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Design Development of Punching and Bending Machine Combination

Fiqi Fendi [a] and Yohanes [b,*]

a) *Technology Production Laboratory, Mechanical Engineering Department, Universitas Riau, Indonesia*
b) *Mechanical Engineering, Universitas Riau, Indonesia*

*Corresponding author: yohanes@lecturer.unri.ac.id

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ABSTRACT

This paper purpose is to study working pressure limit of the machine combination between blanking and punching process. The combination punch and bending machine in this study is a machine that belongs to the press type with the use of punch and die. This machine has a hydraulic drive with a maximum pressure generated of 700 bars. The engine performance is only able to withstand a working pressure of 27.7 bars. Therefore, the utilization of the working pressure must be increased to maximize the working pressure. The analysis was carried out on the machine with two methods, namely simulation and experiment. The simulation method was carried out using Autodesk Inventor software to design and simulate in order to find out the critical points that occur on the machine. It was given working pressure according to the permitted safety factor of 1.5. The experimental method was carried out by measuring the voltage using a Strain gauge sensor positioned at the critical point obtained in the simulation and measuring the deflection using a dial indicator. From these tests, it was found that the initial working pressure before being optimized was 27.7 bars to 49.5 bars after being optimized.

KEYWORDS: Optimization, Punch force, Autodesk inventor, Strain gauge.

NOMENCLATURE

Y	Modulus of Elasticity
δa	Safety Factor
δ_y	Yield Strength
σ	Strain
ε	Stress
P	Pressure
F	Force
SP_T	Theoretical Amplified Signal
SP_E	Experiment Amplified Signal

1.0 INTRODUCTION

A press machine can be used to produce the sheet metal products. The press machine is equipment used for cutting and forming sheet metal plates into the desired production goods with the help of pressing. Press tools can produce products in bulk with uniform quality and in a short time. The press tool is made because when used for the blanking and punching process, it has several advantages, including being able to be used to make products in bulk, being able to produce products with uniform shapes and sizes and being more economical in mass production.

The press tools can be classified into several types according to the work process carried out on the die, namely simple tools, compound tools and progressive tools. During the blanking and punching process, there is a shear force resulting from pressing the workpiece between the punch and the die to separate the part to be removed during cutting, which is called slug or scrap [1]. Rizza (in Budiarto, 1997) [2] states that the press tool was an equipment used for cutting and forming sheet metal into desired production goods with the help of emphasis. Based on this statement, the press tool can implement sheet metal work processes such as blanking, punching and bending using punch and die.

According the previous study on punch machine such as Harianto & Yunus [3] was made a blanking and punching combination machine in production process technology laboratory of the Mechanical Engineering Department, Universitas Riau. This machine was designed to have a dual function, namely the blanking and punching process and the bending process, where these two processes can be distinguished from the type of punch and die tool used. However, that machine has limitation on the load that was applied. There were a deflection experienced by the machine column, hence all specimens were limited to a working pressure of 180 bars [3]. Then, research on this machine was

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2022. Vol.66 No.1

continued by Lubis & Yohanes (2018) [4] with the aim of analyzing effect of tool punch shape on the style and quality of cutting in blanking process. It was found that variations in the shape of the tool punch greatly affect the results of the blanking process, namely the final shape of the work-piece and the height burrs variations [4].

The punch machine assembled at the Mechanical Engineering Laboratory, Universitas Riau used a hydraulic drive with a maximum pump pressure of 700 bars. This machine performed the cutting process with a certain pressure, stress and deflection occurring in the frame. According to Harianto and Yunus [3], based test specimens were limited to a pressure of 180 bars to overcome the deflection that occurs in the frame. However, it was not explained why the pressure limit applied is only 180 bars. The location of the maximum stress and its magnitude that occurs due to working pressure, while the pump on this machine can still work with a pressure of 700 bars. The maximum allowable working pressure in this machine performance needs to study such as plate thickness, size of diameter hole, type of material that can be worked and the punch force required to punch holes in the plate.

According the research that had been done by Ibrahim & Yohanes (2021) [5], the performance of the punch machine column was only able to withstand a load of 27.5 Bars. So, the load beyond 27.5 bars, it would pass through its yield stress and cannot be elastic anymore. Therefore, in this paper aim is to develop the optimal condition for punching and bending machine combination to achieve the machine's performance exceeds of 27.5 bars. This research is expected to analyze the working pressure limit of the machine, to be able to determine the pressure and punch force required on the column during the blanking and punching process.

