FABRICATION AND ANALYSIS OF GRINDING JIG FOR BEVEL END PIPE JOINT TO REDUCE VIBRATION

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

by

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DECLARATION

I hereby, declared this report entitled "Fabrication and Analysis of Grinding Jig for Bevel End Pipe Joint to Reduce Vibration" is the result of my own research except as cited in references.

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Date : 2 August 2021

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Penghasilan serong pada hujung paip untuk sambungan kimpalan biasanya menggunakan mesin canai dan sering dilakukan secara manual. Dalam keadaan ini, getaran yang dihasilkan daripada mesin canai akan memberi kesan kepada kesihatan manusia seperti penyakit yang disebut “Hand Arm Vibration Syndrome” (HAVS). Ia adalah penyakit yang disebabkan oleh pendedahan kepada alat getar untuk jangka masa yang lama. Seterusnya, untuk mengelakkan getaran ini dihasilkan dari mesin canai yang dihantar ke tubuh manusia semasa menggunakan mesin canai. Pembuatan jig dan lekapan menjadi objektif untuk projek ini. Jig buatan dapat mengurangkan getaran yang dihasilkan oleh mesin canai, yang mengurangkan penggunaan dua tangan ketika melakukan pengahsilan serong dari harus memegang paip dan mesin canai secara serentak kepada hanya memegang paip. Jig dan lekapan masih menghasilkan getaran tetapi ia mengurangkan penyerapan getaran ke tubuh manusia yang membuatkan keselamatan pekerja terjamin. Jig dan lekapan difabrikasi dibengkel kerana mesin yang mudah diakses. Jig dan lekapan difabrikasi dengan menggunakan beberapa proses pembuatan seperti pemesinan, penggabungan, pengimpalan dan proses gerudi. Setelah semua bahagian dibuat, proses pemasangan telah dilakukan untuk memastikan jig berfungsi seperti yang dirancang sebelum analisis dapat dilakukan. Analisis dibuat dengan mengurangkan getaran yang dihasilkan dari mesin canai yang terdedah pada tubuh manusia, kemudian membandingkan jumlah getaran dengan mesin canai manual. Jig berjaya memanjangkan jangka masa penggunaan alat yang bergetar dari mencapai had getaran yang boleh membahayakan pengguna. Seterusnya, ketepatan menghasilkan sudut serong semasa menggunakan jig yang dibuat telah diukur. Sebuah meter getaran tangan digunakan untuk menganalisis getaran yang dihasilkan oleh jig pada tubuh manusia untuk membuktikan bahawa getaran dikurangkan dari $2.5 m/s^2$ kepada $1.8 m/s^2$ untuk penggunaan manual. Untuk analisis sudut serong, protraktor serong digunakan untuk memeriksa ketepatan hasil sudut serong pada paip seperti yang dinyatakan pada jig sebelum beroperasi. Jig ini berguna untuk pekerja yang menggunakan mesin canai secara harian seperti industri minyak dan gas di mana proses paip serong dilakukan setiap kali proses paip kimpalan diperlukan.

ABSTRACT

Bevelling a pipe end for a welding joint usually uses the hand grinder, and operators tend to operate it manually. In this situation, the grinder's vibration will affect human health, such as a disease called Hand Arm Vibration Syndrome (HAVS). It is a disease caused by exposure to vibrating tools for a longer time. Thus, it is crucial to avoid this vibration from the grinder transmitted to the human body while operating the grinding machine. Fabrication of a jig and fixture is the aim of this project. The fabricated jig and fixture can reduce the grinder's vibration, which neglects the use of two hands when bevelling from holding a pipe and grinder simultaneously into just holding a pipe. The jig and fixture still produce a vibration, but it is less value of the vibration absorption toward the human body, ensuring workers' safety is secure. The jig and fixtures were fabricated in the workshop because there have accessible machines. Jig and fixture were fabricated using manufacturing processes, such as machining, joining, welding, and drilling. After all the parts were done with fabrication, the assembly process was done to ensure the jig was working as planned before analyzing the project. An analysis was obtained by reducing the vibration produced from the grinder machine exposed to the human body, then comparing vibration with a manual grinder. Then, the accuracy of the bevel angle produced when using the fabricated jig and fixture was measured. A hand-arm vibration meter was used to analyze the jig's vibration on the human body, proving that vibration was reduced from 2.5184 m/s^2 to 1.8408 m/s^2 for manual bevelling. The jig and fixture were successfully extending the period of use for vibrating tools from reaching the vibration limit that can endanger the user. For the bevel angle analysis, a bevel protractor was used to check the bevel angle at the bevelled pipe as stated at the jig before operating. This jig is useful for the operator in daily use of grinders such as the oil and gas industry, where the bevel pipe process is done every time the welding pipe process is needed

DEDICATION

I wholeheartedly dedicate this study
to my beloved father, Zahari Bin Zainal; to my mother, Dara Binti Mokhtar;
to my family;
to my helpful classmates and friends;
to my honorable and resourceful supervisor, PM Dr. Nur Izan Syahriah Binti Hussein
for assisting me by means of giving me moral supports, knowledge, time, cooperation, encouragement and understandings.
Thank You So Much

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Apart from that, I have learned and got a very good experience based on the journey to complete this project and it is very helpful with my research as I get a complete understanding of the fabrication process.

I am also grateful to my family, who provided full support and encouragement whenever I felt discouraged and disappointment to complete this project. Last but not least, I would like to thank to my friend and colleagues for their support and guide me through the report's format.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

اونيۈرسيتي تيكنيكل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF ABBREVIATIONS

FKP	-	Fakulti Kejuruteraan Pembuatan
HAVS	-	Hand Arm Vibration Syndrome
UK	-	United Kingdom
SOCSO	-	Social Security Organization
JSOH	-	The Japan Society for Occupational Health
VEA	-	Vibration Energy Absorption
BP	-	Blood Pressure
BOM	-	Bill of Material
USA	-	United State of America
ASTM	-	American Society Testing Material
GOST	-	Gosudarstvennye Standarty State Standard
EAV	-	Exposure Action Value
ELV	-	Exposure Limit Value
OELs	-	Occupational Exposure Limits
TLV	-	Threshold Limit Value

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF SYMBOLS

mm	-	Millimetre
g	-	Gram
m/s^2	-	Frequency weighted acceleration
%	-	Percentage
Inch	-	Inches
$^\circ$	-	Angle of degree
Hz	-	Hertz
$\bar{X}$	-	Arithmetic mean
σ	-	Standard deviation
u_p	-	Standard uncertainty

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background of Study.

Making bevel end pipe joint is mostly done using a grinder, which is a worker handling it manually or using automatic pipe bevelling machines. Pipe bevelling is the process where an angle is formed between the edge of the pipe or tube end and a plane perpendicular to the surface. A pipe with more than 3mm thickness needs a bevel for the welding joining regarding welding standards. The welding standard of an end pipe joint of bevel angle for welding is 37.5°. However, grinder results also form a non-uniform bevel angle because of many factors, such as unskilled workers.

Vibration while handling tools is common when a worker uses machines or tools frequently without a stop for some time. Exposure to vibration during handling vibration tools or machines can cause harm to the users. Prolonged and intensive exposure to vibration often affects workers. Such vibration exposure may cause vibration-induced white finger or hand-arm vibration syndrome, but effective exposure control remains an important issue (Dong et al., 2020).

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Hand Arm Vibration Syndrome (HAVS) affects many workers who use vibrating tools over the years and can lead to a lifelong disability. Vascular symptoms include cold-induced spasms of the fingers and hands, blanching of the fingers, and atrophic skin changes in the fingertips. According to the Health and Safety Executive, UK stated that in 2019 has 205 cases related to HAVS. Sensorineural symptoms include numbness and tingling in the fingers and hands, reduced sensory perception, and manipulative dexterity. While handling a machine or tools, many factors can lead to this disease if overexposed. The study confirmed that a handheld workpiece's vibration generally resulted from two types of vibration sources: (i) the vibration generated on the machine and transmitted to the workpiece; and (ii) the grinding vibration generated at the grinding interface. In principle, the data of absorption vibration can be obtained from constructing a combination of grinding machine, a jig, and vibration reader tools, similar to those used to simulate the vibration response of a handling a grinding machine (Chen et al., 2017).

1.2 Problem Statement.

Grinding is one of the typical manufacturing processes operated by a machine or manually using a human hand. Because of manual use, the result of the bevel angle is often not uniform. Therefore, performing a standard quality of bevel angle is an important parameter to archive a good welding joint (Deepali et al., 2016). By that, while grinding parts like a pipe using a hand grinder, it will cause some problems such as vibrations absorption while handling it and will affect the workers using it (Vihlborg et al., 2017). Other than that, some significant effects on humans can reduce grip strength, and sometimes the person will be unable to feel the heat of the cup.

Furthermore, fabricating a grinding jig that focuses on reducing vibrations for the bevel end pipe joint must be appropriately planned for workers to do a job safely without harming their health. The shape of the groove is one of the factors that may affect the residual stress of the welding joint (Akbari et al., 2012). This study developed a methodology for performing analyses and evaluations based on a grinding jig for the bevel end pipe joint. First, an analysis will be made by comparing the amount of vibration exposed to the human hand using a traditional method and using this jig and measuring the bevel angle form by a jig. For the second investigation step, the vibration reading response was simulated and measured in a laboratory (Krajnak, 2018). The functional jig and fixture can reduce the grinding machine's vibration while making the bevel end pipe joint. Because of the reduction of vibration, it can also ensure that workers' working process is safe.

1.3 Aim and Objective.

This project aims to make a grinder process for bevel end pipe joint safe for workers who handle it because they will be exposed to continuous vibration. The objectives of this project are:

i. To fabricate jig and fixture for workers to bevel a pipe in preparation for welding to reduce vibration exposure.

ii. To analyze the vibration absorption on workers when using the jig when bevelling an end pipe for the welding joint and to measure the bevel angle while using the jig.

1.4 Scope.

The study was conducted at Fakulti Kejuruteraan Pembuatan (FKP) UTeM workshop. This study was aimed to fabricate a grinding machine's jig for bevel end pipe joint without a worker's need to handle a grinder and analyze a vibration absorption and bevel angle produced by jig through an experiment and analysis. The detailed design of the fabricate jig and fixture already undergoes the previous study's design process and has been drawn using SolidWorks Software. For the fabrication part, the previous research acted as a guide to the fabrication process. The jig parts were assembled as complete jig through several manufacturing processes and then underwent testing and analysis. Due to this process, bolt and nut acted as connectors to connect the hand grinder with the jig. The analysis was conducted using a hand-arm vibration meter to measure the vibration absorption on the fabricate jig and bevel protractor to measure the accuracy of bevel angle produce when using jig and fixture.

1.5 Significant of Study.

This research aims to provide the best way to reduce the vibration absorption produced by jig due to workers' handling for more extended periods, where certain grinding methods should be examined. Collect the data from the vibration produced when the worker operates a grinder machine by hand for a specific time. To analyze the vibrations produced by the grinder machine when conducting a process of bevelling end pipe joint between traditional method or jig features designed to reduce vibration and mainly performed with an automatic machine. This study will help the industry facing this kind of manufacturing process through their daily project. For example, a piping worker needs to welding hundreds of pipes a day before welding it. These can ensure their life is safe while using this jig compare to handling a grinder manually using hand to do bevelling on end pipe.

1.6 Thesis Outline.

Chapter 1 begins with a research background, problem statement, objectives, the scope of the research and fabrication, and analysis of grinding jig for bevel end pipe joint to reduce vibration. This chapter composes the introduction, problem statement, objectives, scopes, the significance of the study, and project framework. Chapter 2, the literature review, is used by looking at previous research about the vibration absorption on humans while operating a grinding machine while bevelling an end pipe. A literature review provides a comprehensive background and supportive material research. Chapter 3 describes the process flow and the methodology of the study. Chapter 4 presents the experimental results by referring to the previously supported study. Chapter 5 discusses the significance of the results. Finally, summarizes and conclude this thesis and come out and recommendation for future work.

1.7 Activity Planning.

A Gantt chart provides a graphical illustration of a schedule that helps plan, coordinate, and track specific tasks in a project. Gantt charts may be simple versions created on graph paper or more complex automated versions using project management applications such as Microsoft Project or Excel. However, to complete this PSM 2 according to the time given, a Gantt chart is compulsory for this project. The Gannt chart is shown in the Appendices of this report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction.

This chapter will review previous research on the journal, book, and internet resources related to vibration affecting workers handling grinding machines. This review's purpose is to review previous studies on the analysis, which included the effective method for reducing vibration and jig design to minimize worker handling of a machine or tools. As a result, various sources were identified and subsequently reviewed. A literature review identifies, evaluates, and synthesizes the relevant literature within a particular field of research. A study on the previous research will illuminate how knowledge has evolved within the field, highlighting what has already been done, what is generally accepted, what is emerging, and the current state of thinking on the topic. Besides, within research-based texts such as a Doctoral Thesis, a literature review identifies a research gap and articulates how a particular research project addresses this gap. In this topic, some research can be evaluated to reduce the vibration absorption during handling a grinding machine with hand while making a bevel for end pipe joint due to starting a welding process of joining a pipe. However, most research is about reducing vibration to avoid getting Hand Arm Vibration Syndrome (HAVS) because of exposure to vibration. The analysis taken from the new method of using modified jig compared to the traditional method is handling a grinding machine manually with hand.

2.2 Hand Arm Vibration Syndrome (HAVS).

(Su et al., 2011) stated that in 2005, 2.3 million Malaysian workers were working, which exposes to the vibration that applied to the Social Security Organization (SOCSO) but only 15 workers sick cause by vibration. Handheld power tools such as grinding machines produce a lot of vibration that can absorb into the human hand when performing a bevelling process at the end of the pipe joint. This vibration will affect human health, such as exposure to a disease such as White Finger Syndrome or Hand Arm Vibration Syndrome (HAVS) (Vihlborg et al., 2017).

The prevalence of HAVS ranged from 5% to more than 80% globally, depending on the types of tools, the extent of vibration exposure, and climatic factors (Su et al., 2011). HAVS is caused by the repeated use of manual vibrating machines - grinder, chainsaws, and power drill, for example. It may also be triggered by the operation or use of vibrating machinery. The vibration causes the condition to be not noticeable. It's possibly because the tiny nerves and arteries in the finger suffer from mild yet frequent injuries. Over time, some of their functions may be lost, and their symptoms may be present. Up to 1 out of 10 people with vibrating tools may probably grow HAVS. Other than that, according to The Japan Society for Occupational Health (JSOH), which uses Occupational Exposure Limits (OELs) as a recommended guide to not exceed 2.8 m/s^2 for 8-hour of working time (World Health Organization, 2009). The Control of Vibration at Work Regulations in 2005 stated that the Exposure Action Value (EAV) and Exposure Limit Value (ELV) is in m/s^2 A (8); the average (A) exposure during an eight-hour (8) day, taking into account the vibration's intensity and duration. A tool or machine's vibration rate is measured in meters (m) per second (s) square. The regulations set the daily EAV as 2.5 m/s^2 A (8), and ELV is 5 m/s^2 A (8). Exposure to hand-arm vibrations is associated with a risk of hand injury in the form of vascular disorders, nerve malfunction, and effects on the musculoskeletal system (Heaver et al., 2011). Therefore, the workers involved are provided with periodic health monitoring. The Guidelines on occupational vibration (DOSH, 2003) were utilized in Malaysia as a reference for workers engaged in the vibration operation of the hand-arm. In this specific recommendation, the threshold limit value (TLV) determined and the time of exposure for vibrations transmitted in A (8):

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

- 4 hours and less than 8 hours = 4 m/s^2
- 2 hours and less than 4 hours = 6 m/s^2
- 1 hours and less than 2 hours = 8 m/s^2
- Less than 1 hour = 12 m/s^2

This disease is not showing the result instantly but will affect the worker who is exposed regularly. Workers will have some problems such as loss of grip strength, tingling, loss of sensation in the fingers, and many more.

Figure 2.1: Hand nerve affected by vibration tools (Sabitoni, 2018).

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Characteristics of HAVS shows such as follow:

i. The constellation of symptoms is caused by ongoing exposure to vibrations.

ii. It can take from 6 months to many years for HAVS to develop, depending on the strength of the vibrations.

iii. Often using vibrating tools, the vibration can damage the internal human systems, such as Figure 2.1.

iv. The damage is irreversible and may leave the worker with a permanent disability.

v. The circulatory system, the muscle, and the nerves in the hands and the arms can be affected.

