

DESIGN IMPROVEMENT AND VIBRATION ANALYSIS OF A FABRICATED PIPE BEVELLING JIG FOR WELDING PREPARATION

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



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DECLARATION

I hereby declare this report entitled "Design Improvement And Vibration Analysis Of A Fabricated Pipe Bevelling Jig For Welding Preparation." This is the results of my own research except as cited in the reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as partial fulfillment of the requirements for a Degree of Manufacturing Engineering (Hons.). The members of the supervisory committee are as

follow:



ABSTRAK

Serong paip ialah satu proses di mana sudut terhasil antara hujung paip dan permukaan yang perlu dikimpal. Dalam serong paip, beberapa piawaian perlu dipatuhi sudut mestilah dalam julat antara 30° hingga 45°. Jari putih akibat getaran (VWF) ialah kesan jangka panjang ke atas pekerja yang terhasil daripada penggunaan alatan tangan yang bergetar dalam masa yang berpanjangan. Ujian awal telah dijalankan untuk mengukur magnitud getaran bagi jig sedia ada dengan menggunakan vibrometer. Magnitud getaran tertinggi berlaku semasa menyerong paip 3.5 inci iaitu 116.59 m/s² dalam masa 5 minit dan 43 saat. Menurut Piawaian ISO Eropah, tahap pendedahan ini menghampiri had pendedahan penunjuk kuning iaitu antara 105 m/s² hingga 150 m/s². Kajian ini berhasrat untuk mencari kaedah terbaik untuk mengurangkan atau menghapuskan pendedahan getaran untuk pekerja apabila menggunakan jig yang direka. Masalah telah dikenal pasti dan kemungkinan penyelesaian telah dicadangkan untuk jig sedia ada untuk mencapai objektif. Pemutar paip automatik dan chuck tiga rahang telah dipasangkan. Selepas penambahbaikan reka bentuk ditetapkan dengan baik, semua data dan analisis telah diambil kira. Ia kemudiannya dibandingkan dengan analisis data ketepatan sudut serong antara mesin serong paip sedia ada dan selepas mesin serong paip menjalani proses penambahbaikan reka bentuk. Ketepatan ukuran sudut serong dapat dicapai hasil daripada penambahbaikan reka bentuk jig yang dibuat. Nilai purata ketidakpastian sebelum penambahbaikan reka bentuk menunjukkan 0°34'41.15", manakala nilai selepas penambahbaikan reka bentuk adalah lebih rendah pada 0°23'55.98". Ia menunjukkan bahawa ukuran sudut serong yang tepat boleh dicapai apabila motor dapat memutarkan paip pada kelajuan malar, yang menghasilkan tahap sudut serong yang berterusan. Mengurangkan pendedahan getaran adalah pendekatan terbaik untuk mengelakkan penyakit yang berkaitan dengan alat getaran seperti Sindrom Getaran Lengan Tangan. Kajian ini diharap dapat membantu industri logam dan fabrikasi dalam proses penyediaan kimpalan paip. Ini adalah untuk memastikan proses persekitaran yang selamat apabila menggunakan jig ini untuk menyediakan serong paip.

ABSTRACT

Pipe bevelling is a process in which an angle is produced between the end of the pipe and the surface that needs to be welded. In pipe bevelling, some standards need to be followed. The angle must be in a range between 30° to 45°. Vibration-induced white finger (VWF) is a long-term effect on the worker that results from prolonged use of vibrating hand tools. Preliminary testing was conducted to measure the vibration magnitude for the existing jig using a vibrometer. The highest vibration magnitude occurs during the bevelling of a 3.5inch pipe which is 116.59 m/s^2 within 5 minutes and 43 seconds. According to ISO European Standards, these exposure levels are nearing the exposure limits yellow indicator, which is between 105 m/s² and 150 m/s². This study intends to find the best methods to decrease or eliminate the vibration exposure for the worker when using the fabricated jig. Problems have been identified and possible solutions have been proposed for the existing jig to achieve the objectives. An automated pipe rotator and three-jaw chuck were developed. After the design improvement was well established, all the data and analysis were considered. It was then compared to the data analysis of bevel angle accuracy between the existing pipe bevelling machine and after the pipe bevelling machine undergoes the design improvement process. The precision of the bevel angle measurement was achieved as a result of the improved design of the fabricated jig. The average uncertainty value before the design improvement shows 0°34'41.15", whereas the value after the design improvement was lower 0°23'55.98". It indicates that precise measurements of bevel angles are possible when the motor can rotate the pipes at a constant speed, which results in a constant degree of bevel angle being produced. Reducing vibration exposure is an excellent approach to avoiding diseases related to vibration tools, such as Hand Arm Vibration Syndrome. This study is hoped to assist the metal and fabrication industry in the process of pipe welding preparation. This ensured a safe environment when using this jig to prepare a pipe bevel.

DEDICATION

I wholeheartedly dedicate this study to my beloved mother, Radziah Binti Ali; to my father, Mohamad Harani Bin Anu;

to my family;

to my very helpful classmates and friends;

to my honourable and resourceful supervisor, PM Dr. Nur Izan Syahriah Binti

Hussein

for helps and guidance by means of giving me moral support, knowledge, time,

cooperation, encouragement and understanding.

Thank You So Much



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LIST OF ABBREVIATIONS

FKP	-	Fakulti Kejuruteraan Pembuatan
VWF	-	Vibration White Finger
ISO	-	International Organization for Standardization
HAVS	-	Hand Arm Vibration Syndrome
EAVS	-	Exposure Action Values
ELVS	-	Exposure Limits Value
HSE	A- MAL	Health and Safety Executive
SDN. BHD.	-	Sendirian Berhad
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LIST OF SYMBOLS

0	- Angle of degree
mm	- Millimetre
m/s ²	- Millimetre per second square
Inch	- Inches
m/s	- Meter per second
%	- Percentage
Nm	- Newton meter
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CHAPTER 1 INTRODUCTION

1.1 Background of Study

Pipe bevelling is a process in which an angle is produced between the end of the pipe and the surface that needs to be welded. There are a few methods to bevel a pipe, such as a portable or stationary bevelling machine or manually using a hand grinder, plasma, or torch cutter. The cheapest way to bevel a pipe is by using a hand grinder. Nevertheless, using a hand grinder for a long time will affect the worker's health when preparing the pipe welding.

In pipe bevelling, some standards need to be followed. The angle must be in a range between 30° to 37.5°, and it will form a 60° to 75° angle for both ends of the pipe by using a hand grinder, the inconsistent bevel quality or angle. A skilled worker must perform this process as the inconsistent bevel quality might affect the weldment quality and defects such as porosity. Using a manual hand-grinder, the probability of achieving an accurate dimension would be low due to the inconsistent grinding method and the grinder's vibration.

The vibration happens when the swinging movements result from the tools, equipment, and machine-generated while working. For an extended period, grinding also will cause the worker to have a vibration white finger (VWF) condition due to prolonged use of vibrating hand tools. Hand-arm vibration syndrome is a common occupational issue that impacts employees in many sectors that utilize vibrating instruments (Shen and House, 2017).

1.2 Problem statement

Pipe bevelling or edge preparation produces an angle at the edge or flat angled surface on the end of the pipe (Prasad & Lingaraju, 2017). A joint usually used in the weldment of pipe is the Butt joint (Khanna, 2014). A machining process usually produces a butt joint. (Singh *et al.*, 2019). Many problems occur when creating a groove at the end of the pipe. The most common problem in pipe bevelling is the consistent duration of preparing the pipe angle each time, as it needs to be done in the fastest cycle time possible.

Moreover, the vibration factor is an essential issue in bevelling a pipe. Most of the worker's hands are not in good condition when handling tools due to the vibration of the grinding machine for an extended period. This is because the workers need to ensure the angle accuracy is consistent. Accuracy is the most important in producing the bevelling angle. V-grooves angles are usually between 60° to 75° for pairing the pipe end. Each pipe must be around 30° to 37.5° depending on the standard to be applied. The welding operations will be simple, and the workpiece's penetration with a high depth will be achieved when producing a good angle (Pathak et al., 2021). At the same time, the root opening for both pipes is between 0.5 mm and 1 mm. The pipe bevelling requirement's tolerance must be followed to get a perfect weld(Prasad & Lingaraju, 2017).

Furthermore, exposure to vibration might affect the worker's health condition longterm. Vibration-induced white finger (VWF) is a long-term effect on the worker that results from prolonged use of vibrating hand tools such as a high-pressure water hose, rotary saw, hand grinding machine, and lawnmower, and more (Kurtul & Türk, 2018). There is no cure for healing this condition, but it is preventable.

ahund all

Lastly, only skilled workers can bevel a pipe manually using a hand grinder (Pathak et al., 2021). This operation makes a flat angled surface at the end of a pipe. The pipefitter created the angled opening, which gives the welder access to the pipe wall's total thickness, enabling the welder to produce a consistent weld that will guarantee the assembly's mechanical continuity (Sanap *et al.*, 2016).

1.3 **Objective of Study**

The objectives of this study are:

- i. To analyze the vibration and angle accuracy of the fabricated bevelling jig for welding preparation
- ii. To perform design improvement of the fabricated bevelling jig for welding preparation.
- iii. To validate the improved design of the bevelling jig for welding preparation.

1.4 Scope of Study

The scope of this study will be conducted at the Fakulti Kejuruteraan Pembuatan UTeM laboratory. This study will improve the existing design of a grinding machine's jig for pipe bevelling preparation to reduce the vibration. The current grinder bevelling machine will undergo a design improvement and the jig and fixture have been designed and fabricated from a previous study and research. The vibration analysis will be measured using a Vibro-Meter (hand-arm vibration meter) at FKP's laboratory to measure the vibration absorption on the worker's hand while bevelling a pipe using this bevelling jig. The bevelling will also be measured using measuring equipment such as a bevel protractor and bridge cam.

