

DESIGN OF A LOW VIBRATION GRINDING JIG AND FIXTURE FOR PIPE BEVELING PRIOR TO WELDING

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ABSTRACT: Pipes are commonly welded through various types of ends, including bevelled ends. Pipe bevelling is a process of forming an angle between the pipe end edge and the plane perpendicular to the surface. The pipe bevel angle depends on the welding standard, including angles such as 30° and 45°. The most convenient way to bevel a pipe in preparation for welding is by using the hand grinding process. Although it is the cheapest way to bevel a pipe, the problem of using a hand grinder is the least safe method of all and time consuming as well as requires skilled operations. Besides, the operator is exposed to vibration during the hand grinding process. The use of a vibrating hand-held grinding power tool is associated with vibration disease that may damage the vascular, sensory or musculoskeletal system. So far, however, limited design has focused on eliminating the vibration on a hand-held power tool. Where eliminating the problem could be challenging, better tool design may help reduce some vibration transmitted to the operator. Therefore, the objective of this study is to design a low vibration grinding jig and fixture system to bevel a pipe in preparation for welding. A pipe of 20 mm diameter is the focus of this design. The design process includes product design specification and conceptual design. Based on screening and scoring methods, the highest net score was 7 for concept design 3. Thus, concept design 3 was selected for the final design, which was technically drawn using Computer Aided Design (CAD) software. The findings of this study will propose a new design that will reduce vibration compared to the conventional method of beveling a pipe.

KEYWORDS: *Design; Grinding; Jig and Fixture; Bevel End Pipe; Welding*

1.0 INTRODUCTION

A jig is a custom made tool to locate and move another tool. The function of the jig is to hold and clamp tools such as tool bit, chamfer and cutter disc. The purposes of the jig are to provide accuracy, repeatability and interchangeability in the manufacturing products. A fixture is a work-holding device, and it is designed for a particular job. Application of fixtures is required in different industries permitting their purpose. According to Pandit [1], a fixture is a unique tool for properly holding a workpiece or specimen during manufacturing. The fixture is generally designed and built to hold, support and position each part within the defined limits to ensure that each part is drilled, ground or machined. The difference is the method of guiding the tool to the workpiece. Fixture differs in size, cost, and complex devices from relatively simple tools. The fixture also helps to ease metalworking operations on special equipment. Fixture plays a vital role in the accuracy, surface finish and precision of the machine parts. It is crucial to develop a proper fixture design.

According to Patil et al. [2], setup planning must be conducted during the designing fixtures process. Setup planning can be divided into three purposes, which are determining the number of setups or configurations, determining the orientation and position of the workpiece, and determining the machining datum features and locating the surface. After the setup planning process, the next step is fixture planning. Fixture planning consists of a few purposes, which are determining location positions, clamping surface and clamping position. After all information or data during the setup process and fixture planning have been obtained, generate a unit design based on the data or information collected and analyse a design to choose which design is suitable.

Designing jig and fixtures depends on many factors of consideration [1, 2]. One of the factors is a study of the workpiece and finished component size and geometry. Besides, the types and capacity of the machine are critical considerations to recognise the capability of the machine to avoid bottlenecking the jig and fixture fabrication. The other factor in designing jigs and fixtures is locating devices in the machines. In addition, a clamping arrangement should be available in the machine. The accuracy available in indexing devices also has been identified as one of the factors in designing jigs and fixtures.

Moreover, the evaluation of variability in the performance results of the machine and rigidity and the machine tool under consideration should be considered in designing jigs and fixtures. Finally, a study of rejecting devices, safety devices and the required level of accuracy in the work and quality to be produced should be considered while designing jigs and fixtures. In this study, the pipe clamping focuses on the clamping type. The standard pipe end types for welding purpose includes plain ends, bevelled ends, threaded ends, threaded and coupled ends and grooved ends. The interest of this research is for bevelled ends pipe. Therefore, for supporting and clamping, the design must be suitable for clamping a pipe for the bevelling process.

