RESEARCH ARTICLE | MAY 02 2023

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AIP Conference Proceedings 2719, 050001 (2023)
https://doi.org/10.1063/5.0133291

Press Tool for the V-Bending Process of Stainless Steel Plate: Designing and Manufacturing

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Abstract. Stainless steel is a plate material that is widely used in the home and transportation industry. In bending stainless steel plates, a bending tool that has a greater compressive ability is needed. This paper was presented to design and manufacture a press tool and aims to produce a V-bending tool for stainless steel sheets. The punch angle variation used is 80º, 85º, and 90º with the die angle of 90º. While the punch radius variation is 2 mm, 4 mm and 6 mm. The research method was performed in several stages, i.e., the literature review stage, the design stage, the manufacturing stage, and the tool testing stage. Based on the test results, the best punch angle and radius are close to 90º for stainless steel with a thickness of 2 mm, namely a punch angle of 90º with a punch radius of 2 mm. The press tool has a capacity that is a bending line length of 60 mm, a bending width of 44 mm, a spring height of 160 mm, a free stroke of 19.5 mm, and an acceptable spring load of 135.39 N. It can be concluded that punch radius is a significant factor affecting the loading and springback.

INTRODUCTION

Nowadays, the process of forming metal plates in the machining industry is growing quite rapidly, especially in the bending process. The bending process is a plastic deformation process of metal to a linear axis with little or no change in surface area. Sheet plate was formed through pressure punch and die forming. In the process of bending, there is stretching on the axis of the neutral plane along the bending area, which results in a straight bending line [1]. The process of forming metal plates is mostly carried out in various manufacturing industries which are triggered by the many uses of mechanical technology in everyday people's lives whose products or components are made of plate metal.

Bending is a process carried out to press the metal plate using a punch until a bend is formed according to the die shape. In the bending process, the stress-strain distribution is very important to achieve perfect bending results according to the desired shape. Thus, when the load is removed, the material tries to take its original shape, and the material that was bent will come back due to stretching. This material behavior is called springback [2]. Several parameters in the bending process that affect the springback results, i.e., punch and die radius, punch and die angle, clearance between punch and die, static and dynamic friction conditions, plate thickness, elastic modulus, and material dimensions.

In the manufacturing industry, a press tool is a production tool that is widely used to form metal, including the plate material bending process, namely the press tool. A Press tool is a type of tool used to cut or shape a product or

The 3rd International Seminar on Science and Technology 2021
AIP Conf. Proc. 2719, 050001-1–050001-8; https://doi.org/10.1063/5.0133291
Published by AIP Publishing. 978-0-7354-4519-2/$30.00

component from sheet metal plates using a press machine as a pressing device that can produce products of uniform quality and in a short time.

Previously, a simple press tool for bending V bottoming was made. This simple press tool is equipped with a 90^{o} angle V-shaped die and punch. This tool functions as a V-bending tool for thin metal sheets with a maximum bending line width of 50 mm. This research uses St 42 steel material. In this tool, there is still a lack of allowance for the bushing that is not standard so that the top plate and bottom plate shake when operating. The bending angle of the plate as a result of bending this tool is generally greater than 90^{o}. This simple press tool is made specifically for laboratory-scale bending V experiment tests [3]. Another research, making press tool bending tool V with an air bending die and bending plate material, namely steel St.37. Air bending is a method of bending in which the workpiece does not touch all parts of the tool (punch and die). Another term for air bending is partial bending or free bending. In this type of bending, the workpiece is only in contact with the two endpoints of the die and one endpoint of the punch. Therefore, the emphasis on the workpiece does not touch the bottom of the die. This press tool has a simple construction and consists of three main sub-assemblies, namely die set, punch and die sub-assemblies. However, the construction of this press tool still has several weaknesses, such as the guidepost component is not precise and the adjustment of the top plate is not standard, so that the precision level of the tool is still lacking. This tool is also a laboratory-scale experimental study tool [4].