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1.5 Significance of Study

This study intends to find the best methods to decrease or eliminate the worker's vibration exposure when using the fabricated jig. Design improvement will be proposed to achieve the objectives. After the design improvement is well established, all the data and analysis must be considered. This will compare the data analysis of vibration between the existing pipe bevelling machine and after the pipe bevelling machine undergoes the design improvement process. This study will help the metal and fabrication industry in pipe welding preparation. It will ensure a safe environment when using this jig to prepare a pipe bevel.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review a passed study, internet sources, and journals related to pipe bevel preparation, bevelling standards, existing pipe bevelling machine, and how the vibration affects the workers while handling grinding machines. This review aims to go through prior research on the topic, such as the most effective approach for decreasing vibration and jig design to reduce worker handling of a machine or tools. Some studies will be reviewed on this topic to minimize the exposure of vibration while conducting a grinding process to prepare an angle at the end of the pipe joint. The literature review identifies, evaluates, and synthesizes the relevant literature within a particular field of research. Some studies may be reviewed on this topic to reduce vibration absorption when operating a grinding machine with a hand while constructing a bevel for an end pipe joint before preparing a pipe welding process.

2.2 Pipe bevel

A pipe bevel is the essential part of pipe welding. Pipe bevelling is a welding preparation method that creates an angle between the pipe's end and the surface to be welded. A bevelled end is when the pipe end is formed with a certain degree of angle. The quality of the bevelled pipe directly impacts the welding quality. Thus, proper preparation must be required to ensure the best weldment quality (Copier, 2020). Besides bevelling, pipe bevelling can also be used as deburring pipe ends for safety and aesthetic purposes.

2.2.1 Pipe Bevelling Preparation

The quality of the pipe joint is directly affected by the pipe joint preparation. In many cases, the failure of the pipe joint may be affected by poor joint preparation. The pipe welder must be familiar with and practice the skills necessary to successfully prepare the joint for welding. Proper selection and preparation of groove angles are critical in fabricating a welded joint. A proper joint design should be chosen to provide the least amount of deformation and residual stresses in the weldment while also being cost-effective (Srinath Reddy et al., 2019).

When pipe ends are bevelled, a weld is better likely to be accepted, lowering repair or cut-out expenses and keeping a project on track. Bevelling pipe ends is a critical aspect of getting a good weld. It improves the weldment surface area, resulting in stronger welds that can withstand higher stress essential for pipe weldment (Dai et al., 2020).

Below is the step in weld joint preparation (Hughes, 2009):

- 1. The weld joint has been appropriately prepared in accordance with the specified procedure.
- 2. The joint is correctly sized, especially the groove angles, groove radius, root face, etc.
- 3. Ensure temperatures are in accordance with Welding Procedure Standards.
- 4. Tack weld the pipes together after any pre-heated requirement.

To weld a pipe, or a single-v but joints are commonly used. Each of the elements of the weldment has its standard name. Those names are usually used in pipe welding, and the welder must be familiar with the terms, as shown in Figure 2.1 (Hoobasar Rampaul, 2003).



Figure 2.1: Welding Process Definition

2.2.2 Pipe bevelling standards

Some guidelines must be followed while bevelling pipes, such as the angle must be between 30° and 37.5°, and it must create a 60° to 75° angle on both ends of the pipe when using a manual grinder to avoid uneven bevel quality or angle. By referring to Figure 2.2, all the dimensions should be followed. Because the bevel quality may affect the weldment quality and failure such as porosity, etc., this technique must be performed by a qualified worker (Lucas, 1991).



Figure 2.2: Dimension of V-groove (Lucas, 1991)

According to the standards, a pipe with a minimum wall thickness of more than 3mm should undergo welding preparation. Table 2.1 shows the joint preparation used in pipe welding (Hoobasar Rampaul, 2003).

Type of pipe joints standards	Description
	A fundamental square edge, close butt joint
UNIVERSITI TEKNIK	arrangement may be used to weld the tubes
	with a wall thickness that is less than 3mm
70 to 90°	A single V butt joint is utilized to weld
(b) 0 to 1.5mm	tubes with more than 3mm wall thickness.

Table 2.1: Pipe Bevelling Standards (Hoobasar Rampaul, 2003)

When the bevel is formed on a thick pipe, it will have a "U" shaped groove to decrease the quantity of welding filler metal utilised. Bevelling is a key aspect of the pipe welding engineering procedure. Due to being welded together, the forms of two pipe ends have been altered by removing some of the metal from each end. Bevelling can be done manually by hand-grinding or automatically by using a machine. Because the pipe ends are

bevelled, it's more likely that welding will be permitted, lowering the cost of repair or cutting while keeping the project on track (Showaib & Elsheikh, 2020).

2.3 Jigs and Fixtures

Nowadays, people's demand for manufactured products has rapidly increased dramatically. As a result, manufacturers have created innovative methods to produce highquality products at a higher production speed to fulfil the rising demand. As stated by Chennu in 2015 Jigs and fixtures are used for various purposes (Chennu, 2015). Decrease in production costs, improvement in production rate, high precision of products with no manufacturing errors, modifiability, simple machining of complicated shaped components, lesser quality control expenses, etc.

Jigs and fixtures are manufacturing tools used to fabricate identical and similar components. It is a tool that acts as a tool-guiding and workpiece holding system designed especially for machining and assembling huge batches of components. The purpose of jigs and fixtures is to remove the need for a specific set-up for each workpiece, allowing faster production while maintaining that each workpiece is produced with a particular tolerance, as stated by (Meduettaxila, 2012). He also identifies that if the jig or fixture has appropriately set up, the number of components can be manufactured quickly and easily without any extra set-up. Figure 2.3shows the example elements in jig and fixture.



Figure 2.3: Elements in jig and fixture (Meduettaxila, 2012)

2.3.1 A Jig for Pipe Bevelling

Lim Dong Jo has invented a grinder equipped with a protractor. A bracket detachably coupled to the body of the portable grinder while being coupled is rotated to the right angle and a right angle that is in close contact with the right angle of the item to be processed. A protractor showing a rotation angle is mounted at the top end of the bracket in the grinder jig constructed with a through groove through which a grinder blade travels through the proper angle and a reference point indicating a reference is shown on the grinder body. It's finished. With this construction, the grinder jig of the present invention may modify the grinder blade's grinding angle by altering the grinder's angle according to the reference point marked on the grinder body and the protractor mounted on the bracket, as shown in Figure 2.4. This jig offers cutting convenience by shifting the angle freely (Lim Dong-Jo, 2006).



2.4 Vibration

A vibration usually occurs in a rotating machine such as a grinding machine. It could have a negative impact on the health of the workers. Vibration is an oscillating mechanical wave that may arise when energy is transferred from one item to another. Human vibration has been intensively investigated in various fields, including physics, mathematics, engineering, medicine, physiology, statistics, psychology, and ergonomics, as stated by (Liljelind et al., 2011). Vibration may be transmitted to the entire body or the hand from various sources, including industrial equipment, buildings, aeroplanes, motorized vehicles such as automobiles, and maritime ships such as boats. Due to the multiple properties of the vibration, exposure to vibration from these situations might cause various symptoms. A study has confirmed that the vibration was affected by the machine tools' unbalanced rotation, misalignment, and poor bearing conditions. Vibration also might cause noise pollution and safety problems (Abu Seman *et al.*, 2019). This study can be related to preparing a pipe bevelling. This process is risky and exposes a few types of disease, such as Hand-Arm Vibration Syndrome (HAVS), if the worker exposes to the vibration for an extended period. If these difficulties arise, it will put the person's life at risk, and if the problem is not resolved, it will result in serious injuries or permanent disability.

The lack of adequate controlled scientific studies on dose-effect correlations makes it challenging to establish this relationship. Vibration is a significant risk factor affecting workers' working environment (Taylor & Wasseman, 1994).

2.4.1 Vibration In Grinding Machine

Nowadays, angle grinder machine is widely used in industries. It is a hand-held tool that can cut or polish any machinable materials. The angle grinder commonly used in industrial is shown in Figure 2.5. The major problem that occurs when handling this grinder is vibration. The vibration occurs when oscillations from a stable position. Vibration also can affect the efficiency and the performance of the machine. An imbalance grinder disc causes vibration for a grinder, the weight of the grinder, wear and tear parts in moving parts, whether it is performing work, and the work material was fixing qualities.



Figure 2.5: Angle Grinder

In a study conducted, vibration measurements were taken on the handles of highcycle electric grinders with 230 mm diameter discs. This study shows that the imbalance of grinding discs was linked to vibration magnitudes on free-running grinders. However, magnitudes were determined by the push pressures used in grinding operations, which were often more significant than free running. With increasing push power, imbalance in the grinding discs on vibration magnitudes appeared to reduce (Nelson, 1991).

Ganeshraja and Dheenathayalan also stated in their research on "Analysis and Control of Vibration in Grinding Machines" in 2014 that it is complicated to measure vibration in grinding machines (Ganeshraja & Dheenathayalan, 2014). The proof can be related to the wave surface on the workpiece and grinding wheel. The common problems that will occur due to vibration are misalignment and balancing. These problems will cause the machine's lifespan, and the tool's lifespan and production efficiency will be affected. The study found that the vibration measured was one of the significant hazards in grinding machines. Maintenance is an essential step in reducing vibration. It should be done regularly to maintain the performance of the machine. Vibration can be recognized early on if maintenance is done correctly (Ganeshraja & Dheenathayalan, 2014).

Work regenerative chatter and regenerative wheel chatter are the two forms of regenerative vibration. Vibration waves created in the workpiece are referred to as work regenerative chatter. Vibration waves created in the grinding wheel are known as regenerative wheel chatter. When the workpiece speed is high, high-frequency vibrations are seen at the commencement of the grinding operation. Because of the vibration, the material developed a surface defect. The presence of vibration has a regenerative impact on the grinding wheel, which causes surface imperfections (Grfifin & Griffin, 1992). When the material speed is low at the start of the grinding, vibration is ignored because the work piece's speed is low. As the work piece's speed increases, the amplitude progressively increases, and surface imperfection is missing. The machine's assembly, including the clamp, jig, fixture, and hydraulics system, is subjected to force and self-excited vibration. Vibration and shock can create surface errors in grinding wheels and damage the workpiece and machine equipment.

The vibrations produced by a grinding machine can impact the human body as well. This vibration usually affects the hand and arm. Vibration enters the human body via a mechanical machine or device that can activate the vibration of the hand-arm, which reduces finger feeling and influences blood flow. Because of the frequent grinding processes, this ailment is also known as HAVS (Hand Arm Vibration Syndrome).