2.3 Bevel.

A bevel is a surface edge that is not perpendicular to the face of the object. For safety, wear resistance, or to ease the joining with another part, a bevel is usually used to soften the edge of an object. Bevelling is carried out prior to welding on thicker pieces of metal, and 37.5° is the standard for bevel angle in welding. On top of that, parameters such as the gas flow rate affected by the current supply and bevel angle can determine the weld's strength (Sathish et al., 2012). The bevel provides the plate or pipe with a smooth, clean edge and allows the correct form to be welded. In addition, to prevent center-line cracking from joining the separate pieces of metal.

The particularly thick pipe will have a "V" shaped groove when the bevel is made. It is to reduce the amount of welding filler metal used. Bevelling is an important part of the engineering method for pipe welding. Due to being welded together, two pipe ends have their shapes changed by removing some of the metal from either end (Deepali et al., 2016). Bevelling can be carried out manually by hand-grinding or by automated bevelling. The bevelling end of the pipe is an important part of achieving high-quality welding. It improves the surface area of the welding area and results in better welds that can withstand more tension. In addition, as the pipe ends are bevelled, there is a greater probability that welding will be allowed, thereby minimizing the cost of repair or cutting and allowing the project to stay on schedule.

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 2.2: Bevelling end pipe manually with hand grinder machine (Stuart, 2015).

2.4 Bevelling Machine.

The bevelling machines are designed to perform bevels or using milling cutters. Besides, bevel using turning machine with bed box is one of the methods. The bed box will rotate the pipe, and the bevelling process will occur at the end of the pipe. (L. Chen & Zhang, 2011). Other than that, the torch cutter also makes bevel to the pipe by using an automated Oxy/Fuel flame cutting head (Abdulateef et al., 2010). Although, Several factors determine the choice of a bevelling machine: the elements size, the bevel dimension, and the type of material to be bevel (Patel & Gandhi, 2013).

Figure 2.3 shows two types of bevelling machines. Figure 2.3 (a) shows a portable bevelling machine, which provides advantages over hand grinding or using a torch or a plasma cutter. For one thing, a portable bevelling machine produces a more reliable bevel than a hand grinder machine. However, a portable bevelling unit has certain disadvantages such as electrical cords a hazard, possible guarding issues, and expensive custom ground tooling. Figure 2.3 (b) shows a stationary bevelling machine that gives consistent bevel each time, including land width and angle, fast, normal cycles time in seconds, minimal and lower cost per bevel.

(a) (b)

Figure 2.3: (a) Portable and stationary (Himmelstein, 2017) and (b) bevelling machine (Wayne, 2013).

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Due to the easiest way to perform a bevel at the end pipe, most workers intend to use a hand grinder because it is faster and cheaper than other bevelling methods. To make the process more interactive and reliable, manual grinding needs to comprise “skill-based design,” which models a person-based machine and can go considerably beyond the concerns of typical human factors and ergonomics to encompass each processing parameter (Das et al., 2018). Besides, while using a bevelling machine is the least safe method of all. It is time-consuming and required skilled operations due to the welding standard for bevel angle of 37.5° before starting a welding process. A hand grinder is also not a suitable method to use because it provides inconsistent bevel due to the workers' skills. Otherwise, a hand grinder is one of the most dangerous tools, and it needs extra care when using to create a bevel. According to (Rovný et al., 2017) there are two types of portable machine tools available today. The most benefit of the portable machine is flexibility, without the need for customized profile cutters. This is the basic principle of the common bevelling machine:

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 2.4: Bevelling machine (Wattchina, 2019).

i. Adjustment of the cutting width of the cutting edge of all bevelling machines is adjusted to 2mm. To adjust, first loosen the fastening screw under the handle, turn the handle, and lift the housing. The adjustable range is 0-15mm.

ii. Adjusting the cutting width to more than 15mm; protects the machine and tools, and each adjustment is 5mm.

iii. Adjustment of chamfer angle, the bevelling angle of all bevelers is adjusted to 45°.

iv. To adjust, first loosen and remove the four fastening screws on the left and right sides of the housing.

v. After the angle adjustment, be sure to tighten the screws. The angle adjustment may slightly affect the cutting width of the cutting edge.

vi. Before machining, please note that the knife is cut in different places, and different operating modes should be used.

vii. Start the machine, move the machine evenly and firmly according to the direction indicated by the arrow.

viii. When the pipe is bevelled, remove the milling cutter table, install the bevel tooling table, and place it on the pipe to adjust the appropriate depth and angle. Before feeding, hold the handrail, move the body, let the blade slowly approach the pipe until the slope cuts to the outer wall, and then slowly advance the knife in the direction of the arrow.

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Because of the complexity of handling this bevelling machine, many workers intend to use a hand grinder rather than a bevelling machine. Hand grinders are much faster and easier to use, and no need for skill to operate, such as complex machines. Due to operation places, such as welding a pipe at the construction site, this machine is not suitable for use in certain situations (Rout, 2016).

2.4.1 Existing Bevelling Machine.

Figure 2.5: PRO-40 PBS (Promotech, n-d).

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Stationary Pipe Bevelling Machine. PRO-40 PBS is made from Bialystok, Poland and it is designed for bevelling and facing pipes, tanks or tubes in a range of diameters from 200 mm to 1000 mm (8-40 inch). High-speed rotary milling head with replaceable inserts enables effective and efficient machining with bevel widths up to 45 mm (1-3/4 inch) and angles between 0° and 60°. Internal bevelling and J-groove end preparation is optionally available. Use of heavy-duty milling head in PRO 40 PBS offers accurate bevels in a fraction of the time compared to traditional single point machining. This feature saves time and money by excellent efficiency. Therefore, PRO-40 PBS not suitable for small pipe and not portable to use at the site for instant process before pipe welding process.

Figure 2.6: PRO-10 PB (Promotech, n-d).

Portable Pipe Beveller & Flange Facer. PRO-40 PBS is also made from Bialystok, Poland. It is a heavy-duty pipe Beveller designed for portable use in pipe machining operations. Self-centring expandable mandrels provide quick and proper alignment to a pipe or a tube prior to machining operations. The first is carriage-type milling machines for pipe severing and bevelling.

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Figure 2.7: APB 32 (Steelmax, 2017)

Automatic Pipe Bevelling System. APB 32 is made from Pennsylvania, USA, and this machine APB32 automatically feeds itself around the pipe. It can mount to pipe with at least a diameter of 10 inches and can bevel outside diameters up to 32 inches. Additionally, the APB-32 can bevel pipe of any diameter over 32 inches with an optional attachment, making this an incredibly versatile solution. Other than that, it is very simple to set up and operate.

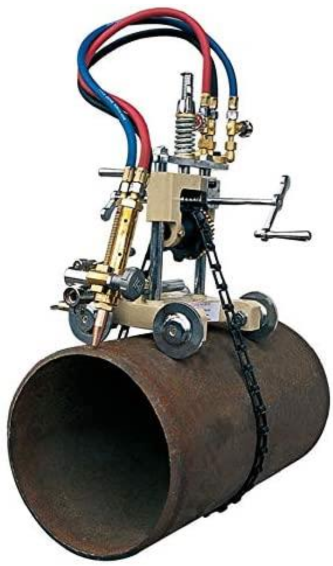

Figure 2.8: Cutting Bevelling Machine Torch (Thokale et al., 2016).

Manual Pipe Cutting Bevelling Machine Torch Track Chain Cutter. With 4 parallel roller wheels, this is a practical and economical pipe cutter. It uses chains to move the pipe to drive the machine forward or backward by rotating the handle. This machine applies oxygen-acetylene for straight cut or bevel cut 45°. Suitable for 108-600mm seamless steel pipe and no need for electricity. Compact in size, portable to carry, especially to use in a wild environment. Perfect pipe cutting machine for petroleum, chemical, mechanical, processing, electricity, construction, mining industries, etc. Aluminium alloy main body, compact and portable.

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2.5 Fabrication of Jig and Fixture.

In principle, the desired design jig is constructed based on parts that have a minimum absorption of vibrations on the grinding machine, pipe, and vibration reader analysis (Śledziński, 2014). Next, this research is comparing and analyses all the potential methods. Still, it is challenging to analyze all the potential methods, so this study will focus on developing the jig model for analyzing the vibration responses of the application while using a jig and hand grinder (Dong et al., 2018).

Depending on the requirements to build a jig, various fabrication methods are used. Any production method can usually be split into two large categories, consisting of removal or deformation processes. Because the jig is attached to the hand grinder, there will be a universal clamp to lock the grinder due to the size of the grinder will be different in the market. These are the methods which are material removal process includes: -

i. Cutting Metal: Mechanical saw blades are one option to cut metal, and less skill operator is required. Other options consist of laser beams and power scissors for thin metal.

ii. Machining: CNC milling is used to remove material from metal with ease. Additionally, cutting through a rotating cutting tool removes the workpiece's material to achieve the desired result.

iii. Drilling: Process of cutting using a drill bit to create a circular cross-section hole into solid materials.

iv. Stamping: Same as a drilling operation, but the difference is that die is used to lift a particular portion of the metal instead of cutting it.

v. Threading: Process of creating a screw thread. More bolts and nuts need to assemble the jig.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.6 Vibration Analysis Tools.

Vibration energy absorption (VEA) into the hand-arm system is one of the most important biodynamic measures that can be used to quantify the vibration exposure for assessing its potential effects. VEA should consider the hand-arm system's physical reaction into consideration, not just the vibration risk calculated on a tool. Some variables, such as hand-arm postures and the hand forces, can be expressed automatically in this analysis (Dewangan & Tewari, 2009). Some of the apparatus or tools used to read the exposure of vibration at hand while operating a vibrating machine:

i. Hand Arm Vibration Meter.

(a) (b) (c)

Figure 2.9: (a) Vibration Meter with accelerometer and (b) Instrument that have X, Y and Z axis data (Qamruddin et al., 2019).

The hand arm vibration meter was designed by Castle Group Ltd from North Yorkshire, England. It is supplied with a simple to attach tri-axial accelerometer with simultaneous X, Y, and Z axis data where readings are taken and displayed on the (a). Measurements can be taken in m/s^2.

ii. HAVWEAR Hand Arm Vibration Safety.

Figure 2.10: Wrist Vibration monitor (Maeda et al., 2019).

A Reactec company made this wrist vibration monitor from the United Kingdom. This tool defined a vibration magnitude and length of time is in use to calculate exposure points. In order to determine the exposure rate that the individual is going to take more action, the tool will deliver an audible warning and vibration.

iii. Digital Finger Pulse Oximeter Blood Pressure Monitor Heart Rate Oximeter.

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Figure 2.11: Finger Pulse Oximeter with digital blood pressure monitor (Siraj et al., 2019).

Blood pressure (BP) measurements were initially produced to reduce human errors associated with the outcome phase in home environments through Oscillometer products. As this vibrating begins to decrease, the diastolic numbers are registered as the cuff still diminishes, which indicates when the blood fluxes smoothly without any arterial appears (Manta et al., 2020).

2.7 Apparatus of Measuring Bevel Angle.

The bevelling strengthens the surface of the weld area in order to attract better joining of pipe. Bevelling involves the removal of metal from the edges of the two pieces of metal being joined. Next, to weld a pipe joint, a bevel is compulsory to join when the two pieces of metal are brought together, the cut results in a V-shaped declivity. In order to measure bevel acceptance for welding specs, bevel measuring tools are either purchased at the hardware stall or custom-made by manufacturers. For alternative functions of welding, different angles were applied. For example, the average angle of the bevelling pipe is 37.5° in most cases. The crucial part to bear in mind is this: Whatever the degree, it is vital for a successful bevel to keep the angle within tolerance. According to (Akbari et al., 2012), (Akbari et al., 2012), the increase in angle leads to higher residual compressive stress on carbon steel but a lower effect on the axial stress on the stainless-steel side. Below shows some of the apparatus used to measure the bevel angle:

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i. Bevel Protractor.

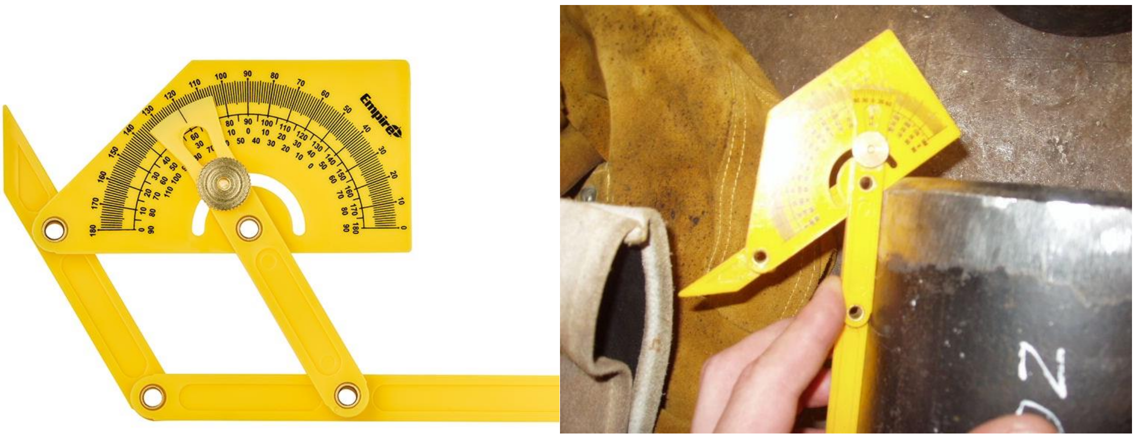

Figure 2.12: Basic angle protractor (Benjamen, 2019).

This useful tool is made by General Tools & Instruments LLC from the USA. It is a practical tool for measuring difficult angles where a standard protractor or t-bevel cannot fit. Measure and mark inside, outside, and sloped angles with ease. The four-piece design is added as versatility for measuring particularly difficult angles.

ii. The Bridge Cam.

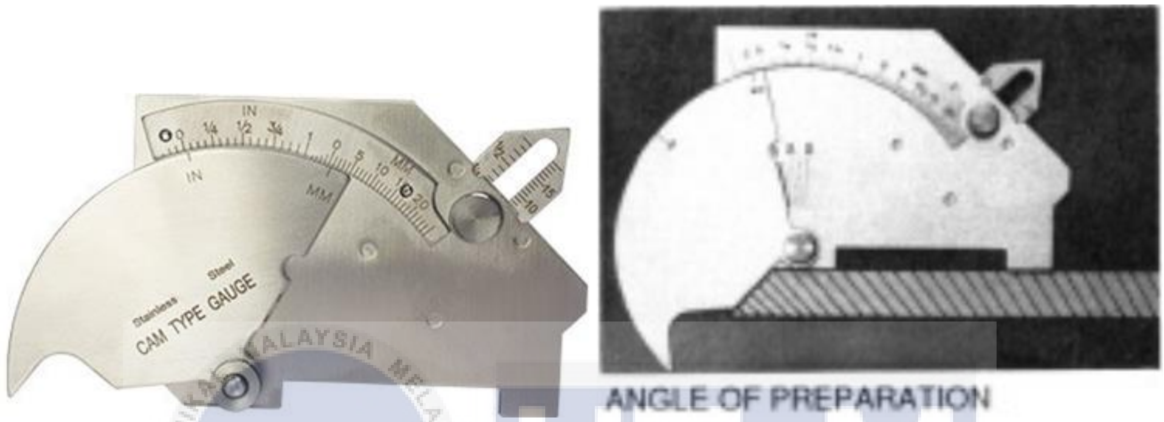

Figure 2.13: Gauge to measure bevel angle (Internal et al., 2004).

G.A.L. Gage Company makes the Bridge Cam Gauge from the USA. It is a multifunctional soldering gauge used in particular on the welded surface and joints. Very handy visual inspection tool for welding inspectors and the angle of preparation from 0 to 60°.

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2.8 Uncertainty Measurement.

Uncertainties of measurement are described as the measurement parameter that describes the dispersion of results between samples by ISO 15189 according to (Farrance & Frenkel, 2012). When measured, the reader assumes typically that there is some accurate or actual value depending on how it defines what is measured. Unfortunately, observation does not exactly reflect the actual value, and the answer to this optimum quantity with the appropriate time and resources is, therefore, the best capacity measurement. The results may differ if distinct methods take measures or when measurements are made using the same method. The most significant contribution to the source of uncertainty may be made by concentrating efforts since the value gained for the combined uncertainty is virtually totally controlled by the major (Li et al., 2015). By identifying measurement uncertainty, it can provide the most accurate estimate of the quantity being measured. This estimate could be the result of a single measurement or the average of a series of measurements. For example, bevel end has a standard angle of 37.5°, which indicates that the angle must be between 35° and 40°. Certain other standards, such as Russia's GOST standards, are set for 35° and 32.5° end angles (Thepipefitting, 2016).

