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Automated Pneumatic System for Car Brake Pedal Test

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ABSTRACT

In the automotive industry especially in the car production company, after filling the brake fluid oil, the brake fluid should be distributed from the brake fluid oil reservoir tank to all the braking system components. Unfortunately, the oil is not well distributed even an air trapped inside. To prevent the new car brake problem, to replace the human pressing the brake pedal manually, to reduce the manpower effort, and to detect the problem as soon as possible after filling the brake fluid oil this automated pneumatic system for car brake pedal test device is created. This research was done by designing, simulating, create the actual device that is ready to use and implemented in the industry. The result is this system is working well after being successfully implemented. There are several achievements during its operation, especially manpower effort reduction. More safety for the manpower compared to pressing the pedal manually. Safety from electric shock because the system is designed using a full pneumatic system without electricity. Poka-yoke for brake oil leakage, for faster analysis and part replacement, and in the end, it also impacts on the increasing profitability.

Keywords: *Automotive Industry; Car Brake; Pneumatic Automation.*

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ABSTRAK

Pada industri otomotif, khususnya pada perusahaan produksi mobil, setelah mengisi minyak rem, minyak rem harus disalurkan dari tangki penampung minyak rem ke seluruh komponen sistem pengereman. Sayangnya, minyak tidak terdistribusi dengan baik, bahkan terdapat udara yang terperangkap di dalamnya. Untuk mencegah masalah rem pada mobil baru, untuk menggantikan manusia yang menekan pedal rem secara manual, untuk mengurangi upaya tenaga kerja, dan untuk mendeteksi masalah sesegera mungkin, setelah mengisi minyak rem, sistem pneumatik otomatis untuk alat uji pedal rem mobil dibuat. Penelitian ini dilakukan dengan merancang, menyimulasikan, dan membuat perangkat aktual yang siap pakai untuk diimplementasikan pada industri. Hasilnya, sistem ini berjalan dengan baik setelah berhasil diimplementasikan. Ada beberapa pencapaian selama pengoperasiannya, khususnya upaya pengurangan tenaga kerja. Selain itu, sistem lebih aman untuk tenaga kerja dibandingkan dengan menekan pedal secara manual. Sistem in juga aman dari sengatan listrik karena dirancang menggunakan sistem pneumatik sepenuhnya tanpa listrik. Poka-yoke untuk kebocoran minyak rem, untuk analisis lebih cepat dan penggantian suku cadang serta pada akhirnya juga berdampak pada peningkatan profitabilitas.

Kata kunci: Automasi Pneumatik; Industri Otomotif; Rem Mobil.

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INTRODUCTION

The brake pedal is an important part of the car that initiates the entire brake system in a vehicle. In manual cars, it's the middle pedal and in automatic cars, it's the pedal on the left side. Brake is used to slow or stop the vehicle during normal conditions or in an emergency time. When pressing down on it, all the components of your braking system swing into action [1]–[3].

In the automotive industry especially in the car production industry, during its normal production, after filling the car brake fluid oil. The brake fluid oil should be distributed and forced out from the brake fluid oil reservoir tank to all the braking system components. Unfortunately, after filling the brake oil, the oil is not well distributed even air is trapped inside[1]–[3].

The common car brake problem in a new car is the brake pedal is soft or drops to the floor of the vehicle and doesn't spring back correctly. This problem is caused by several roots, which is the presence of air in a brake system line, which will reduce the fluid's hydraulic pressure, making the brake pedal feel soft, brake fluid leak, the master cylinder failure, etc. [1]–[4].

To prevent the new car brake problem, to replace the human pressing the brake pedal manually, to reduce the manpower effort, and to detect the problem as soon as possible after filling the brake fluid oil, a new system that is used to press on and off the brake pedal is proposed. This system will be applied during the car production time after filling the car brake fluid oil.

In normal conditions, the operator should press the brake pedal repeatedly on some certain cycle by hand because the car component is not fully assembled even the car seat is not attached yet, so humans can't sit down and press the brake pedal by feet repeatedly.

The rest of this paper is outlined as follows: *Literature Study* talks about the basic theory and how the data will be processed and calculated. *Research Method* describes a step-by-step research flowchart. *Results and Discussion* examines the research results, the calculation data that was based on the formula which is shown in the *Literature Study*, and the detail of how the research results were achieved. Finally, the *Conclusion* gathers the final result of this paper, which does not only show the research results but also the impact of this research on society, especially for the automotive industry.

