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Technology Updates on Plate Bending Machines with Hydraulic Systems

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ABSTRACT

Technological advances in the industrial sector have spurred increases in efficiency and production capacity. This research aims to develop a plate bending machine with a hydraulic system designed to simplify the process of bending plates with a thickness of 1 mm to 4 mm. Research methods include designing, manufacturing, and testing bending machines. The design stages include sketching using Autodesk Inventor, component calculations, material selection, and component assembly. Tests are carried out to measure the time and pressure required to bend plates of different thicknesses. Test results show that this machine can bend a 1 mm plate in 66.5 seconds with a pressure of 35 kg, a 2 mm plate in 72 seconds with a pressure of 65 kg, a 3 mm plate in 75 seconds with a pressure of 150 kg, and a 4 mm plate in 87.5 seconds with a pressure of 215 kg. Machine modifications allow bending various plate shapes, including square shapes, with interchangeable punches. In conclusion, the hydraulic system plate bending machine developed is effective and flexible in increasing efficiency and production capacity and can be applied to various manufacturing industry needs. This research makes a significant contribution to the innovation of more efficient and versatile machining technology.

1. INTRODUCTION

Technological developments in the industrial sector have shown significant progress. Modern industry seeks to increase production in large quantities to meet increasing consumer needs [1], [2]. This advanced technology has a positive impact on everyday life, both in the household, in the market, and in the environment around us. The results of this technological progress are intended to meet human needs. In this effort, humans continue to innovate to create tools that can produce goods in large quantities at efficient production costs. One of the tools that was successfully created was the Pres Tool machine.

Limited human power in the process of bending or forming plates is a challenge in and of itself [3], [4]. Various tools have been created to bend plates, with the aim of increasing production capacity and making product manufacturing easier [5]. This research aims to develop plate-bending technology using a hydraulic system. Hydraulic technology is applied to the plate-forming and bending processes in this research. This pressing machine works by pressing or loading movements using hydraulic power. So that the pressing process runs evenly and precisely, a cylinder is needed that moves the top plate of the punch. This single cylinder has a maximum capacity of 20 tons. It is hoped that this press machine can be operated well and increase production results, especially in the fields of machinery and manufacturing.

In the welding workshop of the Department of Mechanical Engineering at Ujung Pandang State Polytechnic, there are large-capacity hydraulic bending machines and small manual bending machines that do not use a hydraulic system. The hydraulic bending machine has a replaceable punch, but it is too long. Meanwhile, manual bending machines experience problems when bending four sides of the plate because they are blocked by parts of the tool and can only bend thin (galvanized) plates. The tool that will be made is a smaller bending machine that uses hydraulic power and is driven by a lever. In this tool, the punch or bending eye can be replaced according to the length of the plate to be bent.

Previously, a tool with the title "Making Portable Bending Tools Using a Hydraulic Jack System" (Ardianto, 2018) was made.

Figure 1. Development of a Portable Bending Device with a Hydraulic Jack System[6].

One of the drawbacks is that it can only bend one side. Meanwhile, the tool we made can bend the plate from four sides. The difference in design from the previous machine is that the jack is installed upside down. The advantages of our bending machine include the addition of components that were not available on the previous tool, such as a pressure gauge and a punch, which total four and can be replaced as needed.

2. RESEARH METHODS

The method used in this research is the planning and testing method, namely the analysis of the tool design, design, and specifications used, such as calculating the plate bending force, calculating the mass of the load received by the compressive spring, calculating the strength of the compressive spring in accepting the load, and calculating the bolt and joint connections. welding. This research uses the design and build method, with the complete research flow shown in Figure 2 below.