The most convenient way to bevel a pipe in preparation for welding is by using the hand grinding process. Even though it is the cheapest way to bevel a pipe, using a hand grinder is the least safe method of all and time consuming as well as requires skilled operations. Besides, the operator is exposed to vibration during the hand grinding process. In general, vibration is oscillations occurred from a stable position. The performance and efficiency of the machine are affected by this vibration. Chattering is one of the causes that decreases precision and accuracy in the grinding machine. Usually, vibration occurs due to many factors, such as the type of tools used, weight of the grinder, imbalance in the working disc, wear and tear in moving parts, whether it is performing work, the qualities of the work material and fixing. Dong et al. [3] stated that vibration could be divided into two types which are force vibration and self-excited vibration. Force vibration usually occurs due to misalignment, unbalance and eccentricity of a grinding wheel. The hydraulic system installs into a grinding machine also causes force vibration. Self-excited vibration caused by the cutting process in the grinding machine. The regenerating effect is the leading cause of this vibration. There is a chance of waviness formation between the grinding wheel and the workpiece in the rotation of the grinding wheel. The characteristic feature of the grinding chatter is that regenerating effect may occur on both the workpiece and the grinding wheel surfaces [4]. The machine assembly that contains the clamp, jig, fixture and hydraulics system is exposed to the force and self-excited vibration. Both vibrations can cause a surface error in grinding wheels, surface finish, workpiece and machine tools are damaged partially. Paul et al. [5] stated that the energy of the vibration is transferred through the acceleration, frequency, and direction of vibration and the body's (grip strength) connection with the vibration source and hand-arm impedance. The amount of energy consumed by the vibration is more significant than the direction of the vibration or the strength of

the grip of the operator. The vibration produced on a grinding machine also depends on the size of the grinder machine.

Currently, an available method to reduce vibration in grinding tools is reported by Shanks et al. [6], which stated that mechanism and equipment for minimising the vibration transferred to the operator vary from more advanced internal mechanisms to anti-vibration mounting on engines or anti-vibration handles. A selection of vibration-reducing or eliminating products include anti-vibration side handle, grinding wheel balancer, rear handle bushing, comfort grip, elephant trunk suspension system, saw clamping system, drilling rigs, tensioners or spring balances, consumables and sleeve or resilient coatings. Based on this literature, an anti-vibration handle has been selected for this research. Shanks et al. [6] have studied the effect of 8 handle types and 8 machines on the total values of weighted frequency vibration. For the 34 machine-handle combinations for which data were collected, there was no discernible pattern. Several retrofit anti-vibration handles provided a decrease in the vibration measured, whereas others saw an increase in the vibration measured. It was not always the same handle that provided the same decrease or increase in vibration. The measured vibration levels focused more on combining the handle with the machine. All the data collected in this literature suggests that the expected lower vibration level at both hands cannot be predicted by fitting a machine with an anti-vibration handle retrofit. The vibration levels that produce depend on the individual handling the machine and the machine design combination [7]. Also, the vibration level occurs because of the disc size used on a grinder.

There is an existing system to bevel a pipe. Gracia et al. [7] have developed a split frame bevelling machine. This machine uses pneumatic, hydraulic and electric to drive. This device is not adjustable. Both frames are clamped together around the pipe to bevel the pipe. It is for the large diameter of the pipe. Gormany [9] has developed a pipe and bevelling tool based on the use of a welding torch. It uses plasma arc cutting or oxyfuel gas cutting torch. The cutting torch can be adjusted to the desired angle. However, it is meant for the large diameter of the pipe and is less accurate. Karpachevskyy [10] has developed a portable pipe lathe method. It uses pneumatic, hydraulic and electric to drive the system. It can move horizontally during the bevelling process and typically for the medium diameter of the pipe. Figure 1 shows examples of the beveling system as reviewed in this paragraph.

