# Design and Development of Low Cost Bending Machine

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***ABSTRACT***

*The bending process has been a core step in fabricating and manufacturing products nowadays. As the industries are rapidly growing, the demand for machinery is also increasing including the bending machine. However, for personal and light use, a commercial bending machine is relatively expensive and bulky. Thus, this study intended to design, fabricate, and analyse a low-cost manually operated bending machine for light use. The bending machine was design based on the intended function and the ergonomics to users mainly Malaysian. The bending machine was first designed and then fabricated using mild steel as its primary materials due to its high hardness and ease of welding. The bending machine was then tested to pressed two different sizes and two different aluminium sheet thicknesses. Then, Finite Element Analysis was conducted on the bending machine's component which is the bender plate and bending base to find the allowable maximum stress and deformation. The findings show that the bending machine is able to bend both large and small aluminium plate thickness 1.0 mm and below without facing any part deformation or failures.*

***KEYWORDS:*** *Bending; Deformation; Stress; ANSYS; Finite Element Analysis;*

## 1.0 INTRODUCTION

The bending of sheet metal is a common and vital process in the manufacturing industry. Sheet metal bending is the plastic deformation of the work over an axis, creating a change in its geometry. Similar to other metal forming processes, bending changes the shape of the workpiece, while the volume of material will remain the same (Hagenah et al., 2019; Kulkarni et al., 2015).

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In some cases, bending may produce a small change in sheet thickness (Hanoof, Vishwanth, Sureshkumar, & Saravanan, 2014). However, for most operations, bending will produce essentially no change in the sheet metal thickness. In addition to creating a desired geometric form, bending is also used to impart strength and stiffness to sheet metal, to change a part's moment of inertia, for the cosmetic appearance and to eliminate sharp edges (Eltantawie, 2013; Hanoof et al., 2014; Kulkarni et al., 2015).

Figure 1 shows the basic principle of the bending machine. Most of the bending machine in the market are generated and powered by the hydraulic or pneumatic system it was very expensive and difficult to operate. These conventional machines are rather expensive and difficult to move.

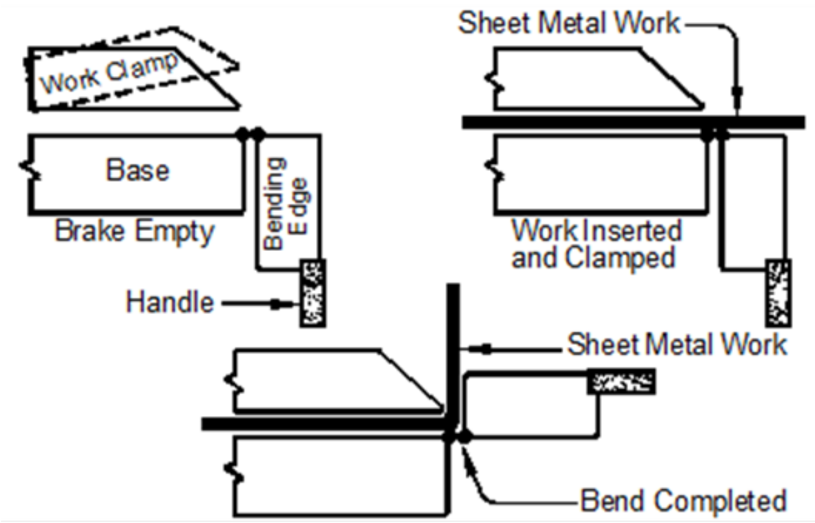


Figure 1: Basic principle of bending machine

Simple work involving a typical plate bending process can be conducted using a simpler version of the bending machine. With a simpler version, costs such as electrical, motor, hydraulic, and components can be reduced.

When designing and fabricating components and machines, there were many aspects to be considered, such as selecting materials, design dimensions, stress and pressure distributions, and ergonomics. It has been discussed by other previous research where the components of the bending machine are susceptible to the tremendous amount of stress as it is working with deforming another material's properties (Engel, Sara, & Hassan, 2017; Yob, Mansor, & Sulaiman, 2013).

