



**Faculty of Mechanical and Manufacturing
Engineering Technology**

**FABRICATION OF BOTTOM MODULAR NOZZLE FOR ABRASIVE
WATERJET MACHINE BY USING HIGH CARBON STEEL**

Muhammad Izzat Bin Jamal Mohamed

Bachelor of Manufacturing Engineering Technology (Process & Technology)

2018

**FABRICATION OF BOTTOM MODULAR NOZZLE FOR ABRASIVE
WATERJET MACHINE BY USING HIGH CARBON STEEL**

Muhammad Izzat Bin Jamal Mohamed

**This report is submitted in accordance with the requirement of the Universiti Teknikal
Malaysia Melaka (UTeM) for Bachelor of Manufacturing Engineering Technology
(Process & Technology) With Honours**

**Faculty of Mechanical and Manufacturing
Engineering Technology**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Fabrication Of Bottom Modular Nozzle For
Waterjet Machine By Using High Carbon Steel

SESI PENGAJIAN: **2018/19 Semester 1**

Saya **MUHAMMAD IZZAT BIN JAMAL MOHAMED**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. ****Sila tandakan (✓)**

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

Alamat Tetap:

NO 25, JALAN TBC 16,

TAMAN BUKIT CHENG, 775250

MELAKA

(TANDATANGAN PENYELIA)

Cop Rasmi:

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby this project report thesis entitled “Fabrication Of Bottom Modular Nozzle For Abrasive Waterjet Machine By Using High Carbon Steel” is the result of my own research except as cited in the references.

Signature :

Name : **MUHAMMAD IZZAT BIN JAMAL MOHAMED**

Date :

APPROVAL

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

Signature :

Supervisor : **ABD KHAHAR BIN NORDIN**

Date :

ABSTRACT

Inside an abrasive jet machining, the nozzle is one of the most important segments. The wear and tear properties and features of the nozzle occur due to the high pressure of the water and the abrasive grain passing through the nozzle during the cutting process. When the defect in this nozzle occurs, it will indirectly impact the deterioration of the predation result and thereby induce unauthorized changes to the workpiece itself. To improve nozzle life, using high carbon steel material. It will be processed and formed using the EDM Wirecut machine, the lathe machine, and the cylindrical grinding machine. Then it will be given heat treatment where it will be heated at high temperature and then cooled to increase the strength of the substance. After the nozzle is completed, it will undergo trial testing to see the results and will collect the data results of cutting the mild steel with different thickness. Then the nozzle and the surface cutting will be investigated to see the corrosion effect that occurs.

ABSTRAK

Di dalam pemesinan jet air yang kasar, muncung adalah salah satu segmen yang paling penting. Sifat dan ciri-ciri muncung yang mudah haus dan terhakis berlaku kerana disebabkan tekanan yang tinggi daripada air dan bijiran yang kasar yang melalui muncung tersebut semasa proses memotong berlaku. Apabila kecacatan pada muncung ini berlaku, ia secara tidak langsung akan membawa kesan kepada kemerosotan hasil pretasi memotong dan di samping itu menyebabkan perubahan yang tidak diingini kepada bahan kerja itu sendiri. Untuk meningkatkan kehidupan muncung, dengan menggunakan bahan keras iaitu keluli karbon tinggi. Ia akan diproses dan dibentuk menggunakan mesin “EDM Wirecut”, mesin larik, dan mesin “Cylindrical Grinding”. Kemudian ianya akan diberi rawatan haba dimana ia akan dipanaskan pada suhu tinggi dan kemudiannya disejukkan untuk meningkatkan kekuatan bahan tersebut. Selepas muncung siap, ia akan melalui ujian percubaan untuk melihat keberhasilan dan akan dikutip maklumat berkaitan hasil memotong keluli lembut yang berbeza ketebalan. Kemudian muncung dan permukaan dipotong akan dikaji untuk melihat kesan hakisan yang berlaku.

DEDICATION

To my parents, Mr. Jamal Mohamed and Madam Norliza Ahmad I will never finish express thank you for everything you do. I dedicated this report to a family which encourages and supports towards my studies and joyful experience. Also, thanks to my friends because help me to go through my studies. And last but not least, my supervisor, Mr. Abd Khahar Bin Nordin, thanks for teaching and encourage me to become a better person in life. May Allah bless all of them.

