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Design and Fabrication of a Prototype Pneumatic Cylinder

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Abstract: Pneumatic systems play a crucial role in the manufacturing industry. Many industrial machine require pneumatic systems to operate at present. In industrial machine systems, pneumatic cylinders are one of the machine parts that operate with a high level of intensity; therefore, it is necessary to replace and maintain pneumatic cylinders. The purpose of this paper is to propose the design and production of a prototype pneumatic cylinder that is inexpensive and suitable for single-unit production. The article proposes an approach for determining, developing, and fabricating a pneumatic cylinder prototype for industrial equipment. From the initial working requirements given, a pneumatic cylinder prototype was designed and simulated on Solidwork software. To demonstrate the accuracy of the model, simulations of motion are also taken into account. Next, the dimensions of the pneumatic cylinder are calculated in full detail based on the preliminary model to ensure that they meet the design specifications. The control circuit system is then designed and calculated in accordance with the system's structure. Then, Automation Studio software is utilized to recalculate and validate the model's accuracy. Finally, a pneumatic cylinder prototype was constructed to validate the model. Prototypes are manufactured by CNC machining with the support of CAD/CAM technology. The prototype's smooth motion demonstrates the accuracy of the design process.

Keywords: Pneumatic Cylinder, Solidworks, Automation Studio, Prototype

1. Introduction

Pneumatic systems play a crucial role in the manufacturing industry [1-4]. Many industrial devices require pneumatic systems to operate at present [5-10]. Both the quantity and quality of compressed air systems are demanded by industries in Vietnam that are expanding their production.

As shown in Figure 1, a pneumatic cylinder is a type of operating mechanism that converts accumulated energy in compressed air into kinetic energy to enable motion. Pneumatic cylinders are powered by compressed air and mechanically generate force, frequently in the form of motion.

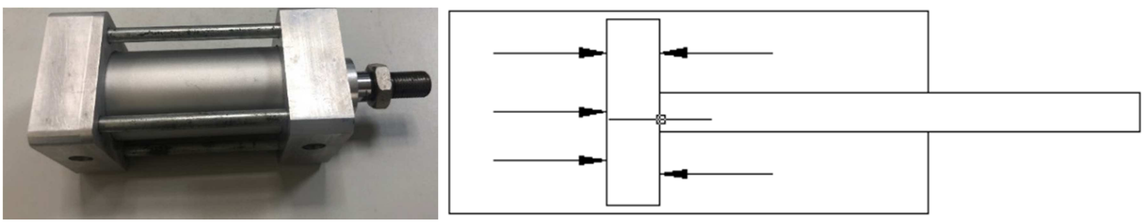

Figure 1. *Pneumatic systems.*

Pneumatic cylinders transmit force by converting the energy of compressed air into kinetic energy in order to perform their function. This is accomplished as a result of the compressed air's ability to expand without external energy input, which is a result of the compressed air's higher pressure than atmospheric pressure. This expansion of air propels the piston in the desired direction. Once activated, air compresses into the tube at the piston's one end, thereby transmitting force to the piston. Consequently, the piston will be pushed by compressed air.

In industrial machine systems, pneumatic cylinders are one of the machine parts that operate with a high level of intensity; therefore, it is necessary to replace and maintain pneumatic cylinders. This article proposes a manufacturing plan for a pneumatic cylinder prototype. The modeling pneumatic cylinders in 3D using Solidworks and motion simulation. Using Automation Studio, we can then construct the model and operation of the system's components. Using Automation Studio software to simulate the pneumatic systems significantly reduces the experimental procedure's time, effort, and cost. Reduce significantly the time required for research and production of test products. Finally, a prototype was constructed to confirm the calculation's accuracy.

2. Methodology

2.1. Pneumatic Cylinder Design Requirements

A few technical specifications for pneumatic cylinders depend on the actual needs of some Vietnam-based devices.

1) Initial pressure on the piston: F = 1600N.
2) Compression stroke S=75 mm.
3) Working pressure of the compression cylinder system: P = 0.6 MPa.
4) Forward time: t_1 = 1.5s.
5) Backward time: t_2 = 1.5s.
6) Holding period time: t3 = 0.5s.