For a shaft rotary bending machine, it was reported that the shaft is the most components that fail after repeatable overload works. Shafts mostly work under the influence of fluctuated loads or combined torsion and bending loads. If a shaft supports a static load, the bending stresses are fully reversed and the torsion is steady (Bello, 2013; Engel et al., 2017; Hanoof et al., 2014; Kadam & Deshpande, 2015).

Rather than conducting a destructive test or reverse engineer of failures, failure analysis is a very simple and cost-effective tool that has been applied widely by the industry sector to develop or improve the product design. There was plenty of research that has been conducted in determining the failure of components/products by using this technique (Engel et al., 2017; Gandhi, Gajjar, & Raval, 2008; Helguero, Ramírez, & Amaya, 2019; Kane, Mishra, & Dutta, 2016; Yob et al., 2013).

To determine the failure modes, analytical, experimental, and computational modelling software analysis methods can be used (Gandhi et al., 2008; Mat Tahir et al., 2017; Yob et al., 2013; Yob, Mansor, & Sulaiman, 2014). This analysis method requires complete information about the component geometry, material, load condition, work environment, and work constraints (Yob et al., 2013, 2014).

This study aimed to design, fabricate, and analyse the stress distribution of a manually-powered bending machine for light purposes in order to provide alternatives to the heavy and expensive conventional bending machine.

## 2.0 METHODOLOGY

The bending machine was designed and fabricated by following the flowchart in Figure 2. The process was first started with the conceptualisation of the design of the bending machine. Then, selection of materials to be used before manufacture the bending machine. The components were then painted before assembled. Lastly, the complete bending machine undergoes testing where if the machine or components fails, the process will be back to the redesign phase.

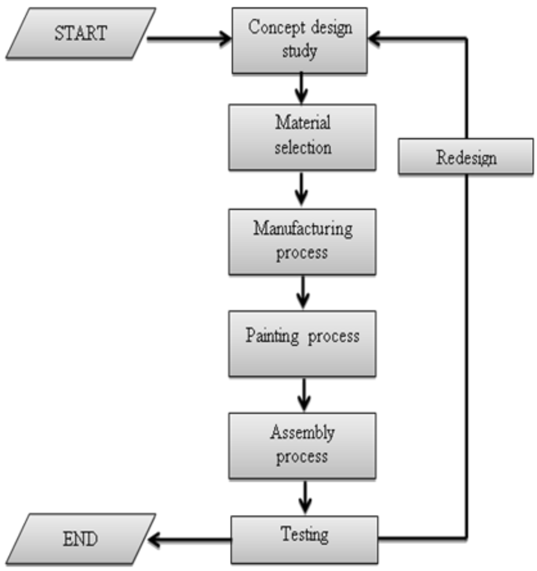


Figure 2: Design process of low-cost manually operated bending machine

Since this bending machine will be manually operated by operators, one of the machine design concerns is the bending machine's height. An unsuitable or inappropriate high of machinery will lead to an unpleasant experience by the operator. This bending machine was designed so that the lever can be moved by a hand while the sheet will be placed at the waist area height. In this case, the bending machine's height must in the range of the waist height and elbow height in the standing position (as shown in Figure 3). According to the anthropometric data for Malay male and female, aged 18 to 24 years, the elbow height in standing position is 769 mm female 5th percentile as the referent for designing the bending machine (Karmegam et al., 2011).

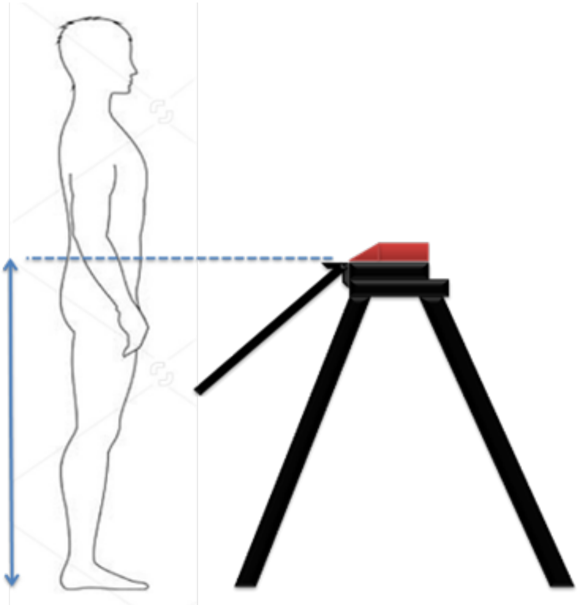

Figure 3: Proposed height of bending machine according to Anthropometric data

## 2.1 Fabrication of Bending Machine

The bending machine was designed by following these three crucial points; easy operation bending machine, small workpiece, and maximum bending of 130°. The material used for the bending machine was mild steel due to its high hardness and eased of being welded. The bending machine was designed to have an 'A-Frame base with two levers welded to the bending place at the left and right operating area. The bending machine is fabricated as shown in Figure 4.