ACKNOWLEDGEMENT

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

Alhamdulillah, I praised to Allah S.W.T for giving me opportunity strength to go through this Bachelor Degree Project. Firstly, I want to thanks my parent Mr. Jamal Mohamed Bin Gulam Rasool and Madam Norliza Binti Ahmad for all of their support and unconditionally love to me. Thanks for all of the prayers and I really love you so much. Secondly, I want to give my highest gratitude to my Final Year Project Mr. Abd Khahar Bin Nordin for supervising and supporting me to go through this project. I really appreciate every opinion, advice, and knowledge that you gave to me, it really helps me to become a better person in the future. I'm very thankful for the time that he had been spent for the study and correcting my mistake even though he had a busy working schedule. I also want to thanks all the technician and Universiti Teknikal Malaysia Melaka for allowing me to use the laboratory in order for me to complete my project. I would like to express thank to all my friend because helping directly and indirectly during the project.

TABLE OF CONTENT

| | PAGE |
|---|-------------|
| DECLARATION | ii |
| APPROVAL | iii |
| ABSTRACT | iv |
| ABSTRAK | v |
| DEDICATION | vi |
| ACKNOWLEDGMENT | vii |
| TABLE OF CONTENT | viii |
| LIST OF TABLES | xi |
| LIST OF FIGURES | xii |
| LIST OF ABBREVIATIONS AND SYMBOLS | xiv |
| | |
| CHAPTER 1 INTRODUCTION | 1 |
| 1.0 INTRODUCTION | 1 |
| 1.1 PROJECT BACKGROUND | 3 |
| 1.2 PROBLEM STATEMENT | 3 |
| 1.3 OBJECTIVE | 4 |
| 1.4 WORK SCOPE | 4 |
| 1.5 PLANNING PROJECT | 5 |
| | |
| CHAPTER 2 LITERATURE REVIEW | 7 |
| 2.0 INTRODUCTION | 7 |
| 2.1 TYPE WATER JET CUTTING | 7 |
| 2.2 PART OF ABRASIVE WATER JET MACHINING | 9 |
| 2.2.1 NOZZLE – ABRASIVE WATER JET | 10 |
| 2.2.2 ORIFICE - ABRASIVE WATER JET | 12 |
| 2.2.3 MIXING CHAMBER - ABRASIVE WATER JET | 13 |
| 2.2.4 HIGH-PRESSURE PUMP | 14 |

| | | |
|------------------|--|-----------|
| 2.2.4.1 | LINEAR INTENSIFIER PUMP | 14 |
| 2.2.4.2 | ROTARY DIRECT PUMP | 16 |
| 2.2.5 | CATCHER - ABRASIVE WATER JET | 18 |
| 2.3 | ABRASIVE WATER JET MACHINING OPERATIONAL | 19 |
| 2.3.1 | PARAMETER ABRASIVE WATER JET MACHINING | 21 |
| 2.3.2 | CHARACTERISTIC ABRASIVE WATER JET MACHINING | 22 |
| 2.3.3 | MECHANISM OF MATERIAL REMOVING | 25 |
| 2.4 | ABRASIVE - TYPE OF ABRASIVE | 26 |
| 2.4.1 | WATER - ABRASIVE WATER JET | 28 |
| 2.4.2 | MIXING THE WATER AND ABRASIVE | 28 |
| 2.5 | TYPE OF JET CUTTING NOZZLE | 30 |
| 2.5.1 | MATERIAL OF NOZZLE | 31 |
| 2.5.1.1 | TUNGSTEN CARBIDE | 31 |
| 2.5.1.2 | HIGH CARBON STEEL | 32 |
| 2.5.2 | HARDENING TO HIGH-SPEED STEEL | 33 |
| 2.5.3 | EROSION IN NOZZLE | 33 |
| 2.6 | EDGE QUALITY AWJM | 34 |
| 2.7 | ADVANTAGES AND DISADVANTAGES AWJM | 35 |
| CHAPTER 3 | METHODOLOGY | 37 |
| 3.0 | INTRODUCTION | 37 |
| 3.1 | PROCESS FLOW | 37 |
| 3.2 | MATERIAL PREPARATION | 38 |
| 3.3 | MACHINING PREPARATION | 39 |
| 3.4 | EDM WIRECUT | 40 |
| 3.5 | LATHE MACHINE | 41 |
| 3.5.1 | LIST OF PROCESS IN LATHE | 41 |
| 3.6 | CYLINDRICAL GRINDING MACHINE | 45 |
| 3.7 | HEAT TREATMENT | 46 |