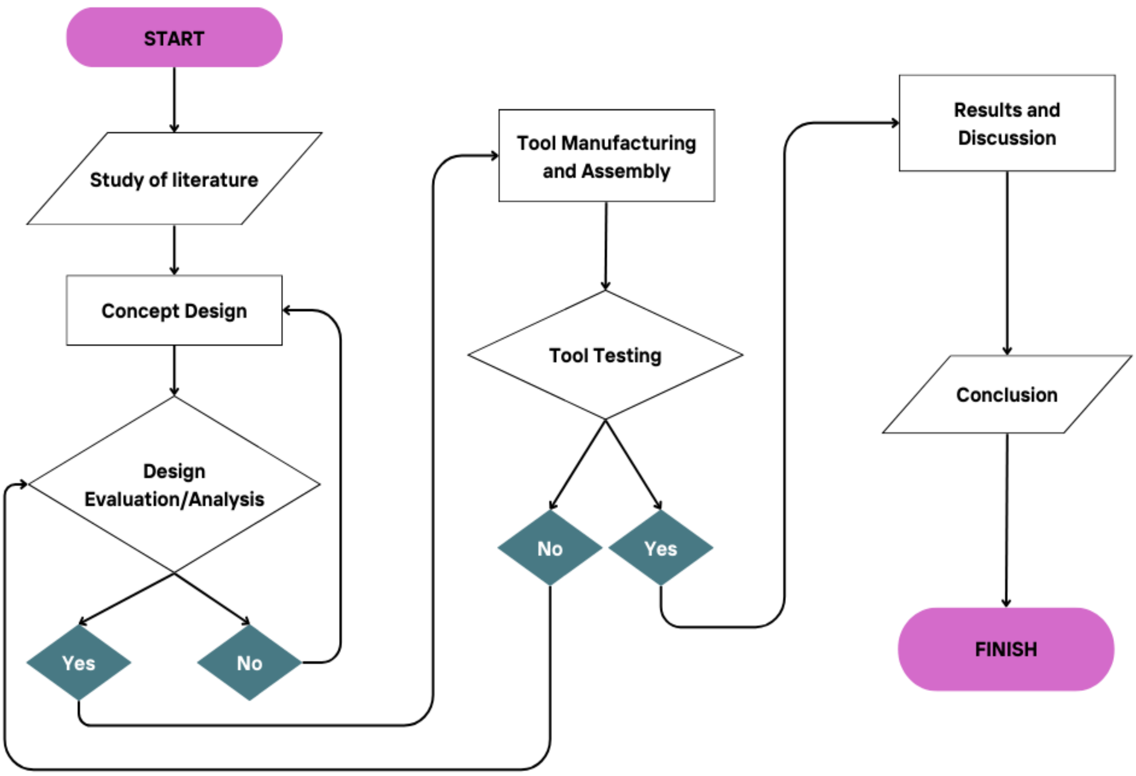


Figure 2. Research flow diagram.

2.1 Tools and Materials Used

In making portable bending tools with a hydraulic jack system, the components used consist of manufactured components and standard components purchased on the market. These components are designed and selected to ensure the bending tool can function optimally and efficiently.

For the process of making bending tools, various machines are needed. The machines used include a lathe and its equipment for cutting and forming metal, a plate cutting machine for cutting plate material to the required size, and a welding machine with its equipment for welding the components to be joined. Apart from that, drilling machines and equipment are also used to make holes in materials, milling machines for more precise metal cutting processes, sawing machines for cutting metal materials, as well as cutting grinders and cutting brands to cut various types of materials with precision. Hand grinders are also used for smoothing and cutting.

Apart from these machines, several other pieces of equipment are also needed in the process of making bending tools. The equipment used includes a vise to clamp the material to be worked on, a caliper to measure the thickness and diameter of the material, and a hammer to deliver blows to the material. A rolling rule is used to measure the length of the material, while rubbing paper is used to smooth the surface of the material. A leveling knife is used to level the surface of the material, and a drill bit is used to make holes in the material. Markers and pencils are used to mark materials and create sketches, while files are used to smooth the edges of materials. Pliers are used to hold and rotate materials; pens are used to record measurements and important notes; and pins are used to make marks on materials. A ruler is used to measure the length and width of materials, a protractor to measure angles, and a ruler to measure right angles.

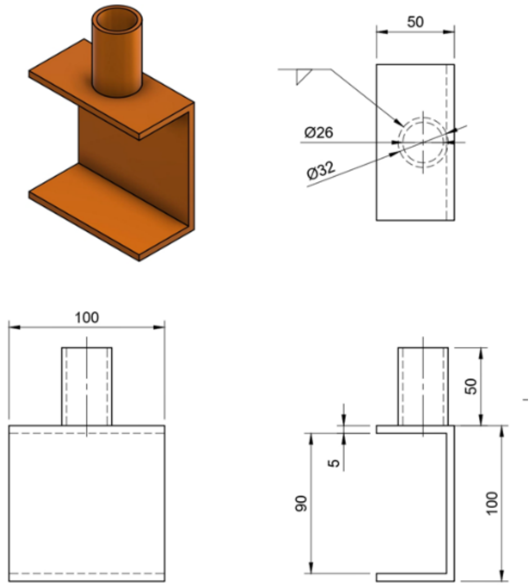
The materials used to make plate bending tools with a hydraulic jack system include steel plates as the main material, 60 × 60 mm square steel for the frame structure, and carbon steel for parts that require high strength. Bushings are used as bearing components, while tension springs and compression springs are used to provide elastic forces. The U profile is used for the frame and support, and the stainless steel shaft is used as the rotating part. In addition, AWS E6018 welding electrodes are used for the welding process and hydraulics (jacks) as a source of hydraulic power. Bolts and nuts are used to connect components, as well as shafts for components that require rotation. With this combination of tools and materials, it is hoped that this portable bending tool with a hydraulic jack system can be made well and function optimally according to needs.