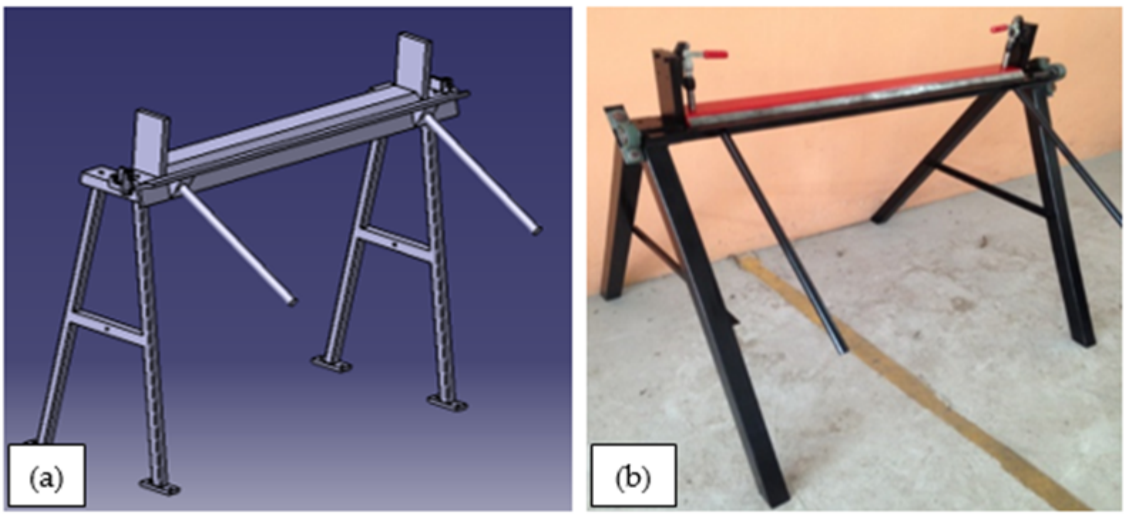


Figure 4: Image of designed bending machine (a) drawing and (b) fabricated

## 2.1 Testing

The test was conducted using four aluminum sheets where each of them is different in width and thickness (2 different thickness; 2 different widths). The test series conducted was shown in Table 1. This test was conducted in order to determine the force needed to push the bender bar according to the metal sheet thickness and the bending angle wanted.

Table 1: Series of test conducted

| Thickness (mm) | Dimension (mm) | Angle(°) |
|---|---|---|
| 0.6 | 170.0 x 75.0 | 45 |
| | | 90 |
| | | 130 |
| 1.0 | | 45 |
| | | 90 |
| | | 130 |
| 0.6 | 815.0 x 95.0 | 45 |
| | | 90 |
| | | 130 |
| 1.0 | | 45 |
| | | 90 |
| | | 130 |

For the simulation studies, a computational modelling analysis named Finite Element Analysis was used in order to determine the stress distributions and deformations of the bending machine components. There were two conditions set for the analysis by involving two parts of the bending machine which are; bender plate and bending base. Both analyses for big and small plates were set at 50N distributed load as shown in


Figure 5.

Figure 5: Boundary load condition for (a) small plate and (b) big plate

## 3.0 FINDINGS

A Von-mises stress analysis result can be considered a method for engineers to design and get information about the design. The design will fail if the maximum value of Von -mises stress induced in the material is more than the material's strength. Figure 6 and 7 shows the Finite Element Analysis for the stress and deformation of the bending machine components respectively meanwhile Table 2 shows the tabulated data.