LITERATURE REVIEW

FluidSIM Software

FluidSIM is a computer program application that runs on the Windows operating system which functions as a simulation tool for pneumatic circuits. This software was developed by Festo Didactic—a multinational industrial control and automation company based in Esslingen and Neckar, Germany, Europe. FluidSIM is used for the design, instruction, simulation, and study of the pneumatic circuit, electro-pneumatic, hydraulic circuit, and electrohydraulic circuit [5].

Pneumatic Cylinder Calculation

An automated pneumatic brake pedal test is a device specifically designed to press on and off the car brake pedal with the purpose to distribute the brake oil and forcing out the trapped air inside its braking system. To press on and off the brake pedal, the main used device is the double-acting cylinder. When the cylinder moves forward, it will press on the brake pedal. Otherwise, when the cylinder moves backward, the cylinder will press off the brake pedal.

These cylinder moves are dependent on a settled timer inside the control panel. The proposed system is only using a pure pneumatic system so there is no electrical equipment in this device. The timer used in this system is also a pneumatic timer and all other control equipment is also pneumatically operated.

According to [6]–[10], there are some basic requirements needed to calculate the pneumatic cylinder. First, we need to know the air operating pressure on the implemented area for this time the operating pressure is 4 bar. Second, we have to do research related to the cylinder bore size and stroke which is available on the markets. Third, we have to calculate the full-bore size of the piston diameter. To calculate the full-bore piston diameter (d), again we need to know the basic requirement for the system. How much load is required to push, what is the operating pressure of the system, the value of gravity, and the value of the mathematical constant of π. The detailed equation about how to calculate the bore size and the value which is used to know the force (F) is shown in Equations 1 and 2.

$$d = \sqrt{\frac{4\, m\, g}{P\, \pi}} \qquad .....(1)$$

$$F = P.\frac{\pi\, d^2}{4} \qquad .....(2)$$

Where d is the full bore piston diameter (m), P is an applied pressure (Pascal, 1 bar = 100 kPa), m is the mass or load of the system (kg), π is mathematical constant in euclidean geometry as the ratio of a circle's circumference to its diameter (3.14), F is the force exerted by the cylinder (N) and g is for gravity (9.8 m/s^2) [6]–[10].

Equation 1 is used for calculating the full bore size diameter and comparing it with the cylinder bore size available on the markets which are shown in Table 1. Equation 2 is used for calculating the force exerted from the cylinder also for comparing and checking the selected cylinder bore size calculation were it calculated correctly or not.

The bore size and stroke length value on the market are always even, so the designer should follow the available part on market. also, during the selection of the bore size please select the size above the value you get based on Equation 1. This is for safety factors if in the future there is any change with the load.

RESEARCH METHOD

The research flow started with the following of the research object determination and the observation of field study and then study literature for the basic theory and identification of problem and research goal. This research was concluded not only done by the researcher but also involving the end-user (operator) for the basic equipment requirement. The detailed step-by-step of this research are presented in Figure 1.

As mentioned in the pneumatic cylinder calculation inside the Literature Study section, we have to do research related to cylinder type which is available on the markets. The cylinder bore size and stroke length which are usually available on the market are shown in Table 1.