| | |
|---|-----------|
| 3.7.1 HARDENING FROM HIGH CARBON STEEL TO HIGH-SPEED STEEL | 47 |
| 3.8 PREPARATION FOR CUTTING OPERATION ABRASIVE WATER JET | 48 |
| 3.9 TESTING PRODUCT | 51 |
| 3.10 DRAWING EXPLANATION | 51 |
| CHAPTER 4 RESULT AND DISCUSSION | 53 |
| 4.0 INTRODUCTION | 53 |
| 4.1 EXPECTED RESULT | 53 |
| 4.2 DIFFERENT HEAT TREATMENT DIFFERENT OUTCOME | 53 |
| 4.3 PREPARATION FOR TESTING | 55 |
| 4.3.1 FLOW OPERATION TESTING | 55 |
| 4.3.2 CUTTING OPERATION TESTING | 57 |
| 4.4 NOZZLE WEAR AND TEAR | 58 |
| 4.5 CUTTING EDGE DIFFERENT BETWEEN NOZZLE | 59 |
| 4.5.1 CUTTING EDGE USING NORMAL NOZZLE AT MARKET | 60 |
| 4.5.2 CUTTING EDGE USING NOZZLE MODULAR HCS | 62 |
| 4.6 FACTOR THAT EFFECT THE RESULT | 63 |
| 4.7 LIMITATION OF RESEARCH | 64 |
| CHAPTER 5 CONCLUSION | 66 |
| 5.0 INTRODUCTION | 66 |
| 5.1 CONCLUSION | 66 |
| 5.2 RECOMMENDATION | 67 |
| REFERENCE | 68 |
| APPENDIX | 71 |

LIST OF TABLES

| TABLES | TITTLE | PAGE |
|---------------|--|-------------|
| Table 1.1 | Gantt chart PSM 1 | 5 |
| Table 1.2 | Gantt chart PSM 2 | 6 |
| Table 2.1 | Characteristics Of Abrasive Water Jet Cutting | 23 |
| Table 2.2 | Mechanism of Abrasive Water Jet Machine | 25 |
| Table 2.3 | Type of Abrasives Used in Abrasive Waterjet Cutting | 26 |
| Table 4.1 | Comparison HRB value | 54 |
| Table 4.2 | Flow Operation Testing Table using oxyacetylene torch | 56 |
| Table 4.3 | Flow Operation Testing Table using hardening furnace | 56 |
| Table 4.4 | Cutting Operation Testing using nozzle furnace hardening | 57 |
| Table 4.5 | Nozzle wear and tear using oxy acetylene torch | 58 |
| Table 4.6 | Nozzle wear and tear using hardening furnace | 59 |

LIST OF FIGURES

| FIGURES | TITTLE | PAGE |
|----------------|--|-------------|
| Figure 2.1 | Pure water pressure jet | 7 |
| Figure 2.2 | Abrasive water jet | 7 |
| Figure 2.3 | Abrasive waterjet machine part | 9 |
| Figure 2.4 | Nozzle Water Jet | 10 |
| Figure 2.5 | AWJ Nozzle Type | 11 |
| Figure 2.6 | Orifice head | 12 |
| Figure 2.7 | Mixing chamber | 13 |
| Figure 2.8 | Linear Intensifier Pump | 15 |
| Figure 2.9 | Rotary Direct Drive Pump | 17 |
| Figure 2.10 | Type of catcher | 18 |
| Figure 2.11 | Abrasive Water Jet Machine Schematic | 19 |
| Figure 2.12 | The Flow abrasive water jet | 20 |
| Figure 2.13 | Type Of Abrasive | 27 |
| Figure 2.14 | Single jet side feed nozzle and multi-jet feed nozzle | 30 |
| Figure 2.15 | Erosion concentration at the nozzle tube | 34 |
| Figure 2.16 | Edge quality of water jet cut | 35 |
| Figure 3.1 | Flowchart as a guild project | 38 |
| Figure 3.2 | High Carbon Steel Material | 39 |
| Figure 3.3 | EDM Wirecut Machine | 40 |
| Figure 3.4 | Turning Process | 42 |
| Figure 3.5 | Facing Process | 43 |
| Figure 3.6 | Drilling Process | 44 |
| Figure 3.7 | Threading Process | 45 |
| Figure 3.8 | Cylindrical Grinding Machine | 46 |
| Figure 3.9 | Software “flowcut” | 48 |
| Figure 3.10 | Flow Simulation Distance Travel | 49 |
| Figure 3.11 | Setting the water and abrasive inlet, low and high pressure. | 50 |