2.9 Study From Previous Research.

The previous researcher provides a useful study about the vibration toward the human body while operating work using a hand grinder. According (Muhammad Syakir Bin Zainuddin, 2019), in his research about how jig and fixture can reduce vibration during the bevelling process. Through his simulation analysis, the amount of frequency transfer on grinder disc and pipe when grinder produces 52.774Hz of frequency is lower than without using a jig and fixture, which is produced 54.934Hz of frequency.

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2.10 Summary of Existing Bevelling Machine.

Based on the existing bevelling machine observation, there are some pros and cons offered by the machine. Some of the limitations on the machines are not available on other machines. Below are the table that shows a difference between those machines: -

Table 2.1: Summary of Literature Review.

	Type of machine.	Author	Description.
1.	 Stationary Pipe Bevel Using Turning Machine	(L. Chen & Zhang, 2011)	-Suitable for big diameter pipe. -Using lathe cutting. -Has chucking system to rotate the pipe. -Bevelling angle range is 0 to 60°.
2.	 Portable Pipe Bevel Machine	(Rovný et al., 2017)	- The system of on-site machine eliminates exposure to harmful factors by human operators. - Min. pipe wall thickness is 15 mm. -Light and easy to operate. -Suited for the onsite severing and bevelling of pipes.
3.	 Pipe Cutting Bevelling Machine Torch	(Abdulateef et al., 2010)	-Moves of torch is horizontally, up & down with cross feed hand wheel & adjustable knob. -Applies oxygen-acetylene for straight cut or bevel cut. -Under normal circumstances, it cannot cut stainless steel. -The increase in cutting speed decreases the quality of the cut resulting

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CHAPTER 3

METHODOLOGY

3.1 Introduction.

This chapter would cover a detailed explanation of the methodology used to complete jig and fixture fabrication. The selecting of materials, manufacturing processes, and analysis have been carried out to complete the fabrication jig and fixture. The method was used to achieve the objective of the project. Next, the methodology would illustrate the project's flow, selecting the materials until the obtained analysis. The flowchart was created to protect against the reporting of poorly constructed studies (Brand et al., 2020). The flow chart in Figure 3. 1 was prepared to guide how this project was fabricated. Starting with identifying the previous design project, selecting materials, selecting corrected manufacturing processes, and making a vibration and bevel angle analysis using the apparatus chosen.

3.2 Project Planning.

The engineer must first identify the corrected manufacturing process for fabricating a jig and fixture and plan the detailed work. The planning had two main objectives: (i) fabricate a jig that could reduce the vibration absorption into the human hand and (ii) analyze the accuracy of the bevel angle produced after using a jig.

3.2.1 Flowchart.

The methods and workflow of this project are represented in a flowchart shows in Figure 3.1: -

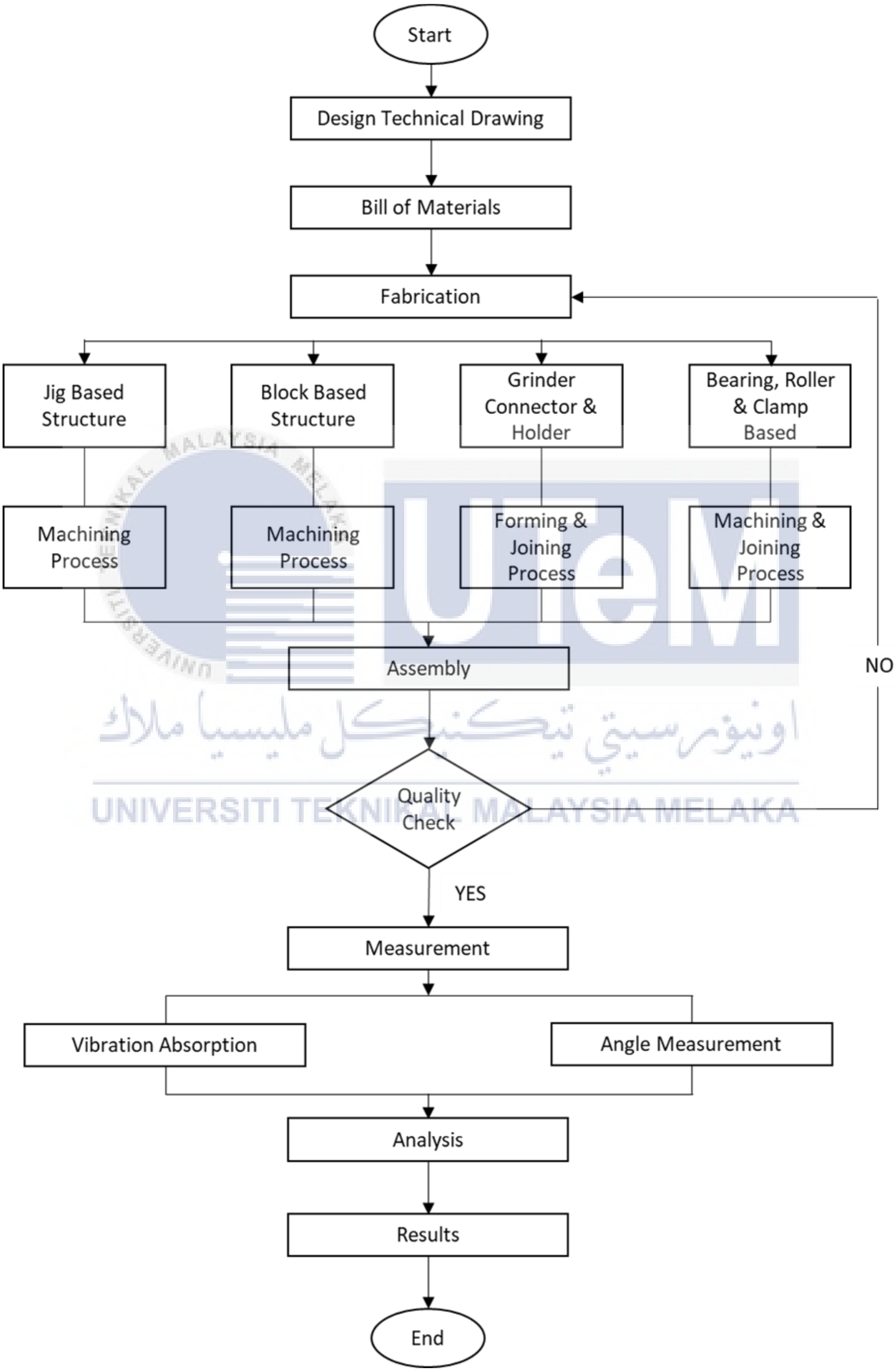

Figure 3.1: Flowchart for the whole project.

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3.3 Design Technical Drawing.

The jig has been designed in previous study by (Muhammad Syakir Bin Zainuddin, 2019). Therefore, the complete design already went through a conceptual design phase. Finally, the final design was obtained. Figure 3.2 shows the complete design fabricated using manufacturing processes and achieving the project's objective. The mechanism of the jig and fixtures to be fabricated was explained in this part. Due to avoid mistakes during the fabrication process, technical drawing acts as a guideline to eliminate error (Chedi, 2015). After undergoing several evaluations related to the suitability of the manufacturing process to fabricate the jig and fixtures, some designs have been changed to facilitate the fabrication process.

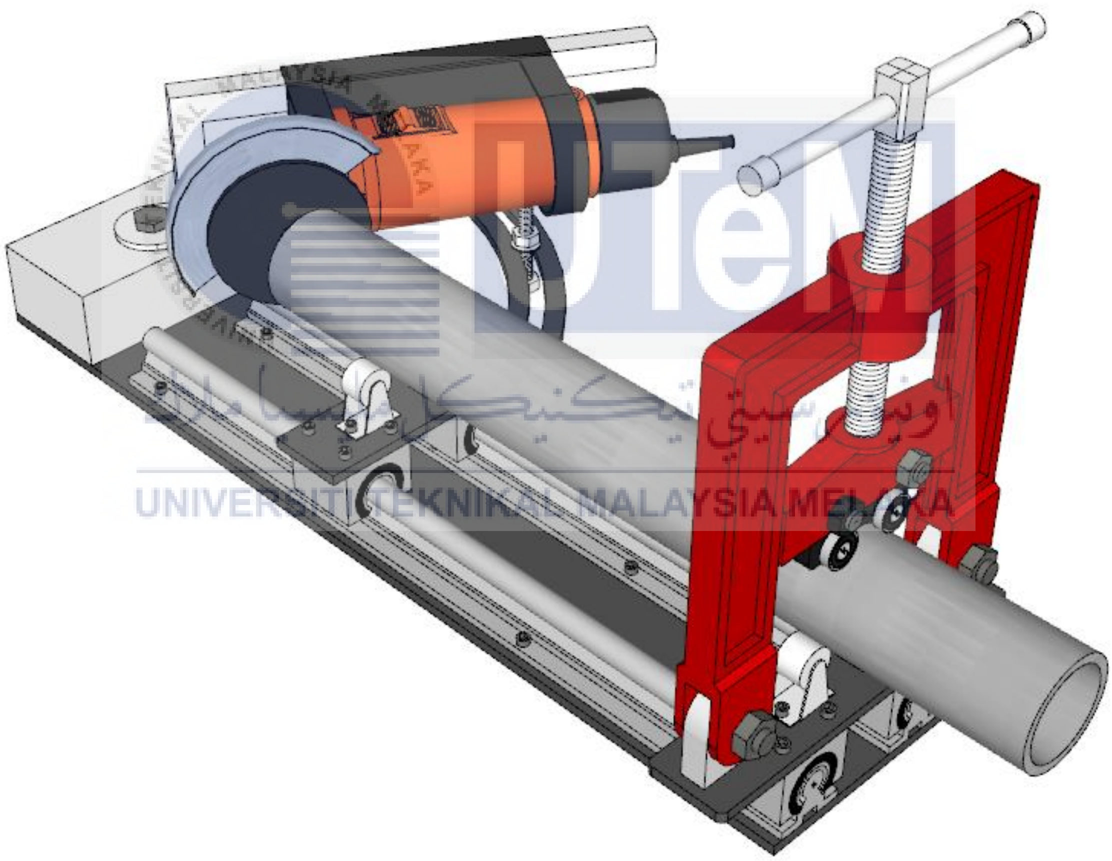

Figure 3.2: Final design that was fabricated.

3.4 Bill of Materials.

Bill of material (BOM) lists all the components, intermedial assembly of a part, necessary sub-components to produce a finished product, or end part (Cinelli et al., 2020). This jig and fixture consist of 18 parts. The BOM has changed due to some of its fabrication procedures changing the way it is manufactured. As a result, some parts and components have been updated. The list of components required for manufacturing is listed below:

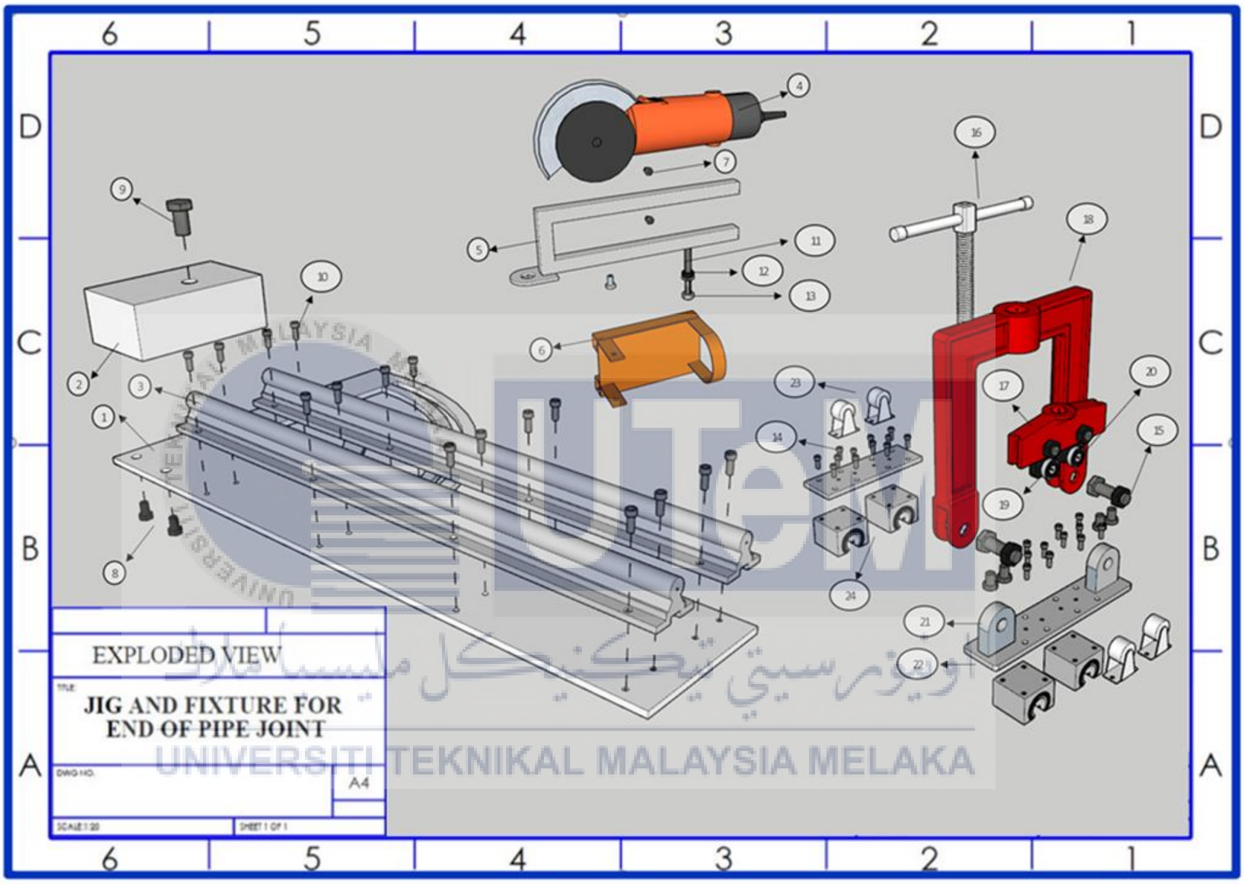

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Figure 3.3: Exploded view of the jig and fixture parts.

Table 3.1: Bill of material.

Item	Part	Quantity
1	Based Structure	1
2	Block Based Structure	1
3	Linear Rail Link	1
4	Grinder	1
5	Grinder Connector	1
6	Grinder Holder	1
7	M6 X 1.0	2
8	M8 X 1.25	4
9	M16 X 2.0	1
10	M5 X 0.8	32
11	M10 X 1.5 Half-Thread	1
12	M10 nut and washer	1
13	M10 lock nut	1
14	M4 X 0.7	4
15	M12 X 1.75	2
16	Clamp Screw	1
17	Upper bearing support	1
18	Clamp	1
19	Bearing	4
20	Linear steel rod	2
21	Clamp bracket	2
22	Roller based	2
23	Roller	4
24	Bearing linear rail	4

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3.5 Fabrication of Jig and Fixture.

This jig has several parts to hold the grinder and pipe. This project's fabrication used mild steel in every significant part. Mild steel was chosen for its low cost and ease of production. In addition, each part's design was exploding in the plane-parts drawing to ease throughout fabrication.

3.5.1 Machining Process on Jig Based Structure, Block Based Structure, and Roller Based.

The jig-based structure is the main part of the jig and fixture fabrication, and it was made of mild steel. The function of this part is to hold and attach another part of the jig. Laser-cut machining is used to cut the jig-based structure due to the complex shape of the part that needs to be assembled on the grinder holder. Figure 3.4 shows the based structure that underwent laser cutting.

Figure 3.4: Based structure.