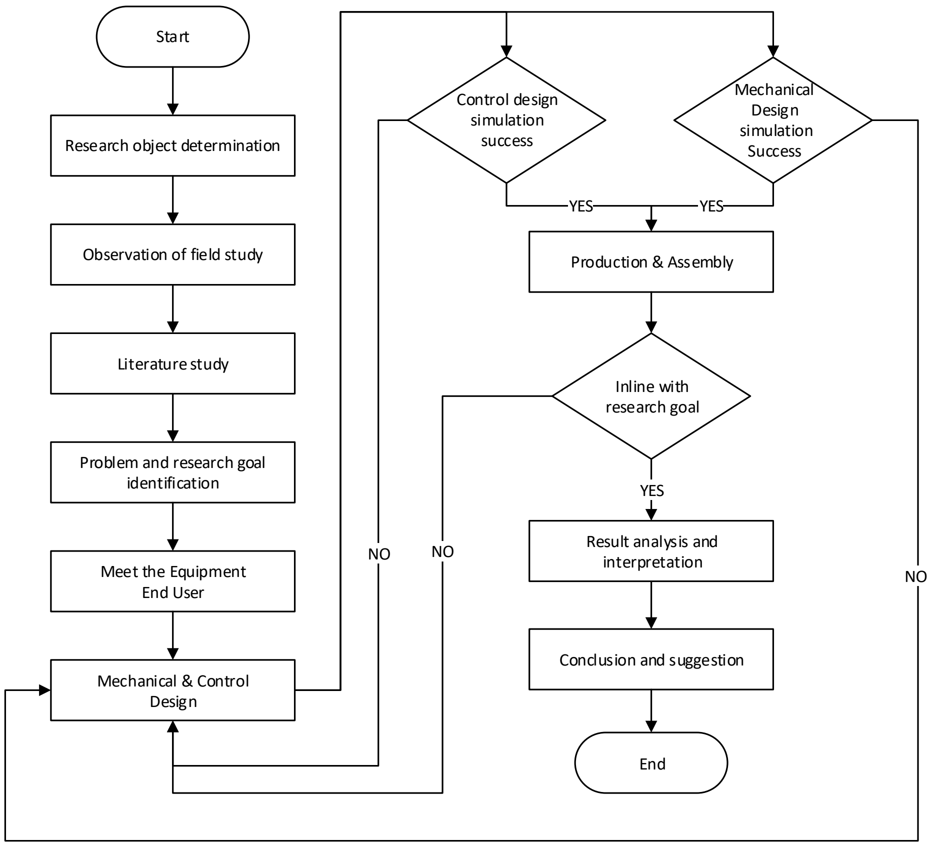

Figure 1. The flowchart of this automated pneumatic for car brake pedal test.

Table 1. Cylinder bore size and stroke length available on market [11].

Bore size (d)	Stroke length (mm)
Ø20 mm	25, 50, 75, 100, 150, 200, 250, 300
Ø25 mm	25, 50, 75, 100, 150, 200, 250, 300
Ø32 mm	25, 50, 75, 100, 150, 200, 250, 300
Ø40 mm	25, 50, 75, 100, 150, 200, 250, 300

RESULT AND DISCUSSION

Pneumatic Cylinder Calculation

The required force to push the car brake pedal is 70 lbs (31.75 kg) [1] and the operating pressure is 4 bar. Following Equation 1, the cylinder bore calculation is following the simple process shown below:

$$d = \sqrt{\frac{4\, m\, g}{P\, \pi}}$$

$$d = \sqrt{\frac{4\ (31.75\ \mathrm{kg} \,.\, 9.8\ \mathrm{m/s^2})}{(400{,}000\ \mathrm{Pa})\ \pi}}$$

$$d = 0.03146\ \mathrm{m}$$

$$d = 31.46\ \mathrm{mm}$$

Based on the calculation, the selected bore size is 32 mm. However, to give a safety factor to the system, the selected cylinder bore size for this device is 40 mm. Following Equation 2, to calculate the exerted force by the single-cylinder is shown below.

$$F = P \,.\, \frac{\pi\, d^2}{4}$$

$$F = 400{,}000\ \mathrm{Pa} \,.\, \frac{\pi\ (0.04^2\ \mathrm{m})}{4}$$

$$F = 502.65\ \mathrm{N}$$

Comparing the result of exerted force from 40 mm cylinder bore size (F = 502.65 N) and the required force (F = 311.15 N) we know that the cylinder selection is good and with 1.5 times of safety factor on a single cylinder.

Control Design and Implementation Result

The simple concept is to move the double-acting cylinder forward until its forward end, and then return to its origin position repeatedly following the settled counting value. During the operation, the system will stop its process and the cylinder will return to its original position following two cases, when the emergency stop button is pressed or when the selected counter value is achieved.

Before beginning the operation, the equipment should be placed in front of the brake pedal of the car, then the operation can be started. The detailed flowchart of this system is shown in Figure 2.

This system is timer-based control, the timer setting value has a high impact on the moving of the cylinder. If the timer value is settled too long, the cylinder will delay for a long time until the next process proceeds. Otherwise, when the timer settled too short, the cylinder moving may not move until its end because the timer value is achieved first. Inside the cylinder move section from Figure 2, the detail about the exact moving sequence is shown in Figure 3.