2.2 Design Stages

The design stage that will be carried out is the manufacture of a plate bending machine with a hydraulic jack system where each component can be installed and removed easily. This tool will produce two types of bending results, namely V-shaped bending and radius-shaped bending. At this stage, there are several important things that need to be considered, such as the strength of the structure, construction, or frame of the tool, as well as the ease of installing and removing each component. The design of this bending tool consists of several stages that aim to determine the shape and function of the tool to be made by considering various existing factors. Several activities that must be considered and carried out in the process of designing the components of this tool include:

1. Make a sketch or drawing of the bending tool that will be made. Making sketches or images is done using software such as Autodesk Fusion 360 [7], [8], [9], [10], [11], [12], [13], [14], [15], [16] to draw digitally on a computer.
2. Calculate the tool components and carry out a feasibility test by calculating the components to be used, both self-made and purchased components. This is important to ensure that each component can function properly and safely.
3. Select the materials for each component that will be used based on the results of the calculations that have been carried out. The purpose of selecting this material is to ensure that each component has the strength and durability that meet your needs.
4. Preparation of tools that will be used in the process of making and assembling bending tools. This preparation includes checking and arranging the tools so they are ready for use.
5. Making components that will be used in portable bending tools with a hydraulic jack system. This manufacturing process includes making tool parts according to predetermined designs and specifications.
6. Assembly and adjustment of each component. After all the components have been made, the next stage is to assemble all the components and make adjustments so that the bending tool can function optimally..