2.0 METHODS

2.1 Research Method

In this research used the simulation and experimental methods to develop and analyze the working pressure limit of blanking and punching of the machine combination. The flow chart in this study can be seen in Figure 1.

2.2 Determining the Stress Limit

The most suitable strength or stiffness criterion for a structural element or component is that generally some maximum stress or deformation should not be exceeded [6]. In this case the rated stress was generally known as the maximum allowable working stress [7]. The maximum stress limit for this punching and bending combination machine was determined by SF (Safety Factor) of 1.5. That based on consideration of the yield stress. This machine used the ASTM A36 material as the frame with σ_y 250 MPa. The stress limit was calculated as following:

$$\delta_a = \frac{\delta_y}{SF}$$
$$\delta_a = 166.66 \text{ MPa}$$

2.3 Making Work-pieces

In this research, the machine was optimized based on the machine that had been made by Herianto & Yunus [3]. This machine design modeling was done based on literature studies, field observations and based on optimization stages. The design results can be seen in Figure 2, Figure 3 and Figure 4.

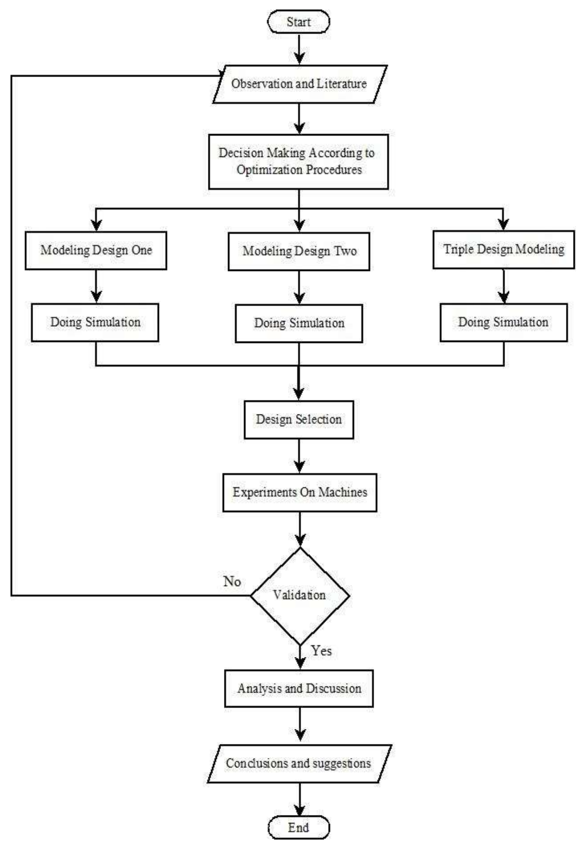

Figure 1: Research flow diagram

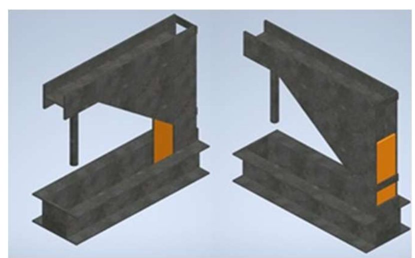

Figure 2: Design 1

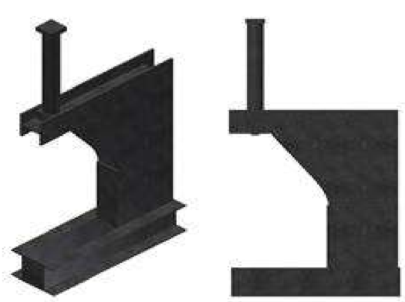

Figure 3: Design 2

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Figure 4: Design 3

One of three designs was chosen, which the working stress criteria on the machine: (1) it did not exceed the yield strength limit of the material, (2) it did not change the dimensions of the column and base, and (3) it did not reduce the work area. This study used the ASTM A36 type of material. The material properties are depicted in Table 1 [8].

2.3 Experimental Procedure

Data collection was carried out experimentally at the Production Technology Laboratory, Mechanical Engineering Department, Universitas Riau using a combination punching machine and plate bending machine. The preparation of tools and materials can be seen in Figure 5. The set-up of measuring instruments can be seen in Figure 6.