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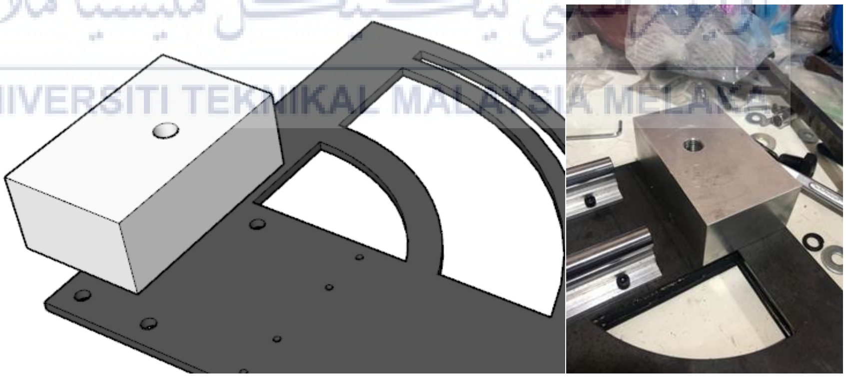
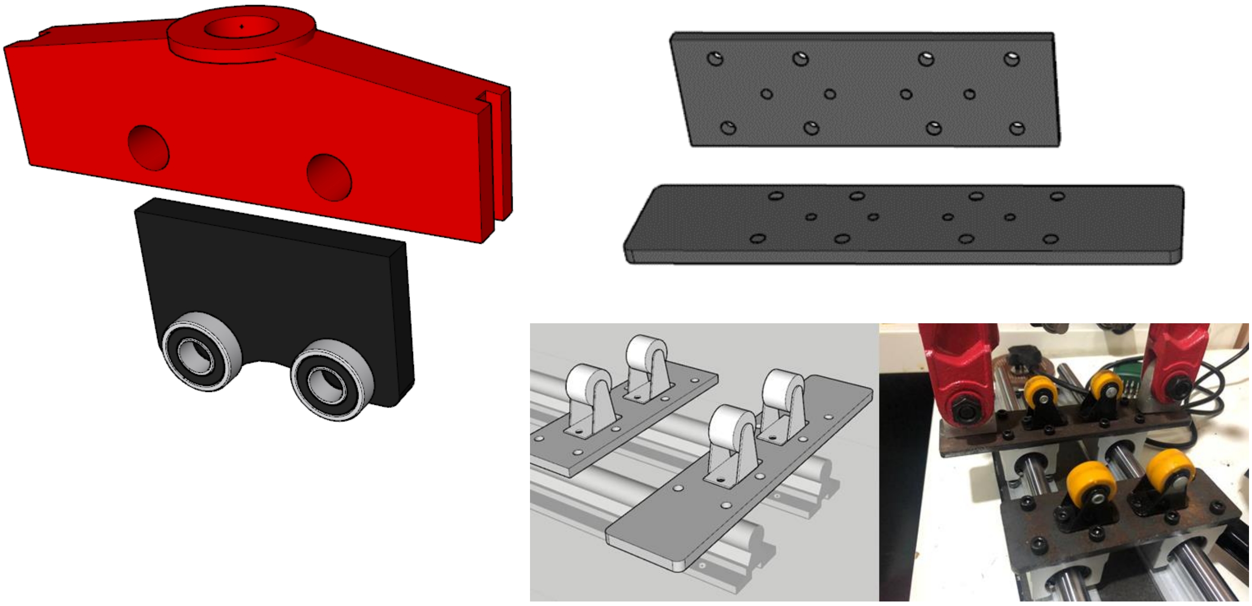


Figure 3.5: Block Based Structure.

The block-based is attached to the main-based structure was made of aluminium and joined together by a bolt. Due to its good machinability, Figure 3.5 shows the block-based structure made of aluminium that has been machined using a lathe machine. It does not involve extensive materials used. The material is lighter than mild steel to reduce the overall weight of the jig and fixture.



(a) (b)

Figure 3.6: (a) Upper bearing support and (b) Roller based.

The upper bearing support plate was made from mild steel dill the hole to allow the rod to hold the bearing. On the downside of the pipe holder, the roller based is made from a mild steel plate then assemble with the roller to hold the pipe in position during the bevelling process. Due to the detachable feature, the bolt and nut were used to assemble and disassemble the part. Figure 3.6 (a) shows the laser-cutting machine cut the mild steel plate into a small plate, (b) laser cutting machines were used to cut plates, then drilling machines are used to drill holes and make threads so it can join with rollers and clamp brackets.

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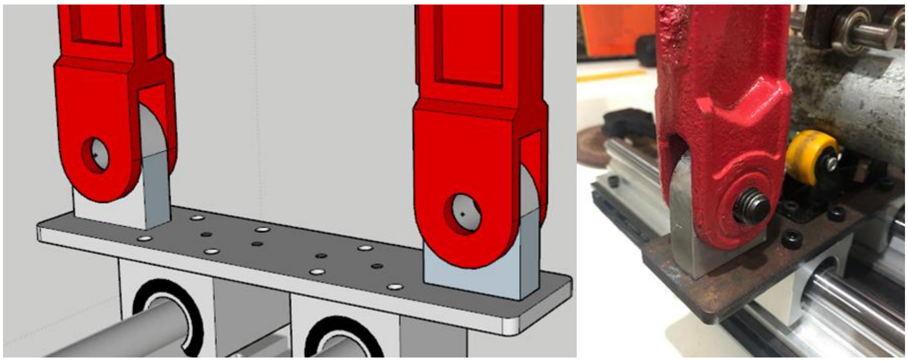

Figure 3.7: Clamp-based.

The clamp-based was made from a mild steel plate and had several holes with thread to connect with the bolt. Due to assemble the clamp and clamp based, the bracket was created. The bracket is made from aluminium, and it being machine using a lathe machine.

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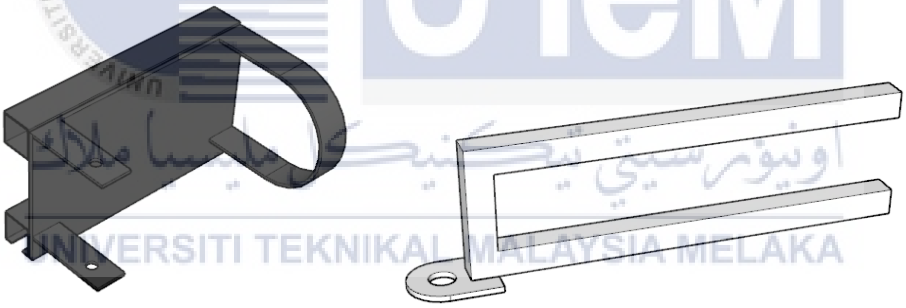
3.5.2 Joining Process Between Grinder Connector.



(a) (b)

Figure 3.8: (a) Grinder holder and (b) Grinder connector.

Figure 3.8 shows the main parts that ensure the fabricated jig is working. First, two separate parts are joined together through a fastening process by bolt and nut. For part (a), the bending process made the curve shape for holding the grinder. Next, part (b) is a connector between the grinder holder and the block-based structure. Finally, part (b) is a simple process that cuts a desired length of steel and makes a slot attached to part (a). By joining parts (a) and (b), the bolt and nut will be used as a fastener rather than a welding joint, a permanent joining.

3.6 Assembly of Jig and Fixture.

After all the parts have already been fabricated according to technical drawing, the assembly processes were required to make the fabricated jig complete and work properly. Some tools were used to assemble parts, such as a spanner to tighten the bolt and nut and connect the based structure and grinder connector. Reliable assembly tools should keep parts and sub-assemblies in a correct position, prevent undesirable movement of parts connectors, or avoid interfering problems in assembly processes. Meanwhile, the addition of a clamp was to hold the end of the pipe. It also can reduce the vibration on a pipe during the bevelling process.

3.6.1 Steps Using Jig and Fixture for Bevel End of Pipe Joint.

Figure 3.9 explained the steps of using a fabricated jig, and A, B, C, D, E, F, H, I, J are used as a reference in order to describe all the steps.

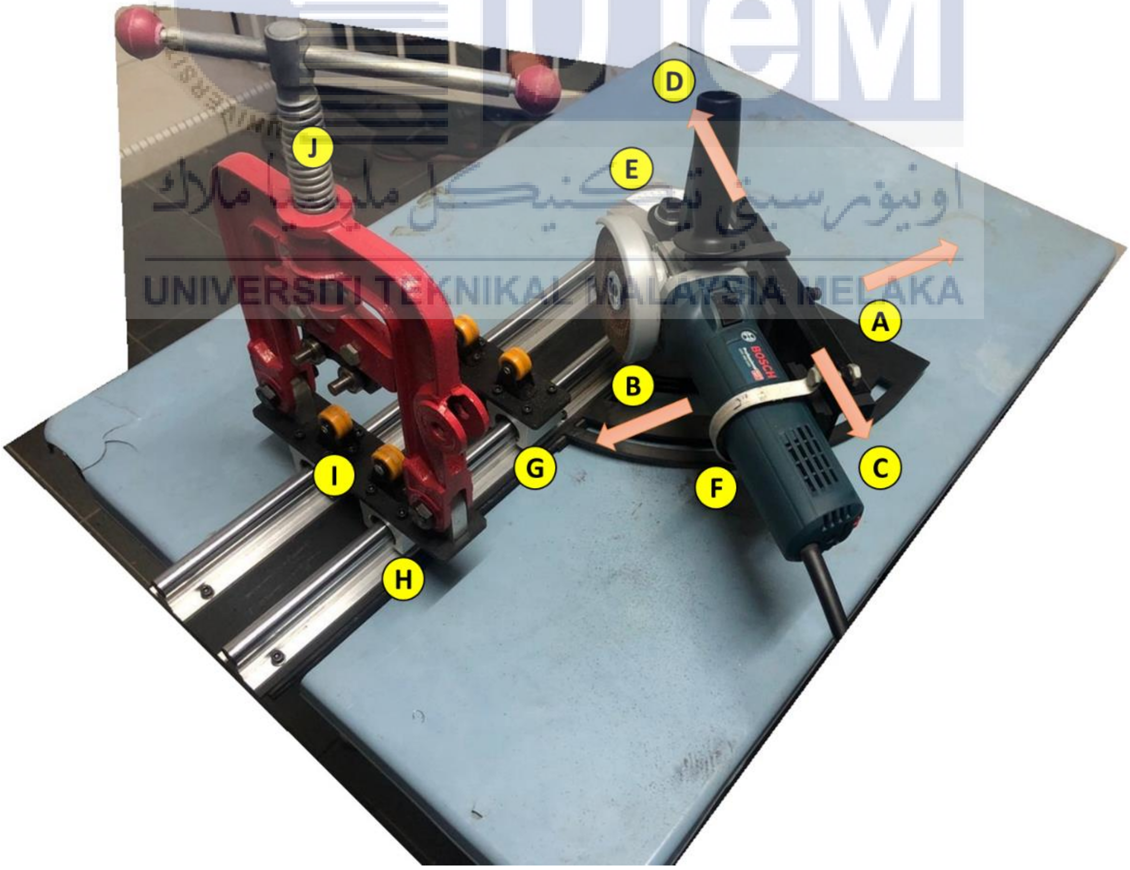


Figure 3.9: Steps of using a jig.

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i. Based on Figure 3.9, the direction of A, B, C, or D is a position of the grinder to be set up for the desired angle and then tighten the bolt and nut at E.
ii. The nut at F was tightened to lock the position of the grinder.
iii. The position of G and H was setup based on the length of the pipe.
iv. The pipe was placed on I, where it rotated by a roller.
v. At a position J, where a clamp tightened pipe.

3.7 Finding Uncertainty Measurement on Angle Bevel Result.

During the measurement process, the result of the pipe's bevel angle probably would not give exact values as set by a grinder holder to cut the desired bevel angle. Therefore, the bevel angle measurement reported in the experimental was based on 3 readings taken for several bevelling processes to overcome this uncertainty measurement. This method was to ensure the efficiency of the jig and fixture outcome. Table 3.2 shows the set of bevel angles on the jig and fixture.

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Table 3.2: Bevel angle

Measurement takes	**Bevel angle value (degree°)**		
	35°	**37.5°**	**40°**
First measurement			
Second measurement			
Third measurement			
Arithmetic mean			
Standard deviation			

Arithmetic mean, $\bar{X}$ for each set of bevel angle was calculate to be: -

$$\bar{X} = \frac{1}{3}\sum_{i=1}^{3} X_i$$

Equation 3.1

The value then rounded off to two decimal places.

Standard deviation, σ for each set of bevel angle was calculate using this formula: -

$$\sigma = \sqrt{\frac{\sum_{i=1}^{3}(X_i - \bar{X})^2}{N-1}}$$

Equation 3.2

The value then converted to 1 significant figure.

If this process is repeated numerous times, a series of mean bevel angle values will be obtained, with each mean value showing a small random variation. The following formula can be used to calculate the standard deviation of these mean values: -

$$u_p = \frac{1}{\sqrt{3}}\,\sigma$$

Equation 3.3

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This measures the width of the distribution of mean values expected and is called standard uncertainty measurement of the mean.

3.8 Measurement of Vibration Absorption and Bevel Angle Accuracy.

The main purpose of fabricating this jig and fixture is to reduce vibration produced by the hand grinder and measure the bevel angle's accuracy when bevelling using the jig and fixture. The vibration occurs when the object moving repetitively back/forward, right/ left, or up/down. HAVS is detected because of vibration produce and been analyze through acceleration, and then the unit is m/s^2. Figure 3.10 shows the apparatus that can use by this project to analyze the vibration produce by the jig and fixture.

Figure 3.10: Hand Arm Vibration Meter (Qamruddin et al., 2019).

This apparatus was used to read the vibration produce because it has reliable measurements. Measurement was conducted through the recommendation of exposure vibration, which does not exceed 2.5 m/s^2 of 8-hour working time (Orelaja et al., 2019). Vibration has been measured by these steps: -

i. Plug the accelerometer on the instrument.

ii. Accelerometer measures back/forward, right/ left and up/down or triaxial x, y and z axis.

iii. Attach the accelerometer to the hand of an operator that handling a grinder.

iv. Switch on the instrument, and read the data shows on the screen of the instrument.

v. Take out the data of peak measurement or vector sum of a triaxial vibration data.

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For the bevel angle accuracy data, it required another approach. The bevel angle produced by the jig and fixture was expected to be more accurate than the bevel using a grinder manually. This is because the jig and fixture simplify locating and clamping the pipe and ensuring the correct positioning of the grinder with respect to the pipe. The bevel angle's accuracy when using a manual grinder is also good if the operator is skilled. Figure 3.11 shows the apparatus to measure the bevel angle produce by the bevelling process using a fabricate jig and fixture. According to the gauge passport, it correlates to the reported production accuracy, which is equivalent to ± 0.25 mm (Weldability-sif, n-d).

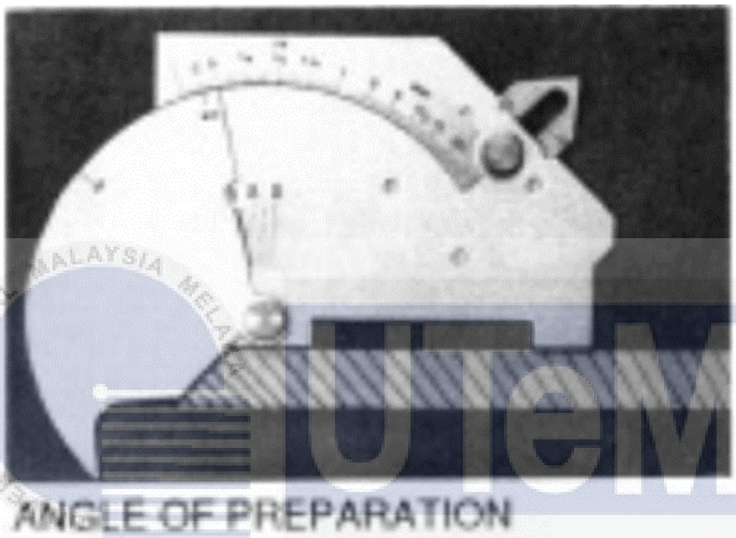

Figure 3.11: The Bridge Cam (Benjamen, 2019).

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i. The first step was to place the small disk in the groove.

ii. After the smaller disk was measured above the surface plate with the help of the upper scale.

iii. The main front of protractor must be tightened.

iv. Note the position of zero value on the meter scale.

v. Read the number of degrees stated on the scale and take 3 times the measurement for the average value.

3.9 Vibration Analysis.

The hand grinder used in the vibration analysis experiment to carry out the vibration result is Bosch Angle Grinder GWS 900-100 S Professional with 1.5 m/s² of total vibration values.

Figure 3.12: Grinder used (Bosch, n-d).