By going through these stages, it is hoped that the plate bending tool with a hydraulic jack system can be made well, has adequate strength, and is easy to install and remove its components. For the component design of this bending tool, several important elements such as frame design, shaft mount, bushing, shaft, punch holder, punch lock, punch, die set, base base, and jack stand have been carefully designed. These designs can be seen in Figure 3 below.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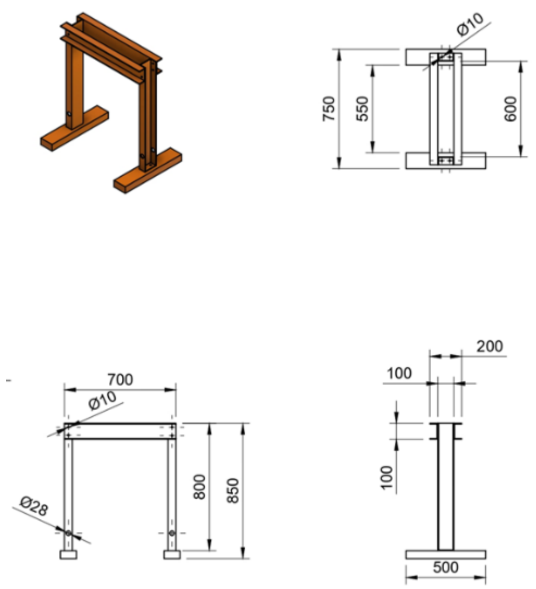
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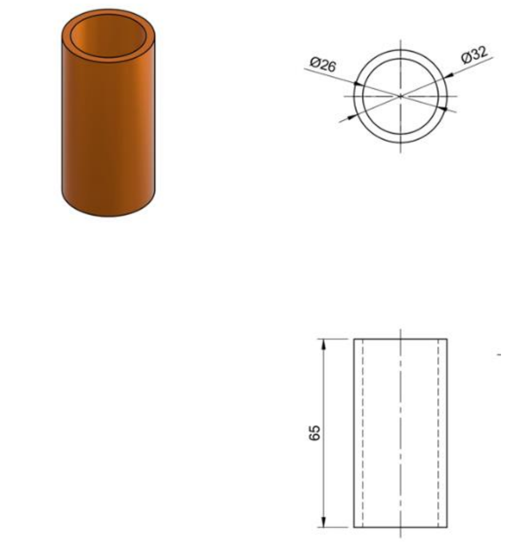
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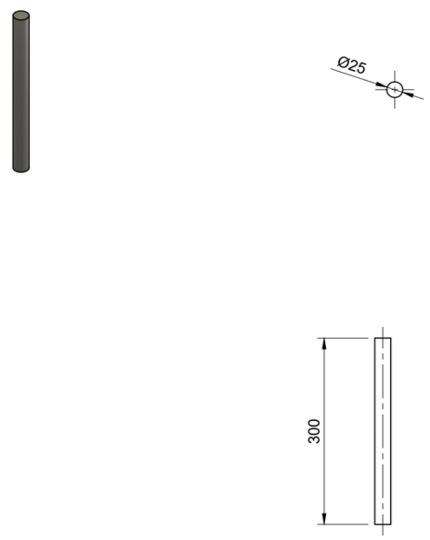
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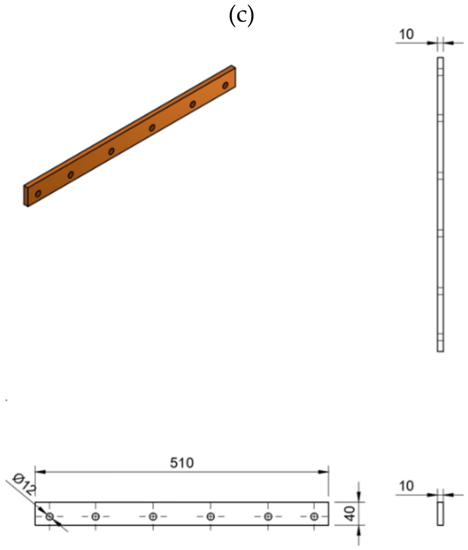
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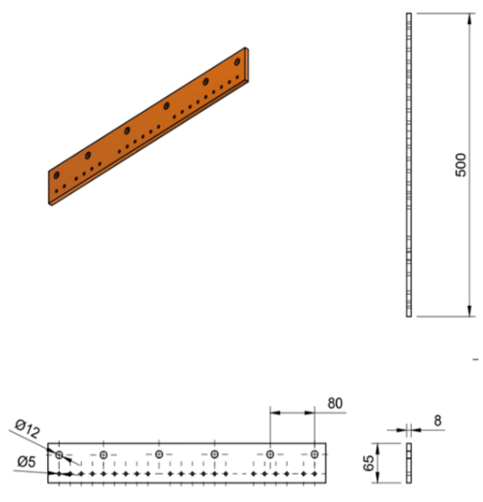
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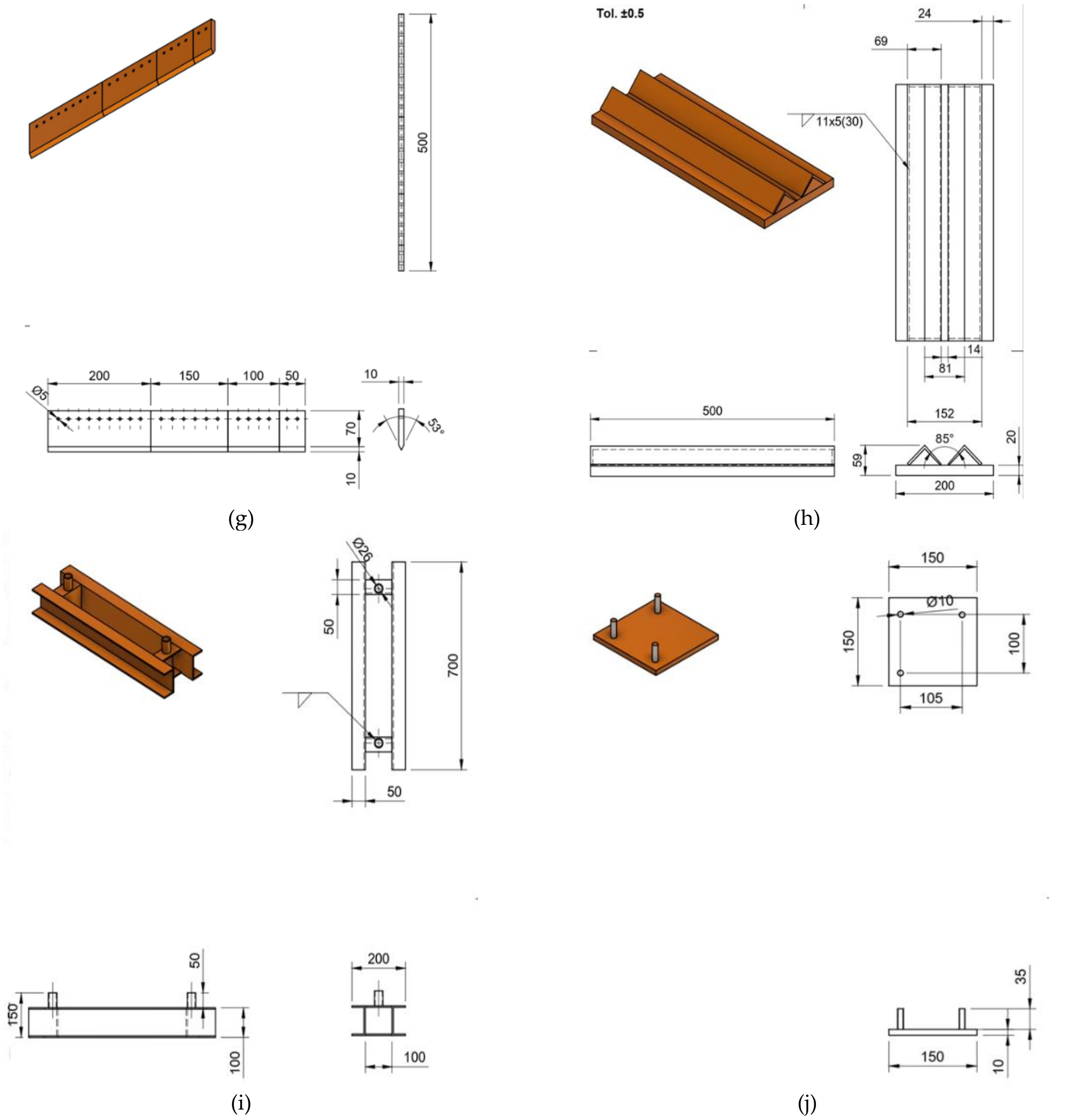

Figure 3. Design (a) shaft holder (b) frame (c) bushing (d) shaft (e) punch holder (f) punch lock (g) punch (h) die set (i) basic foundation (j) jack holder plate.