The research result above it has not been obtained optimal results, both in terms of construction and precision. Therefore, this paper presents a design development and manufacture of press tools for V-bending on stainless steel. Stainless steel is a plate material that is widely used in the home and transportation industry [5].

METHODOLOGY

The schedule for designing and making a press tool is around June until September 2020. The manufacturing of the press tool was performed in the Mechanical of Workshop and Laboratory of the Mechanical Engineering Department, Ujung Pandang State Polytechnic.

Designing the Press Tool

The design of this press tool is based on concepts and ideas that have gone through the process of surveying and reviewing various kinds of literature. Therefore, the initial design process was performed to design and manufacture this press tool. This concept is also used to manufacture the shot peening machine [6] and polishing machine [7]. The initial design of this straw press tool can be shown in Fig. 1.

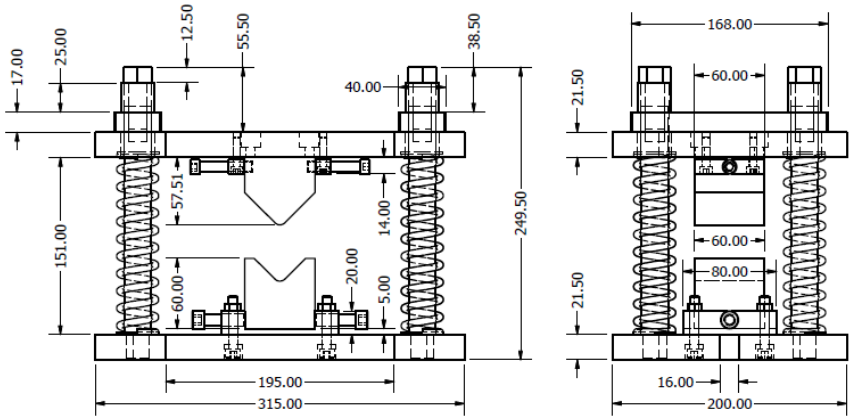


FIGURE 1. Design of press tool for V-bending

Tools and Materials

The press tool can be produced optimally by preparing the tools and materials are needed. The details of the tools and materials used can be detailed in Table 1.

TABLE 1. Materials and tools were used.

Materials	Tools
• Square steel of 60 x 60 mm • Steel plate with a thickness of 22 mm • Carbon steel with a thickness of 30 mm • Shaft steel with a diameter of 30 mm • Stainless steel plate with a thickness of 1 mm and 2 mm • Spring press • Bolt and nut • Bushing	• Milling machine • Lathe machine • Drilling machine • Grinding machine • Jig saw machine • Universal testing machine (UTM) Galdabini

RESULT AND DISCUSSION

In this section, the results of manufacturing a press tool will be described clearly and will be accompanied by a discussion.

Results

The press tool of V-bending was designed and manufactured as follows in Table 2, including parts, tools, and materials, which were used in the manufacturing process.

TABLE 2. Manufacturing parts of the press tool for V-Bending

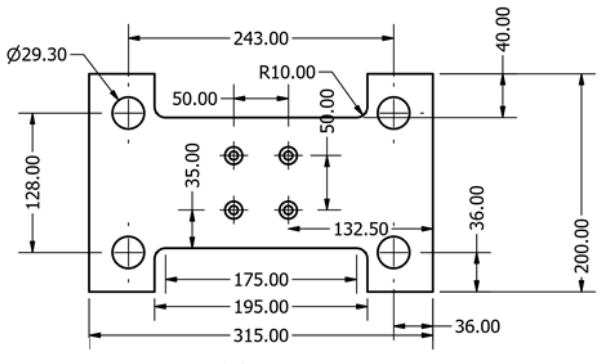
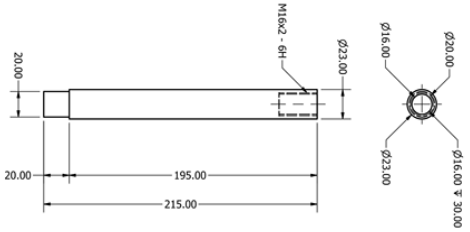
Parts	Manufacturing Process
1. Top Plate 	• Cutting plates using a grinding machine • Facing uses a milling machine to reach 315 mm x 200 mm in size. • Drilling a plate with a diameter of 28 mm and 5 mm into the plate. This hole functions as a bushing fixture. • Making grooves on the plates using a milling machine. • Making thread with the tap of M8 x 1.0 mm
2. Pillar 	• Cutting the material with a size of 260 mm using a jigsaw machine. • Facing the material from ∅25.4 mm to ∅23 mm using a lathe machine • Facing the material from 260 mm to 240 mm in length using a lathe machine. • Drilling in diameter of ∅15 mm for locking the pillar and taping in M16 X 2.0 mm