| | | |
|-------------|---|----|
| Figure 3.12 | Bottom modular nozzle solid work drawing | 52 |
| Figure 4.1 | Graph hardening temperature against time using hardening furnace | 55 |
| Figure 4.2 | cutting surface edge using normal eyes (normal nozzle) | 60 |
| Figure 4.3 | cutting surface edge using stereo microscope SMZ745T (normal nozzle) | 61 |
| Figure 4.4 | cutting surface edge using normal eyes (nozzle modular) | 62 |
| Figure 4.5 | cutting surface edge using stereo microscope SMZ745T (nozzle modular) | 63 |

LIST OF ABBREVIATIONS AND SYMBOLS

| | | |
|------|---|--------------------------------|
| AWJM | - | Abrasive Water Jet Machining |
| AWJ | - | Abrasive Water Jet |
| EDM | - | Electrical Discharge Machining |
| HCS | - | High Carbon Steel |
| HSS | - | High-Speed Steel |
| Mm | - | Millimeter |
| psi | - | Pounds per Square |
| MPs | - | Meter per Second |
| Mpa | - | Megapascal |
| Ksi | - | Kilopound per square inch |
| hp | - | Horsepower |
| kw | - | Kilowatt |
| FTK | - | Fakulti Teknologi Kejuruteraan |
| % | - | Percent |

CHAPTER 1

INTRODUCTION

1.0 Introduction

To disintegrate, dissolve or eliminate an aim material will be using the abrasive water jet machine. It is a machining that will produce the high-pressure water to quicken rough particles which is abrasive and the water for the cutting process. This blend of water, abrasive grain, and the air is fit for slicing the materials from very soft material workpiece to metal, stone, and furthermore pottery. The high-pressure water is quickened completely through a fine hole towards delivering a high-speed stream of water. The section of this stream all through a mixing chamber makes an incomplete vacuum by venturi impact, in addition, to entrains rough particles that are blended at that point quickened in the high-speed water stream inside the nozzle. (Nanduri, Taggart, & Kim, 2002)

AWJM has far above the ground machining versatility plus high flexibility. It is used for cutting an extensive variety of materials. This method is especially very appropriate and also suitable for very soft, brittle plus fibrous materials. This innovation is less delicate to material properties since it does not cause babble. This machinery is generally widely used compared to other non-conventional machinery since of its clear advantages. This method is not going to use much heat generation so the machined surface is at no cost from heat affected zone plus residual stresses. The major disadvantage of this process is, it creates loud noise than a messy working surrounding. (Shah & Patel, 2012)

In the field of abrasive waterjet machining, the nozzle is one of the predominantly critical segments of the machining procedure. Each one of the materials has a divergent property which exhibits the ability of the nozzle toward dragging out its life cycle. Normally, the materials used to make this are tungsten carbide, silicon carbide, boron carbide, tungsten carbide-cobalt and in addition additionally composite carbide. Promptly accessible are different kinds of the nozzle with disparate lengths and widths. (Syazwani, Mebrahitom, & Azmir, 2016)

The nozzle is the most limited lived segment and also basically critical in abrasive waterjet machining, as it will in a straight line affect the performance, precision, functioning in addition to financial matters of the abrasive waterjet machining process. In any case, wear of the nozzle likewise will lead toward the debasement of the nature of the cut surfaces and in addition causes the undesirable changes in the geometry of the workpieces. At that point, the nozzle wear is the impact of the procedure of material disposal as the two surfaces are in sliding contact. (Gupta, 2012)

During the abrasive waterjet machining, the nozzle wear is a typical inconvenience. To handle the issue, a lot of analysts and furthermore producers attempt to solve it. In addition, to enhance the spout life, current nozzle utilizing a tungsten carbide-based material has been made to decrease and lower the wear rate in the product. By utilizing delicate rough materials generally spouts made of hard materials, for example, high carbon steel can decrease the wear too. (Syazwani et al., 2016)

1.1 Project Background

Abrasive Water Jet Machining (AWJM) nowadays has been used in this world because of the convenience of cutting a workpiece in the industrial. The importance of this project is to create the new design of a waterjet nozzle which contains bottom modular. This is to handle the problem that found in the AWJM which is the nozzle is the shortest-lived component. So, this project can overcome the erosion that always makes the nozzle cannot be used for a long time. The nozzle will be produced by using high carbon steel and then going to harden it by heat treatment to become high-speed steel.