2.3 Assembly Stages

The assembly stage is the final step in modifying the plate-bending machine with a hydraulic jack system. At this stage, the components and subcomponents that have been made will be assembled into a single bending tool that is in accordance with the construction design. The following are several steps in the process of combining tool components:

2.3.1 Frame

a) Component Preparation

The first step is to prepare all the components that will be assembled completely and make sure they are available.

b) Frame Unity

Connect the top, bottom and sides of the frame using bolts and nuts. For safety, the edges of the frame are chamfered so that they don't hurt when used.

c) Base Foundation Installation

Install a basic base supported by axle iron on the left and right of the frame to provide stability.

d) Hydraulic Installation
Install the hydraulics upside down on the top plate that has been welded to the upper frame using nuts, ensuring the hydraulics are installed firmly and precisely.

2.3.2 Punch & Dies Set

a) Component Preparation
The first stage in this section is to collect all the components that have been made to facilitate the assembly process.

b) Installation of the Dies Set Table
Install the die set table on the base, ensuring the die set is installed stably.

c) Shaft Installation
Mount the axle on a mount on the base platform to provide a strong pivot point.

d) Spring Installation
Installing a spring on the shaft to provide the necessary return force in the bending process.

e) Punch Mount Installation
Install the punch holder on the shaft, ensuring that the punch holder is installed properly and firmly.

f) Installation of Locking Plate
Install the die set table on the base, ensuring the die set is installed stably.

g) Shaft Installation
Install the locking plate on the front and back of the punch holder using bolts and nuts to ensure the punch remains in position during operation.

h) Punch Installation
Install the punch into the locking plate using bolts and nuts, ensuring the punch is installed firmly and ready to use.

The final design of the assembled bending tool can be seen in the following image. This final result is expected to demonstrate the functionality and reliability of the plate bending tool with a hydraulic jack system that has been designed and modified according to needs.

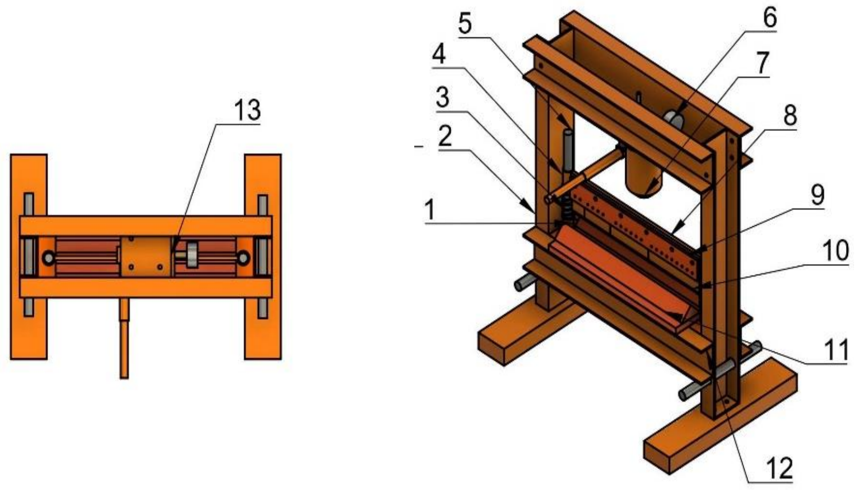

Figure 4. Final design results of the hydraulic system plate bending machine.

Below are described the names of the plate bending tool components equipped with a hydraulic jack system: 1) Shaft Mount, 2) Frame, 3) Spring, 4) Bushing, 5) Shaft, 6) Pressure Gauge, 7) Hydraulic Jack, 8) Punch Holder, 9) Punch Locking Plate, 10) Punch, 11) Dies Set, 12) Base Platform, and 13) Hydraulic Jack Mounting Plate.

2.4 Tool Testing Stages

The test procedure carried out to collect data in testing plate bending tools with a hydraulic jack system includes the following steps:

1. First, prepare samples of test material in the form of plates with various thicknesses, namely 1 mm, 2 mm, 3 mm, and 4 mm. Apart from that, prepare measuring tools, such as a ruler, to measure dimensions and ensure the accuracy of the bending results. Then, mark the bend line on the plate that will be bent to determine the area that will be formed.

Figure 5. Sample of test material.