Before the normal process operation began, the selected counter value must be settled first. To settle the value, the engineer can set it directly on the pneumatic counter device PZV-E-C from Festo [12]. The movement are based on the flowchart in Figure 2 and Figure 3. The detail circuit is shown in Figure 4 as a proposed control system diagram.

The movement of the two cylinders is controlled by a 5/2-way pneumatically operated single solenoid valve and this 5/2-way solenoid valve is controlled by the two timers which work in shifts. While Timer 1 is counting its timer value, Timer 2 is off and vice versa. The Relay 1 valve is a switching device to turn on or off this system. To turn on the system, PB1 should be pressed and to turn off the system, PB2 should be pressed or the counter has given a signal to Relay 1. The counter value is added up while the cylinder is moving forward or pressing the brake pedal and the counter value will be clear if the PB2 is pressed or after the counter is turned on and triggering the Timer 3 to count up and after the settled value is achieved, the timer will on and clear up the counter value.

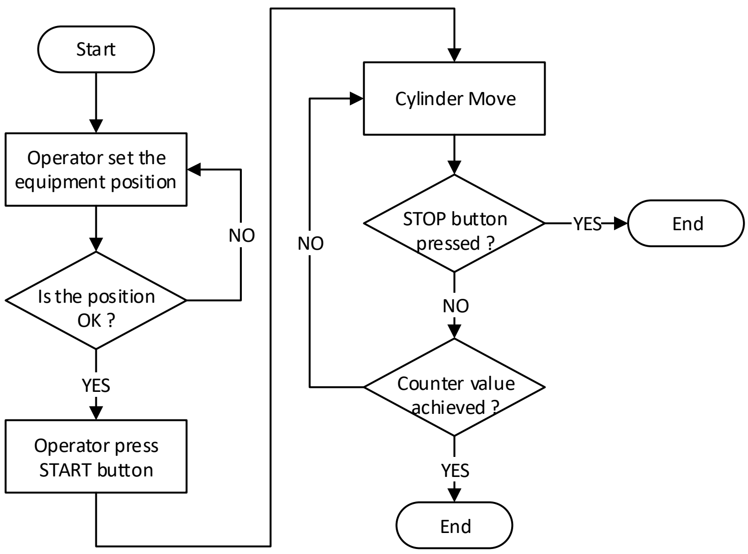

Figure 2. Simple process sequence chart.

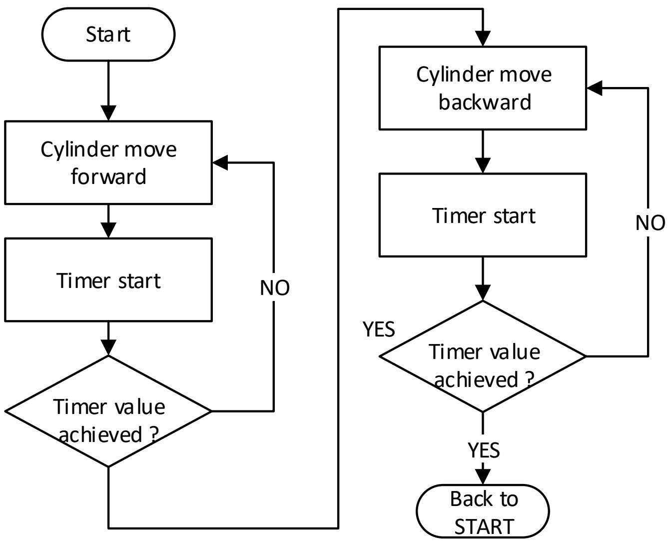

Figure 3. Cylinder moving sequence chart.