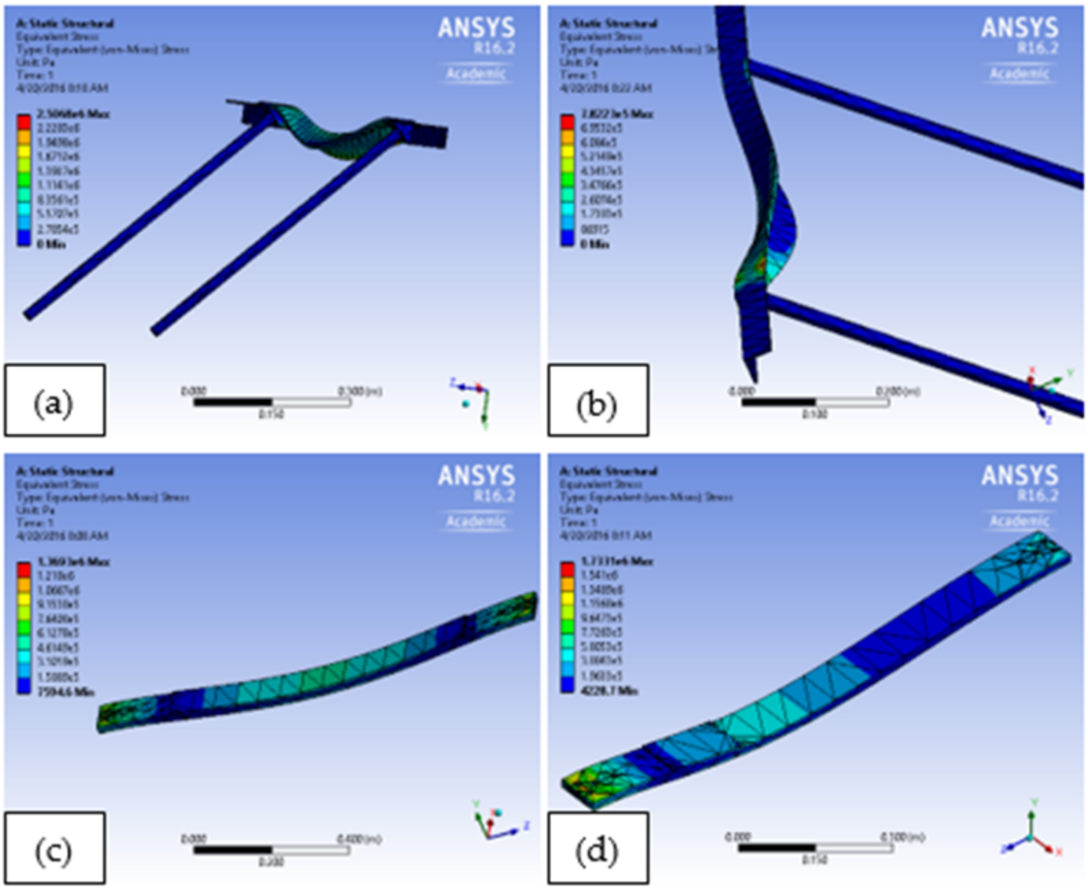


Figure 6: Stress analysis for (a) bender plate for a large sample, (b) bender plate for a small sample, (c) bending base for a large sample, and (d) bending base for small sample

