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EXPERIMENTAL EXAMINATION ON THE THRUST ENERGY OF SHOCK ABSORBERS FOR PNEUMATIC CYLINDERS

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ABSTRACT

Shock absorbers are vital devices for high speed driving with pneumatic cylinders and it is important to select the suitable shock absorbers to use pneumatic systems without trouble. It is commonly believed that the absorbed energy by the shock absorber is the sum of kinetic energy and thrust energy, which are important parameters to set up the pneumatic system. In a typical selecting method of the shock absorber, the value of thrust energy is estimated from the value of only supply pressure. However, the selecting method has been regulated for hydraulic systems and the estimated value of thrust energy in the pneumatic systems is not approximate, because inner pressures in the pneumatic cylinder is not stable and quite different from the supply pressure. Finally there are many bad combinations of the cylinder and shock absorber in the pneumatic system.
In the research, we experimentally investigate the formula for estimation of the thrust energy, which is defined in the selecting method of shock absorbers. Experimental results show that accuracy of the formula to select the shock absorber is inefficient. Additionally we examine on parameters that affect the thrust energy and compensate the formula.

KEY WORDS

Shock absorber, Absorption energy, Evaluation formula, Pneumatics

NOMENCLATURE

E : Collision energy
E_V : Max collision energy with velocity V
E_1 : Kinetic energy
E_2 : Thrust energy
m : Mass of load
P : Differential pressure
F : Thrust of cylinder
E_m : Max absorption energy
V_m : Max velocity of collision
L : Stroke of absorption
V : Velocity of collision
D : Diameter of cylinder
α : Variable of situation
β : Variable of situation

INTRODUCTION

There have been many various systems with pneumatic cylinders in the manufacturing industry. Generally, shock absorbersare used along with the pneumatic cylinders, becauseit is necessary to cushion the impact and vibration when the cylinder is stopped at a stroke end.

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To select the appropriate shock absorbers for the cylinder, it is important that the absorbed energy by the shock absorber, which is composed of kinetic energy and thrust energy, is estimated. In a typical selecting method of the shock absorber the value of thrust energy is derived from the supply pressure. It is a problem that the estimated value is not approximate because inner pressure in the pneumatic cylinder is not stable and quite different from the supply pressure. Finally there are many bad combinations of the cylinder and shock absorber in the pneumatic system.

We have experimentally investigated the formula for estimation of the thrust energy, which is defined in the selecting method of shock absorbers. Especially, an influence of the compressible differencebetween hydraulic and pneumaticis considered.

SHOCK ABSOBER

Figure 1 shows typical charactersaboutthree kinds of shock absorbers. These characteristics depend on the inner structure of shock absorbers. Show inner the structure of shock absorbers in figure 2. First, shock absorber is assist device that generate force for frequency and shock at stroke end. Naturally it isn't good thateven if force to generate is too strong and weak. Thus, the selection of shock absorber is very important.

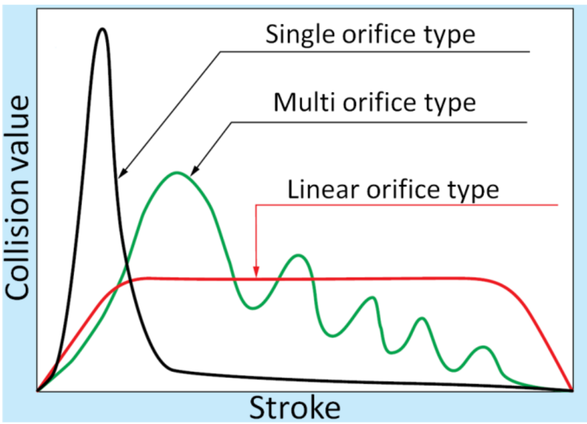
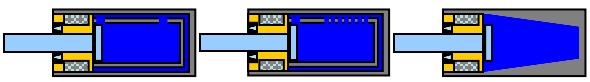


Figure 1 Characters of shock absorbers



(a) Single (b) Multi (c) Linear

Figure 2 Inner structure of shock absorbers

SELECTED FORMULA

Selected formulas, to use now, are shown in Eq.(1)~(3).