2.2. Simulation Analysis

The paper proposes a practical application for the pneumatic cylinders shown in Figure 2 as part of the opening and closing system. This system is one of the industrial applications of pneumatic cylinders.

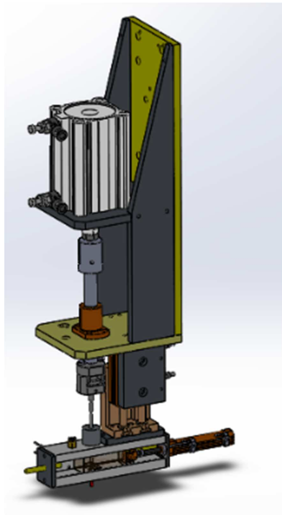

Figure 2. *Opening and closing system on CAD design.*

The simulation of the operation of the pneumatic cylinder at every step is depicted in Figure 3. The diagrams shown above illustrate each of the system mechanism's operational phases. The simulation duration is only displayed in relation to actual time.

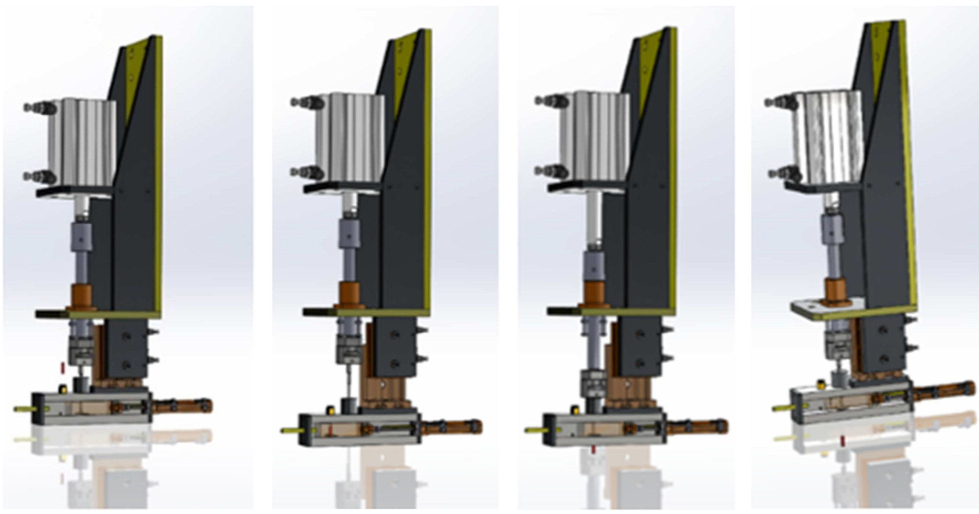

Figure 3. *Simulation of the opening and closing mechanism using the Solidwords software.*

2.3. Developing Pneumatic Circuits

The diagram of the pneumatic control system for the opening and closing mechanism designed by Automation Studio software is shown in Figure 4.