2. Next, move the hydraulic jack lever by hand until the punch presses and bends the plate on the die. At this stage, it is important to calculate the time and read the pressure on the pressure gauge needed to bend the plate. This data will be used to analyze tool performance and determine the strength and efficiency of the hydraulic system used.
3. After the plate has been bent, reduce the pressure by loosening the valve on the hydraulic jack so that the punch returns to its initial position by rising upwards. This step ensures that the tool is ready to be used in the next bending process.
4. Finally, observe and evaluate the plate that has been formed. Pay attention to whether the bending results match the specified bend line and ensure that the resulting shape meets the desired standards. This observation is important to assess the accuracy and quality of the bending tools that have been made..

2.5 Data Analysis Techniques

The data obtained from the test results of plate bending machines with a hydraulic system will be analyzed using the comparison method. This method involves comparing the time and pressure required to bend plates of different thicknesses. In this way, we can see how variations in plate thickness affect the efficiency and performance of the bending machine.

After time and pressure data are collected, analysis is carried out descriptively to provide a clear picture of the precision of the bending results. This descriptive analysis will include observations of the shape and bending angles, as well as the consistency of results at various plate thicknesses. The aim is to assess the extent to which the bending machine can produce bends that are accurate and in accordance with the desired specifications. The data generated from these tests will provide valuable information about the performance of the bending machine, helping to identify the strengths and weaknesses of the hydraulic system used.

3. RESULTS AND DISCUSSION

3.1 Construction Design Calculations

The construction design calculation for a plate-bending machine with a hydraulic jack system includes several important aspects. Each of these aspects is important to ensure that the tool can function optimally and safely. Here are some calculations that need to be done:

3.1.1 Calculation of Plate Bending Force

To calculate the bending force required to shape the plate into a V shape, we will use the relevant equation for St. 37 material with a maximum stress of 370 N/mm2. In this case, the plate to be bent has a thickness of 1 mm, 2 mm, 3 mm, and 4 mm, with a length of 100 mm and a width of 30 mm, respectively. The basic equation used to calculate the bending force (F) is [6]:

$$F = \frac{2\, b\, s^2\, \sigma b}{3I} = \frac{0{,}7\, b\, s^2\, \sigma b}{I} \quad (1)$$

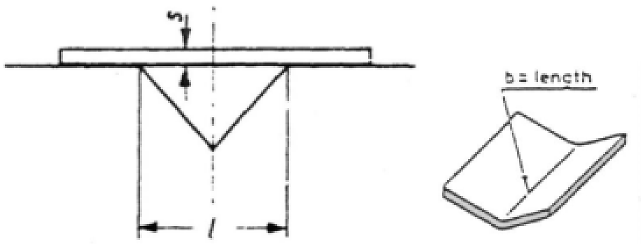

Figure 6. Parameters of the plate to be bent.

Explanation of the formula above:

F	= Bending Force (N)	b	= Bending Width (mm)
S	= Plate width (mm)	σb	= Bending stress of material (N/mm2)
Mb	= Curvature Moment (N.mm)	W	= Flexural load (N)
I	= V-shaped channel width (mm)		

The type of plate used is St37 material so that we can calculate the bending stress:

$$\sigma b = 0{,}8 \times \sigma t \text{ dimana } \sigma b = St37 = 370\ N/mm^2$$

$$\sigma b = 0{,}8 \times 370\ N/mm^2$$

$$\sigma b = 296\ N/mm^2$$

So, to calculate the plate bending force, namely :

1. Plate with dimensions 100x30x1 mm

$$F = \frac{0{,}7.b.s^2.\sigma b}{I}$$

$$F = \frac{0{,}7 \times 100 \times 1^2.296}{30}$$

$$F = 690{,}6\ N$$

2. Plate with dimensions 100x30x2 mm

$$F = \frac{0{,}7.b.s^2.\sigma b}{I}$$

$$F = \frac{0{,}7 \times 100 \times 2^2.296}{30}$$

$$F = 2.762\ N$$

3. Plate with dimensions 100x30x3 mm

$$F = \frac{0{,}7.b.s^2.\sigma b}{I}$$

4. Plate with dimensions 100x30x4 mm

$$F = \frac{0{,}7.b.s^2.\sigma b}{I}$$

$$F = \frac{0,7 \times 100 \times 3^2.296}{30}$$

$$F = 6.216\,N$$

$$F = \frac{0,7 \times 100 \times 4^2.296}{30}$$

$$F = 11.050,6\,N$$

The calculation results show that to bend a carbon steel plate using a plate bending machine system using a hydraulic jack, a bending force is required that varies depending on the thickness of the plate. A plate with a thickness of 1 mm requires a bending force of 690.6 N, while a plate with a thickness of 2 mm requires a bending force of 2,762 N. A plate with a thickness of 3 mm requires a bending force of 6,216 N, and a plate with a thickness of 4 mm requires a bending force of 11,050. N. This analysis shows that the thicker the plate, the greater the force required to bend it, which means the machine must be designed with the appropriate capacity to handle various plate thicknesses effectively. These calculations provide an important guide for machine design and testing to ensure optimal performance in the plate-forming process.

