy which provides information about the nature of surface layer produced in machining.

Believing the information relating about machining hard material such as AISI D2 using plasma assisted machining is inadequate, this project was conducted to investigate about the surface integrity of AISI D2 steel when machining using plasma assisted machining. The methodology used in this project is experimental procedures. A device called Scanning Electron Microscope (SEM) is employed to accomplish research objective.

This experimental will be performed by using Plasma Assisted Machining. The parameters that will involve in this plasma cutting process are current, feed rate, air pressure and arc gap. Plasma arc cutter used to cut AISI D2 Tool Steel 100 mm x 100 mm x 20 mm based on the selected parameters setting.

## 1.2 Problem Statement

AISI D2 Tool Steel is the most common material used in cutting tool industry because it exhibit great mechanical properties such as high wear resistance, high strength and toughness. Plasma Cutting is the most ideal machining that is suitable to machined AISI D2. Plasma cutter is a type of machining that utilizes heat as a medium for cutting. In this process, plasma torch use high velocity of ionized gas called plasma to remove metal by melting. Typically, the operating temperature of Plasma is in the range of 20,000° to 50,000° F (11,000° to 28,000° C). Despite the great qualities produced by plasma cutting, however the most common issue arises is that the high temperature of plasma will modify the surface integrity of the material. The material changes occur at the subsurface zones or internal features. The properties at the sub-surface zone are distinctive from the properties at the bulk material. This structure changes is referred to as altered material zones (AMZ) or layers. It is also known as Heat Affected Zone (HAZ). The changes of surface integrity will affect to the performance of materials. Besides, this study is conducted due to the limited study about the surface alteration encountered by AISI D2 using plasma cutting. Besides, this study is conducted due to the limited study about the surface alteration encountered by AISI D2 using plasma cutting.

## 1.3 Objectives

The objectives of this experiment are:

a) To characterize the surface integrity of the AISI D2 when machining using plasma assisted machining.

b) To investigate the effect of the cutting parameters selected of air plasma =cutting on the surface integrity.

## 1.4 Scope of Project

The scope of this project is to perform machining operation for AISI D2 Tool Steel by using Air Plasma Cutting. The parameter varying is air pressure, current, feed rate arc gap. The performance measure to be evaluated is surface integrity.. Analysis about the surface integrity of AISI D2 after machining by using plasma arc cutting is made with the aid of special devices called Scanning Electron Microscope (SEM). Aspect to be covered when evaluating the surface integrity is surface metallurgy which involves microstructure alteration, phase transformation, heat affected zone and microhardness of AISI D2.

# CHAPTER 2

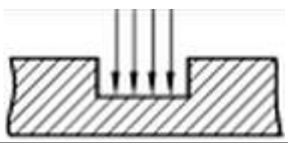
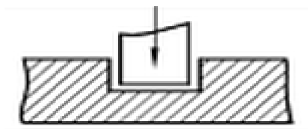
## LITERATURE REVIEW

This chapter covers about general knowledge of this thesis. The aim of literature review is to establish a theoretical framework with substantive findings and methodological contribution to this project which includes all the knowledge such as process, work piece will be explained.

### 2.1 Classification of Machining Process

Machining process can be classified based on the type energy used. Table 2.1 below display the machining process are group according to the type of energy used. Generally the machining processes are classified into three mechanisms of energy which are mechanical, thermal and chemical.