The direction of vibration exposure was also significant and was calculated in specified directions. Vibration frequencies and duration of exposure are also determined. As expected, the jig and fixture reduced the vibration because neglection of operating with two hands while operating the bevelling process. The comparison was made between vibration absorption using the fabricated jig and manually bevelling using a hand grinder. According to (Liljelind et al., 2011) a grinder machine with a specs vibration value of 2.5 m/s² and exposure to vibration depends on work posture to increase to 3.5 m/s² vibration value when performing a 1 min grinding process. The World Health Organization does not recommend not exceeding 2.5 m/s² as an 8-hour working time. For the analysis, the jig and fixture were analyzed. The Hand Arm Vibration Meter data took three times its readings for the average value then compared with vibration produced by manual grinder process whether vibration value was reduced. Table 3.2 shows the standard vibration produce by the hand grinder.

Table 3.3: Vibration magnitude by grinder (Safe Work Australia, 2015).

Tool	Type of Tool	Vibration magnitude (m/s²)
Small size of angle grinders	Typical	2-6

With the use of continuity for a longer time, this vibration exposure can harm the operator. Then, the comparison was made to illustrate the difference in vibration produced between without and without jig and fixture.

3.10 Accuracy of Bevel Angle.

In this study, the fabricate jig also approaches another advantage, providing better bevel angle accuracy. Make a sample of several pipes that undergo the bevelling process through a different angle; (i) the bevel angle produced using a jig and fixture. The data was obtained by adjusting the grinder holder's position to set the jig and fixture to the desired angle.

Table 3.4: Data analysis for different bevel angles.

Set up angle on jig. (degree°)	**Measure value using bevel protractor**
35°	
37.5°	
40°	

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CHAPTER 4

RESULT AND DISCUSSION

4.1 Fabrication of Jig and Fixture.

There were several factors in designing jigs and fixtures, and one of the factors was a study of the workpiece and finished component size and geometry. The fabricated jig and fixture underwent redesign from the previous researcher, Muhammad Syakir Bin Zainuddin (2019). Referring to that design, the manufacturing process to fabricate the jig and fixture was reselected based on the machine and process availability.

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4.2 Design Improvement.

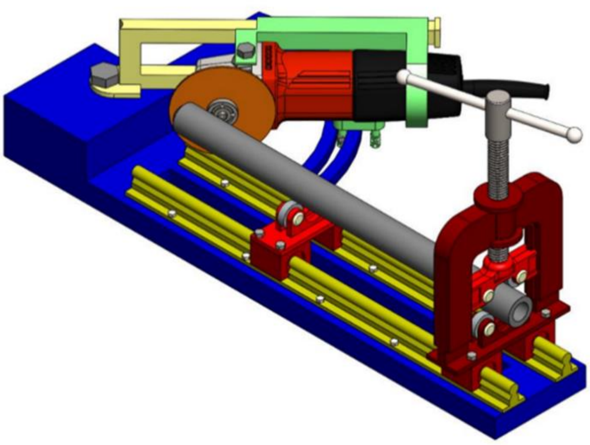


Figure 4.1: Previous design (Muhammad Syakir Bin Zainuddin, 2019).

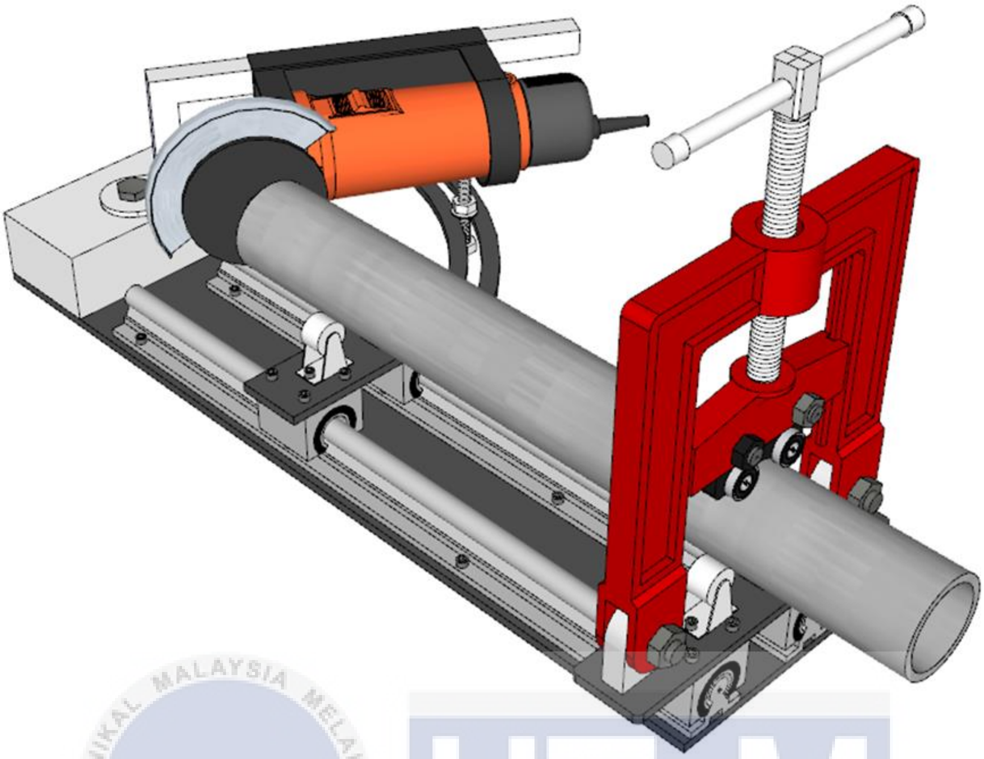
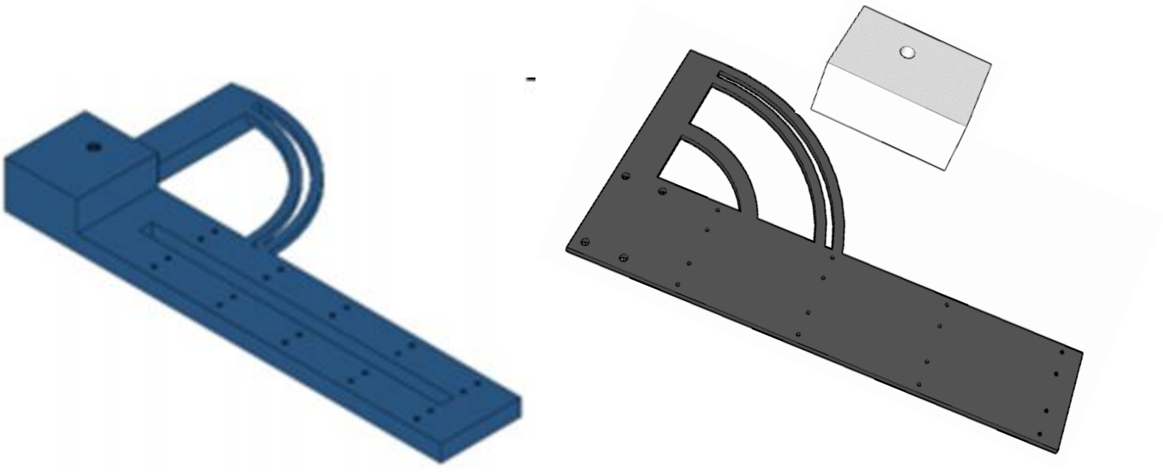


Figure 4.2: Final design that was fabricated.

The design of the fabricated jig was an improvement from the previous researcher. In addition, the fabricated jig and fixture have some new features, such as detachable bearing based, which was, joining parts of the clamp and linear rail link. This feature provides the ease of assembling and disassembling the jig to be stored. Following are the parts that redesigned due to fabricating the jig and fixture: -

4.2.1 Based Structure.

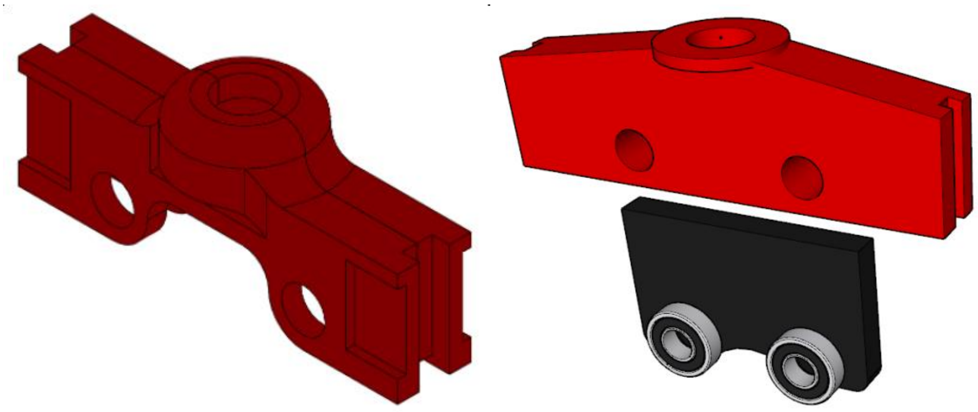


(a) (b)

Figure 4.3: (a) Previous design-based structure and (b) fabricated based structure.

A mild steel plate was used to fabricate the based structure using a laser cutting machine. The base was fabricated separately between the block-based and based structures, then joined using a bolt. The block-based structure was fabricated using a lathe machine, and the material used was aluminium. This manufacturing process is selected to reduce the weight for the overall size of jig and fixture, where the previous design was designed to fabricate in one piece part. Instead of using a bulky size of mild steel for one piece of based structure, that process needs to be machined layer by layer was not good because it causes wasted material due to removing unnecessary parts by machining process.

4.2.2 Upper Bearing Support.



(a) (b)

Figure 4.4: (a) Previous design upper bearing support and (b) fabricated upper bearing support.

Considering the selection of the manufacturing process for bearing-based is crucial because it was attached with the upper bearing support. Roller-based and upper bearing support acts as a holder to hold the pipe in between during the bevelling process. Fabricated upper bearing support was fabricated using a laser cut machine, where the mild steel plate is replacing the bearing connector. This process is easy to fabricate compared to using the casting process as planned by the previous design. Furthermore, the detachable upper bearing support part was reliable for the pipe diameter because the upper bearing support plate can easily be fabricated for a bigger size.

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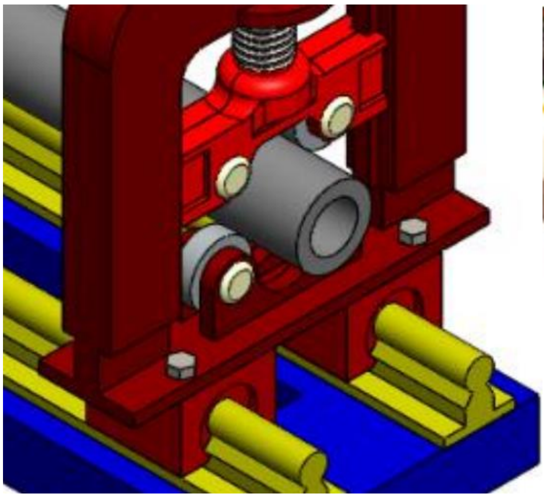
4.2.3 Clamp Based.



(a) (b)

Figure 4.5: (a) Previous design clamp based, (b) fabricated clamp based.

The manufacturing approach by previous design is to cut the piece of metal plate, then weld it permanently to the clamp. This process made the clamp and roller based assemble permanently, and its problem when storing the jig and fixture. The aluminium bracket was fabricated using a lathe machine then assemble on clamp-based instead of welding, and this process can make the clamp detachable from the bearing linear rail.

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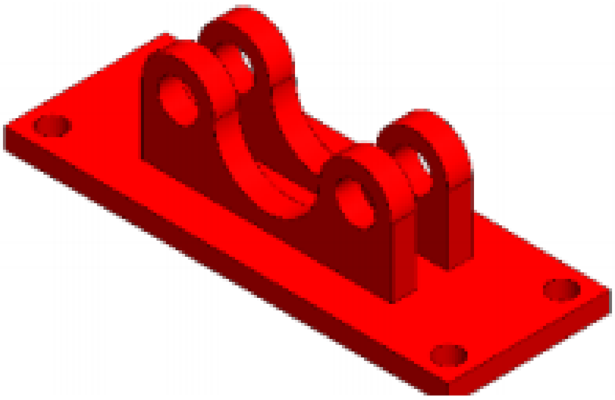
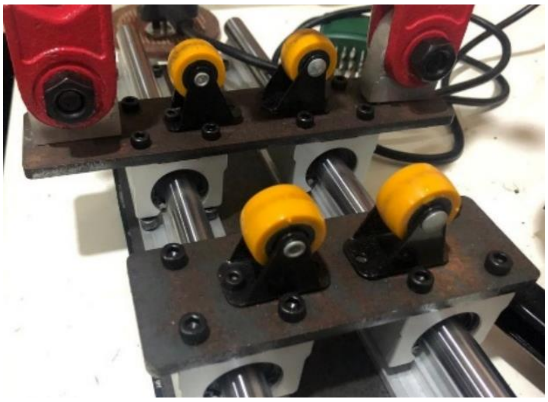
4.2.4 Roller based.





(a) (b)

Figure 4.6: (a) Previous design Roller based, (b) fabricated Roller based.

The bearing with a metal plate connected to roller-based was also fabricated by replacing the bearing with a roller. This manufacturing process offers detachable features to the jigs and fixtures, which can be disabled after using them. It also reduces the weight of the jig and fixture from being made of a single part.

4.3 Fabrication of Jig and Fixture.

Selecting the manufacturing process for the part that needs to be fabricated comes with challenges due to the capability of the manufacturing process itself to fabricate the part with ease. The jig and fixture have a medium size of scale around 610mm X 330mm with 2kg of a hand grinder. According to Muhammad Syakir Bin Zainuddin (2019), in this research, the weight of the jig and fixture is 33809.32g. The entire weight of the jig and fixture is significant since several important parts are fairly heavy, such as a clamp, a base structure, a hand grinder, and some other parts that are quite heavy. Therefore, this process requires some parts to be reselected their material selection and manufacturing process to reduce weight for the overall size of jig and fixture.

Due to the detachable jig and fixture joined the parts through fasteners such as bolt and nut. Some parts required bulky material size to use, but it will have a waste of material when performing a machining process. The engineer must note this process before fabricating jig and fixture, so no material waste when machining the bulky part.

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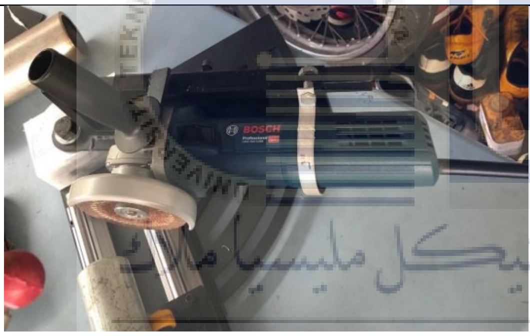
4.4 Analysis of Vibration Produced by a Jig and Fixture.

The vibration analysis was conducted using a hand grinder. It produces and transmits the vibration from the hand grinder into a jig instead of the worker's hand. The jig and fixture were specially designed to lock and place the hand grinder using a grinder connector and grinder holder on the jig that allows the operator to avoid handling a hand grinder. In this investigation, a hand grinder was assembled to a jig and fixture and performed a bevelling process on a pipe end. The jig and fixture hold the hand grinder in position with the desired angle setup for making a bevel end pipe joint. An investigation was carried out where the worker did not have to hold the hand grinder to bevel because he only needed to hold the pipe to make the bevel end pipe joint. The vibration reading device is placed in the hands of the worker during the operation as an experiment. The purpose of the vibration reading device is to read the vibration produced by the hand grinder where they have transmitted the vibration from the hand grinder into a jig and fixture instead of directly transmitting it to the worker's hand.

4.4.1 Experimental Setup.

Vibration analysis has been conducted using a vibration reading device or Hand Arm Vibration Meter. The function of this device is to measure the vibration produced by the jig and fixture toward the worker’s hand when bevelling the end pipe. The 2- and 3-inch diameter pipe are used in this experiment and also undergoes several setups, which are: -

Table 4.1: Experiment setup.

Using Jig and Fixture	**Manual Bevelling**
1.  Hand grinder was connected into jig and fixture.	1.  Both hand was used to hold the hand grinder and pipe in the beginning of the bevelling process.
2.  Setup the desired angle (for angle measurement analysis) for hand grinder’s disk to cut the pipe.	2.  Hand Arm Vibration Meter was attached to the worker’s hand during the bevelling process.