$$\mathbf{E_V = \frac{V \times E_M}{V_M}} \quad (1)$$

$$\mathbf{E = E_1 + E_2 = \frac{mV^2}{2} + F \cdot L} \quad (2)$$

$$\mathbf{F = \frac{\pi D^2}{4} \times P} \quad (3)$$

It is made up two elements: we consider that given energy of shock absorber equal total of kinetic energy and thrust energy, E_1:kinetic energy, E_2:thrust energy. Especially, thrust energy is influenced by compaction property of working fluid. Hence, supply pressure by tank is employed when calculation of thrust,but it is not always true that the value equal actual value.

COLLISION EXPERIMENT

We experimented with device such as figure 3.This device is simply, because, we installed speed controller, load, displacement gauge, pressure gauge on rodless cylinder and connected tank. We let work collide in shock absorber as well as record displacement of work, pressure of supply side and exhaust side. Show the list of changed parameter in experiment for table 1.

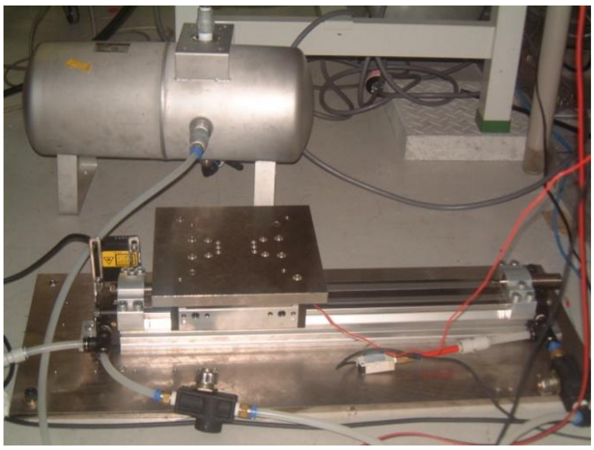


Figure 3 Experimental device

Table 1 Changing parameter

Supply pressure[MPa]
0.3, 0.35, 0.4, 0.45, 0.5
Diameter of cylinder[mm]
16, 25, 40
Load[kg]
2, 4, 9 (D=16)
2, 4, 9, 14, 19, 24, 29 (D=25,40)

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RESULT AND DISCUSSION

Result of experiment

First, show an example of the experimental results in figure 4.

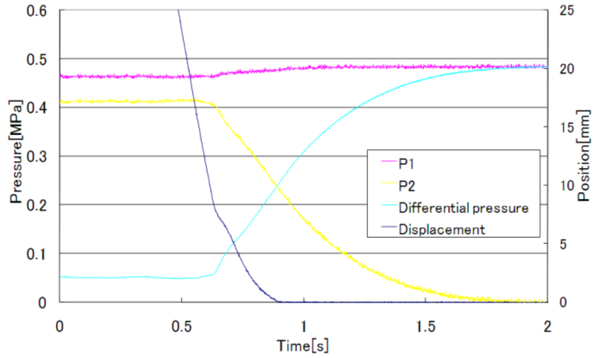

Figure 4 Experimental results (D=16, m=2, P=0.5)

Aqua line of figure 4represents differential pressure in experiment. This value is important to calculate collision energy, because, it yields thrust, Eq.(3). Stroke of shock absorber with experiment device is 10[mm], so we can consider that work was starting to collide in shock absorber when displacement of figure 4 equal 10. So, we assumed differential pressure when stareting to collide in it is reference value for parameter P. On that basis, we calculated theoretical and experimental value of collision energy. Figure 5 shows theoretical and experimental values of collision energy.