The use of vibrating hand-held grinding power tools has been associated with vibration disease that may result in damage to the vascular, sensory or musculoskeletal system. Where eliminating the problem could be challenging, better tool design may help reduce some vibration transmitted to the operator. The available design has a limitation to beveling a pipe at different angles, pipe size and accuracy.

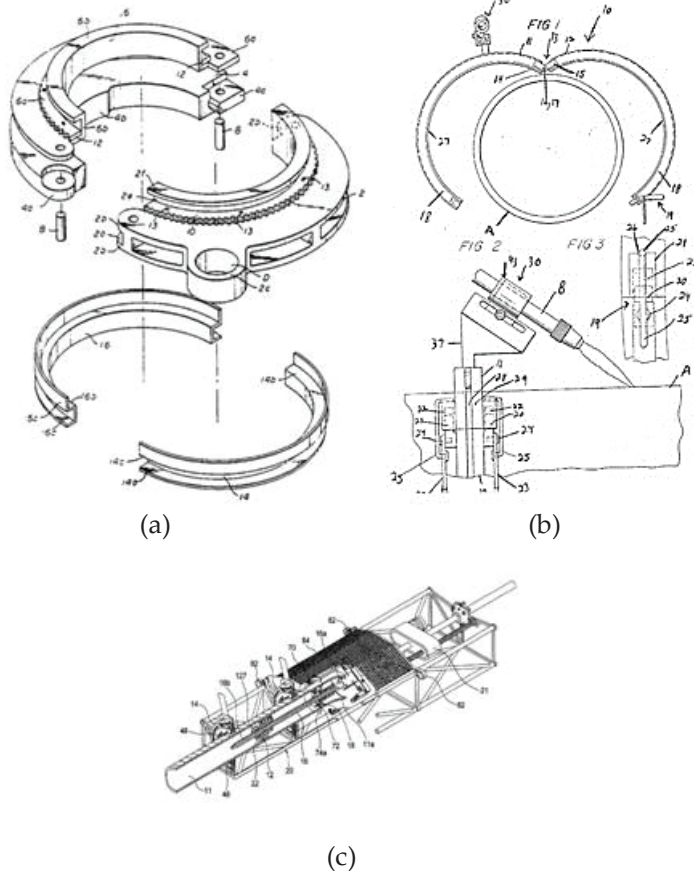


Figure 1: (a) Split frame beveling machine [8]; (b) beveling torch cutter [9]; (c) portable pipe lathe method [10].

According to Jiang et al. [11], vibration can be divided into two types which are force vibration and self-excited vibration. Force vibration usually occurs due to misalignment, unbalance and eccentricity of a grinding wheel. The hydraulic system installs into a grinding machine also causes force vibration. Self-excited vibration caused by the cutting process in the grinding machine. The regenerating effect is the leading cause of this vibration. There is a chance of waviness formation between the grinding wheel and the workpiece in the rotation of the

grinding wheel. The characteristic feature of the grinding chatter is that such a regenerating effect may occur on both the workpiece and the grinding wheel surfaces [12]. Based on Shanks et al. [6], most power tools that exist nowadays are frequently advertised as anti-vibration or vibration reduced. Dong et al. [3] suggested effective engineering methods for controlling handheld workpiece vibration in the grinding process. The vibration responses of the workpiece hand-arm system evidently were simulated and measured in a laboratory [13].

Therefore, the objective of this study is to design a low vibration grinding jig and fixture system to bevel a pipe in preparation for welding. The findings of this study will propose a new design that will reduce vibration compared to the conventional method of beveling pipe.

2.0 METHODOLOGY

A pipe of 20 mm diameter is the focus of this design. The methodology describes the design process, including product design specification, conceptual design, screening and scoring methods, and conceptual development. Factors related to vibration reduction are considered in the design process.