3.1.2 Compressive Strength of Springs in Accepting Loads

To calculate the ability of the compression spring to restore the load after the bending process in the punch holder, bushing, punch lock, and punch, we can use the basic Hooke's Law equation. This equation is used to calculate the force exerted by the spring in response to the deformation it experiences. In general, Hooke's Law equation is [6]:

$$W = \frac{\delta\, G\, d^4}{\delta\, D^3\, n}$$

To calculate the strength of the spring in accepting the load, we will use the concept of the shear modulus of the spring material, in this case steel, as a general assumption. Given:Spring outer diameter D = 32mm, spring wire diameter d = 3mm, shear modulus G = 83×103 N/mm² (or 83 GPa in SI units). Then the strength of the spring in accepting the load is:

$$W = \frac{\delta\, G\, d^4}{\delta\, D^3\, n}$$

$$W = \frac{(L_o - L_i)\ \times G\ \times d^4}{\delta \times D^3 \times\ n}$$

$$W = \frac{(92 - 75)\ \times 83\ \times 10^3 \times 3^4}{8 \times 32^3 \times 5}$$

$$W =\ 87,197\,N$$

Load Accepted by Springs (348,788 N or 35,566 Kg): This is the total load received by the 4 springs on the die set, calculated theoretically. Total Component Load (Wtot = 9.621 Kg): This is the total load of all components that must be borne by the compressive spring in the plate bending machine application. Conclusion: The compression spring is safe. This conclusion is based on a comparison between the load that the spring can accept (348,788 N or 35,566 Kg) and the total component load (9,621 Kg). If the load that can be accepted by the spring is greater than the total required load (Wtot), then the compression spring used is considered safe because it has sufficient capacity to bear the load given under operational conditions.

Thus, by ensuring that the load received by the spring is greater than the total load encountered in practical applications, it ensures that the compression spring system in the plate bending machine is able to operate safely and effectively.

3.2 Design and Modification Results

In order to optimize the performance of plate bending machines with a hydraulic system, modifications have been made to create a machine unit that meets the specific needs of the plate forming process. This machine was designed with three main sub-assemblies in mind: frame sub-assembly, drive sub-assembly, and die-set sub-assembly.

The frame sub-assembly consists of eight UNP iron profiles measuring 100 x 50 mm, which are assembled using bolted connections, allowing for easy assembly and disassembly as needed. The drive sub-assembly is equipped with a hydraulic system using a jack and spring, which plays an important role in moving the punch to press the plate and return it to its initial position. Meanwhile, the die-set sub-assembly includes table and die components. The design of attaching the punch to the punch holder involves the use of two punch locking plates that are attached with a bolted connection. This is designed to make it easier to replace the punch according to the size of the plate to be bent. With this arrangement, this machine is not only able to increase production efficiency but also provides flexibility in the use and maintenance of key components. This modification aims to provide a better solution in the plate-forming process by integrating hydraulic technology and a modular design.

The results of the design and modification of the hydraulic system plate bending machine can be seen in the following picture:

Figure 7. Design and Modification Results.

The Hydraulic System Plate Bending Machine has the following specifications:

Table 1. Main Component Specifications of the Tool

No	Main Component Specifications of Tools
1.	Press Equipment Capacity: 20 Tons
2.	Frame size: length 700 mm, width 500 mm and height 850 mm
3.	Base platform capacity: Length 500 mm, width 200 mm and height 100 mm
4.	Pressure: Hydraulic jack system
5.	Hydraulic stroke length 95 mm
6.	Dies Set Size: Height 58.9 mm, table length 500 mm, top width of dies 81.36 mm, bottom width of dies 152 mm
7.	Punch size: Length 200 mm, 150 mm, 100 mm, 50 mm, width 10, height 80 mm
8.	Punch: V-shaped
9.	Dies: V-shaped angle 850

3.3 Test result

Based on the data above, the test results obtained were using plates with a length of 100 mm, width 30 mm, and thickness 1, 2, 3, and 4 mm as follows:

Table 2. Test Data Results

No	Thick (mm)	Time (Second)	Average	
			Pressure (Kg)	Time (Second)
1.	1	65	35	66.5
2.	1	68		
3.	2	70	65	72
4.	2	74		
5.	3	73	150	75
6.	3	77		
7.	4	85	215	87.5
8.	4	90		