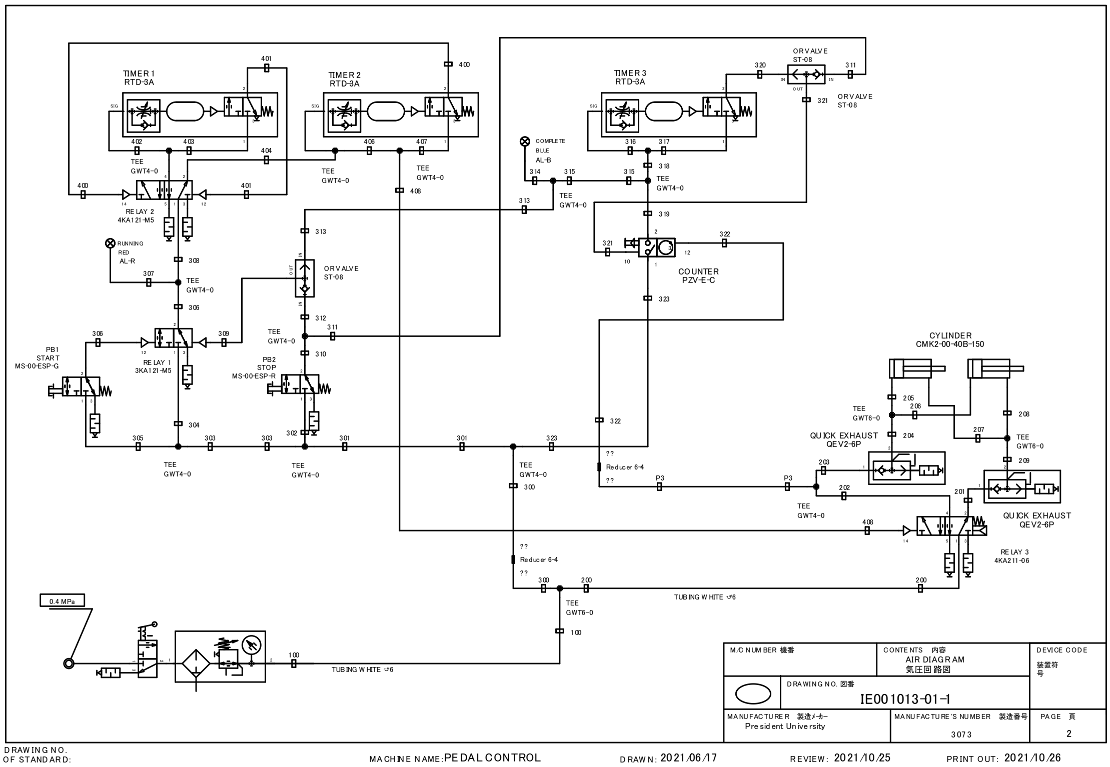

Figure 4. Proposed control system diagram.

Implementing the pneumatic system without electricity for this equipment is the best choice because this device has to be portable. Implementing electricity on this equipment will generate an electric shock when the cables are peeled off due to the frequent movement.

Mechanical Design and Implementation Results

After completing the control design, the 3D mechanical design after fabrication and assembly is shown in Figure 5. From this Figure 5, it is shown that the force exerted by the cylinder at applied pressure 4 bar is able to press on the brake pedal which is proved by during the cylinder move to forward, the pedal brake is already pressed. Also, we know that the start pneumatic pushbutton is placed along with the cylinder with purposes to make an easier operation.

After successfully implemented, the operator just has to place this equipment in front of the brake pedal then push the start button and leave this equipment working automatically until the process finishes. Afterward, the operator can take out this equipment to its home position. During this simple process, we know that this new device has led to manpower effort reduction and more safety for the operator because the operator does not have to manually press the brake pedal. Before implementing this equipment, during pressing the brake pedal manually, the production line is still moving and the seat is not installed yet.

Figure 5. Proposed 3D mechanical design.

CONCLUSION

There are some conclusions that can be drawn from the experimental results: (1) This automated pneumatic for car brake pedal test device is successfully created. Control and mechanical design on this equipment are already implemented and work well without any problem. Furthermore, the proposed system only utilizes a pure pneumatic system, so there is no electrical equipment in this device, including the timers and all other control equipment which make it safe from electric shocks; (2) The system for pressing on and off the car brake pedal repeatedly follows the settled counter value. To press on and off the brake pedal, the main use device is the double-acting cylinder. When the cylinder moves forward, the cylinder will press on the brake pedal. Otherwise, when the cylinder moves backward, the cylinder will press off the brake pedal; (3) Based on the basic specification, the required force exerted by the cylinder ($F_{Required}$) is 311.15 N and the selected cylinder bore size is 40 mm. If we calculated it using Equation 2, the force exerted by the cylinder (F_{Final}) will be 502.65 N. So, the safety factor for this equipment is 1.5 times from $F_{Required}$; and (4) After being successfully installed, there are several achievements during its operation, especially manpower effort reduction. More safety for the manpower compared to pressing the pedal manually. As we know that during the process, the line is still moving. Poka-yoke for brake oil leakage, for faster analysis and part replacement, and at the end, it will also be impacting on increase the profitability.

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