Design and Fabrication of Automatic Metal Plate Cutting Machine

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ABSTRACT
The use of manual plate cutting tools has weaknesses, including low production speeds, uneven pieces of pieces, and expensive production costs. The design process is needed to resolve these problems and manufacturing a knife cutter can automatically operate. This study aimed to design an automatic metal plate cutting machine based on a pneumatic system. The design of this machine is focused on developing cutting machines in the knife manufacturing industry. The method of making machine design consists of movement simulation processes and pneumatic control using fluid simulator software (fluid SIM), cutting machine design using Autodesk inventor software, and mathematical design calculations. The results achieved in this study are prototypes of pneumatic system plate cutting machines that can work automatically with a capacity of 400 pieces per hour, the need for cutting force of 552 N, pneumatic pressure of 6.2 bar, and air debit 11.5 liters/minute. The results of this study show that machine design has several advantages. The manufacturing process is faster, the energy used is relatively small, and the use of labor is more efficient so that productivity increases. Some things recommended to be analyzed in the future include operator work safety factors, periodic maintenance systems, and the ease of getting spare parts.

Keywords: *automatic cutting machine, design, fabrication, pneumatic*

1. INTRODUCTION

Automation is one of the fields of technology that develops in the world. Innovation in the automation sector can increase time, energy, and cost-efficiency. At present, automation has been implemented in various fields, including automotive fields, food processing, manufacturing, pharmacy, and the biomedical industry. Many areas previously done manually have been converted into semi-automatic and automatic. In the era of the Industrial Revolution 4.0, automatic machines have become an essential field of daily human life. Besides being able to save most of the time and energy when doing specific tasks, Automatic machines. The increase has led to a more competitive method and faster in doing something [1].

One of the main challenges in manufacturing process innovation is making equipment or systems that are affordable and compatible for small industries and large-scale businesses. Automation is a combination process of mechanical fields with electronic fields. The automation system can be run to operate and control a production process with the help of computers and software. The advantage of this automation process is that it can reduce the time of the manufacturing process, can increase labor productivity, and improve workers safety [2].

Cutting machines are one machine often used in the industrial world. Machine designers try to develop sophisticated and modern machines and are equipped with a control system to manufacture products more economical. Machines produced new methods continue to be designed to produce various products at lower prices and high quality [3].

In many industries, sheet metal cutting is a critical process [4]. This automatic metal plate cutting machine is a form of application of technology whose primary function is to cut metal plates as raw material for making kitchen knives. This tool can function automatically so that slaughtering metal plates can be faster, more precise, more cost-effective, and safer. This machine uses a pneumatic system with its main components: a pneumatic cylinder, service unit or compressor, limit switch, solenoid valve 5/2, and manual plate cutting. Because of its flexibility and compactness, pneumatic cutting machine is beneficial to small

sheet metal cutting enterprises [5]. The working principle of this tool is that the metal plate is inserted into the scissors by pressing the touch lever on the limit switch. Then the connecting component will contact the NO terminal and break the NC contact. Terminal NO sends a voltage to the Solenoid Valve [6].

As shown in figure 1, it is a two-position three-way direct acting solenoid valve, consisting of the valve body, coil, static core, movable core, spring and so on. Its operating principle is described as follows: when the valve electrified, the coil produces electromagnetic force, the static core sucks up the movable core (valve core) and the pressure port relates to the working mouth after the valve opens. On the contrary, in the movable core closes the valve exhaust under the action of the spring when the power is cut off. The coil in the Solenoid Valve gets a voltage supply will turn into a magnetic field and move the plunger on the inside; when the plunger moves positions, the output hole of the solenoid valve pneumatic will release pressurized air originating from the supply (service unit). According to the operation principle of the solenoid valve, the whole model can be divided into four parts: the aerodynamic model, the equivalent circuit model, the equivalent magnetic circuit model, and the mechanical motion model. When the solenoid valve is energized, the electromagnetic coil generates electromagnetic suction, and the valve moves under the action of spring force, electromagnetic suction, gravity, friction, and aerodynamic force [7].