1.2 Problem Statement

The nozzle is the most limited lived segment and also basically critical in abrasive waterjet machining because of the erosion and the wear resistant. The factor of the wear resistant and erosion at the nozzle includes abrasive because of type, shape, and size. The orifice diameter and water pressure input into the nozzle also can be the main factor for the problem. The parameter of the nozzle shape will be influenced wear includes the bore diameter, nozzle length.

Beside of that, wear of the nozzle going to prompt the debasement of the nature of the cut surfaces in a roundabout way causes the bothersome changes in the geometry of the workpieces. Other than that, the erosion at the taper also the factor the nozzle cannot use for a long time. And last but not least, the material itself use for the current nozzle also has brittle properties.

1.3 Objective

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

- i. To fabricate the new design of water jet nozzle bottom modular by using high carbon steel.
- ii. To study the erosion of the surface cutting edge material.
- iii. To study the erosion of high carbon steel water jet nozzle.

1.4 Work Scope

In this Final Year Project, the experiment will be conducted at the FTK Manufacturing Process Laboratory by using the Abrasive Water Jet Machine (AWJM) use is modeled Mach2 1313b with 80 mesh of the abrasive size. Meanwhile, the nozzle will be produced are using High Carbon Steel. The software will go to use for this AWJM is Flow Master Software while the catcher tank content is tap water. The workpieces materials are aluminum and mild steel.

From this project, it will collect the data and compare with the data from the existing nozzle that AWJM use in FTK Laboratory. This project will explore the life tools of the nozzle for 30 hours. Indirectly, we can obtain the data cutting for data cutting mild steel for different thickness which is 2mm, 3mm, and 6mm with 5mm nozzle height and lastly to study the erosion of the nozzle by material high carbon steel.

