A METHOD OF DETERMINING THE FRICTION FORCE IN PNEUMATIC CYLINDERS

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ABSTRACT
The frictional force inside pneumatic cylinders has a significant influence on the motion characteristics of the pneumatic cylinder transmission. Therefore, it’s very difficult to determine this force, especially at high speed and high acceleration of the piston. In this paper, a dynamic method to determine the friction force in pneumatic cylinders is described.

Keywords: friction force, pneumatic cylinder, speed, pressure

1 INTRODUCTION
Nowadays, in mechanical engineering and industry pneumatic transmission systems including pneumatic cylinder have a wide application, which can be explained by the simplicity of realizing the mode of straight motion.

As we have known, the analysis of the motion characteristics of pneumatic transmission systems is necessary and important, especially in the design period, in which, the parameters of the system, particularly nonlinear friction, which can not be determined exactly by only analytic methods, is the most influencing factor in such systems.

This paper presents a method of effective determination of friction characteristics in the pneumatic cylinders, which depends on important values (such as speeds, pressures etc...), and to propose a perspective of the efficient application of these results. Beside of the automatisation of this method in measuring, in further treatment and calculation, it’s also effective to consider the cost of the equipment and the time that is spent on changing the experimental objects. So, the application of this method gives the possibility of quick determination of friction characteristics helping to calculate and design systems.

2 METHOD OF DETERMINING AND RESULTS
An experimental scheme is set up as shown in the figure where the pneumatic cylinders are installed and tested. Both cylinders with rods or without rods could be tested for the friction force on this scheme.

Fig. 1 shows pneumatic cylinders of various types are established on the sliders with changing loads. Two slide valves electrical controlled WV1 and WV2 type 5/3 are used in the testing system for controlling the cylinder system.

Fig. 1: Scheme of experimental system for testing the frictional force in pneumatic cylinders
Examining the force balance of piston during the motion we will have the following equation

\[ \sum F = 0 = p_1 A_1 - p_2 A_2 - ma - F_L - F_R, \quad (1) \]

where

- \( p_1, p_2 \) - pneumatic pressure in two chambers 1 & 2;
- \( A_1, A_2 \) - acting surface of piston;
- \( m \) - mass of block of piston, slider and load;
- \( a \) - acceleration of motion;
- \( F_R \) - frictional force;
- \( F_L \) - force of load

\( F_L \) in this case can be neglected. So we will have

\[ F_R = p_1 A_1 - p_2 A_2 - ma \quad (2) \]

By changing the air pressure in the acting chambers of cylinders, and changing of mass on the slider, it is possible to have various actings on the motion of the piston and on the frictional force, which is to be examined.

The experiment process will be as following: the chamber \( A_2 \) is closed properly after getting some value of pressure. After that the chamber \( A_1 \) is connected to the gas source through the value WV1. The gas pressure in this room increases very fast, until the value of pressure on the working surface \( A_1 \) of piston exceeds the resistance force and causes the movement with acceleration of the piston. The piston begins a process of “vibration” and will stop when it obtains the static situation of force balance.

This method is based on the collection of the measured values, which are changing during the process of movement with the aid of computer. In further calculation (also with computer’s assistance), the measured data will be treated, the frictional force is calculated and described as a function of the time, speed, pressure etc. The whole process of experiment is commanded automatically, following the program of control.

The below diagram shows an example of the testing result for the cylinder with diameter \( \phi \, 32 \times L150 \), with \( m = 6.7 \, \text{kg} \).

![Fig. 2: Frictional force with speed](image)

The achieved results of experiment show that the frictional characteristics of pneumatic cylinders depend not only on the type of material of sealing and lubricants, but also on various important dynamic parameters as speed of pistons in cylinders, acting pressures and difference of pressures in the working chambers of cylinders, rest time of pistons etc.... One another result also achieved by this scheme is the effect of stick - slip - a phenomena of undesirable discrete movement in the case of low speeds, causing a serious failure of exact working functions of the transmission system.

Being different from other method, this is dynamic method, when speed of cylinders could change in a large space, so it could make easier the test of friction. Besides, this scheme of experiment has some disadvantages: the difference of the pressures between two chambers of cylinders is considerably small, even when the initial pressure has been adjusted, or when the load on the slider have been changed. So it’s very limited when we analyze the frictional force depending on difference of pressures.

To get rid of these disadvantages, another experimental system is proposed in Fig. 3.

Hereby, two similar cylinders with opposite pressures are linked together, so we can make the desirable difference of pressures between chambers of cylinders. Furthermore, this difference doesn’t change during the process of the movement. These two cylinders are transmitted by the third pneumatic cylinder firmly linked with them, which has the same length as the other two. The process working in this third transmitting pneumatic cylinder is the same as shown in the above scheme. However, the subject of our testing is not the friction in the transmitting pneumatic cylinder, but it’s in the pneumatic cylinder A (which is linked with the slider through a box of force measurement F).

3 CONCLUSION

For the analysis of static and dynamic characteristics of pneumatic transmission systems very important is the determination of system parameters, including nonlinear friction characteristics which can not be determined by pure analytic methods. To solve this problem, we look for a method to collect and determine frictional characteristics of pneumatic cylinders, in their dependency on important factors (i.e. speeds, pressures...).

Based on the study and valuation of some used experimental methods, a scheme of “vibrations” type is proposed for the test of frictional force inside pneumatic cylinder. This scheme has brought some advantages and important results, which could test the motion with high speed, not high cost of equipment and fast experiment change etc. However, there is a disadvantage of this method: the test of frictional force is limited, because of the small differences of pressures between the chambers of cylinders.

The second experimental scheme is proposed without the above mentioned disadvantages.
Fig. 3: Second experimental system for testing the frictional force in pneumatic cylinders

4 REFERENCES