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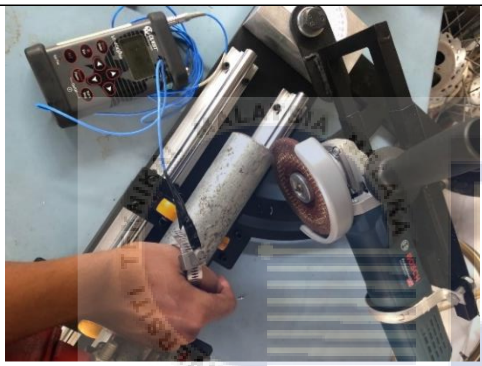
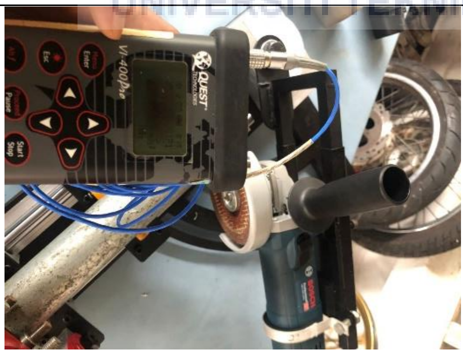
3.  Placed the pipe on the jig and fixture's roller based.	3.  Started the bevelling process by turn on the hand grinder and observe the vibration value on the Hand Arm Vibration Meter.
4.  Hand Arm Vibration Meter was attached to the worker's hand during the bevelling process.	
5.  Started the bevelling process by turn on the hand grinder and observe the vibration value on the Hand Arm Vibration Meter.	

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4.4.2 Collecting Vibration Data.

The experiment starts with placing the Hand Arm Vibration Meter with brand Quest VI-400Pro. This portable vibration analyzer simultaneously measures the triaxial vibrations from the accelerometer on the worker's hand while performing a bevel end pipe joint to galvanized steel and stainless-steel pipe. Next, an experiment has been conducted until the bevelling process was done because want to get a vibration value from the Hand Arm Vibration Meter. Then, this process was repeated to the conventional method. Finally, the hand Arm Vibration Meter was placed again on the worker's hand to get the vibration value when manually bevelling using a hand grinder. Finally, the result of the experiment was compared with their respective vibration value toward humans regarding the EAV is 2.5 m/s^2 and ELV is 5 m/s^2 average over 8 hours according to The Control of Vibration at Work Regulations 2005.

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Figure 4.7: Worker performing a bevelling process using a jig while Hand Arm Vibration Meter detect the vibration produce by the hand grinder.

Figure 4.8: Worker performing a manual bevelling process while Hand Arm Vibration Meter detect the vibration produce by the hand grinder.

The value from the Hand Arm Vibration Meter has been transferred into the QuestSuite Professional II software to validate the result of the experiment performed. In addition, the Hand Arm Vibration Meter was applied to both methods with the same type of hand grinder and pipe to determine that the vibration absorption on humans does not exceed the EAV and ELV. Figure 4.9 below shows the QuestSuite Professional II software that evaluated the Hand Arm Vibration Meter data for both methods.

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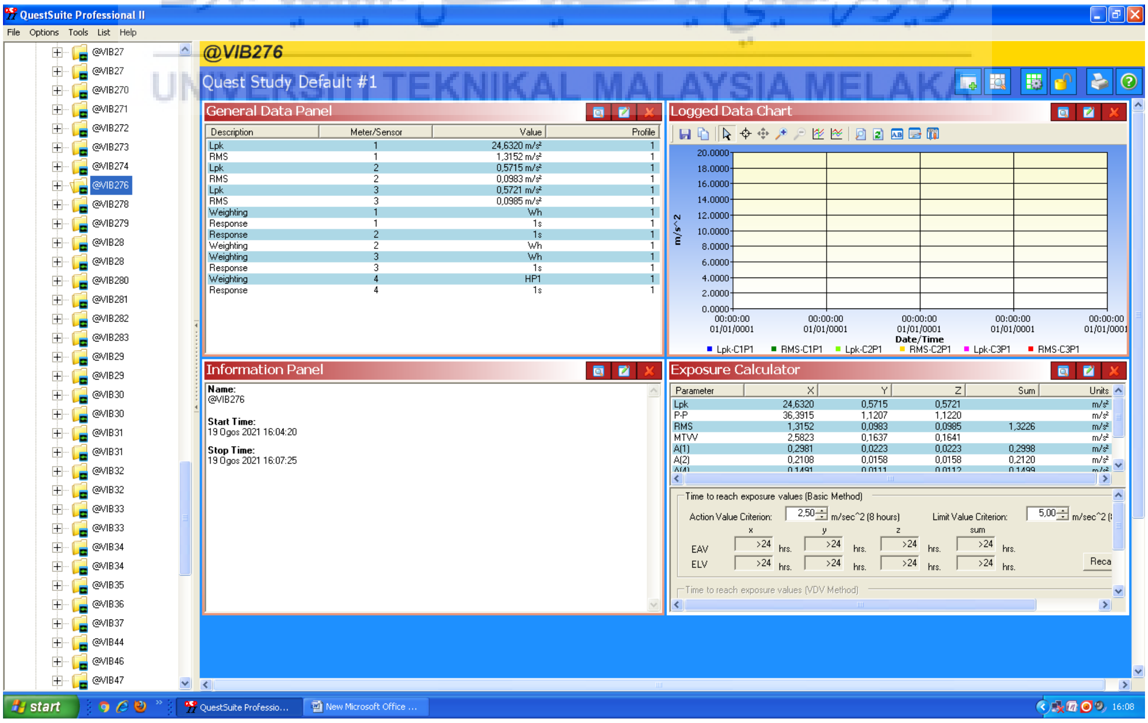
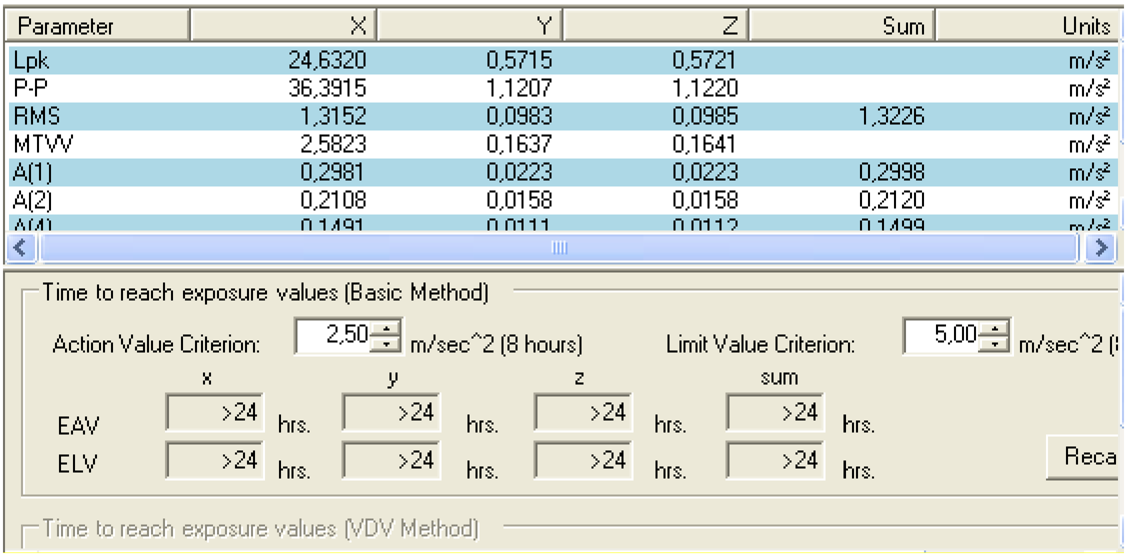
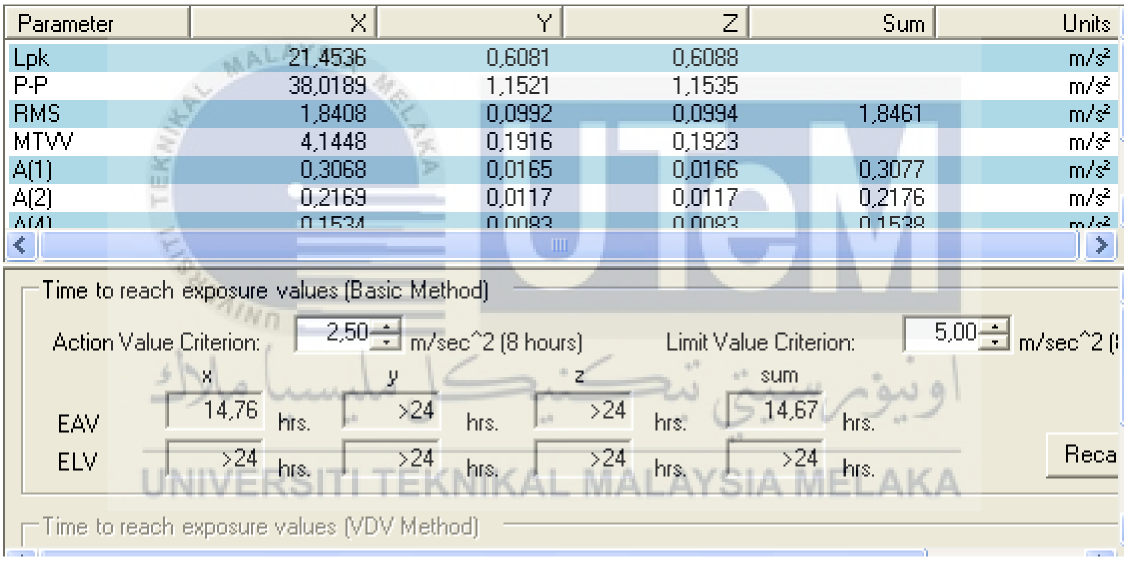


Figure 4.9: Interface of QuestSuite Professional II software.



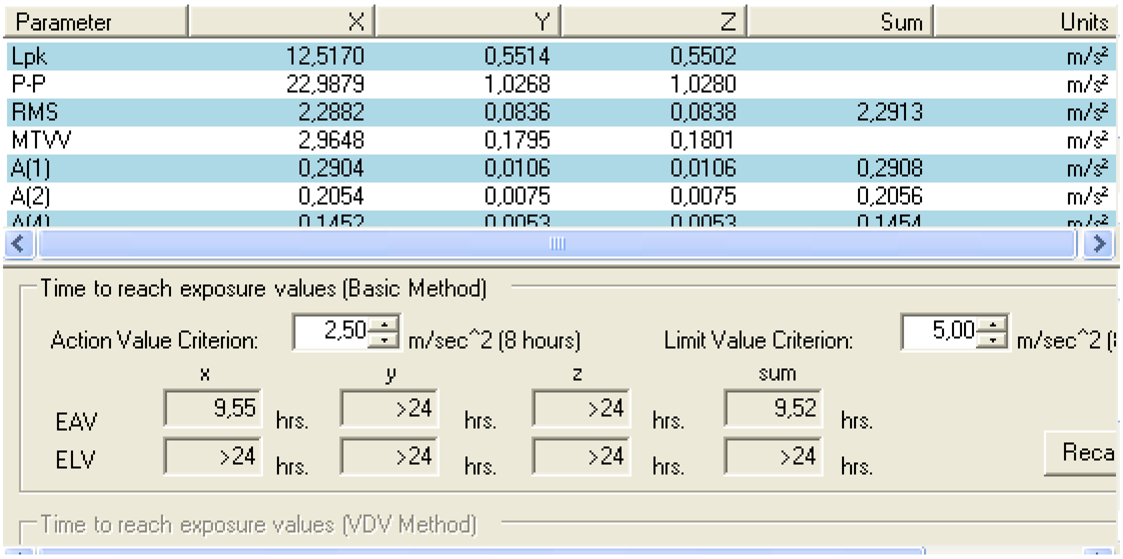
(a)



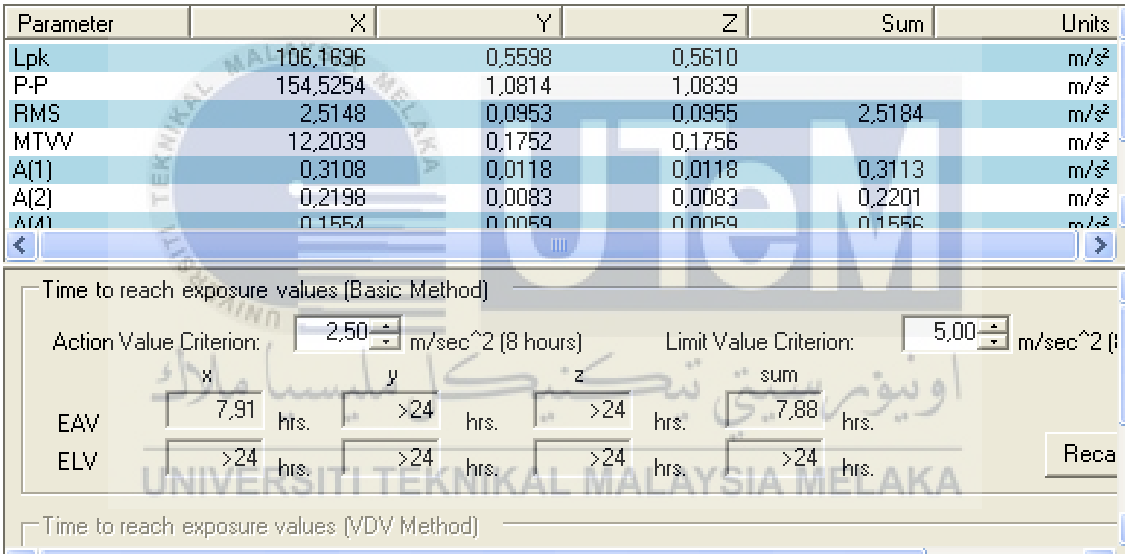
(b)

Figure 4.10: Vibration value while using jig and fixture to perform a bevelling process. (a) 2-inch galvanized steel test and (b) 3-inch stainless-steel test.

Figure 4.10 shows only the RMS value that has been monitored. The values that have been obtained during the bevelling process are 1.3152 m/s² and 1.8408 m/s².



(a)



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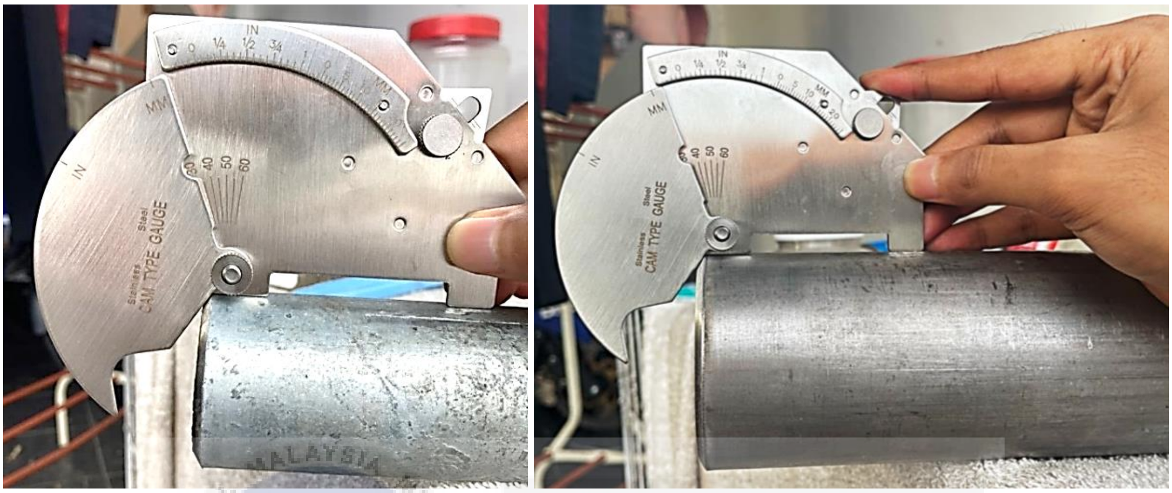
(b)

Figure 4.11: Vibration value when performing a bevelling process through conventional method. (a) 2-inch galvanized steel test and (b) 3-inch stainless-steel test.

The vibration value increases when using the conventional method because it causes the worker to use their hand to hold the grinder directly. For example, Figure 4.11 shows the value are 2.5184 m/s^2 and 2.2913 m/s^2, and it states that the value is very exposing to workers when performing the bevelling process.