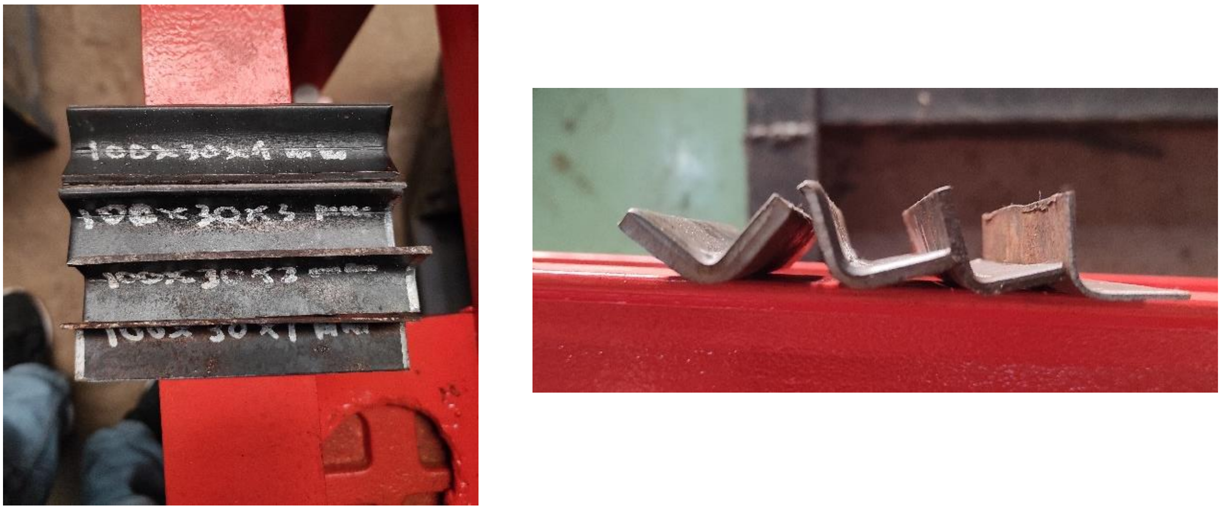

Figure 8. Examples of tested samples.

In the bending process, time and pressure are measured to determine how long and how much pressure are needed to bend plates of various thicknesses. Tests were carried out on plates with different thicknesses, namely 1 mm, 2 mm, 3 mm, and 4 mm. Each plate thickness is tested using the maximum bending line. Data is taken when the punch drops and bends the plate being tested, with the help of a stopwatch and pressure gauge to measure the time and pressure required. The test was carried out twice with four plate samples each, as follows:

First try:

a) In the first experiment, a 1 mm plate took 65 seconds to form into a V with a pressure of 35 kg.
b) In the first experiment, a 2 mm plate took 70 seconds to form into a V with a pressure of 60 kg.
c) In the first experiment, a 3 mm plate took 73 seconds to form into a V with a pressure of 140 kg.
d) In the first experiment, a 4 mm plate took 85 seconds to form into a V with a pressure of 200 kg..

Second Try:

a) In the second experiment, a 1 mm plate took 68 seconds to form into a V with a pressure of 40 kg.
b) In the second experiment, a 2 mm plate took 74 seconds to form into a V with a pressure of 70 kg.
c) In the second experiment, a 3 mm plate took 77 seconds to form into a V with a pressure of 160 kg.
d) In the second experiment, a 4 mm plate took 90 seconds to form into a V with a pressure of 230 kg.

From the results of tests carried out in two experiments for plates with a thickness of 1 mm, 2 mm, 3 mm, and 4 mm, the average time and pressure were obtained as follows: a) 1 mm plate: requires an average of 66.5 seconds to form into a V with an average pressure of 35 kg. b) 2 mm plate: requires an average of 72 seconds to form into a V with an average pressure of 65 kg. c) 3 mm plate: requires an average of 75 seconds to form into a V with an average pressure of 150 kg. d) 4 mm plate: requires an average of 87.5 seconds to form into a V with an average pressure of 215 kg..

These results provide a clear picture of the performance of the bending tool in the process of bending plates of various thicknesses, showing that the thicker the plate, the greater the pressure and time required to achieve the V shape. This data is important for optimizing the operating parameters of hydraulic system plate bending machines for various applications.

4. CONCLUSION

After carrying out two tests with detailed descriptions of the results of the activities, it can be concluded that this plate bending machine with a hydraulic system shows consistent and efficient performance in the bending process. The following conclusions can be drawn:

1. Plate Bending Machine Performance:
   This hydraulic system plate bending machine is capable of bending plates of different thicknesses at varying times and pressures. For a plate with a thickness of 1 mm, the average time required is 66.5 seconds with an average pressure of 35 kg. For a plate with a thickness of 2 mm, the average time required is 72 seconds with an average pressure of 65 kg. Meanwhile, for a plate with a thickness of 3 mm, the average time required is 75 seconds with an average pressure of 150 kg. And for a plate with a thickness of 4 mm, the average time required is 87.5 seconds with an average pressure of 215 kg.
2. Machine Flexibility:
   Modifications made to this hydraulic system plate bending machine allow the machine to bend various plate shapes, not just one type. For example, this machine is capable of forming plates into box shapes according to the length of the punch used. This shows that the machine has high flexibility in use, making it a very useful tool in a variety of plate bending applications.

Thus, this modified hydraulic system plate bending machine is not only efficient in terms of time and pressure required but also offers flexibility that allows various bending shapes according to needs. These results show great potential for increasing productivity and efficiency in the plate manufacturing process.

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