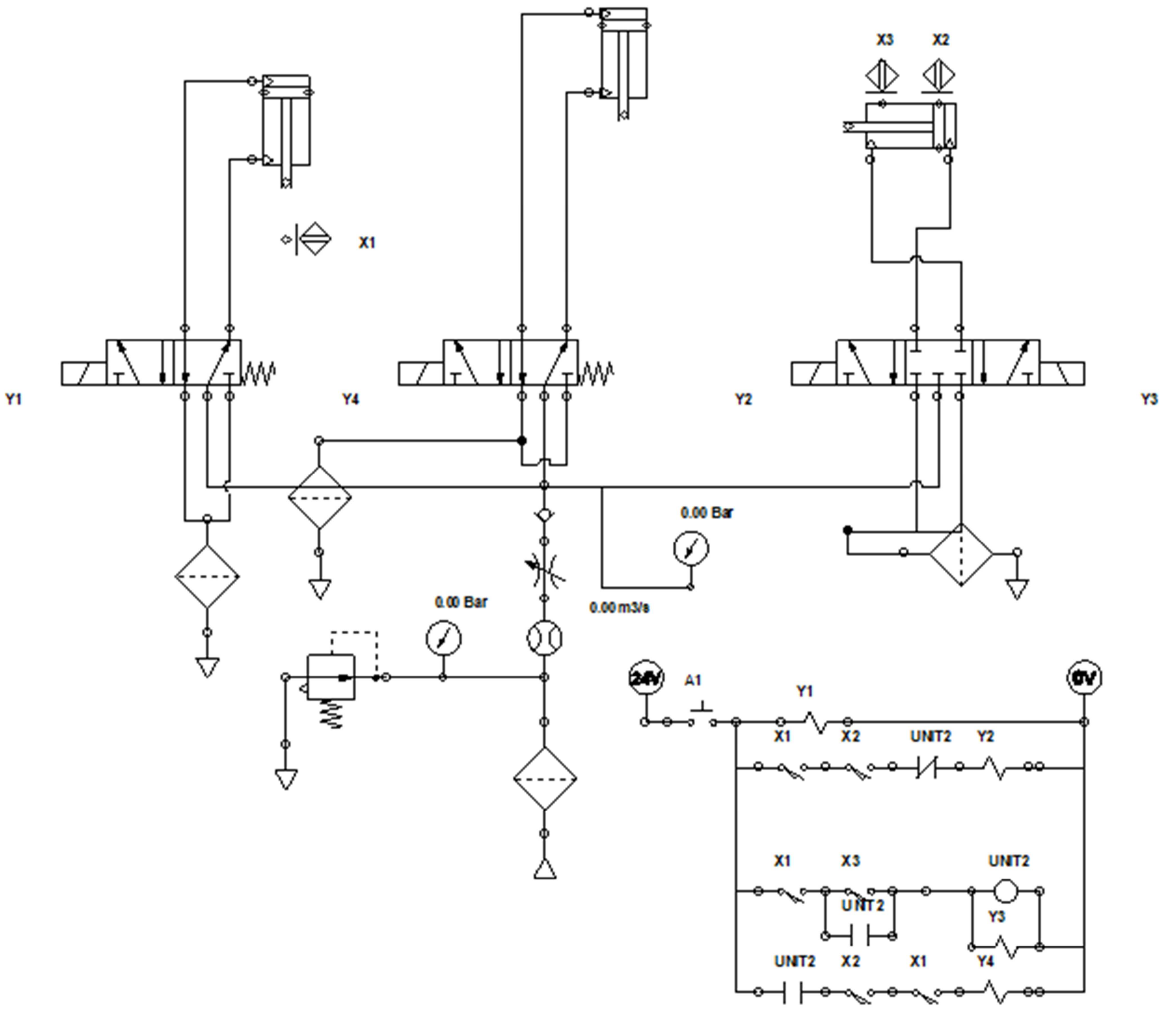

Figure 4. *Diagram of pneumatic system and control.*

When the power switch A1 is closed, Y1 receives a signal that commands the valve (5/2) to move to the right. At this time, compressed air is supplied directly to the horizontal cylinder assembly, pushing the piston downward to perform the pressing process. positioned in order to be closed. When the cylinder completes its stroke, the X1 sensor should be pressed.

When sensor X1 is touched, switch X1 in the control circuit is closed, valve 2 (5/3) moves to the right, and compressed air is supplied to cylinder No. 2, bringing the bearing from the right to the right. left. When this cylinder reaches the contact sensor X3 position.

Switch X3 in the control circuit is closed, Y3 has a signal to move valve 2(5/3) to the left, and the supply of compressed air to cylinder No. 2 continues, causing the bearing to move from left to right. At this point, the bearing retracts to the closed position. When this cylinder is completely filled, activate sensor X2.

When the switch X2 in the control circuit is closed, the signal from Y4 causes valve 3 (5/2) to move to the right, and compressed air is supplied to the cylinder to drive the piston downwards during the closing process.