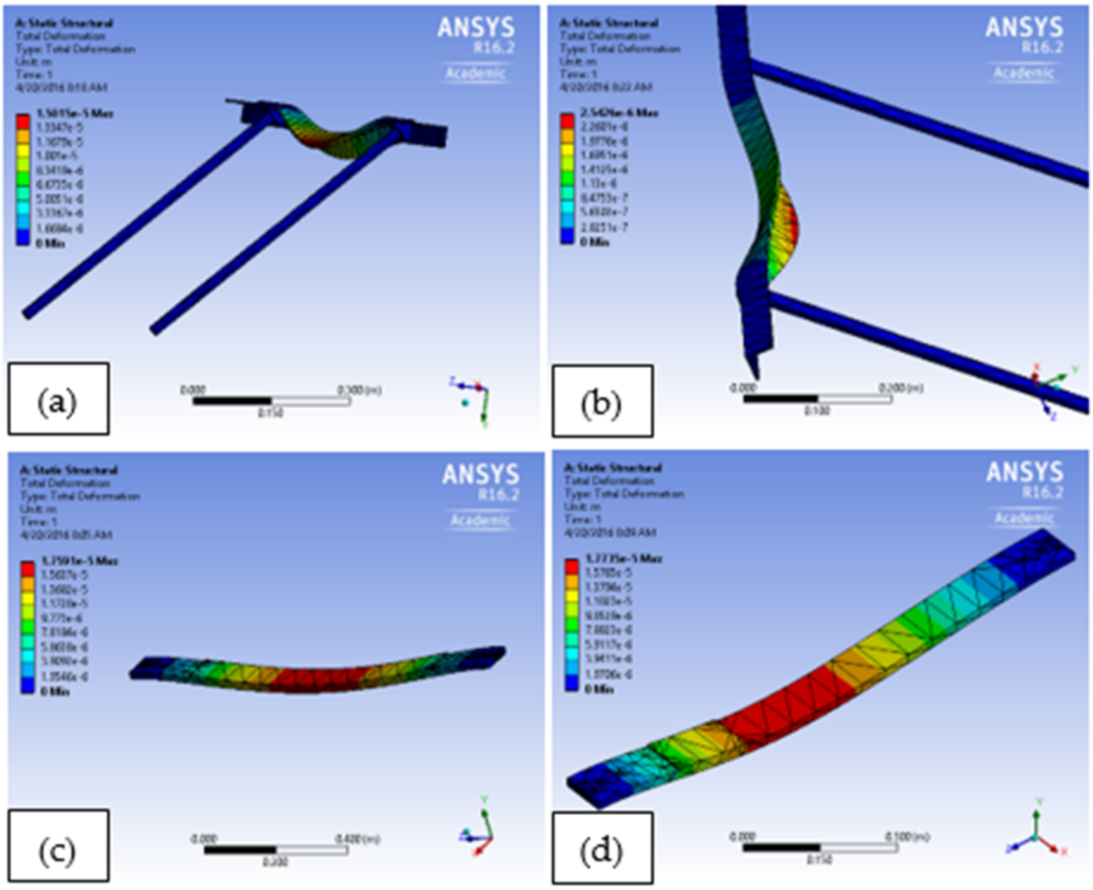


Figure 7: Deflection analysis for (a) bender plate for a large sample, (b) bender plate for a small sample, (c) bending base for a large sample, and (d) bending base for small sample

Table 2: Stress and deformation analysis for bender and base

| Part | Allowable Stress (MPa) | Dimension (mm) | Result Stress (MPa) | Maximum deflection (mm) |
|---|---|---|---|---|
| Bender plate | | 170 (small) | 0.782 | 0.0177 |
| | 240 | 815 (large) | 2.510 | 0.0176 |
| Bending Base | | 170 (small) | 1.730 | 0.0025 |
| | | 815 (large) | 1.370 | 0.0150 |

Figures 6 and 7 show that the analysis shows the high stress area with red color while no stress or '0 stress' are coloured with blue. From the images, it can be analysed that the high stress area is the area where the components meet directly with the pressed plate.

Through the obtained results, it can be seen that the designed bending machine able to bend both small and large aluminum plates (thickness of 1.0 mm and less). The analysis also showed that the bending machine might function in good condition, with no wear and tear caused by other deformation issues. Based on the tabulated result, it can be seen that a large sheet produces more stress on the bender plate. However, the stresses on the bending base are almost the same. The maximum stress obtains only 2.51 MPa at the bender plate. For the deflection, the maximum deflections are almost the same for both small and large sheets for the bender plate. However, the deflection at the bending base shows a small sheet produces a lot of lesser deflection than the big sheet.

## 4.0 CONCLUSION

It can be concluded that the designed bending machine is sturdy and able to perform its intended purposes. The bending machine shows no sign or hint of failures on both stress and deflection analysis when the constraints are applied for both conditions (bending small and big aluminum plate). By varying the thickness, the aluminum sheet tested (1.0 mm) while the stress and bending analysis shows that the components could withstand the applied force with only small deformations.

The designed and the fabricated bending machine performs well in the testing. However, it was believed that the bending machine could perform better. Thus, in the future, it is recommended that the test parameters be expanded by increasing the thickness and varying the materials of the plate intended to bend. This variety of parameters provided versatility to the bending machine and is believed to have the potentials to be commercialised.

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