Table 2 continued…

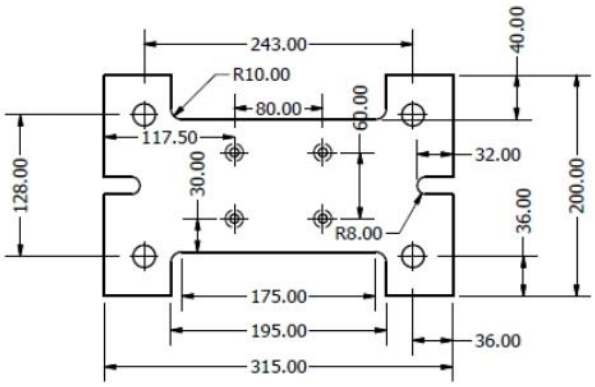
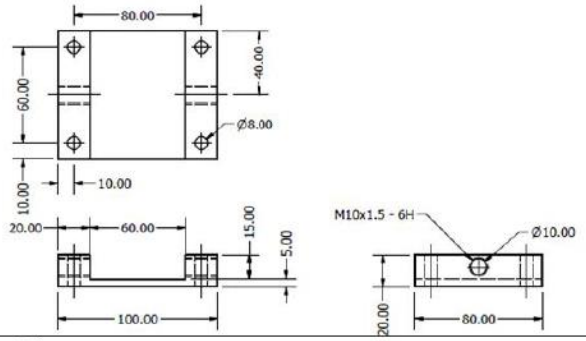
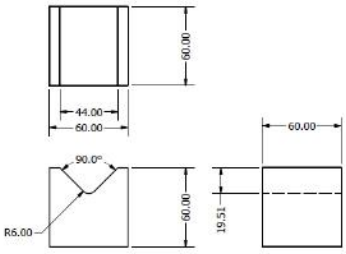
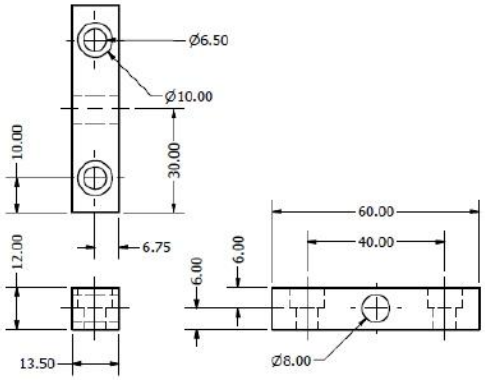
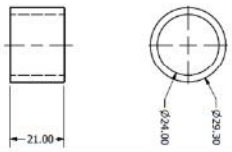
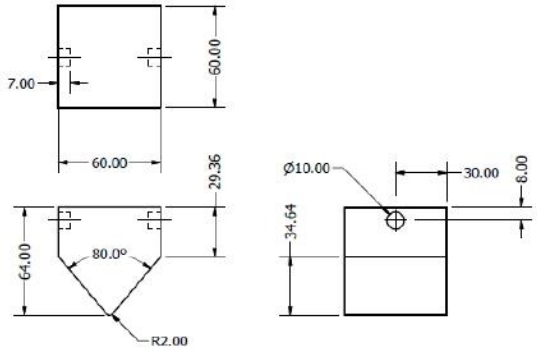
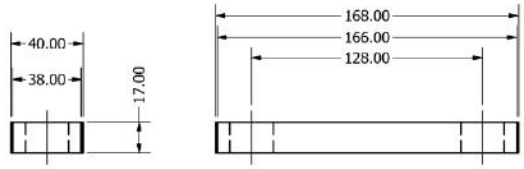
Parts	Manufacturing Process
3. Bottom Plate 	• Drilling a plate with a diameter of 25 mm into the plate. This hole functions as a bushing fixture. • Making grooves on the plates using a milling machine.
4. Die gripper 	• Facing the material by using a milling machine. • Making grooves on the plates using a milling machine. • Drilling 7 mm in diameter to penetrate the plate. This hole serves as a screw fixer for the die clamp
5. Die 	• Facing material to size 60 x 60 x 60 mm using a milling machine. • Making a V groove using a milling machine.
6. Punch gripper 	• Making grooves on the plates using a milling machine. • Drilling a plate with a diameter of 6 mm through the plate. This hole functions as a bolt fastener for the die clamp