If the stress that occurs on an object is getting bigger, it will cause the strain of the object to be even greater [9]. This relationship is in accordance with Hooke's law and is expressed in Young's modulus [9]. In this study, the simulation and experimental results can be compared. The simulation voltage was 166.66 MPa. Then, the allowable stress was known by determine the stress that occurs in the machine that used the following formula [9]:

$$Y = \frac{\delta_a}{\varepsilon}$$
$$\varepsilon = \frac{\delta_a}{Y}$$
$$\varepsilon = 0.0008135$$

Table 1: The mechanical properties of ASTM A36 [8]

Physical Properties	Metric	English	Comments
Density	7.80 g/cc	0.282 lb/in³	Typical of ASTM Steel
Tensile strength, ultimate	400 - 550 MPa	58000 - 79800 psi	
Tensile strength, yield	250 MPa	36300 psi	
Elongation at break	20% 23%	20% 23%	in 200 mm In 50 mm
Modulus of elasticity	200 GPa	29000 ksi	
Bulk modulus	160 GPa	23200 ksi	Typical for steel
Poisson's ratio	0.26	0.26	
Shear modulus	79.3 GPa	11500 ksi	

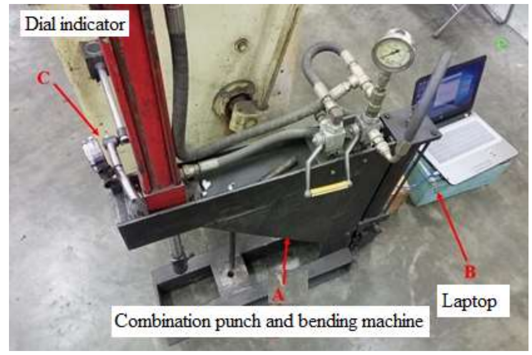

Figure 5: Test set-up

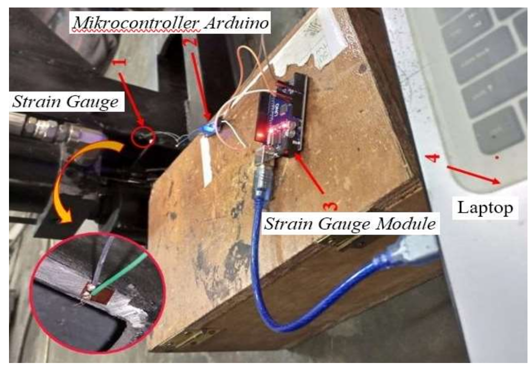

Figure 6: Measuring tool set-up

The machine was loaded, the critical strain that was transmitted to the strain gauge and then to the strain module. However, the reading on the strain module was not the strain, but the output voltage of the Wheatstone bridge. So, the strain needs to be converted to voltage first. The input voltage (E_i) was used 5 volts and the strain gauge was used 350 ohms with *GF* of 2. The conversion of strain into voltage was calculated using the following equation [10]:

$$\Delta E = \frac{\mathrm{GF} \times \varepsilon \times E_i}{4}$$
$$\Delta E = 0.00203375 \text{ v}$$

Because the change in voltage was very small, then it needed to be enlarged by Arduino. Therefore, the gain (G) was amplified by 235, which was available on the strain gauge module by rotating the potentiometer.

$$\text{SP} = \Delta E \times Gain$$
$$\text{SP} = 0.00203375 \text{ v} \times 235 \text{ times}$$
$$\text{SP} = 0.47793125 \text{ v}$$

The results of the voltage reading displayed on the Arduino serial monitor are still analog data. To convert the voltage into analog data, the following equation was used [11]:

$$\Delta Da = \frac{SP \times 1023}{Ei}$$
$$\Delta Da = 97$$

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Table 2: Analog data change

	Data Change		Data Change
Sensor	263	Sensor	268
Sensor	266	Sensor	266
Sensor	268	Sensor	266
Sensor	269	Sensor	268
Sensor	268	Sensor	269
Sensor	269	Sensor	268
Sensor	268	Sensor	267
Sensor	269	Sensor	266
Sensor	268	Sensor	266
Sensor	267	Sensor	269
Sensor	268	Sensor	269
Sensor	269	Sensor	267
Sensor	268	Sensor	268
Sensor	267	Sensor	268
Sensor	270	Sensor	265
Sensor	267	Sensor	267

The difference in analog data (ΔDa) displayed on the Arduino serial monitor during the experiment should not exceed and as much as possible approached [12],[13]. The the analog data change is depicted in Table 2.

3.0 RESULT

The results of simulation and experiment tests were shown in Table 3. It can be seen in Table 3 the comparisons before and after optimization, the machine has improved better than before. The performance of the machine increased after being optimized. The previous study on machine has a performance of working pressure of 27.5 bars, while after being optimized the machine has a working pressure of 49.5 bars. Details results of stress, deflection and working pressure, which was conducted by simulation and experiment, it can be seen in Table 3. For more details, it can seen in Figure 7, the comparison of graphs before and after optimization study results.