**Table 2.1:** Classification of machining processes based on energy used (Grzesik, 2008)

| Category of Basic Process | Fundamental removal method | Examples of the process |
|---|---|---|
| Mechanical |  | Water Jet Cutting<br>Abrasive Jet Machining |
| |  | Ultrasonic Testing |

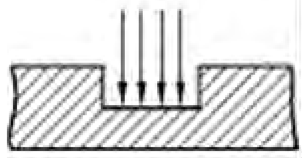
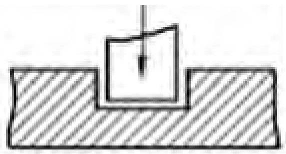
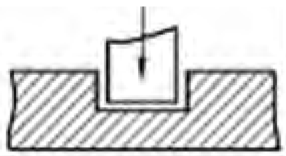
| | | |
|---|---|---|
| Thermal |  | Plasma Arc Machining<br>Electron  Beam Machining<br>Laser Beam Machining |
| |  | Electrical Discharge Machining |
| Chemical |  | Electrochemical Machining |

**Table 2.2:** Comparison of plasma cutting with other cutting methods ( Akkurt, 2009 )

| Comparison Aspect | Plasma Cutting | Laser Cutting | Milling Cutting | Oxygen Cutting |
|---|---|---|---|---|
| Material Thickness | B | C | B | A |
| Cutting Quality | C | A | B | C |
| Lateral feed rate | B | A | B | B |
| Multipurpose Use | B | D | B | C |
| Heat Affected Zone | D | D | B | D |
| Precision Cutting | B | A | A | D |
| Secondary Treatment requirement | B | B | B | C |
| Slurry Formation | C | C | B | B |
| Production Flexibility | C | B | A | D |
| Total machining time | D | B | B | C |

A: Perfect  B : Good C : Acceptable D : Unacceptable

## 2.2 Advanced Machining Thermal Energy Processes

As mentioned earlier in Table 2.1, machining can be divided according to the energy processes. The thermal energy process includes electrical discharge machining, plasma arc machining, laser beam machining and electron beam machining. Material removal processes based on the thermal energy are characterized by very high local temperatures, which is hot enough to remove material by fusion or vaporization. Physical and metallurgical damage on the work surface occurred due to the high temperature utilized in this process. In some cases, thermal energy process produced poor surface finish and secondary machining required to smooth the surface.