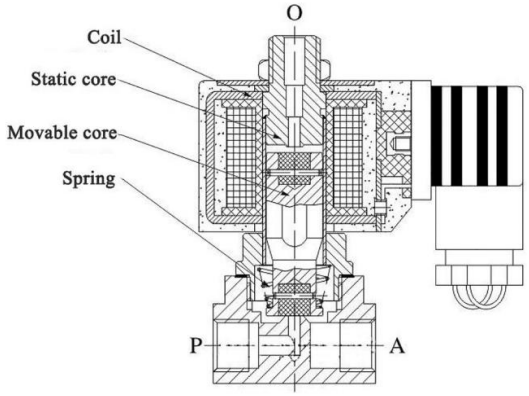

Figure 1. Structure of a two-position three-way direct acting solenoid valve

The pressure airflow from Solenoid Valve pushes pneumatic cylinder pistons to move forward according to the desired pressure. The pneumatic cylinder pushes the lever so that the knife performs the cutting function. The cutting plate falls through the hopper so that the pressure on the switch limit is reduced, and the no and NC positions on the limit switch return to their original position. The NC terminal will be connected and give a signal to the solenoid valve. The plunger changes positions and the output hole of the solenoid valve pneumatic will release pressurized air that comes from the supply (service unit). The pressurized airflow from Solenoid Valve pushes pneumatic cylinder pistons to move backward according to the desired pressure. The pneumatic cylinder pulls the lever so that the knife is open.

The metal cutting process is used to replace the form of a metal product (machine component) with the cutting method. The metal slaughtering process is the most activity implemented in the manufacturing industry. This process can create pieces that have complex dimensions with geometry accuracy and large size. The principle of slaughtering metals can be defined as an action of a cutting tool that is contacted with an object and removes part of the object surface in a furious form. Although the definition is simple, the metal slaughtering process is very manufactured [8].

Making a kitchen knife includes a basic manufacturing process, cleaning surface process, handle installation process, finishing process, and packing process. This study aims to design a metal plate cutting machine based on a pneumatic system. The design of this machine is focused on the design of the cutting machine in the knife manufacturing industry.

2. METHODS

Making a machine design consists of the process of simulation movement and pneumatic control using fluid simulator software (fluid SIM). Fluid simulator software (Fluid SIM) is one of the computer software

for fluid flow simulation demonstrations, especially for wind flow. This software runs in a Windows system. Festo Didactic, Germany, developed this pneumatic fluid simulation. This software is a supporting program for fluid (wind) simulation demonstrations, especially in the pneumatic circuit system. Before using the actual device, it is highly recommended to use this fluidsim software. After the design is simulated in this application, apply it to the actual device. This festo fluidsim application has two types, namely hydraulic and pneumatic [9]. The interface display of the fluid simulator software is shown in Figure 2.

Design of the automatic metal plat cutting machine using Autodesk Inventor software. Autodesk Inventor software is software used to create design drawings in both 3D and 2D. In addition to functioning for the design process, Autodesk Inventor software can also carry out analysis processes such as voltage analysis, dynamic simulations, and other processes. The following criteria influence material selection for engineering applications: 1) Material availability 2) The material's suitability for the essential components 3) The price of the materials[10].

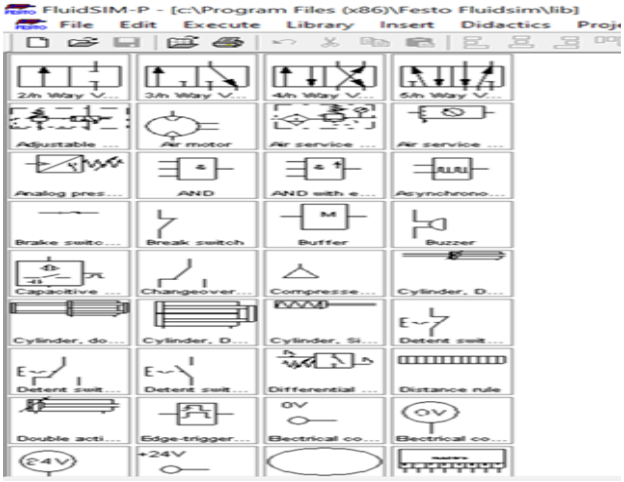

Figure 2. Interface Display from Fluid Simulator Software.