4.5 Analysis of The Accuracy of Bevel Angle.

The 2- and 3-inch diameter pipes were used to test the capability of the jig and fixture to bevel the end pipe joint with 35°, 37.5°, and 40°. Figure 4.12 shows the bevel angle of 35° for 2- and 3- inch pipe measured by The Bridge Cam Gauge.



(a) (b)

Figure 4.12: Bevel angle of 35° on (a) 2-inch pipe and (b) 3-inch pipe.

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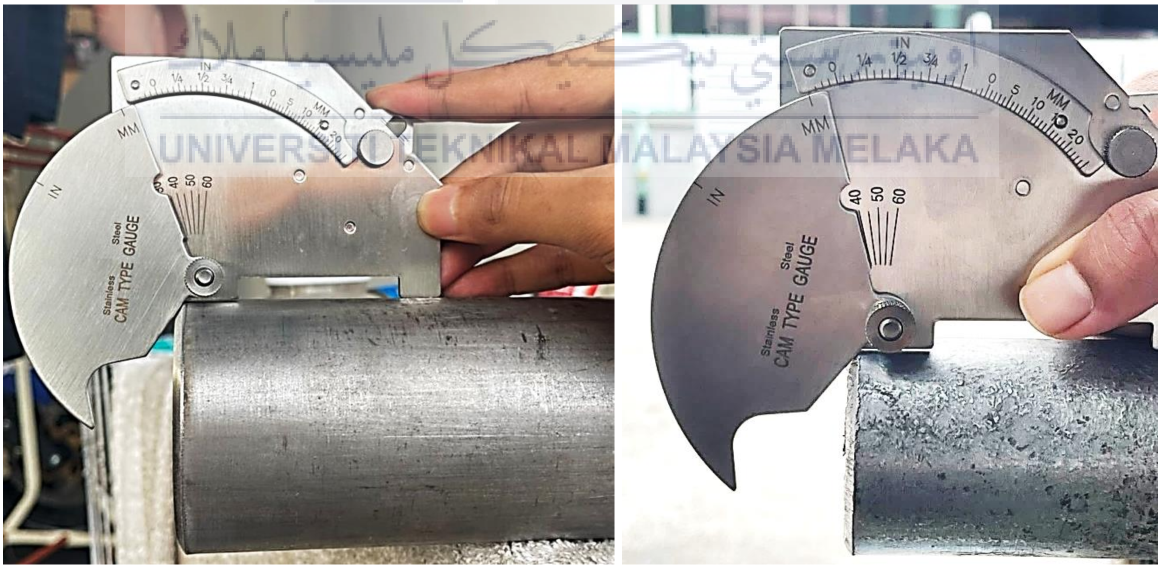

(a) (b)

Figure 4.13: Bevel angle of 37.5° on (a) 3-inch pipe and (b) 40° on 2-inch pipe.

4.6 Discussion of Experiment.

4.6.1 Discussion of Vibration Analysis.

The vibration produce by the jig and fixture was proof that it reduced the transmission of vibration into the worker's hand while performing a bevelling process using a hand grinder. According to the simulation prepared by Muhammad Syakir Bin Zainuddin in 2019, the amount vibration frequency transfer from grinder to a pipe without applying jig and fixture during a bevelling process is 54.934Hz of frequency, while by using a jig, the amount of frequency was dropped to 52.774Hz.

The EAV is 2.5 m/s^2, and ELV is 5 m/s^2 average over 8 hours according to The Control of Vibration at Work Regulations 2005. Both methods are considered safe from exposing the worker from getting a HAVS because they still do not exceed the ELV limit, and the worker does not do the bevelling process for 8 hours. Table 4.2 below shows the EAV and ELV related to both methods.: -

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Table 4.2: EAV and ELV value for 3-inch pipe that related to both methods.

Method	**EAV is 2.5 m/s^2 average over 8 hours (Standard)**	**ELV is 5 m/s^2 average over 8 hours (Standard)**
Using Jig and Fixture	Before reaching the EAV, the use of the jig and fixture with a value of 1.8408 m/s^2 is safe to use for 14.67hrs.	Before reaching the ELV, the use of the jig and fixture with a value of 1.8408 m/s^2 is safe to use up more than 24hrs.
Manual Bevelling	Before reaching the EAV, the use of a hand grinder with a value of 2.5184 m/s^2 is safe to use for 7.88hrs.	Before reaching the ELV, the use of a hand grinder with a value of 2.5184 m/s^2 is safe to use up more than 24hrs.

4.6.2 Discussion of Bevel Angle Measurement.

The bevel angles were measured at three different angles, and the angles were 35°, 37.5°, and 40°. Each of these angles was taken multiple measurements to obtain the accuracy of the measurement.

Table 4.3: The uncertainty value while using the Bridge Cam Gauge.

Attempt	**Bevel angle (degree°)**		
	35	**37.5**	**40**
1st measurement	35.2	37.4	41
2nd measurement	35	38	40
3rd measurement	34.8	37.2	40

For 35° of bevel angle: -

Arithmetic mean, $\bar{X}$ $= \frac{35.2+35+34.8}{3} = 35$

$$= 35.2 - 35 = 0.2 \longrightarrow (0.2)^2 = 4x10^{-2}$$

$$= 35 - 35 = 0 \longrightarrow (0)^2 = 0$$

$$= 35 - 34.8 = 0.2 \longrightarrow (0.2)^2 = 4x10^{-2}$$

$$\text{Total} = 8x10^{-2}$$

Standard deviation, σ $= \sqrt{\frac{8x10^{-2}}{2}} = 0.2$

$$= \pm 0.2°$$

Standard uncertainty, u_p $= \frac{1}{\sqrt{3}}\,(0.2) = 0.115°$

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For 37.5° of bevel angle: -

Arithmetic mean, $\bar{X}$ $= \frac{37.4+38+37.2}{3} = 37.5$

$$= 37.4 - 37.5 = -0.1 \longrightarrow (-0.1)^2 = 1x10^{-2}$$

$$= 38 - 37.5 = 0.5 \longrightarrow (0.5)^2 = 3x10^{-1}$$

$$= 37.2 - 37.5 = -0.3 \longrightarrow (-0.3)^2 = 9x10^{-2}$$

$$\text{Total} = 4x10^{-1}$$

Standard deviation, σ $= \sqrt{\frac{4x10^{-1}}{2}} = 0.4$

$$= \pm 0.4°$$

Standard uncertainty, u_p $= \frac{1}{\sqrt{3}}(0.4) = 0.231°$

For 40° of bevel angle: -

Arithmetic mean, $\bar{X}$ $= \frac{39.7+40+40.3}{3} = 40$

$$= 39.7 - 40 = -0.3 \longrightarrow (-0.3)^2 = 9x10^{-2}$$

$$= 40 - 40 = 0 \longrightarrow (0)^2 = 0$$

$$= 40.3 - 40 = 0.3 \longrightarrow (0.3)^2 = 9x10^{-2}$$

$$\text{Total} = 2x10^{-1}$$

Standard deviation, σ $= \sqrt{\frac{2x10^{-1}}{2}} = 0.3$

$$= \pm 0.3°$$

Standard uncertainty, u_p $= \frac{1}{\sqrt{3}}(0.3) = 0.173°$

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With the information (Farrance & Frenkel, 2012), they show that the uncertainty measurement provides the true value of estimating the mean value of a series of measures. The uncertainty measurement shows the accuracy of the value is near to the gauge passport reported in product details, which is equivalent to ± 0.25 mm. Due to the vibration, the movement of the grinder holder and connector may be slightly moved from the angle that was already set.

4.7 Costing Analysis.

Estimation of costs is an assessment of a plan, project, or expenses operated. The cost estimation is the result of the method of calculating costs. The cost estimate has a single total value, and the component values may be identifiable. Cost analysis is a basic methodology for comparing the market interest in a project to its production cost. In the cost estimation analysis of a product, two important costs were calculated: variable cost and fixed cost.

4.7.1 Variable Cost.

A variable cost is a business expense that varies in the volume of production. Based on a business's manufacturing, variable costs rise or decrease; they rise as demand rises and decline as output declines. For example, table 4.2 shows the variable cost estimation of parts in producing the jig and fixture for the bevel end of the pipe joint.

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Table 4.4: Variable cost of the project.

Item	Part	Quantity	Make(M) / Purchase(P)	Price (RM)
1	Based Structure	1	M	60.00
2	Block Based Structure	1	M	50.00
3	Linear Rail Link	2	P	500.00
4	Grinder	1	P	320.00
5	Grinder Connector	1	M	15.60
6	Grinder Holder	1	M	15.60
7	M6 X 1.0	2	P	0.36
8	M8 X 1.25	4	P	1.40
9	M16 X 2.0	1	P	1.10
10	M5 X 0.8	32	P	4.16
11	M10 X 1.5 Half-Thread	1	P	1.50
12	M10 nut and washer	1	P	1.30
13	M10 lock nut	1	P	0.25
14	M4 X 0.7	4	P	0.60
15	M12 X 1.75	2	P	1.60
16	Clamp Screw	1	P	-
17	Upper bearing support	1	M	12.00
18	Clamp	1	P	50.90
19	Bearing	4	P	8.80
20	Linear steel rod	2	P	15.90
21	Clamp bracket	2	M	20.00
22	Roller based	2	M	17.80
23	Roller	4	P	23.60
24	Bearing linear rail	4	P	-
Total Variable Cost				**RM 1122.47**

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4.7.2 Fixed Cost.

A constant cost is an expense or cost that does not change with the increase or reduction in the amount of items or services generated or consumed. Fixed costs are expenses that an organization has to pay, regardless of any economic transaction. For example, fixed costs could include rental, housing, equipment, and much more. Table 4.5 illustrates the project's fixed cost.

Table 4.5: Fixed cost of the project.

No.	Fixed Cost	Amount	Cost (RM)
1	Electricity Bills	1 Month	400.00
2	Transportation fees	1 Month	250.00
3	Maintenance fees	1 Month	160.00
4	Water Bills	1 Month	200.00
5	Insurance	1 Month	150.00
6	Labour	1 Month	1000.00
Total			**RM 2160.00**

(Assumption 1 month = 10 unit produced)

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4.7.3 Manufacturing Cost.

Manufacturing cost $= \frac{\text{Total fixed cost+Total variable cost}}{\text{Amount produced}}$

$= \frac{2160.00+1122.47}{10}$

$= \text{RM } 328.25$

Profit margin 20% $= \text{RM } 328.25 \text{ X } \frac{20}{100}$

$= \text{RM } 65.65$

Selling Cost/unit $= \text{Manufacturing Cost } + \text{ Profit Margin Cost}$

$= 328.25 + 65.65$

$= \text{RM } 393.90$

Manufacturing costs are the quantity of all resources consumed throughout the production process. Fixed and variable manufacturing costs are the sum of costs divided by the assumption of the production unit product. A profit margin of 20 percent was computed from manufacturing costs. The product's selling costs per unit are therefore the sum of manufacturing costs plus profit margin costs. The selling costs of a jig and fixture unit for the bevel end of the produced pipe joint product were calculated to be RM 393.90.

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Overview.

This chapter aims to bring the project closure by reflecting on the results and analysis from the previous chapter. Following the conclusion, recommendations were made for future research that can be carried out.

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5.2 Conclusion.

This project has two objectives, and all of the objectives have been fulfilled as a result of the analyses conducted. In conclusion: -

i. The fabrication of a jig to bevel a pipe in preparation for welding was accomplished effectively through machining, forming, and joining processes. The designed changes have resulted in a reduction in overall weight from 33.8kg to 19kg.
ii. Compared to the conventional method, the fabricated jig significantly reduces the operator's vibration exposure. Following that, a standard uncertainty method was calculated, and the results revealed that the bevel angle accuracy was improved when a jig was applied.
    a. 3-inch pipe = 1.8461m/s^2 (using jig).
    b. 3-inch pipe = 2.5184m/s^2 (without using).

5.3 Recommendation for Future Study.

Further recommendations are made according to make this jig performance even better for future purposes. To improve the accuracy of the jig and fixture, the high precision machine should be used because some parts still have an amount of vibration due to the joining process that has been fabricated inaccurately. High precision also provides a better final cut and dimension for the jig and fixture design. In addition, the jig and fixture can have some automatic features, such as a horizontal holding chuck that will improve the movement of the pipe when the bevelling process is performed. The horizontal holding chuck must be able to rotate the pipe automatically on the roller base. There are numerous advantages to using the automatic feature. They include: the user does not need to touch a pipe during a bevelling process, and at the same time, vibration transfer can be avoided into human hand arm that can cause hand arm vibration syndrome (HAVS).

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PRO-10 PB: Pipe Beveller & Flange Facer. PROMOTECH. https://www.promotech.eu/en/products/portable-pipe-beveller-flange-facer/.

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APPENDIX (A)

Gantt chart PSM 1

No.	Activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Selection of PSM Title														
2	PSM briefing and discussions with supervisor														
2	Chapter 1 (Introduction)														
3	Chapter 2 (Literature review)														
4	Chapter 3 (Methodology)														
5	Thesis writing														
6	Logbook submission														
7	PSM 1 presentation														
8	PSM 1 report submission														

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Gantt chart PSM 2

No.	Activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Briefing and discussion with supervisor															
2	Preparation of fabrication the jig and fixture															
2	Review of previous chapter															
3	Assembling process															
4	Running an experiment															
5	Chapter 4 (Result and discussion)															
6	Chapter 5 (Conclusion and recommendation)															
7	Logbook submission															
8	PSM 2 presentation															
9	PSM 2 report submission															

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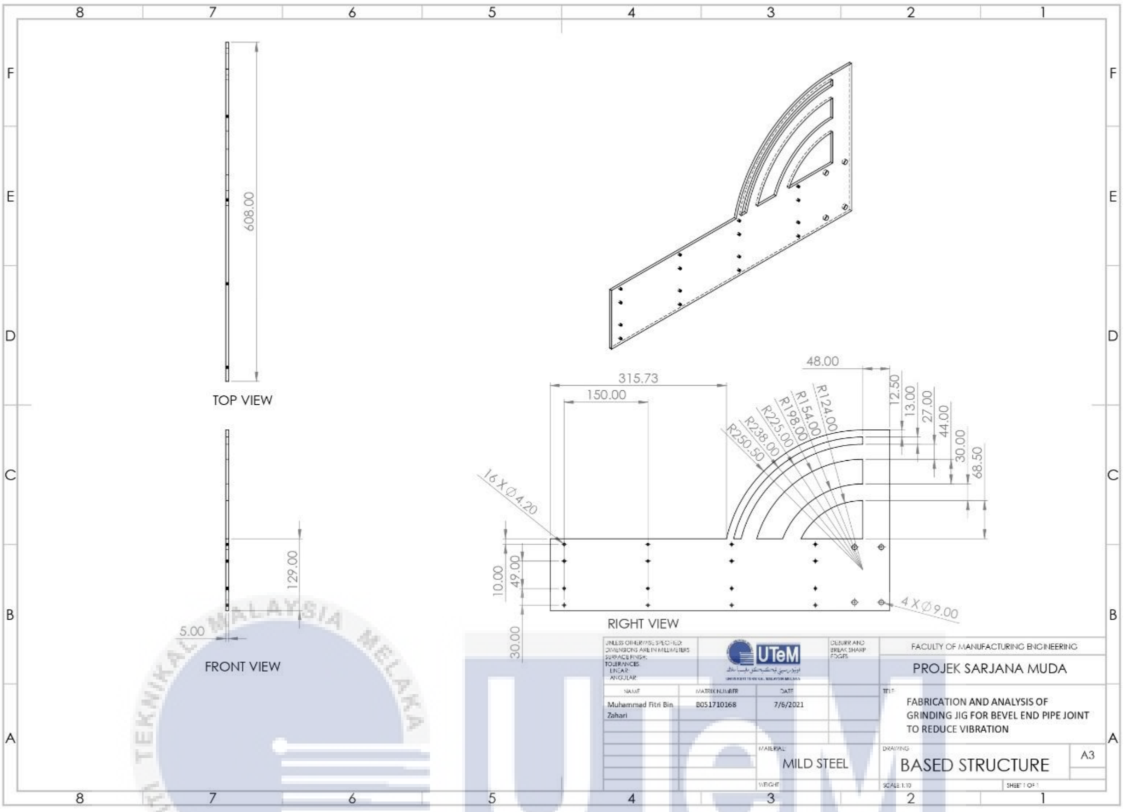
APPENDIX (B)