2.1 Quality Function Deployment (QFD) and House of Quality (HOQ)

Quality function deployment (QFD) is a planning process for products that start with the voice of the customer. By using the QFD, it allows the charting of customer wants and the technical how, which results in a better understanding of design relationships. The house of quality (HOQ) is part of a more extensive process of QFD. The purposes of HOQ are to understand the customer desires and priorities, design features and technical requirements and the relationship between the design and features. This study generated the HOQ.

2.2 Conceptual Design

Conceptual design is an early form of background work involving many complex evaluations and decision-making tasks. Conceptual design can be divided into three steps which are concept generation, concept evaluation and concept development. The tool used in concept generation was brainstorming. Brainstorming was conducted to generate an idea. A list of ideas collected based on the observation from

the various resources was jotted down. Then, it was considered to be selected if there was a higher potential for the product to be developed. After the concept generation, a concept evaluation was performed. All concepts based on the concept clamp, design of the jig and fixture and grinder position were combined. A pipe of 20 mm diameter is the focus of this design.

2.3 Screening and Scoring Methods

Screening a new product concept is perhaps the most critical activity in new product design and development [14]. The Go/No Go screening method sets specific criteria for ideas that should be continued or dropped. After the screening process, the scoring method was performed. A new table was formed, which consists of weight. The highest percentage was given for the most important criteria. Rating and weighted scores were given to conceptual design based on various selection criteria. A weighted score was obtained from the multiplication of percentages by rating.

2.4 Concept Development

After the evaluation and decision-making, the concept was drawn in detail using Computer Aided Design (CAD), Solidworks 2018. The selected conceptual design was designed, in fact, by considering all the dimensions and specifications until the final design was carried out.

3.0 RESULTS AND DISCUSSION

3.1 Quality Function Deployment (QFD) and House of Quality (HOQ)

Figure 2 shows the developed HOQ. Customer demand quality includes reducing vibration, low cost, easy to assemble and disassemble, lightweight and feasibility. The technical requirement includes degree adjustable for bevel, set up time, quality of bevelling surface, size and weight. The target of the limit value was set according to the technical requirements. Competitive were based on the literature review [8 – 10] that was split frame machine, beveling torch cutter and lathe-chamfer tools.

3.2 Conceptual Design

Table 1 shows a table of concept generation based on the vital rating obtained from the HOQ. There were 3 design concepts, namely concept

design 1, concept design 2 and concept design 3. The concept design was based on the concept clamp, design of the jig and fixture and grinder position.

Concept design 1 in Figure 3 (a) was built in one part only that can attach a grinder and support a pipe. An operator can rotate the pipe and move the pipe vertically by using either both hands or one hand while performing the beveling process. This design can only produce one bevel angle, which is 45° . It is a simple and low-cost design. This factor agrees with the findings of Naruka et al. [15], that claimed the best angle of inclination for the working heat pipe is 45° as the thermal performance of the heat pipe is optimal at this angle.

In design concept 2, as shown in Figure 3 (b), the clamp was added as fixtures to clamp a pipe. A grinder is attached to a jig, which can be moved up and down. The main reason for a clamp was to increase safety while performing the beveling process. This justification is in line with Afandiyev and Nuriyev [16] claimed that clamping device design could significantly improve their gripping capacity and reduce the risk of accidents. The pipe can be rotated and moved vertically in this design, similar to design concept 1. However, during the beveling process, the operator must use one hand to guide the movement of the pipe and another hand to control the direction of the grinder. The bearing was used in the clamping device. This design can produce a variety of angles of bevels by setting the position of the grinder on a jig. The disadvantages of this design are the clamp might not be stable when a pipe is put on it, and thus, the angle of the bevel surface might not be accurate.