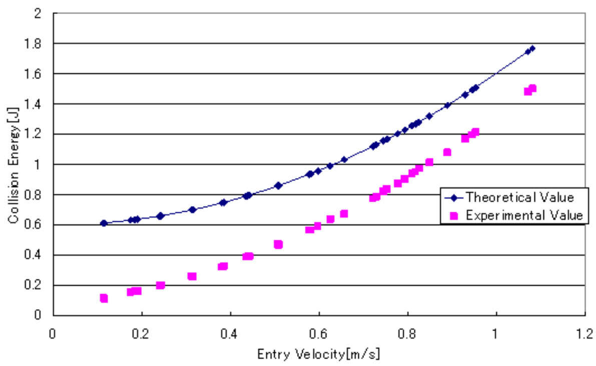

Figure 5 Collision energy (D=16, m=2, P=0.3)

Influence of pressure

We showed collision energy in figure 5, but collision energy encompasses kinetic and thrust energy. Of them, as for value of kinetic energy, both theoretical and experimental are the same. Now, therefore, figure 6 is derived thrust energy from collision energy and plots each velocity.Figure 6 represents that experimental value is generally lower than theoretical value and changed by velocity. So, change of experimental values by supply pressure is smaller than theoretical values. From Eq. (2),(3) selected formulas don't contain velocity term. Conversely, selected formulas contain pressure term. These things are new items considered by us.

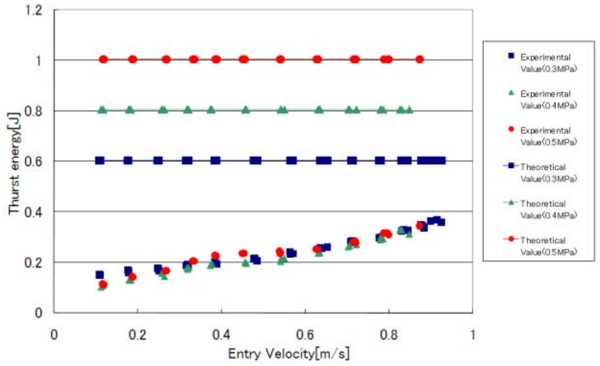

Figure 6 Change of thrust energy (D=16, m=2)

Influence of load

In this section, an influence of loadis considered. Figure 7 shows results of changing load.We can make sure two type that change of thrust energy is effected from load.One is made up two straight lines, another is made up line and curve.

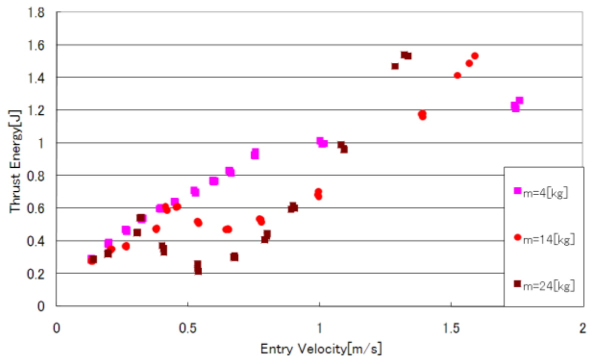

Figure 7 Result of changing load (D=25, P=0.5)

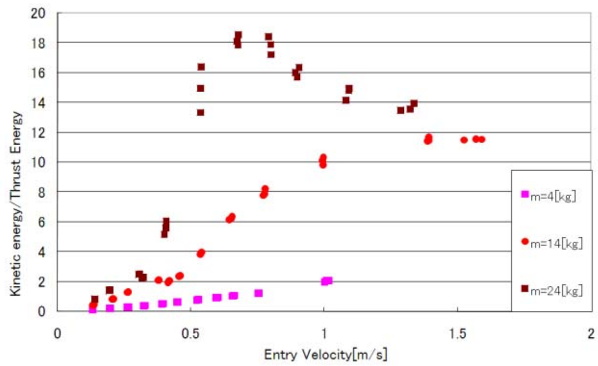

Figure 8 Kinetic energy and thrust energy（D=16, P=0.5）

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Straight line is dominant when low load, curve is dominant when heavy load. Thrust energy term of selected formula also doesn't contain load term. However, effect of load isn't only thrust energy. Figure 8 shows ratio of thrust energy to kinetic energy.
If load is heavy, ratio of kinetic energy becomes big and effect of thrust energy is small. By contraries, if load is low, ratio of kinetic energy becomes small and effect of thrust energy is big. So, difference between heavy and low load is a little when velocity is low. Hence, we have to become more chariness to use shock absorber when velocity is not high.