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FRONT VIEW
RIGHT VIEW
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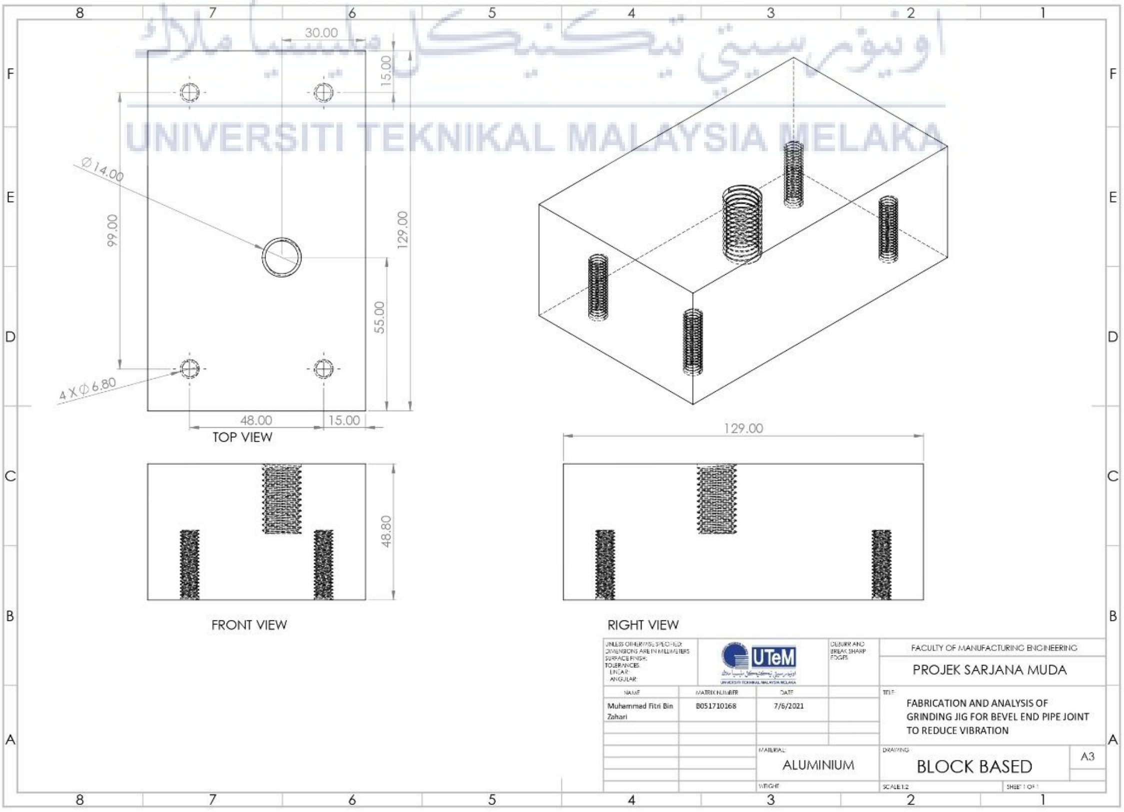
129.00
5.00
315.73
150.00
48.00
16 X Ø 4.20
4 X Ø 9.00
FACULTY OF MANUFACTURING ENGINEERING
PROJEK SARJANA MUDA
Muhammad Fitri Bin Zahari
B051710168
7/6/2021
FABRICATION AND ANALYSIS OF GRINDING JIG FOR BEVEL END PIPE JOINT TO REDUCE VIBRATION
MILD STEEL
BASED STRUCTURE
A3



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15.00
Ø 14.00
99.00
129.00
55.00
4 X Ø 6.80
48.00
15.00
TOP VIEW
48.80
FRONT VIEW
129.00
RIGHT VIEW
FACULTY OF MANUFACTURING ENGINEERING
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Muhammad Fitri Bin Zahari
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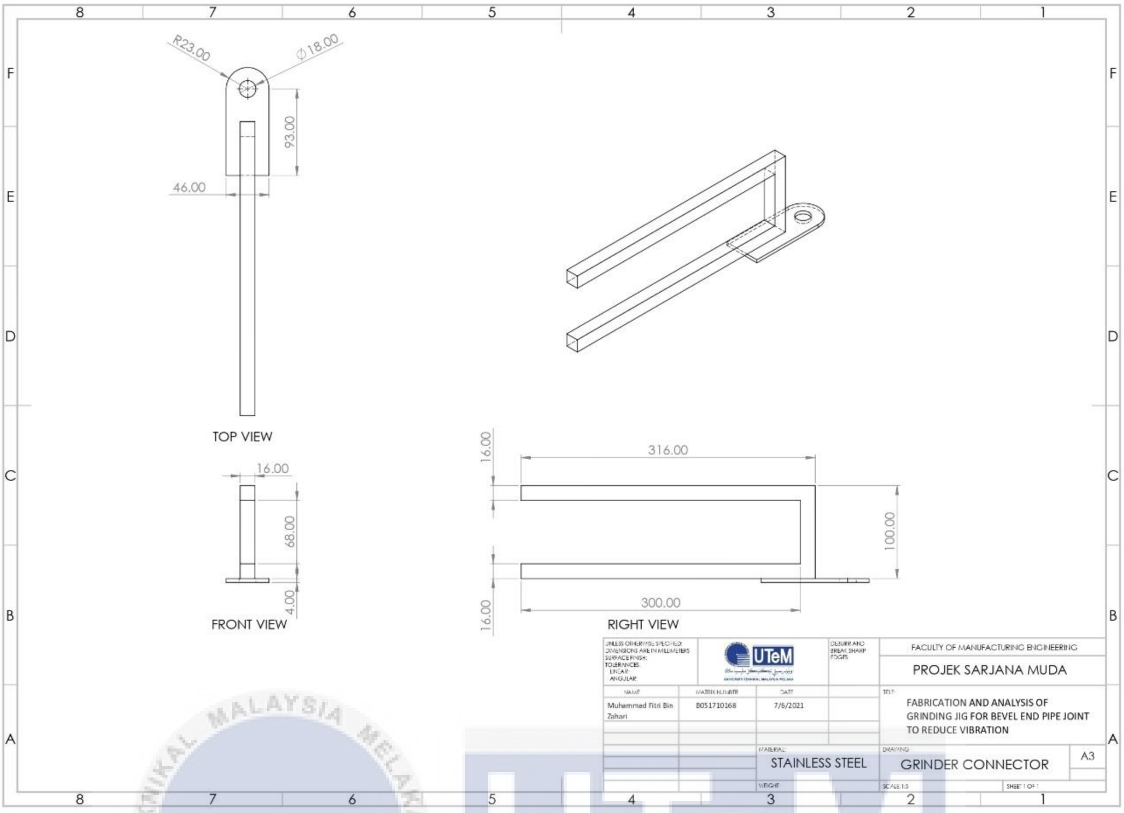
7/6/2021
FABRICATION AND ANALYSIS OF GRINDING JIG FOR BEVEL END PIPE JOINT TO REDUCE VIBRATION
ALUMINIUM
BLOCK BASED
A3



UTeM
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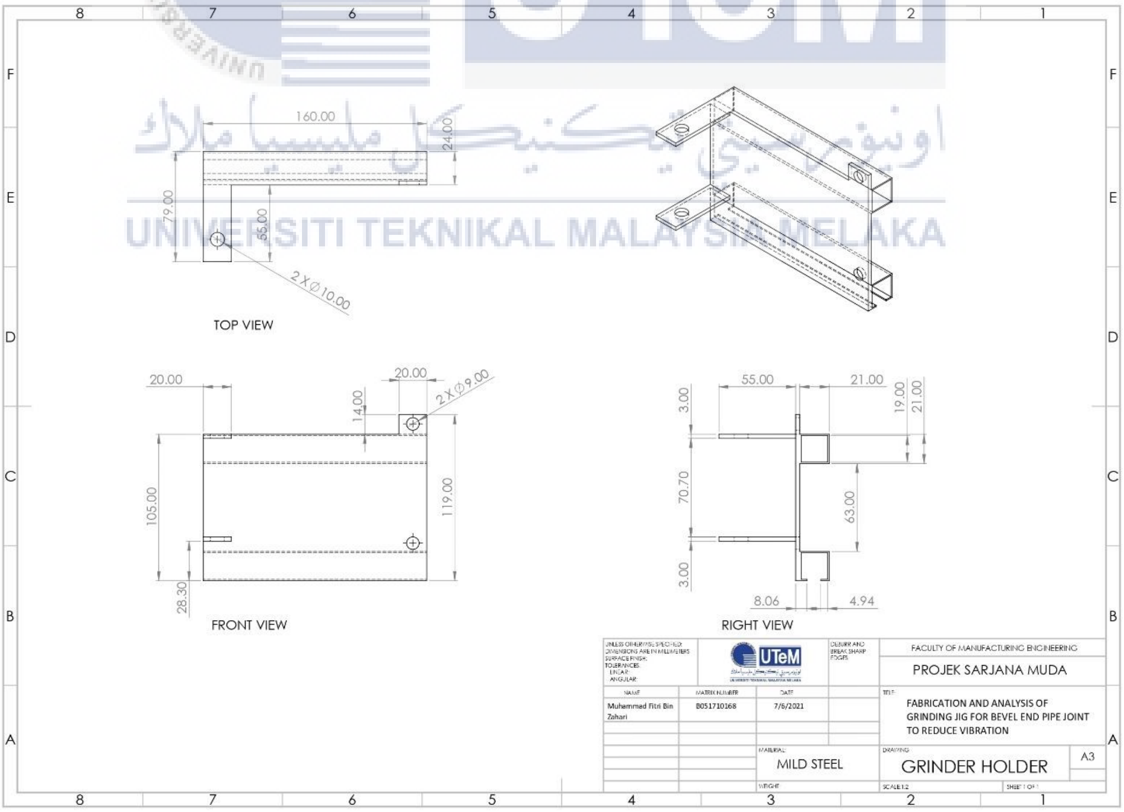

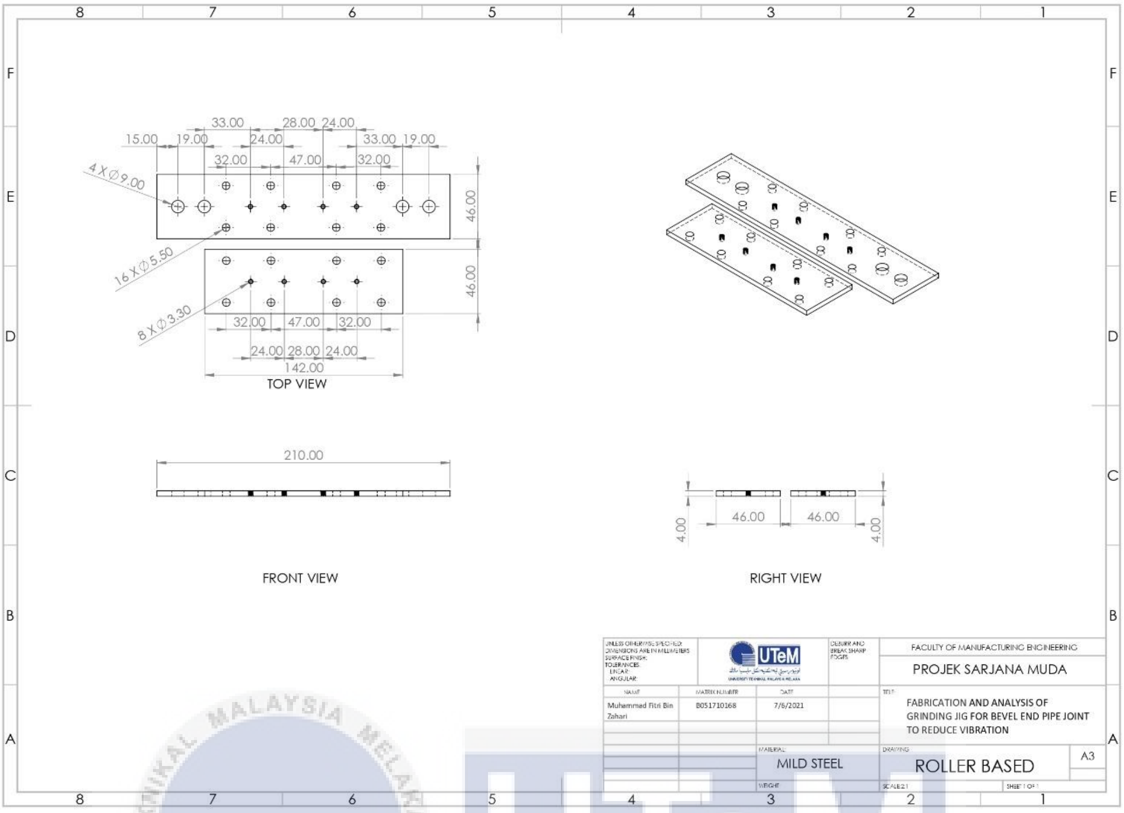
TOP VIEW
FRONT VIEW
RIGHT VIEW
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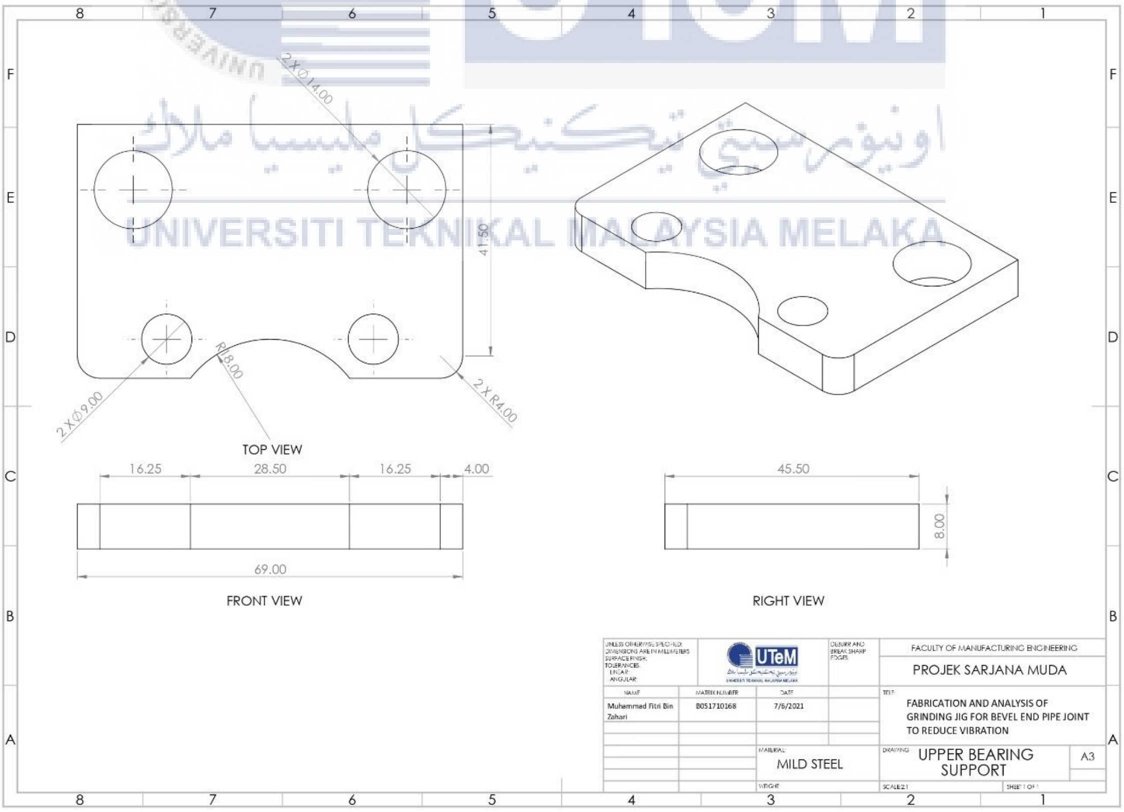
FABRICATION AND ANALYSIS OF GRINDING JIG FOR BEVEL END PIPE JOINT TO REDUCE VIBRATION
MILD STEEL
ROLLER BASED
A3


TOP VIEW
FRONT VIEW
RIGHT VIEW
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Muhammad Fitri Bin Zahari
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7/6/2021
FABRICATION AND ANALYSIS OF GRINDING JIG FOR BEVEL END PIPE JOINT TO REDUCE VIBRATION
MILD STEEL
UPPER BEARING SUPPORT
A3