Table 2 continued…

Parts	Manufacturing Process
7. Bushing 	• Facing the material using lathe machine to reach the diameter of 29.30 mm. • Cutting the material to get the length of 21 mm using jigsaw machine. • Drilling with a diameter of 23 mm.
8. Punch 	• Cutting material using a jigsaw. • Facing material into a size of 60 x 79.04 mm using a milling machine. • Making a groove in width of 10 mm and depth of 10 mm using milling machine. • Making a V groove of 85° and a radius of 2°. • Drilling with a diameter of 6 mm
9. Locker of pillar and plate 	• Facing the material in dimension of 168 mm x 17.00 mm using milling machine • Drilling with diameter of 23 mm. This hole serves as a bushing fitting.

After the process of designing and manufacturing press tool has been completed, then the assembly process for all components, both manufactured and purchased, is carried out, as shown in Fig. 2 and Fig. 3.

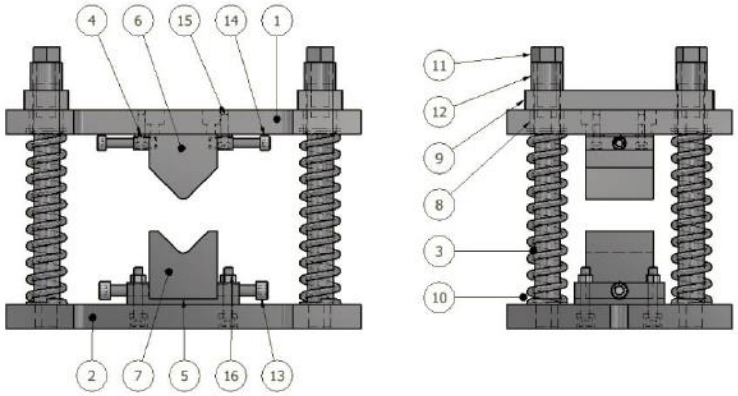


FIGURE 2. Result of assembling die set of press tool

Description:

1. *Top Plate*
2. *Bottom Plate*
3. *Pillar*
4. *Punch gripper*
5. *Die gripper*
6. *Punch*
7. *Die*
8. *Bolt M8*
9. *Mur M8*
10. *Bushing*
11. *Locker of pillar and plate*
12. *Spring*
13. *Bolt*
14. *Ring*
15. *Bolt M10*
16. *Bolt M8*

FIGURE 3. Result of the die set of press tool after design development

The next step, the die set bending test, was conducted experiments on several samples of stainless steel plate. The bending results can be seen in Fig. 4.

