Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 [6] May 2014: 223-233

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

An analysis of Effective applying Parameters on the speed of Pneumatic Cylinders

Abbasali Taghipour Bafghi[1], Fateme Khodaei Chegeni[1], Ali Afrous[2]
Department of Mechanical Engineering, Dezful Branch, Islamic Azad University, Dezful, IRAN
Department of Water Engineering, Dezful Branch, Islamic Azad University, Dezful, IRAN
Email: taghipoor460@yahoo.com

ABSTRACT
In this paper, the effective factors on the speed of pneumatic cylinders and the effect of pneumatic cushions in speed and simulating cylinders by Fluid Sim software have been studied. It is necessary to mention that the compressibility of the compressed air causes oscillating and escalating movement in pneumatic cylinder and consequently resulting in a non-uniform movement. Here, based on the practical findings of the experiments solutions have been offered in order to prevent escalating movement in pneumatic cylinders.
Keywords: *pneumatic cylinder, Fluid Sim, damper, velocity*

Received 12.01.2014 Revised 25.03.2014 Accepted 12.04. 2014

INTRODUCTION

In pneumatic systems,actuators are used to change the energy of compressed air into mechanical work in which pneumatic cylinders change the energy of compressed air into a linear movement. During the piston movement in a cylinder, different factors such as enviromental, outlet load, friction, acceleration, process resistances and pressure affect the speed and performance of the cylinder [1]. Then, many designers add the real static load by %50 in order to make up for the additional resistances some of which are frequently changing during the cylinder movement. Fig.1, shows the relationship among the incoming pressure, load, speed and acceleration[2]. Actuation the power valve causes the movement of the cylinder in the 'going' phase, and at this point it can be observed that the amount of air is reduced with high pressure in the circular direction of the cylinder because of being added to the atmosphere. Similarly, the speed on the direction of cylinder piston changes to the direction of minimum pressure[2]. During this phase, the resisting power against movement is higher than the force of generating movement and then no movement is observed. When the situations are reversed and the force of generating movement is higher than the resisting power against the movement, the piston starts moving and reduces the acceleration. When the generating force and the resisting force are equal, the piston speed is fixed. When the piston arrives at the damping phase, the outlet air is limited and it inspires an increased pressure. This increased pressure disturbs the forces balance and reduces the piston acceleration. Damping is a requirement of pneumatic cylinder since absorbing the kinetic energy of a moving object damages the piston or its terminal plugs at the final stroke[3].

THE ANALYSIS OF CYLINDER SPEED

The necessity of determining the achievement of cylinder in a system can be very critical for the generating rate of a machine. In this analysis, a double-acting single-bar cylinder with a damper has been chosen which is controlled by a (2/3) direction control valve. To measure the complete stroke surveying, the cycle phases should be determined. These phases are:

Phase 1 (T_1)

The responding time of direction -control valve which can be determined by the technical specifications suggested by valve designers and is normally a fixed amount for a valve.

Phase 2 (T_2)
It is the necessary time to reach the damping phase of the cylinder and includes the necessary time for increasing enough pressure to overcome the friction resistance, loads inertia and accelerating forces. The load nature will be effective on T_2. After the phases of stance and acceleration, the monotonous speed depends absolutely on the feeding pressure and load situations. Anyway, in most cases when the feeding pressure exceeds 4 bars and the load is less than %50 of maximum thrust force of the cylinder in work pressure, a choking situation arises in the outlet process. Under these situations, the uniform speed of the cylinder is controlled only by the surface of the cylinder and the capability of directing outlet Port of valve (C_e).

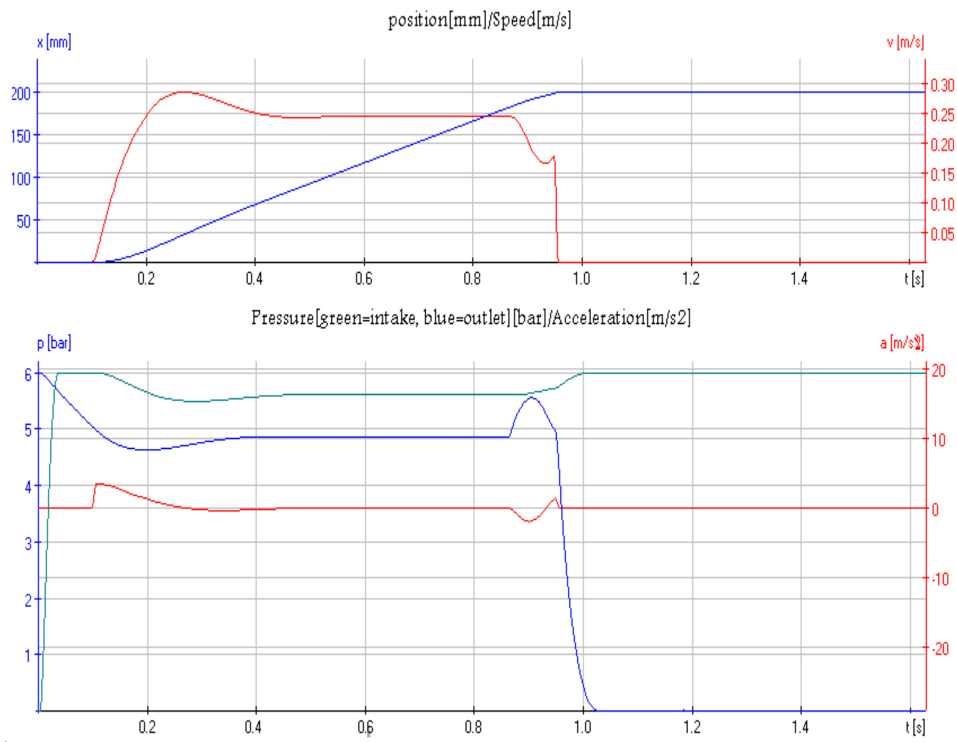


Fig. 1 The changes of pressure according to the time of 'going' in a double-sided cylinder