The pressure in a closed fluid can be considered uniform throughout a simple system; this equality is known as Pascal's law [14]. The pressure exerted on a closed fluid would be transmitted without reducing to every part of the fluid and the walls of the vessel [14]. In this study, the performance of the machine increased, so that, the force acting on the machine can be calculated with the following equation:

$$P = F/A$$
$$F = P \times A$$
$$F = (49.5\ \text{Bar})(1964.3\ \text{mm}^2)$$
$$F = (4.95\ \text{MPa})(1964.3\ \text{mm}^2)$$
$$F = 9802.857\ \text{N}$$

Because the force was known, then thickness of plate punching or blanking can be calculated using the following formula:

$$t = \frac{F_r}{0.7 \times \pi \times L \times UTS}$$
$$t = \frac{9802.857\ \text{N}}{0.7 \times 3.14 \times (15\ mm) \times (110\ N/mm^2)}$$
$$t = 2.7\ \text{mm}$$

Table 3: Comparison before and after optimize study results

Comparison items		Stress (MPa)	Deflection (mm)	Working Pressure (Bar)
Previous study results	Simulation	162.7	0.9865	26
	Experiment	154.6	1.15	27.7
	Error (%)	4.98	16.57	6.54
Current study results	Simulation	157.9	1.016	45
	Experiment	155.83	1.2	49.5
	Error (%)	1.32	15.33	10

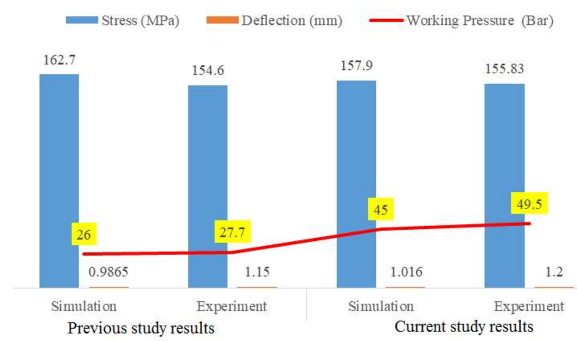

Figure 7: The comparison results of graph before and after study

By knowing the maximum thickness that can be punched, the plate thickness should not exceed 2.7 mm for aluminum material. The results of plate thickness calculations can be applied to each type of material (Table 4).

Table 4: Type of material and thickness of punching or blanking plates

Material	Tensile Strength	Force (N)	Actuator Cross-sectional Area (mm2)	Working Pressure (bar)	Diameter (mm)	Plate Thickness (mm)
Aluminium	110	9802.857	1964.3	49.5	6	6.76
	110	9802.857	1964.3	49.5	8	5.07
	110	9802.857	1964.3	49.5	10	4.05
	110	9802.857	1964.3	49.5	12	3.38
	110	9802.857	1964.3	49.5	14	2.90
	110	9802.857	1964.3	49.5	15	2.70
Brass	124	9802.857	1964.3	49.5	6	5.99
	124	9802.857	1964.3	49.5	8	4.50
	124	9802.857	1964.3	49.5	10	3.60
	124	9802.857	1964.3	49.5	12	3.00
	124	9802.857	1964.3	49.5	14	2.57
	124	9802.857	1964.3	49.5	15	2.40
Steel	241	9802.857	1964.3	49.5	6	3.08
	241	9802.857	1964.3	49.5	8	2.31
	241	9802.857	1964.3	49.5	10	1.85
	241	9802.857	1964.3	49.5	12	1.54
	241	9802.857	1964.3	49.5	14	1.32
	241	9802.857	1964.3	49.5	15	1.23

4.0 CONCLUSION

This research aim is to determine the pressure and punch force required on the column of the punching and bending machine combination during the blanking and punching

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processes. The performance of this machine revealed an increasing of the working pressure from 27.7 bars in the experiment to 49.5 bars after being optimized. The working pressure condition was given a safety factor of 1.5. After being optimized, this machine was able to withstand a working pressure of 85 bars. However, the machine would experience plastic deformation after being given working pressure, this machine did not return to its original shape. Therefore, a safety factor of 1.5 must be applied to the yield strength of the material. The maximum punch or blank forces that can be applied to the machine of 9802.857 N. The maximum plate thickness should not exceed 2.7 mm for aluminum material.

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