The piston push produced by the cylinder depends on the pressure created by the compressor, the diameter of the piston and rod piston, and the friction resistance of the seal component.

The required cut force can be calculated using the following formula:

$$\boldsymbol{F = \tau . A} \quad \text{.....1}$$

Where f = force, σ = shear stress and a = outside cross-section [11][12]. Low Carbon Material Shear Voltage C.R. Sheet with the shear of 276 N/mm^2 [13]. The piston push is theoretically calculated for the following formula:

Steps forward

$$\boldsymbol{F = \frac{1}{4}\pi(D^2).P.\eta} \quad \text{.....2}$$

Step back

$$\boldsymbol{F = \frac{1}{4}\pi(D^2 - d^2).P.\eta} \quad \text{.....3}$$

Where f = piston force, d = diameter of the piston (m), d = diameter of the piston stem (rod), P = working pressure and η = load ratio [9].

The required thrust to move the pneumatic cylinder originates from the pressurized air supplied from the service unit. The pressurized air needs needed for multiple work cylinders using the following equation:

$$\boldsymbol{Q = 2.s.n.q} \quad \text{.....4}$$

Where Q = pressurized air requirements, S = length of piston step, n = number of steps every minute, and Q = air requirement per centimeter step piston.

3. RESULTS AND DISCUSSION

Design process

The design results using fluid simulation software are shown in Figure 3.

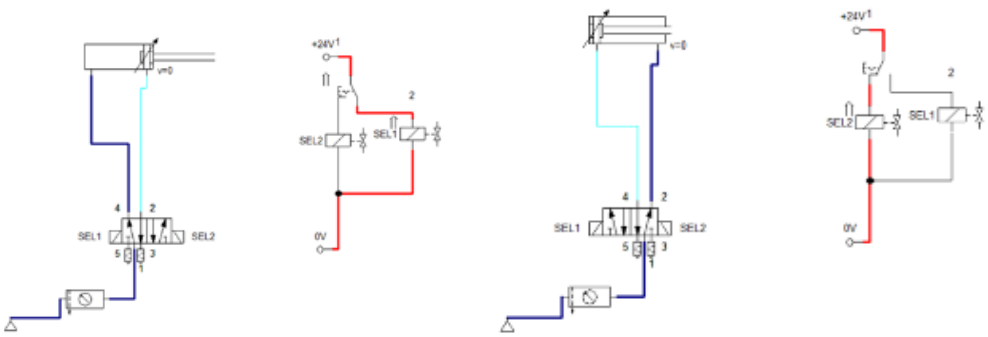

Figure 3. Simulation of advanced and backward motion mechanism of pneumatic

The design results using Autodesk Inventor software are shown in Figure 4 and Figure 5.