Transition of differential pressure

Transition of the thrust energy is linked withtransition of the differential pressure. The differential pressure is affected by compressibility of pneumatic, and it changes by situation of the experimental device. Figure 9 show example of transition ofthe differential pressure.

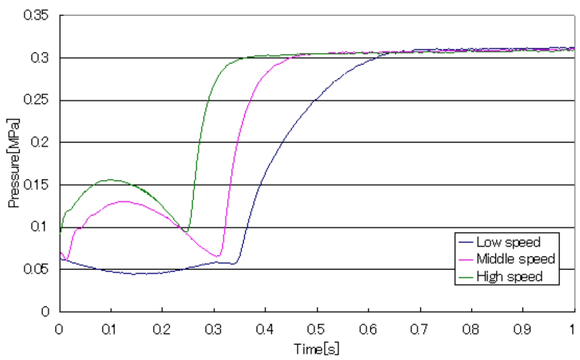

Figure 9 Transition of differential pressure

Approximate equation

If it is assumed that values of the velocity and load are small and the thrust energy is proportional to the velocity, the approximate equation become to Eq. (4).

$$\mathbf{E_2 = \alpha V + \beta} \qquad (4)$$

α and β represent variable of situation. These change upon situation of experimental device. For example, supply pressure, stroke of cylinder, etc. Especially, we consider five points is important from compaction property of pneumatic and experiment.

1. Supply pressure
2. Stroke of cylinder
3. Velocity
4. Diameter of cylinder
5. Load

Figure 10 and 11 show actually appliedEq. (4).If apply Eq. (4), have to fix α and β. In this case, we fixed from many experiment. But, there is a problem in precision still more. Experimental value is nearly linear when diameter of cylinder is small. However, error becomes large when diameter of cylinder is big. Even so, compensation value is more accurate than theoretical.

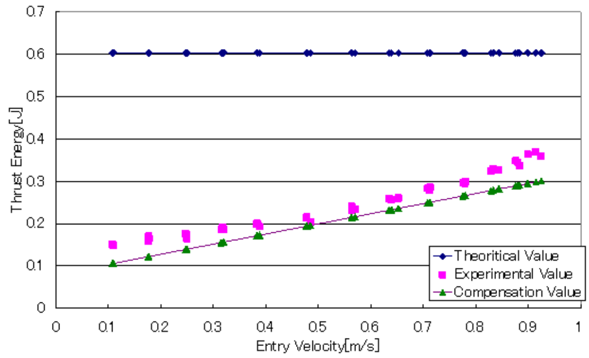

Figure 10Results of compensation (D=16, m=9, P=0.3)

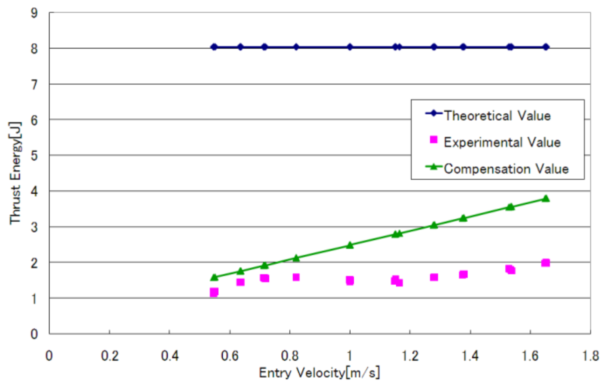

Figure 11Results of compensation (D=40, m=4, P=0.4)

CONCLUSION

Weexperimentally investigate the formula for estimation of the thrust energyin the typical selecting method of the shock absorber.Experimental results show that accuracy of the formula by the supply pressure is inefficient. Additionally we examine on parameters that affect the thrust energy and compensate the formula. The formula with the compensationis as follows.

$$\mathbf{E = E_1 + E_2 = \frac{m \times V^2}{2} + (\alpha V + \beta)} \qquad (5)$$

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