2.4.2 HAVS White finger

Raynaud's phenomenon, linked to hand-arm vibrations, was first identified in 1862. Professor Giovanni Lori ga discovered a condition that initially emerged on the fingers of mineworkers using hammer drills in Italy in 1911, followed by pallor, cyanosis, and chills. In the 1970s, the illness was termed "white finger syndrome"(Noël, 2000). "Vibrationinduced Reynaud's phenomenon," also known as "vibration white fingers" VWF, is a circulatory disturbance caused by vibration from hand-held instruments that are mainly absorbed in the skin of the hand (Gemne, 1994). This disease is also caused by using hand power tools or holding material during machine operation. Hand-arm vibration syndrome is caused by vibrations transmitted from tools or materials to the hands and arms, harming sensory nerves, muscles, and joints (HAVS). The fingers have a negative circulatory and neurological impact that has a negative circulation effect. The side effect of the HAVS includes numbness and pain (Hargude, 2014). The peripheral circulatory system, peripheral neurological system, and muscular-skeletal system of the hand and arm are all affected by HAVS. It is desired to forecast a rate of progress and take prompt preventive action by reducing or eliminating harmful exposure. At the same time, workers with moderate illness and those who prefer to continue working with handheld power tools should limit their exposure to hand-arm vibration. Using low-vibration instruments, wearing vibrationreducing gloves, and altering work schedules to limit exposure time The disease development of these employees should be checked on a regular routine (Youakim, 2019).

The impact of vibration on workers is determined by several factors, including individual sensitivity, the severity of the vibration, the frequency of exposure, the duration, the level of insulation, grip strength, the body part affected by the source, and the maintenance and repair of used machine or equipment (Bilir, 2016). According to the interaction of the body with the vibration source, it is separated into two parts: whole-body vibration and hand-arm vibration. Workers with moderate illness and those who prefer to continue working with handheld power tools should limit their exposure to hand-arm

vibration. Using low-vibration instruments, wearing vibration-reducing gloves, and altering work schedules to limit exposure time. The disease development of these employees should be checked regularly.

Hand Arm Vibration Syndrome will affect the dominant hand first, based on Figure 2.6. It usually starts at the fingertips area and then spreads to the other area over time. The Thumbs area is the least affected by this syndrome, but it depends on the exposure. As the illness worsens, the frequency, intensity, and duration of symptoms arise. Fingers may become irreversibly cyanotic and develop tissue necrosis or gangrene in the late stages. In addition, the pain and cold sensation in the hands may become continuous (Shixin & A. House, 2017).



2.4.3 Vibration Analysis

Vibration is measured in $[m/s^2]$. The International Standards Organization (ISO) research has been studied to develop standards and guidelines on the exposure of vibration a day before it will cause injury to any individual. Table 2. 2 provides the value of exposure in 8 hours per day versus the vibration magnitude transmitted by the tool in a given unit of $[m/s^2]$.





According to the guidelines by ISO, This European Standard specifies daily exposure levels at which employers will be required to take action to control risks. These are known as Exposure Action Values (EAVs). The regulations also set out Exposure Limit Values (ELVs). When certain levels have been reached, the employer must take steps to limit daily exposure. For hand-arm vibration (HAV), the daily ELV is 5 m/s² A (8) and the daily EAV is 2.5 m/s² A(8). The value of vibration magnitude for the angle grinder ranges from 2-6 m/s² as measured by the Health and Safety Executive (HSE) UK (HSE UK, 2012).

2.5 Pipe bevelling machine

There are various types of bevelling machines that manufacturers have produced. The process commonly used in preparing pipe bevelling uses oxy-acetylene gas and cutting tools. Every pipe bevelling machine has its pros and cons. Below is an example of a bevelling machine found through patent search and existing products.

2.5.1 Patent Search

I. Pipe beveling machine (US3572669)



In Figure 2.7, A pipe the bevelling machine was invented by Daniel Brand and was patented on March 30, 1971. He developed a pipe bevelling machine that travels around a pipe on an elongate band attached around a pipe. This machine uses oxy-acetylene gas as the gas for cutting. The angle that will be cut is 45°. The machine rotates through the attachment of a rotatable member with an endless flexible member encircling the pipe. This bevelling machine doesn't use any electricity to perform the process. The advantage of this bevelling machine is that it can bevel a large diameter of pipes. For the disadvantages, the surface finish is not smooth compared to the other bevelling machine.

II. Portable Pipe End Bevelling Tool (US4257289)



Figure 2.8: Portable Pipe End Bevelling Tool (Groothius, 1979).

The Portable Pipe End Bevelling tool in Figure 2.8 was invented by William Groothius in Canada and was patented on March 5, 1979. A Portable Pipe End Bevelling Tool has a shaft with a forward end portion mounted on a mandrel with moveable jaws that engages inside a pipe end to hold the shaft coaxial with the pipe. A tool hub is rotatably supported by a rearward end portion of the shaft, the tool hub carrying cutting tools for bevelling the end of the pipe. A special mounting arrangement for cutting tools allows the tool hub, and thus the entire apparatus, to be relatively small and light. In addition, the sleeves project outwardly beyond the hub, allowing the hub to be much smaller than the pipe to bevelled while providing adequate support for the cutting tools. The advantages of this pipe bevelling are portable, good surface finish, and it can eliminate the exposure of harmful factors for the operators. For the disadvantages, this machine can bevel a medium and small diameter of the pipe.



Figure 2.9: Pipe Cutting And Beveling Machine (I. Choi, 2018)

The machine in Figure 2.9 was invented by Insung Choi and was patented on March 30, 2018. It is a machine that enables to cut and bevel a pipe. After gripping and fixing the pipe, a cutter rotates around it, cutting any surface of the pipe. The machine consists of the main body through which a pipe passes to be fixed and a cutter unit coupled to the central body unit that rotates around the fixed pipe to cut or bevel the pipe. Aside from the cutter unit, a locking unit on one side can restrain or release the cutter unit. A control plate for entry; and a clutch are formed on the lever's rotation shaft so that the restraint is released when the lever is lifted or pressed in the axial direction.

2.5.2 Existing Pipe Beveling Machine

I. Stationary Pipe Beveling Machine



Figure 2.10: Stationary Pipe Bevelling Machine (PROMOTECH, 2020)

The PRO-40 PBS in Figure 2.10 is a stationary pipe bevelling machine designed and manufactured to produce angles and facing pipes, tanks, or tubes. The pipes that can be machined are in a range between 200mm and 1000mm. This machine has a high-speed rotary milling head with replaceable inserts, enabling effective and efficient machining with bevel widths up to 45mm. Furthermore, this machine can produce angles between 0° and 50°. Compared to traditional single-point machining, using a heavy-duty milling head in the PRO 40 PBS allows for more accurate bevels in a shorter amount of time.

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II. Split-Frame O.D. Mount Pipe Cutting and Bevelling Machines



Figure 2.11: Split-Frame O.D. Mount Pipe Cutting and Bevelling Machines (Esco Tool, 2020)

Split-Frame O.D. Mount Pipe Cutting and Bevelling Machines are machines that Esco Tool Company manufactured in 2020. It is a machine that can switch whether to choose the power is hydraulic/pneumatic or electric. This machine produces a bevelling angle range between 30° and 45°, including J-Bevel, Compound Bevel, and customized blades. It is available in arranging from pipe size 2 inches up to 54-inch pipe diameter in the standard range. Both frames are clamped together around the pipe to produce a pipe bevel.

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III. N. K.O. Portable Pipe Beveler



Figure 2.12: Portable Pipe Beveler (N. KO Machines, 2021)

Portable Pipe Beveller was designed and manufactured by N.KO Machines in 2021. It is a pipe bevelling machine that can bevel a pipe with a range of 16 to 330 mm pipe diameter. This machine was designed to produce an angle, flatten the front edge, and internal calibration of pipe diameter. Moreover, this machine can also get the end of pipes rapidly and repeatedly ready for welding. It is suitable for all types of machinable metals. Concentric inner clamping guarantees perfect securing and centering of the machine. Clamping vertically to the pipe axis might be advantageous in certain limited situations. There are two options available which are electric and pneumatic systems. This bevelling machine is able to produce a good quality pipe bevel as it offers a good surface finish and accuracy to produce a bevel angle.

2.5.3 Fabricated Grinding Jig For Bevel End Pipe Joint (Fitri Bin Zahari. 2021)



Figure 2.13: Fabricated Grinding Jig for Bevel End Pipe Joint (Fitri bin Zahari, 2021)

As shown in Figure 2.13, Grinding Jig for Bevel ends Fitri Bin Zahari fabricated Pipe Joint in 2021 (Fitri et al., 2021). Muhammad Syakir Bin Zainuddin previously designed it (Muhammad Syakir, 2019). The primary purpose of producing this jig is to ensure that a constant degree of bevel angle can be achieved rather than the manual grinding operation. This jig can produce 0° until 70°. There are limitations to this fabricated jig. The pipe length must be less than 304.8 mm or 1 foot and the diameter must not exceed 76.2 mm or 3 inches. This jig can also reduce the worker's vibration exposure when preparing a pipe bevel using a grinding machine. But the workers are still exposed to vibration when the workers need to roll the pipe. Further design improvement can be obtained to eliminate vibration exposure by using this grinding jig.
2.5.4 Summary of Pipe Bevelling Machine

The summary of the existing pipe bevelling machine and the patents are summarized in Table 2.3.

Patent	Description	Existing
(Brand, 1971)	 Able to bevel a large diameter of the pipe. Moves horizontally around the pipe Using chain and gear mechanism 	(PROMOTECH, 2020)
(I. Choi, 2018)	 Portable bevelling machine. Eliminates the exposure of vibration for the workers. Using a hydraulic and pneumatic system Suitable for a mediumsize diameter of the pipe. Able to cut and bevel a pipe 	(Esco Tool, 2020)
(Groothius, 1979)	 Made for a small diameter of the pipe. Portable pipe bevelling Using a pneumatic hydraulic and electric system to drive. 	(N. KO Machines, 2021)

Table 2.3: Summary of pipe bevelling machine
--

2.6 Design Improvement

In this study, design improvement is related to the engineering design process. A sequence of methods guides the engineering team in solving problems. Design is a creative and innovative process that uses technical engineering knowledge to obtain the necessary support for the development of the various type of products, services, and benefits aimed at society characterized by consumption. As a way to leverage innovation, a closer relationship between design and engineering proves to be one of the possible adequate strategies. A design methodology must be resorted to in the search for process and product optimization, innovation, benchmarking, and better results for users and their needs. This type of methodology is called the "Design Process" (Khandani, 2005).