1.5 Planning Project

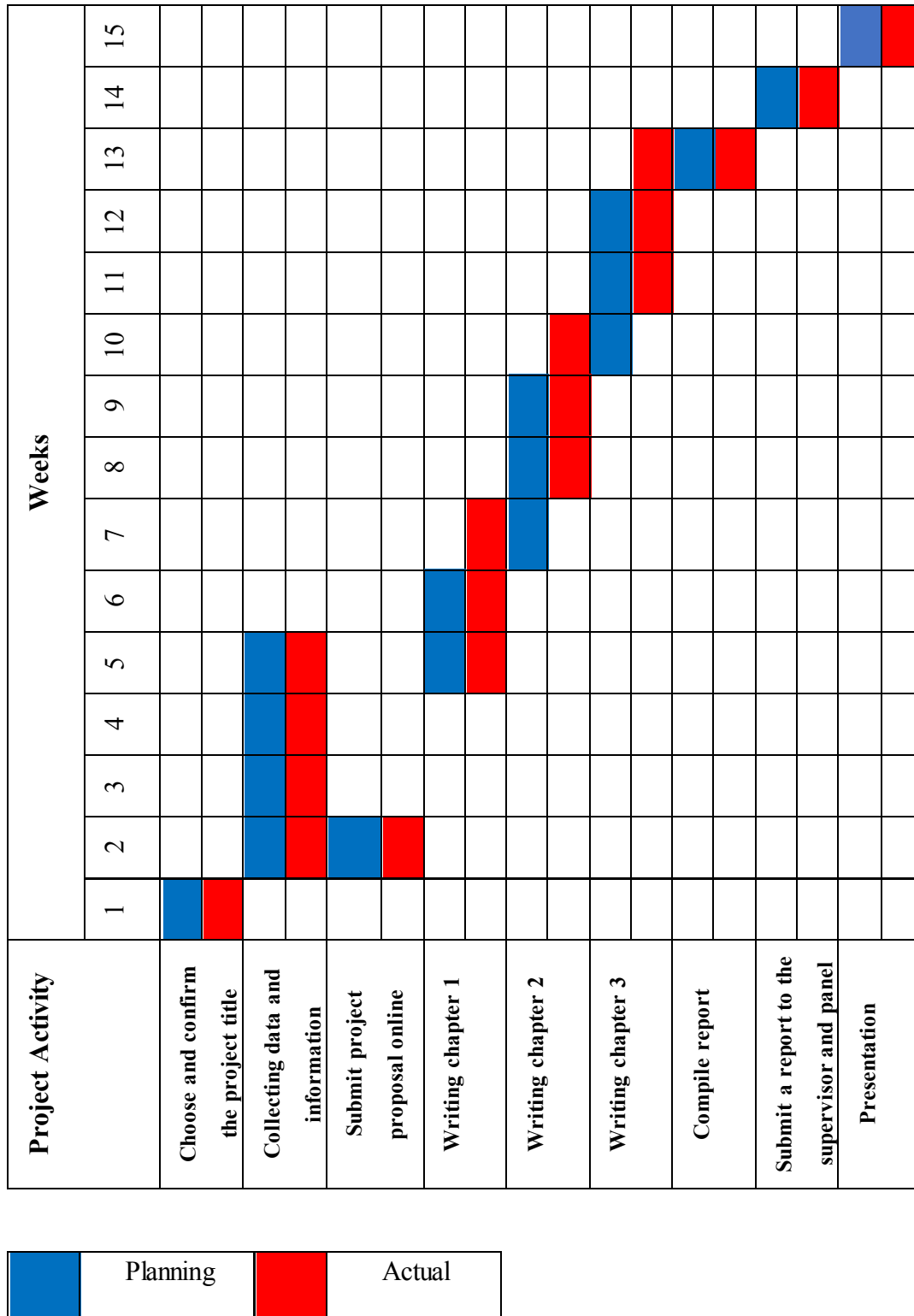


Table 1.1: Gantt chart PSM 1

| Project Activity | Weeks | | | | | | | | | | | | | | |
|------------------------------|----------|----------|----------|--------|---|---|----------|--------|----------|----------|--------|----------|----------|----------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Conforms the parameter | Planning | Actual | | | | | | | | | | | | | |
| Prepare the material | | Planning | Actual | | | | | | | | | | | | |
| Machining the material | | | Planning | Actual | | | | | | | | | | | |
| Testing the product | | | | | | | Planning | Actual | | | | | | | |
| Data analysis | | | | | | | | | Planning | Actual | | | | | |
| Writing chapter 4 & 5 | | | | | | | | | | Planning | Actual | | | | |
| Compile report | | | | | | | | | | | | Planning | Actual | | |
| Submit a report to the panel | | | | | | | | | | | | | Planning | Actual | |
| Presentation | | | | | | | | | | | | | | Planning | Actual |



Table 1.2: Gantt chart PSM 2

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

From this chapter, it will have the background information I gathered from the journal, books also article about abrasive waterjet machining. Indirectly, it will help me to with the project I want to produce which is “Fabrication of Bottom Modular Nozzle for Abrasive Waterjet Machine By Using High Carbon Steel”. This chapter will provide the facts about Abrasive Water Jet Machining (AWJM) include the part or component, the concept how the machine makes the cutting process, the parameter of the abrasive water jet and other important things about this machine.

2.1 Type Water Jet Cutting

In the water jet cutting manufacturing, there are available two types of water jet cutting machine;



Figure 2.1: Pure water pressure jet

Figure 2.2: Abrasive water jet

Source: <http://www.xinology.com/Glass-Processing-Equipments-Supplies-Consumables/glass-cutting/water-jet-cutting/overview/two-types-of-water-jet.html>

Waterjet cutting equipment is one of the quickest growing machining processes in this world right now. Near the beginning 1970s for cutting soft materials like cardboard, plastics, rubber, pure waterjets are being used as a process to cut the material. Meanwhile to cut hard and solid materials like metal, ceramic, stone, glass, composite materials. The abrasive waterjet machining was introduced to develop the capabilities of the tool during the mid-1980s, (Mhamunkar, 2016)

Waterjet cutting systems are currently generally used in a number of industrial applications since of their illustrated capability to cut such materials like plastics, leather, asbestos, corrugated board, plus soft rock more efficiently and economically than conventional cutting systems. A system has been developed also tested tentatively to cut these harder materials by means of a water with the abrasive particles entrained in an extremely high-speed velocity. The operational principle of these abrasive water jets is the acceleration of abrasive particles by blending them with a stream of water driven by pressures of up to 45,000 psi. This blending and acceleration procedure takes place in a mixing chamber made of a durable material such as tungsten carbide or else boron carbide. The extremely focused and coherent slurry jet has the capability of cutting even the hardest materials. (Mohamed Hashish, 1984)