After the process of closing the system is complete, press the off switch A1. At this point, the spring pushes both valves 1 and 3 back to their original position, and the compressed air pushes the cylinder back to its original position. There is no need to reposition Valve No. 2 and Cylinder No. 2 in preparation for the next close.

2.4. Pneumatic Cylinder Design

Figure 5 depicts a piston-type cylinder that can generate compression when compressed air pressure is applied to the piston's top surface and can return when liquid pressure is applied to the piston's bottom surface.

Initial conditions F = 1600N, p = 0.5 Mpa

Area of cylinder

$$S_{tt} = \frac{F}{p} = \frac{1600}{5.10^5} = 0.0032(m^2)$$

Preliminary diameter of cylinder

$$D_{tt} = \sqrt{\frac{4S}{\pi}} = \sqrt{\frac{4\times 0.0032}{\pi}} = 0.063831(m) = 63.831(mm)$$

Select cylinders according to Hydraulic and Pneumatic cylinders basic parameters standard: D = 63 mm, d = 20 mm

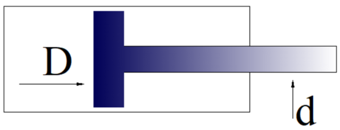

Figure 5. *Piston-type cylinder.*

2.5. Determine the Cylinder's Pressure

Cylinder working area

$$A_{lv} = \frac{\pi \times D^2}{4} = \frac{\pi \times 0.063^2}{4} = 0.003318\ (m^2)$$

Force of propulsion exerted by the cylinder during the expulsion motion:

$$F_1 = P \times A_1 = P \times \pi \times R^2 = P \times \frac{\pi . D^2}{4}$$

$$\rightarrow F_1 = 0.5 \times \frac{\pi \times 63^2}{4} = 1558.7\ (N)$$

The cylinder's traction force during the return stroke:

$$F_2 = P \times A_2 = P \times \pi \times (A_1 - A_3) = P \times \frac{\pi . (D^2 - d^2)}{4}$$

$$\rightarrow F_2 = 0.5 \times \pi . \frac{63^2 - 20^2}{4} = 1401.5(N)$$

Working pressure:

$$P_{lv} = \frac{F}{A_{lv}} = \frac{1659.2}{0.003318} = 500046.3\ (\text{N/m}^2) \approx 5\ (Bar)$$

Choose a standard cylinder with the parameters D = 63 mm and d = 20 mm using the specifications listed above.

2.6. Required Flow for Cylinder

The velocity of the piston during toward movement:

$$v_1 = \frac{S}{t_1} = \frac{0.075}{1.5} = 0.05(m/s) = 50(mm/s)$$

Then the required flow for the process

$$Q_1 = A_1 \times v_1 = \frac{\pi \times D^2}{4} \times v_1 = \frac{3.14 \times 0.063^2}{4} \times 0.5 = 0.001559(dm^3/s) = 0.0935(l/ph)$$

The velocity of the piston during backward movement:

$$v_2 = \frac{S}{t_2} = \frac{0.075}{1.5} = 0.05(m/s) = 50(mm/s)$$

Then the required flow for the process

$$Q_2 = A_2 \times v_2 = \frac{\pi \times (D^2 - d^2)}{4} \times v_2 = \frac{3.14 \times (0.063^2 - 0.02^2)}{4} \times 0.5 = 0.001402(dm^3/s) = 0.0841(l/ph)$$

2.7. Simulation Software from Automation Studio for Testing Cylinders

The simulation of cylinders has been calculated using the Automation Studio software, as shown in the Figure 6. The initial conditions are determined based on the given boundary conditions, as calculated in the previous concept.