The technical and creative design process has roots deriving from engineering and is inherent to design. It consists of adapting the usual conception and development methods for both areas. The project is also worked on in stages involving the concept of organizational ergonomics, from the creation phase to the final product. The article that Barcellos and Botura Junior have written proposes a brief analysis of the "Design Process" methodologies, seeking to clarify the points in the Design and Engineering processes, demonstrating that bringing these areas together can improve the design performance of products and services. By identifying this common orientation, the study demonstrated that the partnership optimizes results, potentially improving innovation generation (Barcellos & Botura Junior, 2016).

The fundamental six-step problem-solving technique may also be utilised to solve design problems. Because design issues are sometimes poorly defined and have a variety of proper answers, the process may include backtracking and iteration. Solving a design challenge is a continuous activity subject to unexpected complexities and changes as it progresses. Figure 2. 14 shows the sequence in the engineering design process.



The first step is to define the problem. This step will clearly define the problem or any information about the product functions and features by comparing to the other product. The next phase gathers important information for the product's design and functional requirements. Once the design specifics are defined, the design team develops several options to meet the design's objectives and criteria with input from the test, production, and marketing teams. The detailed design and analysis approach enables a comprehensive review of all possible options, resulting in selecting the final design that best meets the product criteria. Following this phase, the design is prototyped and functional testing is conducted to validate and possibly improve the design (Khandani, 2005).

2.7 Motor Selection

Proper size and selection of a motor for a machine are critical to guarantee the machine's performance, dependability, and cost. It also influences the efficiency of the machine. A few factors must be focused on in selecting a motor, for example, motor speed, motor power ratings, motor load torques, motor losses, motor efficiency, etc. There is a procedure that needs to be referred while selecting a motor, and these procedures will be required for the load calculation, which is the dimension of the mass load, the mass of each part, and the Friction coefficient of the sliding surface of each moving part (Capehart *et al.*, 2020).

Then, the factors that need to determine the required specification for the application are as follows:

- Operating speed and operating time
- Positioning distance and positioning time
- Resolution
- Stopping accuracy
- Position holding
- Power supply and voltage
- Operating environment
- Specific features and requirements such as; Open-Loop, Closed-Loop, Programmable, Feedback, IP rating, Agent approvals, etc.

3 factors must be calculated to determine the motor's performance: Moment of Inertia, Torque, and Speed (Capehart *et al.*, 2020).

2.7.1 Moment of Inertia For Hollow Cylinder



Figure 2.15: Schematic diagrams of direct drive loads (Capehart et al., 2020)

Formula mass moment of inertia for hollow cylinder;

$$J_{L} = \frac{1}{8}m(D_{1}^{2} + D_{2}^{2}) \quad [kg.m^{2}]$$
(Equation 2.1)
$$\pi \qquad (Equation 2.2)$$

$$I_m = \frac{\pi}{32} \rho L \left(D_1^4 - D_2^4 \right) \quad [kg. m^2]$$
 (Equation 2.2)

$$J_T = J_L + J_M \qquad [kg.m^2] \qquad (Equation 2.3)$$

2.7.2 Torque required for a motor

e required for a motor

$$T_{a} = J_{T}a = (J_{L} + J_{M}) \frac{\omega_{1} - \omega_{0}}{t} [N.m] \quad (Equation 2.4)$$

$$T_{T} = T_{L} + T_{a} \quad [N.m] \quad (Equation 2.5)$$

$$T_{M} = K_{s}T_{T} \quad [N.m] \quad (Equation 2.6)$$

 $J_L = Inertia \ of \ the \ load \ [kg.m^2]$

 $J_M = Inertia \ of \ the \ motor \ [kg.m^2]$

$$J_T = Inertia \ of \ the \ System \ [kg.m^2]$$

$$m = weight of load [kg]$$

 $D1 = External \ diameter \ of \ disc \ [m]$

$$\rho = \text{Density of the load} \left[\frac{kg}{m^3} \right]$$

L = Length of the load

 $\omega_{0} = Initial \ velocity \left[\frac{rad}{s}\right]$ $\omega_{1} = Final \ velocity \left[\frac{rad}{s}\right]$ $t = Time \ for \ elocity \ change \ [s]$ $T_{a} = Acceleration \ torque \ [N.m]$ $T_{L} = Load \ torque \ [N.m]$ $T_{T} = Total \ calculation \ torque \ [N.m], \ T_{T} = T_{L} + T_{a}$ $T_{M} = Required \ motor \ torque \ [N.m], \ T_{M} = K_{s}T_{T}$ $K_{s} = Safety \ factor \ (reference \ value \ is \ 1.5 \ to \ 2.0)$

2.8 Anti-Vibration Pad

Anti-vibration materials can be utilized to reduce the vibration in the previous design bevelling jig. Anti-vibration Rubbers in a machine serve a crucial function in reducing vibrations. Many studies have been conducted on utilizing natural rubber for anti-vibration applications. A study conducted by Choi and Lee in 2018 with the title "Shape Optimal Design of Anti-Vibration Rubber Assembly to Reduce the Vibration of a Tractor Cabin" has utilized the vibration isolation capability of an anti-vibration rubber assembly to reduce the vibration that occurs at the cabin of a tractor. The rubber's stiffness was determined from this curve and used as input for the cabin's harmonic studies. The findings were validated using test data. The ideal form of the anti-vibration rubber assembly was determined using Taguchi's parameter design technique, which showed a configuration with lower stiffness. The use of anti-vibration rubber has reduced the cabin structure's vibration by up to 35% compared to the original design, as seen in Figure 2.17 (H.-J. Choi & Lee, 2018).



Figure 2.16: Anti-vibration rubber installation (H.-J. Choi & Lee, 2018)



Figure 2.17: Frequency response of cabin frame with optimized anti-vibration rubber assembly (H.-J. Choi & Lee, 2018)

2.8.1 Existing Anti-Vibration rubber

Rugaval Rubber Sdn. Bhd. Manufactured various types of rubber padding. Rubber padding is mainly used in the vibration of the isolation industry. Figure 2.18 is made from synthetic rubber and acts as an insulation layer between the ground and the machine to eliminate unwanted vibration. Numerous applications need a rubber membrane, which may be thin or thick, depending on the weight and quantity of physical and resonant vibratory noise. A rubber pad's composition may vary from solid, synthetic closed cell rubber to breathable recycled rubber. RUGAVAL offers various and appropriate solutions for the rubber pad required for a specific application. Thickness is available in 10mm, 15mm, and 20mm (Rugaval Sdn. Bhd. , 2021).



Figure 2.18: Rugaval rubber padding (Rugaval Sdn. Bhd., 2021)

2.9 Tools and equipment

2.9.1 Vibration Analysis

During each vibration cycle, the speed of a vibrating item fluctuates from zero to maximum. It travels the fastest when it transitions from its normal stationary posture to an extreme position. As the vibrating item approaches the extreme, it slows down and reverses direction via the standing position toward the other extreme (Maeda et al., 2019). A vibration's speed is measured in meters per second (m/s). Vibration's speed can be measured by using the instruments below;

- Figure 2.19: Hand-Arm Vibration Meter (Pulsar, 2021)
- I. Hand Arm Vibration Meter

Hand Arm Vibration Meter was manufactured by Pulsar Instruments. This instrument is able to measure the vibration of handheld power tools. It has a tri-axial accelerometer that is easy to install and uses three axes to capture simultaneous X, Y, and Z measurements showed on the screen in real-time as the device moves. Measurements may be conducted in either M/S2 or G, and data are provided for Aeq, Peak, and Vector Sum, among other things. The measured data is also calculated into the HSE's simple colour-coded points system, which also displays the Exposure Action Value (EAV) and Exposure Limit Value (ELV) times, as well as the exposure action value (EAV) and exposure limit value (ELV) times.

2.9.2 Measuring Bevell Angle

The quality of the bevel angle affects the quality of weldment. Therefore, a close tolerance in angle measurement should be considered. Bevelling involves the removal of metal from the edges of the two pieces of metal being joined. It is compulsory to make sure the bevel angles are intolerant to avoid any error that influences increasing angles that can lead to higher residual compressive stress on carbon steel but a lower effect on the axial stress on the stainless-steel side. Below are some of the apparatus that are used to measure the bevel angle:

I. Bevell Protractor



Figure 2.20: Bevell Protractor

As shown in Figure 2.20, a bevel protractor is a tool that measures angle to very close tolerance. Measuring an angle using these tools makes the measuring work much more accessible. It is capable of measuring angles with an accuracy of up to 5 arcminutes, and it can measure angles of up to 360 degrees. It provides exceedingly precise measurement. It can establish and test to tolerate angles that have a very near tolerance.

II. Bridge Cam



Figure 2.21: TWI Bridge Cam Welding Gauge

The Bridge Cam Gauge in Figure 2.21 is made by The Welding Institute. It is a multipurpose welding inspection gauge used to check the angle of preparation $(0 - 60^\circ)$, excess weld metal (capsize), depth of undercut, depth of pitting, fillet weld throat size, fillet weld leg length, and misalignment (high-low).



2.10 Statistical Analysis

2.10.1 Uncertainties of Measurement

The closeness of agreement between the measurement result and the ideal actual value of the measurement technique can be defined as measurement result accuracy. Uncertainty in measurement results is an attribute of the measurement result that describes the dispersion of values (Valícek et al., 2013). When anything is measured, the reader usually expects some actual value, depending on how the measurement is defined. Unfortunately, observation does not accurately represent actual value. Thus the best capacity assessment responds to this ideal quantity with the proper time and resources. The results may change when different methods are used to take measurements or when the same method is used to take measurements. Concentrating efforts can provide the most substantial contribution to the source of uncertainty since the value obtained for the combined uncertainty is almost entirely determined by the major (Majda & Jastrzębska, 2021). It can offer the most precise estimate of the amount measured by recognizing measurement uncertainty. This estimate might be based on a single measurement or averaging several readings.