Figure 3 (c) shows the concept design 3. A clamp was added as a fixture device to clamp a pipe. Improvement was made based on design concept 2. The improvement was the clamp. A linear bearing rail slide guide shaft was added to the design to support the clamp and load of pipe. In addition, this device also can move the clamp horizontally. For the jig, a grinder is attached to a jig, and the angle position of the grinder can be adjusted. On the jig part, there was a screw slot which was used to set the angle position of the grinder. This jig can produce 30° and 45° angles of the slope. The operator only needs one hand to control pipe movement during the beveling process. Compared to the available design of [8 – 10], the new design offers additional strengths of the device being adjustable, able to bevel medium to small diameter pipe, no significant heat affected zone, and minimal contact from the operator during the bevelling process.

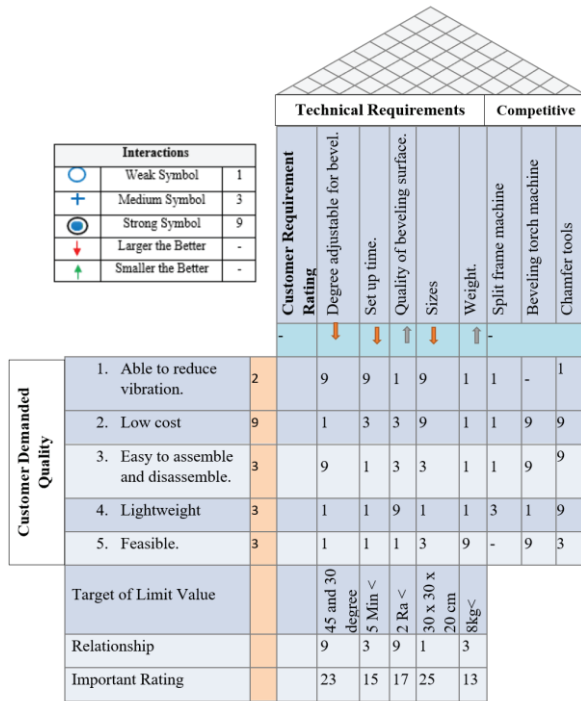


Figure 2: House of Quality (HOQ)

Table 1: Concept generation for designs 1, 2, and 3

Item	Design 1	Design 2	Design 3
Concept of clamp			
Design of jig and fixture			
Grinder position			
Angle of bevel	45°	30° and 45°	30° and 45°