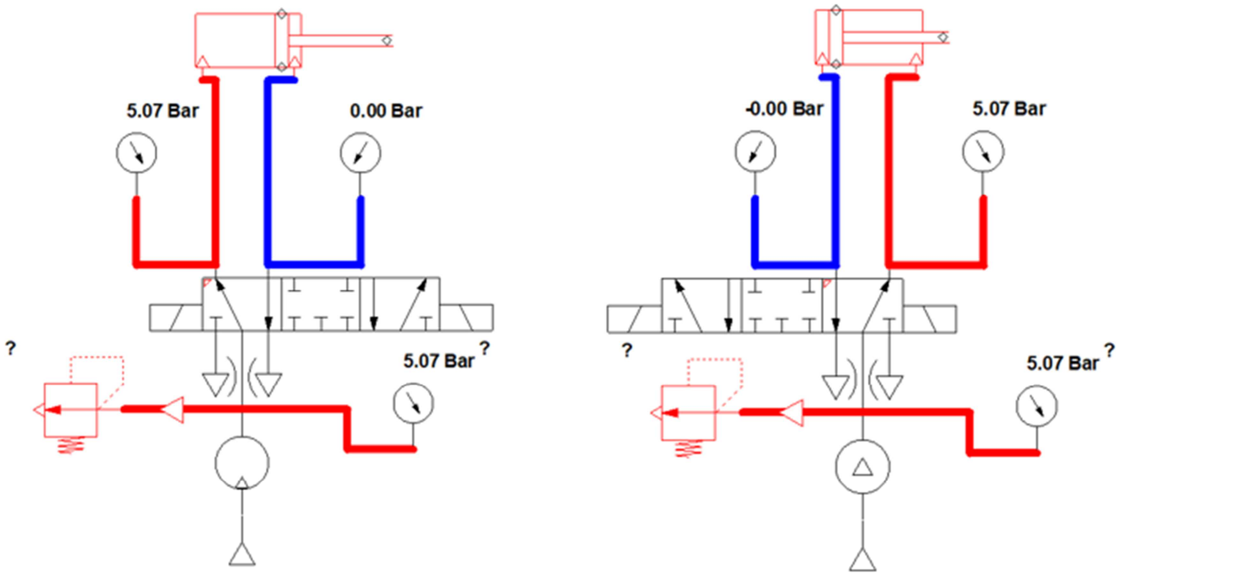

Figure 6. *Illustration of the cylinder's push-out and pull-back operation.*

The operating pressure of the cylinder, as shown in the image, is 5.07 Bar. We can see that the cylinder functions normally and with the theoretically calculated parameters. Therefore, we can use the theoretical formulas to calculate the basic parameters of the pneumatic cylinder.

3. Design and Manufacture of Pneumatic Cylinders

Using CAD-CAM-CNC technology, a cylinder prototype was designed and manufactured based on the calculated cylinder parameters. First, the model is created in Soliworks using the exact dimensions depicted in Figure 7. The model is then divided into pieces, which are then machined on a CNC machine using CAM tools. As depicted in figure 8, a prototype was built successfully. According to the recommended dimensions, the piston forward and backward strokes of the prototype operate without problems.