2.10.2 Measures of Dispersion

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Standard Deviation indicates the dispersion of the data from the mean. For many parameters, the standard deviation is interchangeably used to represent the variability of the measurement (Chittaranjan, 2020). The results of any sample can be described by two parameters; mean and standard deviation. The sample mean is the measurement average and the center of distribution (central tendency). Standard deviation will describe the dispersion of measurement about the mean. As a result, a low standard deviation indicates less variability, and a high standard deviation indicates more extensive data (Barde & Barde, 2012).

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter covers the details of the methodologies used to improve the fabricated jig's design. First, the fabricated jig has undergone preliminary testing to define the problems. Next, the possible solutions, design concepts, and analysis were carried out to achieve the project's objective. Then, the methodology illustrates the project's flow from the beginning of the preliminary testing until the analysis that has been obtained.

3.2 **Project Planning**

This chapter explains the method related to this study. The method used for design improvement consists of defining the problem, developing possible solutions, conceptual design, prototype fabrication, material selection, and manufacturing process preparation.

3.2.1 Flowchart

The workflow of this study is represented in a flowchart, as shown in Figure 3.1



Figure 3.1: Flowchart

3.3 Description of Fabricated Jig



Figure 3.2: Step in using a fabricated jig

As shown in Figure 3.2, a grinding jig for the bevelling end pipe joint was fabricated by Fitri Bin Zahari in 2021 (Fitri, 2021). Muhammad Syakir Bin Zainuddin previously designed it (Muhammad Syakir Bin Zainuddin, 2019). The primary purpose of producing this jig is to ensure that a constant degree of bevel angle can be achieved rather than the manual grinding operation. This jig can produce 0° until 70°. There are limitations to this fabricated jig. The pipe length must be less than 304.8 mm or 1 foot, and the diameter must not exceed 76.2 mm or 3 inches. This jig can also reduce the worker's vibration exposure when using a grinding machine to prepare a pipe bevel. But the workers are still exposed to vibration when the workers need to roll the pipe. Further design improvement can be obtained to eliminate vibration using this grinding jig.

3.3.1 Step in Using Fabricated jig

Several steps need to be followed in using this fabricated jig. The parts are marked to describe all the steps, as shown in Figure 3.2.

- i. According to Figure 3.2, the direction of A, B, C, or D indicates the location of the grinder that should be adjusted to achieve the correct angle before tightening the bolt and nut at E.
- ii. The nut at F was tightened to secure the grinder's position.
- iii. The pipe's length determined the location of G and H.

- iv. The pipe was positioned on I and rotated using a roller.
- v. At location J, the pipe was tightened with a clamp.

3.4 Preliminary Testing

Preliminary testing has been conducted to measure the vibration and the bevel angle for the existing fabricated jig. After the design improvement for the fabricated jig has been implemented, this result will be compared.

3.4.1 Vibration

The vibration has been measured using the Hand-Arm vibration meter, as shown in Figure 3.3, to analyze the vibration produced by the fabricated jig. This instrument was used to determine the magnitude of the vibration produced since it provides accurate readings. The readings were recorded in Table 3.1.



Figure 3.3: Hand-Arm Vibration Meter (Pulsar, 2021)

The vibration can be measured by following these steps;

- i. The accelerometer should be plugged into the instrument.
- ii. Accelerometers measure the back/forward, right/left, and up/down axes and the triaxial x, y, and z axes.

- iii. Strap the device to the operator's hand when using a grinder.
- iv. Turn on the instrument and read the data on the instrument's screen.
- v. Observe and record the peak measurement data or the vector sum of triaxial vibration data.

Readings	Vibration magnitude $\left[\frac{m}{s^2}\right]$			
	Fabricated Jig			
Size of pipe	1 st Reading	2 nd Reading	3 rd reading	Average
2.5 inch				
Time taken (minutes)				
3 inch				
Time taken (minutes)				
3.5 inch	LAYSIA MA			
Time taken (minutes)	LAK.			
TEK	*			
E				

Table 3.1 Vibration magnitude table for preliminary testing

3.4.2 Bevel Angle Accuracy

It is essential to get an accurate bevel angle for the fabricated jig. The bevel angle produced by the jig and fixture was more precise than the bevel using a grinder manually. This is because the jig and fixture facilitate finding and fastening the pipe and assuring the grinder's proper location. Only skilled workers can produce an accurate bevelling angle using a manual grinder. A bridge cam can be used to check the angle of preparation $(0 - 60^\circ)$. The measurement will be recorded in Table 3.2.



Figure 3.4: Bevel Protractor

These are the steps to use the bridge cam;

- i. The large clamp on the front part of the protractor was unscrewed. It loosens the blade so that it can be swivelled.
- ii. After that, the base of the protractor was aligned on one side of an angle and then swivel the blade to make the other side of the angle.
- iii. The huge clamp was tightened.
- iv. The zero on the Vernier scale has been spotted. The Vernier scale was smaller on the inner side of the protractor
- v. Read the number of degrees stated on the main scale, directly above the zero present on the Vernier scale. Make sure to repeat three times to make an average value.

	Measurement using Bevel Angle (degree °)					
Diameter	Fabricated Jig					
size of pipe	1 st reading	2 nd reading	3 rd reading	Mean	Standard Deviation	Standard uncertainty, μ_p
2.5 inch	E					
3 inch	200					
3.5 inch	10-	Wn ,				
	ملاك	ليسيا	کل م	يكنيه	بوہر سیتی ز	اون

Table 3.2: Bevel accuracy for preliminary testing

3.5 Define Problem RSITI TEKNIKAL MALAYSIA MELAKA

Some parts of the fabricated jig required improvement based on the existing design. Through the design improvement, the functionality of the jig will be improved. Therefore, the problems that occur in the current design must be identified and defined. By defining the problem, it is easy to specify the possible solution that could solve the problem. This problem must be solved because the issues will lead to vibration. The vibration affects the bevel angle accuracy and the operator's health, HAVS, if the vibration still occurs. Each problem has been stated, and the recommendation will be proposed to achieve the project's objective.

3.5.1 Base structure



Figure 3.5: Base structure

The base structure part with a red box, as shown in Figure 3.5. There is no vibration absorption padding placed under the base structure for the previous design, and it caused a loose or misalignment of the joined parts that were using bolt and nut due to the vibration. Anti-vibration rubber padding was installed to absorb the vibration.

3.5.2 Hands exposure



Figure 3.6: Operator's hand exposure

This jig still needs workers to rotate the pipe with their hands, as shown in Figure 3.6. The bevel angle around the pipe was produced when the workers rotated the pipe along with the roller, exposing the worker to vibration caused by the grinder. Considering an

automated pipe rotator, a motor with a three-jaw chuck could solve this problem. However, the torque requirement to rotate the pipe must be calculated to ensure the machine functions correctly. But then, this jig significantly reduces the operator's vibration exposure, which is 1.8461m/s² compared to the conventional method, which is 2.5184m/s² without using a jig. Using the motor will eliminate the vibration exposure for the worker, but the vibration on the jig itself must be observed Using the motor eliminated the vibration exposure for the worker, but the vibration on the jig itself must be observed.

3.6 Develop Possible Solution

A few problems have been identified with the existing fabricated jig. The possible solution for the current problem has been recommended as follows;





Using the fabricated jig, a motor has been considered to eliminate vibration exposure while producing a bevel angle. First, the motor was attached to the jig to rotate the pipe automatically. This motor helps the worker rotate the pipe and, simultaneously, eliminate the exposure of vibration for the worker. Then, the torque requirement is 1.76 Nm to rotate the pipe by considering the safety factor. Next, the motor was mounted on the lifting base to adjust the centre of the pipe. The motor's shaft was then attached with a 3 jaw chuck, which can grip and rotate the pipe.

3.6.2 Anti-Vibration Padding

As shown in Figure 3.8, a vibration padding has been suggested to reduce the vibration. It is made from synthetic rubber and acts as an insulation layer between the ground and the machine to absorb the vibration. Rubber padding was mainly used in the vibration of the isolation industry. It is because rubber has high shear modulus compared to other materials. When stress from vibration is applied to rubber materials, the rubber padding absorbs greater vibratory stress before breaking or transferring the vibration. The anti-vibration padding was attached under the base structure jig to absorb vibrations from a motor and a hand grinder. Various thicknesses can be chosen depending on the magnitude value of vibration. This anti-vibration padding helps reduce the steel-based structure's vibration and improve the bevel angle's accuracy. Below are the example of anti-vibration padding that will be installed under the base structure



Figure 3.8: Vibration padding (Rugaval Sdn. Bhd., 2021)

3.7 Design Improvement

The design improvement for the fabricated jig was implemented after the possible solution for every problem had been identified. By starting with a morphological chart, various applications, designs and concepts are proposed to consider the best design and the dimension for design improvement of the fabricated jig. Different types of clamp positions were offered. Other than that, different mechanisms to rotate the pipes were also have been proposed to ensure no vibration will be exposed to the worker while using this jig. Several

motor placements were also being proposed to consider the proper placement of the motor. The placement of the motor is important because it will decide which mechanism is used for the fabricated jig. There is a variety of choices to be selected to achieve the objectives.

3.7.1 Morphological chart

Option Criteria	Option 1	Option 2	Option 3
Clamp Position			
Kully	Near to grinder	Centre of jig	End of jig
Motor position 문	ER End of a jig (moveable & adjustable)	Side of jig	End of a jig(static)
Type of mechanism			11
to rotate a pipe	3 Jaw chuck	Belting with tensioner	Internal 4 jaw chuck

3.7.2 Concept Evaluation

The option combinations in the morphological chart create the three most suitable concept designs. Each design was described based on its functionality. The generated conceptual design designs are tabulated and combined are as follows;

3.7.2.1 Concept Design A



By referring to Figure 3.9, the concept design uses a three-jaw chuck to clamp to the pipe. First, the motor will be placed at the end of the jig and can be moved toward the pipe to secure it. Then the three-jaw chuck will be attached to the motor. It is a direct mechanism where the torque occurs at a three-jaw chuck. Next, the motor's height will be adjusted by using the lifting base to meet the centre of the pipe. Lastly, the pipe clamp will be moved near the grinder to avoid misalignment when the line rotates.