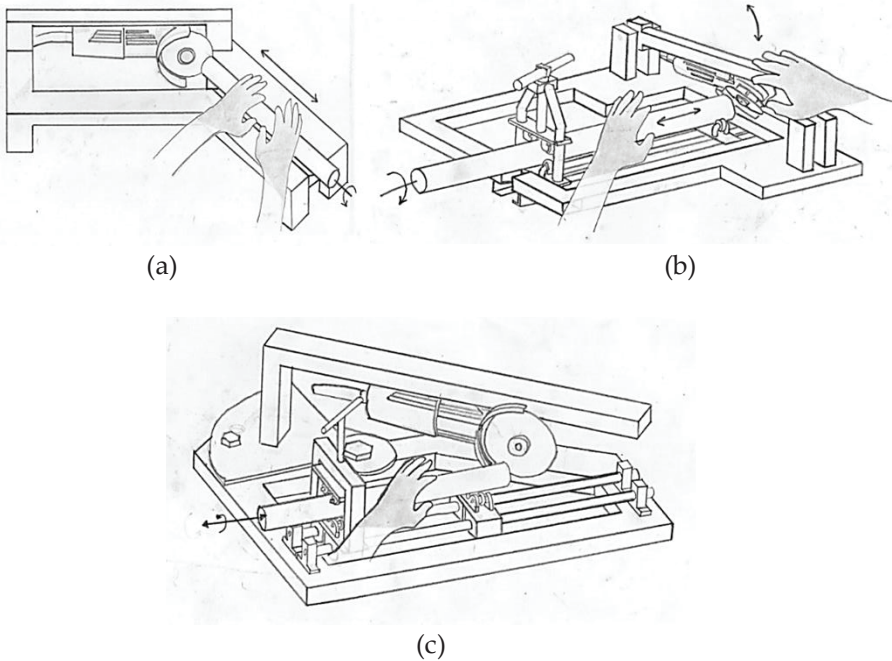


Figure 3: (a) Concept design 1, (b) concept design 2 and (c) concept design 3

3.3 Screening and Scoring Methods

Table 2 shows the Go/No Go screening for concept design 1, concept design 2 and concept design 3. The selection criteria include reducing vibration, low cost, easy to assemble and disassemble, lightweight and feasible. Based on the screening, concept design 2 was omitted. Concept design 1 and concept design 3 were evaluated for the scoring method.

Table 3 shows the scoring method for concept design 1 and concept design 3. The highest percentage was given for the most important criteria. Rating and weighted scores were given to conceptual design based on various selection criteria. A weighted score was obtained from the multiplication of percentages by rating. Based on the scoring method, concept design three was selected.

Table 2: Go or no go screening method

Selection Criteria / Concept	Concept Design 1	Concept Design 2	Concept Design 3
Able to reduce vibration.	0	++	++

Low cost	++	+	+
Easy to assemble and disassemble.	++	++	+
Lightweight	++	0	+
Feasible.	-	-	++
Sum of +	6	5	7
Sum of 0	1	1	0
Sum of -	1	1	0
Net score	5	4	7
Rank	2	3	1
Continue	YES	NO	YES

Table 3: Scoring method

Selection criteria	Weight	Concept			
		Concept 1		Concept 3	
		Rating	Weight Score	Rating	Weight Score
Able to reduce vibration	30%	3	0.9	5	1.5
Low cost	10%	5	0.5	4	0.4
Easy to assemble and disassemble	10%	5	0.5	4	0.4
Lightweight	20%	5	1	4	0.8
Feasible	30%	2	0.6	5	1.5
Total	100%	3.5		4.6	
Rank		2		1	
Continue		No		Yes	

3.4 Concept Development

Concept design 3 was selected based on the screening and scoring methods. Figure 4 shows the CAD drawing of the final design. The components include a based structure, linear rail link, bearing linear rail, bearing based, clamp, bearing shaft, bearing, grinder adjustable grinder holder, and upper bearing support.

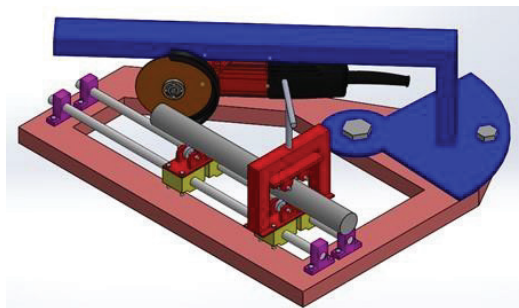


Figure 4: The low vibration grinding jig and fixture for pipe beveling prior to welding

4.0 CONCLUSION

A pipe of 20 mm diameter was the focus of this design. The QFD and HOQ were used to understand the customer desires and priorities, design features and technical requirements and the relationship between the design and features. There were 3 design concepts, namely concept design 1, concept design 2 and concept design 3. The concept design was based on the concept clamp, design of the jig and fixture and grinder position. The concept designs were sketched. Based on screening and scoring methods, concept design 3 was selected for the final design, which was technically drawn using CAD software. The findings of this study have proposed a new design that will reduce vibration compared to the conventional method of beveling pipe.

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AUTHOR CONTRIBUTIONS

N.I.S Hussein: Conceptualisation, Methodology, Writing - Original Draft Preparation, Supervision; M.N. Ayof: Conceptualisation, Supervision; M.S. Zainuddin: Conceptualisation, Software, Validation, Writing - Review; J. Srithorn: Proofreading and Editing

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest in the manuscript.

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