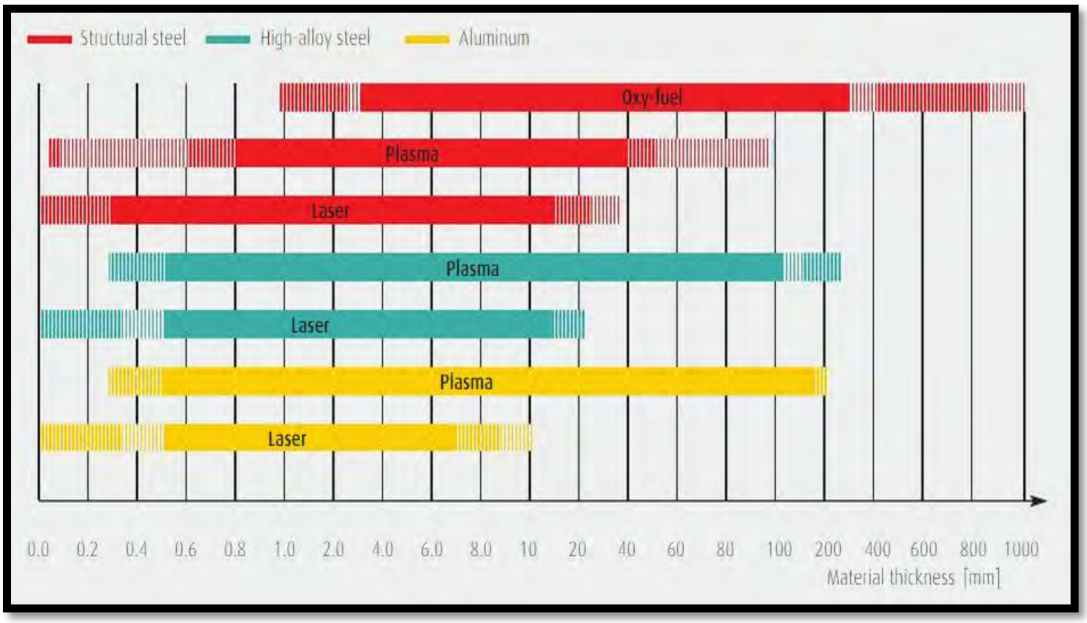



**Figure 2.1:** Areas of application of thermal cutting process (Ahmad, 2011)

## 2.3 Plasma Assisted Machining

The term plasma can be referred as the fourth state of matter after solid, liquid and gas phase. Radovanovic and Madic (2011) states plasma is formed when adding energy to gas state, thus it will cause the changes in physical properties which transform gas state into plasma state. Radovanovic and Madic ( 2011) adds that plasma is a highly ionized, hot gas that composed up of ions, electrons and neutral particle. The transformation state occurs when solid material is heated to a certain temperature. As the temperature increases, the solid transform to liquid and liquid to gas. Further increase in temperature cause the third stage, gas to charged particles, and the material enters the plasma stage.

Solid ⟶ Liquid ⟶ Gas ⟶ Plasma

**Figure 2.2:** Sequence of state transformation (Chattopadhyay, 2004)

According to Chattopadhyay (2004), plasma has been used for a large number of thermally assisted surface engineering processes. The list of surface engineering processes based on plasma includes thermal spraying, welding, vapor phase deposition and includes thermal based non-conventional process, plasma arc cutting.

Plasma Assisted Machining is a concept of non-traditional machining which utilizes the thermal energy as a medium to machining materials. The idea of using hot machining is proposed by Grzesik ( 2008 ) who employed the plasma assisted machining to improve machinability of glasses, engineering ceramics, sintered high speed steel and alloy steel. Plasma assisted machining use extremely high temperature plasma arc to provide controlled source of localized heat, which soften only a small portion of workpiece. Softening of the workpiece zone just in front of the cutting tool releases very high energy densities and confines the heat.

Previously, Azhar ( 2014) have developed the study on the depth of cut produced when machined using plasma assisted machining. In that research the plasma assisted machining was developed by combining the CNC milling machine and Air Plasma Cutting. The purpose of designing this new hybrid machining is to obtain accurate result of plasma cutting. This is because manual plasma cutting is based on labor skill. Thus, consistent result is hard to achieve. Figure 2.3 illustrate the combination of CNC machine with Air Plasma Cutting.

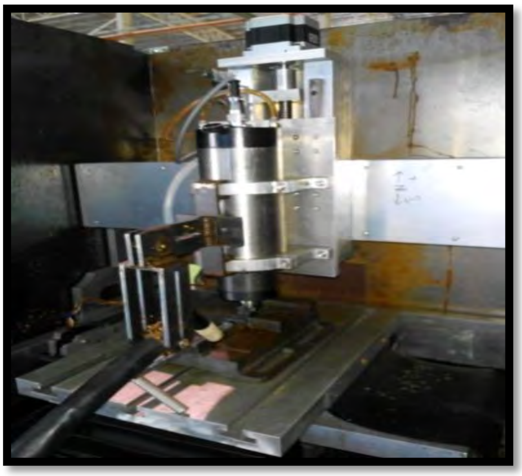


**Figure 2.3.**: Mini CNC Machine with plasma torch attached in front of the spindle

## 2.4 Milling Machine

The mechanism of milling machine is that the material removal is done by removing chips away from the raw material to produce finish product. Milling machine can be divided into two different classes which are vertical and horizontal milling machines. Milling machine can be manually operated or automated by computer numerical control (CNC).

### 2.4.1 CNC Milling Machine

Computer Numerical Control CNC is a machine which widely be used in manufacturing industry. CNC machine is a non-traditional machine where the process of milling, cutting, drilling, shaping and boring that operated by trained engineer have been replaced by computer control machines (Ryan,2004). This means a computer converts the design produced by Computed Aided Design Software (CAD) into a numbers. The numbers will be the coordinate of a graph and act as control the movement of cutter. Therefore, the computer will be control the process of cutting and shaping of material (Ryan,2009).