Figure 3.10: Concept design B

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As shown in Figure 3.10, Concept design B uses a belting with a tensioner mechanism to rotate the pipe. The motor was placed at the side of the jig, and the clamp is still at its original position. This concept design can bevel any pipe size with less than a 3.5-inch diameter. The function of the tensioner is to grab the pipe, which rotates based on the torque produced by the motor. The disadvantage of this design is it will require a maintenance cost to replace the belt. While for the belting mechanism, there might be slipperiness between the belt and pipe because of the pipe's smooth surface finish.

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Figure 3.11: Concept design C

Concept design C uses a direct mechanism to rotate the pipe, as shown in Figure 3.11. It uses a four-jaw chuck to clamp the pipe. The motor position is placed at the jig's end, and the pipe clamp is placed jig's centre. The torque occurred at the four jaw chuck produced by the motor. This design's disadvantage is that it cannot adjust the height centre of the pipe. It will rotate for a 3-inch diameter size the pipe.

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3.7.2.4 Screening and scoring method

The screening method in Table 3.4 eliminates the concept design with the lowest score, concept design C. While concept designs A and B were going through the next phase, the scoring method selected the best design among all the design concepts.

Concept	Design Concept A	Design Concept B	Design Concept C
Selection Criteria			
Ease of fabrication	-	0	+
Able to reduce vibration	++	+	+
Able to rotate the pipe	+	-	+
Ease of assembling and	0	+	++
disassembling	LANG -		
Require maintenance	+	+	0
Able to adjust the centre	==++		-
of the pipe			
Sum of +	6	- 4.	5
Sum of 0	P	1 9.	V J.J 1
Sum of - UNIVER	SITI TĖKNIKA	L MALÂYSIA N	IELAKA ¹
Net score	5	2	4
Rank	1	3	2
Continue?	YES	NO	YES

Table 3.4: A screening method

Relative	Symbol
Performance	
Better than	+
Same as	0
reference	
Worse than	-

Relative	Symbol
performance	
Much better	++
than	
Worse than	

Net score = (sum of +) - (sum of -)

Based on Table 3.5, the weight of each selection criteria has been decided based on the more important criteria for the product. Therefore concept design A has been chosen as

the final design. Concept design A has fulfilled all the requirements, resulting in the highest score compared to concept designs B and C.

Solootion Critorio	Waisht	Concept			
Selection Criteria	weight	Concept A		Concept C	
		Rating	Weight Score	Rating	Weight Score
Ease of fabrication	15%	2	0.3	3	0.45
Able to reduce vibration	23%	5	1.15	4	1.15
Able to rotate the pipe	22%	5	1.1	5	1.1
Ease of assembling and	10%	4	0.5	4	0.4
disassembling					
Require maintenance	10%	5	0.5	3	0.3
Able to adjust the centre of the	20%	5	1	0	0
pipe	RE				
Total	100%	4	.55	3	.4
Rank				V	2
Continue		Y	ES	N	0

Table 3.5: Scoring method

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3.7.2.5 Concept Development

The product was developed in detail using Solid Works 2020 after the concept evaluation and decision-making had been done. Then, the final concept design was designed by considering all the dimensions and specifications until the final design was implemented. Figure 3.12 below shows the chosen design that improved the functionality of the previous design of the fabricated jig.



Figure 3.12: Final concept design

3.7.2.6 Technical Drawing Design

The technical design was essential in constructing this jig and fixture since it avoided mistakes, delays and expensive issues. In addition, the technical design displayed the correct specifications, and therefore the technique of manufacturing this fabrication was simple. The most significant technical drawing was drawing with full dimensioning and **a**ssembly drawings. Figure 3.13 illustrates the assembly design of the jig and fixture for the bevel end of the pipe joint.



Figure 3.13: Technical drawing

3.7.2.7 3D Model Development

Figure 3.14, Figure 3.15 and Figure 3.16 show the 3D Model Development consisting of 3 views of a design: a top view, side view, and front view.



Figure 3.15: Side view



3.7.2.8 Exploded View

The exploded view was made to give a specific view for every part of the bevelling jig. In Figure 3.17, all the parts have been marked with a number to be filled in the bill of material.



Figure 3.17: Exploded view

3.7.2.9 Bill of Material (Design Improvement Part)

Bill of materials is used in the manufacturer of a product and should contain raw materials, sub-assemblies, sub-components, parts, and quantities. This jig and fixture consist of 27 parts, as shown in Table 3.6 below.

Item	Part Name	Quantity
1	Based Structure	1
2	Vibration Mat	1
3	Linear Rail Link	2
4	Linear Rail Link Screw	2
5	Bearing Linear Rail	8
6	5mm Bearing	4
7	Linear Bearing Screw	16
8	M10x1.25 Bolt	-1
9	M10x1.25 Nut	1
10	M14x2.0 Bolt	
11	Lifting Based Mount Screw	4
12	Motor Bracket Screw	4
13	Adjustable Grinder Holder	1 .
14	M10x1.25 Bolt	ويبوره سير
15	M10x1.25 Nut	2
16	Bearing Shaft	SIA MELAKA
17	Grinder	1
18	Pipe Vise	1
19	Lifting Based Mount	1
20	Pipe Vise Mount	1
21	Roller mount	1
22	Grinder Bracket	1
23	Motor Bracket	2
24	Motor	1
25	Lifting Base	1
26	3 Jaw Chuck	1
27	Pipe	1

3.8 Material Selection for Motor Mount

The material selection for the motor mount must go through four essential steps to ensure it is the best material to be selected for that particular part. Only metal can be used for the motor mount due to its high mechanical strength to hold the motor while rotating. However, the material must meet the required properties for the part intact on the product and can function well without any problem occurring while using the machine.

3.8.1 Translation

The motor mount's design improvement part is preferably designed to withstand the force of the motor while it is rotating. Considering the rotational force applied on the motor mount, the motor mount must be high tensile strength, toughness, weldability and durability. The material must also be lightweight because the fabricated jig was designed to be portable. Then, the material cost needs to be minimized to reduce the cost of production. Lastly, the motor mount should be resistant to corrosion, and it must be easy to fabricate. The selection material impacts the part that has been chosen to guarantee it can function effectively and be user-friendly without any problem occurring in the future. The goal for the design part that has been selected is to determine which material selection has the high strength but with minimum cost and reduce the weight. Table 3.7 shows the design requirement for the motor mount.

Function	To hold and support the motor		
Constraints	High tensile strength and toughness		
	• Weldability		
	• Durable		
	• Lightweight		
	Corrosion resistance		
	• Easily to fabricate		
Objective	Minimize the weight		
	Minimize material cost		
Free Variable	Manufacturing process		

Table 3.7: Design Requirement

3.8.2 Screening

The data and attributes of the selected material collected based on Table 3.8 were retrieved from the CES software. The value indication used from the data is in unit metrics.

	Materials			
Properties				
rioperties	Low alloy steel	Low carbon steel	Aluminium alloy	
Density (kg/m^3)	7.8e3 - 7.9e3	200 - 215	2.5e3 - 2.9e3	
Young's Modulus	205 - 217	345 - 580	68 - 82	
(GPa)				
Tensile Strength	550 - 1.76e3	108 - 173	58 - 550	
(MPa)				
Hardness (HV)	140 - 693	41 - 82	12 - 151	
Fracture Toughness	14 - 200	1.75 - 1.90	22 - 35	
(MPa x m^0.5)				
Price per kg (RM)	1.80 - 2.06	1.75 - 1.90	7.36 - 8.07	

Table 3.8: Screening table

3.8.3 Ranking

Based on the screening Table 3.9, we can rank the materials based on the attributes of the chosen part. The ranking score was made by ranking the material from 1-5 based on the value of each property. اويونرس

Table 3.9: Ranking table

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Properties					
Topenies	Low alloy steel	Low carbon steel	Aluminium alloy		
Density	4	5	1		
Young's Modulus	3	4	1		
Tensile Strength	2	5	3		
Hardness	4	5	1		
Fracture Toughness	5	4	2		
Price per kg	3	5	1		
Total	21	28	9		
Rank	2	1	3		

The ranking results show in Table 3.9 that stainless steel has the highest ranking with a total score of 28, which is low-carbon steel, followed by low alloy steel with a total score of 21 and aluminium alloy with a total score of 9.

3.8.4 Documentation

The Documentation was performed based on the ranking table; which material has the highest score will be selected to undergo more study about that material specifically. This documentation explores the best material for the motor mount part to ensure its stability and longer life cycle.

Therefore, the ranking table that has been done shows that low carbon steel has the highest numerical rating compared to low alloy steel and aluminium alloy, with a total score of 28. In comparing the young's modulus and tensile strength, it can be seen that low carbon steel has the highest-ranking than low alloy steel and aluminium alloy. Low carbon steel is the cheapest among low alloy steel and aluminium alloy despite having the highest density, making it heavier than the other.

Hence, the best material selection as a design requirement for the motor mount is based on low carbon steel material. This material has been selected because of its properties to meet the objective and constraint requirement to produce this part. Due to its high tensile strength, which is between 345 MPa to 580 MPa, it can withstand such a higher force before it breaks. Moreover, the young's modulus for low carbon steel is 200 - 215 GPa, which is quite stiff before it falls into plastic deformation. The price for low carbon steel is also reasonably affordable for the given characteristic compared to other materials.

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3.9 Fabrication for Design Improvement Part

This jig has undergone the design improvement process in which the motor and the anti-vibration padding were attached to the jig to eliminate the vibration exposure.
3.9.1 Motor Mount and Lifting Base



Figure 3.18: Motor mount and lifting base

The base lifting and motor mount include the cutting, joining, and bending process. Most of the parts will be fabricated by the cutting process. Then it will go through a bending process to make the desired curved shape. Then, a drilling process is needed to drill a hole at the bottom part. Finally, a joining process uses a bolt and nut to join the parts.



Figure 3.19: Base structure with Anti-Vibration padding

Anti-vibration pad was installed under the base structure, and the pad was cut according to the exact dimension of the base structure. Heavy-duty adhesive tape was used to attach the anti-vibration padding under the base structure. This improvement helps reduce the vibration from the grinder and the motor attached to the jig. The base structure was extended, involving the steel plates and the linear rail to be extended for motor base placement as in Figure 3.19.