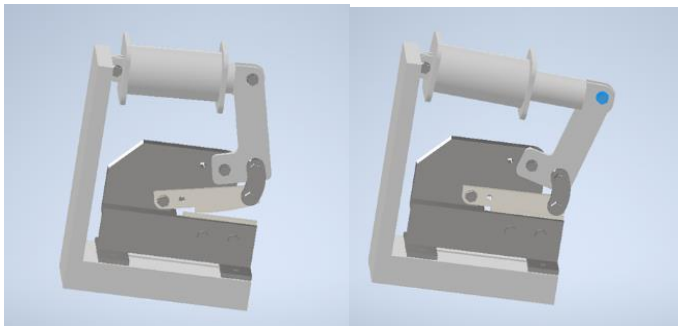

Figure 4. Design image of a cutting mechanism

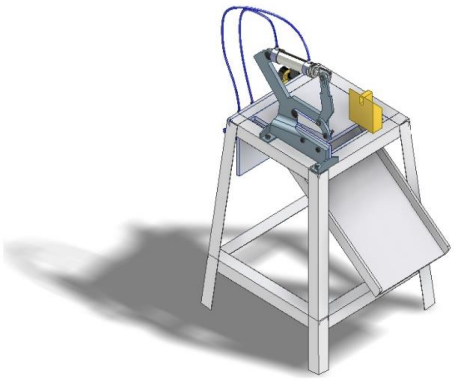

Figure 5. Plate Cutting Machine Design

Based on the formula (1) and (2), assuming the load ratio is taken 0.7 and the air requirement of the piston step per centimeter is taken 12.5 cm3, the cross-sectional area of the plate is taken 10% x 20 mm2 obtained, the need for pneumatic range in Table 1.

Table 1. Design data

No	Properties	Value	Unit
1	Cutting Force	552	N
2	Pressure	6.2	Bar
3	Air debit	11.5	Liter/menit

Manufacturing process

The manufacturing process of this plate cutting machine is as follows:

1. Making the front and back cylinder holders.
2. Installation of the cylinder on the holder that has been made.
3. Installation of a tube fitting
4. Making a sensor holder
5. Making frame
6. Assembly process
7. Testing process
8. Finishing process

The result of the manufacturing process and its parts is shown in Figure 6.

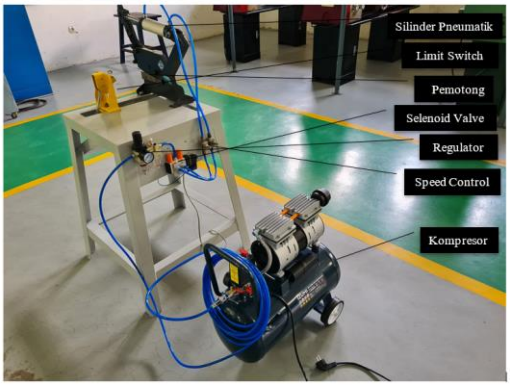

Figure 6. Name of Plate Cutting Machine

Tool use procedure

The procedure for using this machine can be explained in the following stages 1) Ensuring work safety equipment such as glasses, helmets, masks, gloves, and footwear. 2) Check all existing hose connections and ensure the connection is in the correct position. 3) Connect the power supply cable to the electrical socket until the compressor will live and the compressor filling process will run. 4). Waiting for a moment until the compressor is filled to the maximum, the compressor will automatically stop. This filling will affect the working pressure of the existing pneumatic system. 5) After the compressor has the required pressure, open the compressor valve, and set it in a pressure position of 6 bar. 6) Insert the plate material into the cutting knife until it touches the limit of the switch. 7) When the plate touches the limit switch, the knife will automatically move down to do the cutting process. 8) Plates that have been cut will fall through the hoper, and the limit switch will return to its original position. 9). The limit switch movement will order a knife to return to its original position, and the process can run continuously

Machine testing

Machine testing is done to determine the engine ability in the process of slaughtering plates. The test was carried out by cutting the metal plate of the raw material of the knife by 200 mm per piece. The position of entering the plate to the cutting is shown in Figure 7. Based on the tests that have been carried out, the conclusion of the machine can be able to work with a maximum capacity of 400 plates/hour

Figure 7. The position of inserting the plate into the cutting knife.

4. CONCLUSION

The design and manufacturing process of automatic metal plate cutting machines has been successfully implemented to realize the engine prototype. The design process is assisted by using fluid simulator software (Fluid SIM) to simulate its pneumatic system movements, machine construction design using Autodesk Inventor software, and mathematical design calculations. The results achieved in this examination are prototypes of pneumatic system plate cutting machines that can work automatically with a capacity of 400 pieces per hour, the need for cut force is 552 N, air pressure 6.2 bar, and air requirements 11.5 liters/minute

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