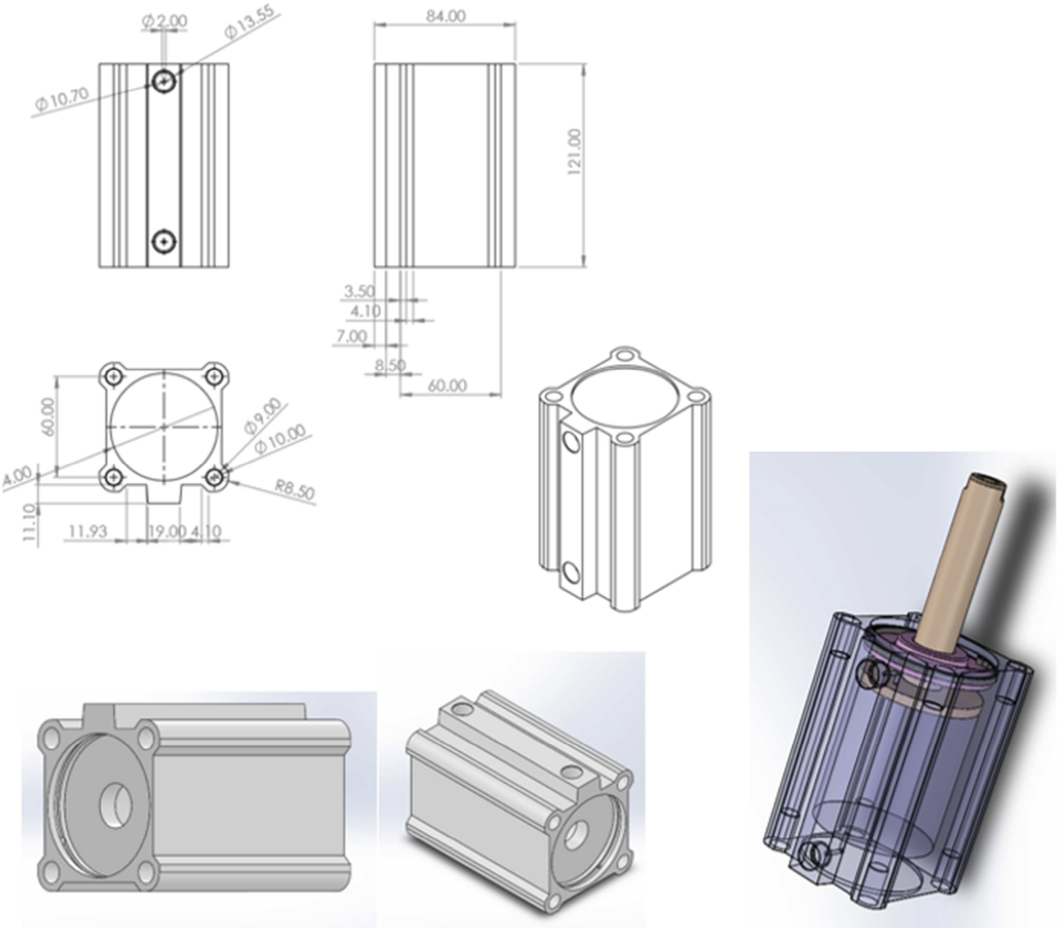

Figure 7. *Cylinder design in 3D CAD model.*

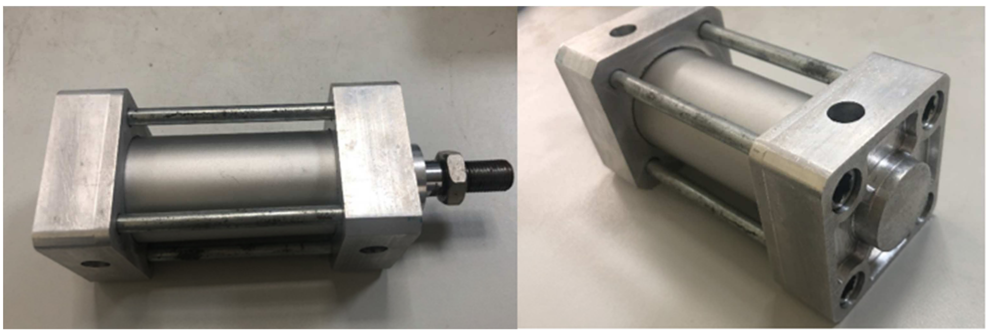

Figure 8. *A prototype pneumatic cylinder.*

4. Discussion

A pneumatic cylinder prototype has been successfully made in accordance with the requirements presented to demonstrate the reliability of the design calculation procedure. Usually, previous research on pneumatic cylinders has focused on issues of control, friction, lifetime and lubrication [11-15]; manufacturing issues have been mentioned infrequently. In the case of single-unit production, the article also describes a relatively straightforward and inexpensive method for CNC-cutting pneumatic cylinders.

5. Conclusion

The article provides a method for calculating the prototype design of a pneumatic cylinder. First, the motion of the pneumatic cylinder is simulated in Solidworks to validate the correctness of the machine principle. Then, based on the initial conditions, the dimensions of the cylinder are proposed. These dimensions are tested again using the software Automation Studio. After confirming the results, a prototype based on the proposed design was constructed. The prototype's smooth motion demonstrates the accuracy of the design process. Future work may involve a specific method of machining various pneumatic cylinder models for simple, low-cost applications. In addition, the modeling processes will be expanded to include conditions that correspond to the actual application of the cylinder in each machine system.

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