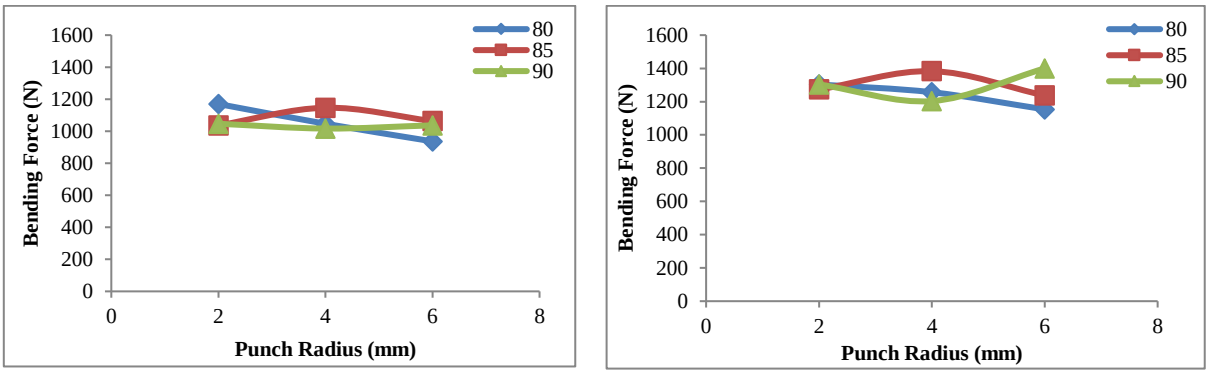
FIGURE 4. Bending result of stainless steel plate

Discussion

Based on the results of designing and manufacturing the die set for press tool, the die set was testing in Ultimate Tensile Machine (UTM) Galdabini for different loading. Punch radius was used in this experiment, i.e., 2 mm, 4 mm, 6 mm [8]. The result data was obtained and presented in Table 3 and Fig. 5.

TABLE 3. Loading data in different of punch angles and punch radius for 1 mm and 2 mm of stainless steel plate.

Punch Angle	**Punch Radius**	**Loading (Newton)**							
		Plate thickness of 1 mm				**Plate thickness of 2 mm**			
		Punch Travel				*Punch Travel*			
		18.5	*19*	*19.5*	*Average*	*18.5*	*19*	*19.5*	*Average*
80	2	1110	1150	1250	1170.00	1300	1310	1300	1303.33
	4	1030	1060	1050	1046.67	1220	1240	1310	1256.67
	6	920	940	950	936.67	1130	1130	1200	1153.33
85	2	1020	1030	1060	1036.67	1240	1290	1290	1273.33
	4	1140	1140	1160	1146.67	1300	1400	1450	1383.33
	6	1050	1070	1070	1063.33	1210	1240	1260	1236.67
90	2	1040	1040	1060	1046.67	1250	1290	1370	1303.33
	4	1010	1020	1020	1016.67	1150	1200	1260	1203.33
	6	1020	1040	1050	1036.67	1220	1350	1630	1400.00



(a) *(b)*

FIGURE 5. Loading graphical on punch radius for different of punch angle in thickness of 1 mm (a) and 2 mm (b)

Table 1 and Fig. 5 present several things, namely: for a punch angle of 80°, the bending force will decrease with increasing punch radius for both 1 mm and 2 mm thick plates. The punch angle of 85° gives different results, where the load increases at a punch radius of 4mm and then decrease at a punch radius of 6mm. On the other hand, at a 90° punch angle, there is a tendency for the load to increase as the punch radius increases. This result is also strengthened by the study presenting that the punch radius affects the load used in the bending process with ANSYS simulation [8] and FEA simulation [9]. Regarding the punch radius, the results of other studies have found that the addition of the punch radius will increase the springback when bending stainless steel plates [10] and iron sheets [11], medium carbon steel [12][13]. Overall, it can be seen that the required load is greater to bend 1 mm and 2 mm.

CONCLUSION

Process of designing and manufacturing the die set of press tool was completed and has been performed to bending of stainless steel plates. The results show that the die set of press tool has worked and functioned well to bend the stainless steel plate. From the results of experiments, it can be concluded that punch radius is a significant factor affecting the loading and springback. In the air V-die free bending process, the punch radius is the most significant parameter to be considered.

ACKNOWLEDGMENTS

We would like to acknowledge the Ministry of Education and Culture for funding the research (Research Contract Number: B/49/PL10.13/PT.01.05/2021). We also acknowledge the Director and P3M of Politeknik Negeri Ujung Pandang who provided the opportunity to support in this research program.

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