3.10 Steps in Using Jig and Fixture for Bevel End of Pipe Joint

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- i. Based on Figure 3.20, the direction of A, B, C, and D is the grinder's position to be set up for the desired angle, and the bolt is tightened at E.
- **ii.** The nut F was tightened to lock the position of a grinder.
- iii. The position of G and H was adjusted according to the length of the pipe.
- iv. The pipe was placed at J, and at position K the pipe was tightened by the clamp.
- v. Move I until it is attached to the pipe and clamp it using a three-jaw chuck at L. Make sure the centre height is adjusted according to the pipe.
- vi. Turn on the motor at M, and the pipe starts to rotate.

3.11 Conduct Experimental

3.11.1 Vibration

For the vibration analysis, the improved design of the fabricated jig was eliminated. The motor and three-jaw chuck rotated the pipe until the desired angle was achieved. Thus, there was no vibration exposure for the workers, and the vibration of the improved jig design is expected to be higher due to the additional motor.

3.11.2 Accuracy

According to (Hoobasar Rampaul, 2003), the bevel angle varies from 70° to 90°. Therefore each pipe must be less than 45° and more than 35° bevel angle. Bevelling was a crucial aspect of the pipe welding engineering procedure, and the bevel angle must be in between the bevel angle standards to avoid uneven bevel quality angles. Because the bevel quality may affect the weldment quality and failure such as porosity, etc., this technique must be performed by a qualified worker. A bevel protractor was used to measure the angle, which was recorded in Table 3.10. All the data were compared between the previous and the current design in Table 3.11.

		10 10	<u> </u>	- 1 V	20 1 200	2017 -
	LINIV	Me	asurement	using Bevel An	gle (degree °)	
		lines i "i "gi" i i i	6 Base 6 B. I. B. B. B. B. B.	Fabricated Jig	and the total from the set to the	
Diameter	1 st	2 nd	3 rd		Standard	Standard
size of pipe	reading	reading	reading	Mean	Deviation	uncertainty,
	reading	reading	reading		Deviation	μ_p
2.5 inch						
3 inch						
3.5 inch						

Table 3.10: Bevel measurement

Pine Diameter	Degree of uncertainty			
	Before design improvement	After design improvement		
2.5 inch				
3 inch				
3.5 inch				
Average				

Table 3. 11: Comparison of previous and current design

Arithmetic means were calculated by referring to Equation 3.1:

$$A = \frac{1}{n} \sum_{i=1}^{n} a_i$$
 Equation 3.1

The standard deviation for each measurement was calculated by referring to Equation 3.2.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{N - 1}}$$
Equation 3.2

The measurement of the bevel angle has been repeated several times, and a series mean of bevel angle measurements was obtained where the value shows a small random variation. The uncertainty measurement of the mean can be calculated by using Equation 3.3.

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$$_{u_p} = \frac{1}{\sqrt{3}} \sigma$$
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Equation 3.3

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Preliminary Testing

Preliminary testing has been conducted to measure the vibration and the bevel angle for the existing fabricated jig. The vibration analysis was obtained after the measurement of vibration magnitude for the existing fabricated jig using a Hand-Arm vibration meter. The bevel angle measurements were taken accordingly after recording the vibration magnitude. A preliminary test is important to find the existing problem, and a possible solution has been proposed and applied. After the design improvement for the fabricated jig has been implemented, this result will be compared.

4.1.1 Vibration Analysis

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The vibration was measured using the Hand-Arm vibration meter to analyse the vibration produced by the fabricated jig. This instrument was used to determine the magnitude of the vibration produced since it provides accurate readings. 2.5, 3, and 3.5-inch diameter pipe was used in this experiment and underwent several setups shown in Table 4.1. The readings will be recorded in Table 4.1: Experimental Setup.



Table 4.1: Experimental Setup



The data collection was collected using Quest VI-400Pro Hand Arm Vibration Meter, and all the data were transferred into QuestSuite Professional II software. The QuestSuite Professional II software interface was shown in Figure 4.1, where all the data shown in the software were needed to proceed with the analysis. The instrument simultaneously measures the triaxial vibrations from the accelerometer on the worker's hand to the steel pipe while bevelling process. The time for each cycle was recorded to complete the bevelling process. Three bevel angle readings were recorded in this experiment, and the average value was calculated.



Figure 4.1: QuestSuite Professional II software interface

Readings	Vibration magnitude $\left[\frac{m}{s^2}\right]$					
	Fabricated Jig					
Size of pipe	1 st Reading	2 nd Reading	3 rd reading	Average		
2.5 inch	65.53	45.92	74.30	61.92		
Time taken (minutes)	04:55	05:37	07:19	05:57		
3 inch	86.09	70.67	64.34	73.69		
Time taken (minutes)	04:58	05:25	04:34	04:59		
3.5 inch	121.89	130.83	97.05	116.59		
Time taken (minutes)	05:43	04:43	04:55	05:43		

Table 4.2: Vibration magnitude for preliminary testing

4.1.2 Bevel Angle Accuracy Previous Design

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The bevel angle accuracy was measured using a bevel protractor and the bevel angle after the vibration magnitude was recorded. 9 pipes have been bevelled using the fabricated jig consisting of 3 pieces of 2.5-inch pipe, 3 pieces of 3-inch pipe and 3 pieces of 3.5-inch pipe. A 45° angle has been set up on the jig. 3 measurements will be taken, and the average will be calculated to get the standard deviation values. The measurement will be recorded in Table 4.3.

		Measurement using Bevel Angle (degree °)				
Diameter						
	1 st	and	ard		0, 1, 1	Standard
size of	150	2""	314	Mean	Standard	uncertainty,
pipe	reading	reading	reading		Deviation	И.,
						мp
2.5 inch	43° 40'	42° 35'	44° 55'	43° 43' 20"	1° 10' 3.57"	±0°40'26.93"
3 inch	42° 35'	43° 25'	43° 40'	44° 13' 20"	1° 11' 7.32"	±0°41'3.74"
3.5 inch	44° 50'	44° 45'	45° 55'	45° 10'	0° 39' 3.07"	±0°22'32.77"
Average					±0°34'41.15"	

Table 4.3: Bevel accuracy for the previous design

4.1.3 Discussion for Preliminary Testing

The bevel angle produced by the jig and fixture was more precise than the bevel using a grinder manually (Fitri et al., 2021). The average value of the uncertainty was $\pm 0^{\circ}34'41.15''$, which indicates the bevelling jig could produce a constant degree of bevel angle. This is because the jig and fixture facilitate finding and fastening the pipe and assuring the grinder's proper location. The vibration exposure while using the previous design fabricated jig was still safe. The highest vibration magnitude occurs during the bevelling of a 3.5-inch pipe which is 116.59 m/s² within 5 minutes and 43 seconds. Referring to ISO European Standards in Table 2.2: Vibration exposure (AS ISO 5349.1-2013.), this exposure level is within the yellow indicator between 105 m/s² and 150 m/s². It indicates that the levels were approaching the exposure limits. When certain levels have been reached, the employer must take steps to limit daily exposure. Therefore, the improved design of the fabricated jig could eliminate the vibration exposure to the workers while bevelling a pipe using the jig.

4.2 Fabrication for Design Improvement

Considering the workpiece and completed component size and shape was one of the elements in creating jigs and fixtures. The fabricated jig and fixture were redesigned by the previous researcher, Fitri Bin Zahari (2021). Referring to the improved design, the manufacturing process to fabricate the jig and fixture was reselected based on the machine and process availability. The fabrication of the jig consisted of 3 parts: the base structure, the motor with lifting base and the vibration pad.

4.2.1 Design Improvement

The design improvement for the fabricated jig will be generated after the possible solution for every problem have been identified. From the previous design, as shown in Figure 4.2, the design still requires a worker to rotate the pipe to produce the bevel, exposing the worker to vibration while bevelling a pipe. An automated pipe rotator and a three-jaw chuck have been proposed and fabricated to solve those problems. This design improvement

has significantly helped to eliminate the worker's vibration exposure. The improved design of the fabricated jig has been designed and fabricated as shown in Figure 4.3 and Figure 4.4.



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Figure 4.4: Improved design of the jig

4.2.2 Base Structure



The base structure has been extended and involves the steel plates and the linear rails for the placement of the motor lifting base, as shown in Figure 4.5. The manufacturing process involved completing the extension utilizing a laser cutting machine. The linear rails and the base structure have been attached by using bolt and nut.

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4.2.3 Motor with Lifting Base



Figure 4.6: 3D model of the motor with lifting base parts



Figure 4.7: Fabricated motor with lifting base parts

Based on Figure 4.7, the motor has been attached to the lifting base by using a bolt and nut according to the design in Figure 4.6. The hole on the lifting base was drilled using a milling machine at FKP's workshop. The hole on the lifting base must be precise to mount the motor so that it will not affect the rotation of the pipe. The pipe rotation resulted in the quality of accuracy of the bevel angle measurement. Three jaw chuck has been mounted to the motor by using the shaft adapter.

4.2.4 Vibration Pad



Figure 4.8: Attachment of vibration pad

A vibration pad has been installed under the base structure. The pad has been cut accordingly to the dimension of the base structure. The heavy-duty tape was used to attach the vibration pad. The attachment helps to reduce the vibration from the grinder and the motor on the jig. The vibration pad helps to absorb vibration effectively. A previous study that has been proved by H.-J. Choi and Lee in 2018, the use of anti-vibration rubber has reduced the cabin structure's vibration by up to 35% compared to the original design.

4.3 Experimental for Design Improvement

Vibration exposure to the worker has been eliminated since the improved design jig utilizes a motor to rotate the pipe. As the pipe rotates, the grinder will produce the desired bevel angle. A 45° angle was set on the jig to begin the experiment. Three readings have been collected, and the mean of the data has been calculated by referring to Equations 3.1 and 3.2 in Chapter 3. The value of the standard uncertainty was calculated based on Equation 3.3.

		Measurement using Bevel Angle (degree °)					
		Fabricated Jig					
Diameter	1 st	2nd	3rd		Standard	Standard	
size of pipe	reading	reading	reading	Mean	Deviation	uncertainty,	
	reading	reading	reading		Deviation	μ_p	
2.5 inch	44° 15'	44° 30'	43° 30'	44° 5'	0° 31' 13.5"	±0° 18' 1.67"	
3 inch	44° 35'	45° 40'	44° 30'	44° 13' 20"	0° 39' 3.07"	±0° 22' 32.77"	
3.5 inch	46° 20'	45° 25'	44° 40'	45° 28' 20"	0° 50' 5"	±0° 31' 13.5"	

Table 4.4: Bevel measurement for design improvement



Figure 4.9: Bevel angle measurement for a) 2.5 inches, b) 3 inches, c) 3.5 inches of pipes

4.4 Discussion for Bevel Angle Accuracy

According to (Hoobasar Rampaul, 2003), the bevel angle varies from 70° to 90°. Therefore each pipe must be less than 45° and more than 35° bevel angle. The above results show that the improved design of the fabricated jig achieved accuracy for the bevel angle measurement. The bevel angle is still within the range of the bevelling standard, which lies between 35° and 45°. The measurement instrument, Bevel Angle, helps to measure the

bevelling angle precisely. Bevelling is a crucial aspect of the pipe welding engineering procedure. The bevel angle must be between the standards to avoid uneven bevel quality angles because the bevel quality may affect the weldment quality and failure. The standard uncertainty is an important statistic because it provides information on the accuracy of the measurement (McHugh, 2008). The standard uncertainty of the improved design fabricated jig was lower than the old design, which is the average value of uncertainty the before design improvement indicates 0°34'41.15". At the same time, the value after the design improvement was slightly lower, which is 0°23'55.98". It shows that the accuracy and precise measurement of bevel angle can be achieved due to the motor's constant speed rotation to rotate the pipes to produce a constant degree of bevel angle.

	Degree of uncertainty			
Pipe Diameter	Before design improvement	After design improvement		
2.5 inch	±0°40'26.93"	±0°18'1.67"		
3 inch	±0°41'3.74"	±0°22'32.77"		
3.5 inch	±0°22'32.77"	±0°31'13.5"		
Average Average	0°34'41.15"	0°23'55.98"		

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Table 4.5: Comparison of bevel angle measurement before and after design improvements

4.5 Costing Analysis RSITI TEKNIKAL MALAYSIA MELAKA

Cost estimation evaluates a strategy, project, or operating expenditures. The procedure for determining expenses has produced an estimated total cost. The cost estimate comprises total and component values. The analysis of costs is a fundamental approach that compares the amount of interest in a project to the amount of money it takes to produce it. Two essential expenses were calculated in estimating the expenses associated with producing a product: variable cost and fixed cost.

4.5.1 Variable Cost

A variable cost is a kind of cost incurred by a company that varies depending on the number of products produced. Variable expenses depend on a company's production; they will increase as demand increases and decrease as output decreases. Table 4.6, for example, shows an estimate of the variable cost of parts used to fabricate the jig.

Item	Part Name	Quantity	Fabricate (F) Purchase (P)	Price
1	Based Structure	1	F	110.00
2	Vibration Mat	1	Р	64.60
3	Linear Rail Link	2	Р	172.30
4	Lifting Base	1	Р	38.80
5	M6 X 1.0	2	Р	0.80
6	M8 X 1.25	4	Р	1.40
7	M16 X 2.0	4	Р	4.40
8	M5 X 0.8	52	Р	10.40
9	M10 X 1.5 Half-Thread	1	Р	1.50
10	M10 nut and washer	8	Р	10.40
11	M10 lock nut	1	Р	0.25
12	M4 X 0.7	4	Р	0.60
13	M12 X 1.75	4	Р	3.20
14	M8 nut	16	Р	1.60
15	Bearing Shaft	8	P	
16	Grinder	1	Р	320.00
17	Grinder Connector	1	М	25.60
18	Adjustable Grinder Holder	. 2 :	М	15.60
19	Pipe Vise	an 1 an	G.PVJ.	50.90
20	Lifting Based Mount	KAL MALA		KA 10.40
21	Pipe Vise Mount	2	М	23.40
22	Roller mount	2	М	15.60
23	Motor	1	Р	201.80
24	3 Jaw Chuck	1	Р	192.20
25	Roller	4	Р	10.00
26	Motor shaft adapter	1	Р	5.90
	Total Variable	Cost		RM 1291.65

Table 4.6: Variable cost of the project

4.5.2 Fixed Cost

Costs that don't change when sales or production increase or decrease are called "fixed costs" because they are not directly involved in producing a product or providing a service. As a consequence, fixed costs were categorised as indirect costs. For example, rent,

housing, equipment, and much more could be fixed costs. These fixed costs were assumed in one month when 20 units were produced. Table 4.7 shows the fixed cost of the project.

No.	Fixed Cost	Duration	Cost (RM)
1	Electricity Bills	1 Month	400.00
2	Transportation fees	1 Month	350.00
3	Maintenance fees	1 Month	150.00
4	Water Bills	1 Month	80.00
5	Insurance	1 Month	150.00
6	Labour	1 Month	1500.00
Total			RM 2630

Table 4.7: Fixed cost for producing the jig

4.5.3 Manufacturing Cost

All the resources used during the production process define manufacturing costs. Fixed and variable manufacturing costs were the total cost of producing something divided by the number of units made. Manufacturing costs were used to figure out a profit margin of 20%. So, the selling price per unit is equal to the sum of the costs of producing the product plus the costs of the profit margin. The cost of selling a jig and fixture unit for the bevel end of the pipe joint that has been made was calculated to be RM 1707.78.

 $\begin{aligned} \text{Manufacturing Cost} &= \frac{\text{Total fixed cost} + \text{Total variable cost}}{\text{Amount produce}} \\ &= \frac{\text{RM 2630} + (\text{RM 1291.65})20}{20} \\ &= \text{RM 1423.15} \end{aligned}$ $\begin{aligned} \text{Profit margin 20\%} &= \text{RM 1423.15 X 20\%} \\ &= \text{RM 284.43} \end{aligned}$

Selling cost per unit = Manufacturing cost + Profit margin = RM 1707.78

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project has three objectives that have been fulfilled successfully.

In conclusion:-

- i. The vibration and the angle accuracy of the previous design of the fabricated jig have been analysed where the bevel angle produced by the jig and fixture was more precise rather than the bevel using a grinder manually where the average value of the uncertainty was ±0°34'41.15", which indicates the bevelling jig was able to produce a constant degree of bevel angle. This is because the jig and fixture facilitate finding and fastening the pipe and assuring the grinder's proper location. The vibration exposure while using the previous design fabricated jig was still safe. The highest vibration magnitude occurs during the bevelling of a 3.5-inch pipe which is 116.59 m/s² within 5 minutes and 43 seconds. According to ISO European Standards, these exposure levels are nearing the exposure limits yellow indicator, which is between 105 m/s²untill 150 m/s². Employers must restrict daily exposure when specific levels are reached. The improved design of the fabricated jig eliminated worker vibration when beveling a pipe.
- ii. The design improvement of the fabricated bevelling jig was implemented after the vibration analysis identified the problems. The previous design required workers to rotate the pipe to bevel, exposing them to vibrations. An automated pipe rotator and three-jaw chuck were developed to solve these problems. This design improvement eliminates employees' vibration exposure. The fabrication of the jig consisted of 3 parts: the base structure, the motor with lifting base and the vibration pad.

iii. The improved design of the bevelling jig for welding preparation has been validated through bevel angle accuracy analysis. The precision of the bevel angle measurement was achieved as a result of the improved design of the fabricated jig. The average uncertainty value before the design improvement shows 0°34'41.15", whereas the value after the design improvement was lower 0°23'55.98". It indicates that precise measurements of bevel angles are possible when the motor can rotate the pipes at a constant speed, which results in a constant degree of bevel angle being produced.

A fabricated bevelling end pipe joint will helps the pipe bevelled to prepare the pipe in a safe condition. A constant degree of bevel angle can be achieved rather than the manual grinding operation. Improved design has been proposed to reduce the vibration exposure for the worker. The problems have been identified, and the solution has been implemented to improve the design and functionality of the existing fabricated jig. The improvements will help eliminate the exposure of vibration for the workers when conducting the pipe bevelling preparation by using the existing jig. The vibration produced from the improved design is expected to be higher due to additional vibration from the motor. The bevel angle accuracy is expected to be higher since the motor's rotational speed is consistent rather than using a manual operation where the worker must turn the pipe manually by using the jig. Reducing vibration exposure is an excellent approach to avoiding diseases related to vibration tools, such as Hand Arm Vibration Syndrome. By using the improved design of the fabricated jig, it is safer to be used in preparing the pipe bevel compared to manual hand grinding operation.

5.2 Recommendations

2 recommendations can be implemented for further research and studies. The recommendations are as follows:

- i. The improved design jig needs to be fabricated using a high-precision cutting machine to reduce reworking and waste or scrapping components that are not quite up to standards.
- ii. Design a better mechanism for rotating a pipe to produce a bevel angle for various lengths and diameters of pipe.

5.3 Sustainability Element

The sustainability element that exists in this project is the design. The sustainable design aims to improve the jig functionality by minimising negative effects on the natural environment and the well-being and level of comfort experienced by building occupants. The primary goals of sustainability are to lower the use of non-renewable resources, cut down on waste as much as possible, and create healthy and productive environments. The material used to fabricate this jig was mostly mild steel. It is one of the world's most sustainable materials that are permanent, forever reusable and the most recycled substance on the planet. The cost of producing this jig is much lower than buying the existing commercial pipe beveling machine, which causes a large cost.

5.4 Life-long Learning Element

Life-long learning is a process of constant learning and development that incorporates continuous professional development, in which all individuals need to engage in a time of rapid change. Life-long learning is important to acquire skills that enable survival and help us through our daily lives. Throughout this project, it has developed skills and knowledge to enhance the quality of life and design development. This jig was able to reduce vibration, and it is simple and easy to use as it is a result of design improvement development.

5.5 Complexity Element

In this project, the complex elements occur in developing the engineering design. Engineering design is the process of transforming customer's demands into design solutions. Fundamental conceptual weaknesses that occur due to the selection of a poor design solution may never be fully recovered by any subsequent design improvement. The complexity element occur in this project is when brainstorming a new idea to develop a proper design to solve the problem existing on the previous design of the jig. The successful engineering design solution brings a few advantages by utilizing this bevelling jig for daily life. It offers portability because this jig's weight and size are much lower than a commercial bevel angle machine. The fabrication cost is also much lower when compared to buying the commercial, and it may caused a few more times greater than the fabrication cost.



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