In order to measure T_2, it is better to act on the average speed of the cylinder[4].

$$V_{max} = \frac{10^3 C_e}{a} \tag{1}$$

$$V_{ave} = K.V \quad , \quad 0.5 < k < 1 \tag{2}$$

V_{max}: maximum velocity of cylinder (m/s), Ce: direction capability, a: the base surface of outlet cylinder (mm^2), K: constant amount.
In the general case, the coefficient 2/3 is selected. The necessary time(T_2) for reaching the cushion can be estimated by the following formula[4]. D: piston diameter (mm)

$$T_2 = = \frac{L - L_c}{\frac{2}{3} \times 10^6 \times \frac{c_e}{a}} \approx \frac{1.2(L - L_c)D^2}{C_e \times 10^6} \tag{3}$$

Although this amount is a relatively accurate amount of maximum speed of the piston, its achievement may not be possible at this speed because of the cushion specifications such as bounce, the overload pressures of the cushion, or absorbing forces at the end of absorbing phase.
We assume the kinetic energy of a related mass is lost considerably during the whole process of absorption. If the energy limit of the cushion is E, then we have[5]:

$$E = \frac{1}{2} m (V_{\max})^2$$
$$V_{\max} = \sqrt{\frac{2E}{m}} \qquad (4)$$

The new T_2 is calculated through the relationship [6].

$$T_2 = \frac{L - L_c) \times m^{1/2}}{10^3 \times 2/3 \times (2E)^{1/2}} = \frac{3(L - L_c)}{10^3 \times 2} \sqrt{\frac{m}{2E}} \qquad (5)$$

Considering the advanced absorbing cylinders, it can be assumed that the capability of the cushion energy, equal or bigger than %50 of maximum axiomatic force at the speed of 0.5 m/s[6] :

$$E = \frac{\frac{1}{2}(P \times A) \times V^2}{2g} \qquad (6)$$

$$E = \frac{\frac{1}{2}(P \times A) \times (0/5)^2}{2g}$$

$$E = \frac{\frac{1}{2}(P \times \pi D^2 \times (0/5)^2}{2g \times 4}$$

$$E = 5 \times 10^4 P \times D^2 \qquad (7)$$

P: feeding pressure (bar)

Then this is the amount of energy for the cylinder to 'return'. For the 'going' phase of the cylinder, the formula is justified this way:

$$E = 5 \times 10^4 P(D^2 - d^2) \qquad (8)$$

From (4) and (5) with justification of fixed amounts:

$$T_2 = 0/05 \times (\frac{L - L_c}{D}) \sqrt{\frac{m}{p}} \qquad (9)$$

$$T_2 = 0/05 \times (L - L_c) \sqrt{\frac{m}{p(D^2 - d^2)}} \qquad (10)$$

(9) and (10)equations show the shortest time for the load movement in the surveying stroke before starting absorption. So, these equations are used to determine the length of surveying.

Phase 3 (T_3)

It is the time spent in the cushion in the process of reducing acceleration. The amount V_i, is variable for each application of the cylinder and is set according to different loads to limit the shoke load. In the case of a cylinder which has a very light loading, the limiting speed factor can be considered as the intensity of the passing current through a completely open cushion. Then the specifications offered by the producer should be taken into consideration.

The equipment used in the experiments

The pneumatic cylinders used in the experiment are of the double-acting kind made by Festo Company. The cylinders diameters are 40, 160, 200, 250, and 320 mm. The inlet and outlet of cylinders have couplings and by using them the installation of tubes and air outlets is done easily. The air used in pneumatic system should be free of oil, humidity, and dust, according to the producing company. Then for this work, single- action one-cylinder compressor made by Profimaster has been used. SAE 30 oil is used for lubrication of compressor piston. Having passed through the compressed air in unit FRL, the air is ready to be used in pneumatic circuit. To join the air outlets from the unit of preparing and producing compressed air, tubes with 6 mm made by pneumatic baderan company have been used. In order to join pneumatic tubes to the reservoir, pneumatic divider has been used. To control the movement direction of pneumatic actuator from the directional control valve (DCV) made by Festo company was used. This valve has five ports and three positions (3/5).Changing the position is done manually. The five ports of the outlet include the compressor, (P) two discharge outlets, (T) and the actuators A, and B. To prevent the loud noise during the exit of compressed air, a muffler has been used in pneumatic circuit. In order to install the equipment, a framework like that in Fig. 2, is used. In this panel, horizontal bolsters with nips are used to hold the different parts of the pneumatic circuit. To determine the speed of pneumatic cylinder in each point of the path and also the maximum speed in the course of pneumatic cylinder a video cam is used on whose lens sensors different diodes are used and also function like a camera, fig. 3. To simulate the pneumatic cylinder and pneumatic circuit the Fluid Sim Software has been used. Having done the simulations, parameters such as velocity at the end of the path, (V), the average velocity (V_{ave}), the maximum velocity(Vmax), the time required for covering the stroke of pneumatic cylinder (t) and the amount of air used (Q) are extracted. Also, the software has the capability to draw the diagram of the pressure in front of the piston, velocity and acceleration based on time.

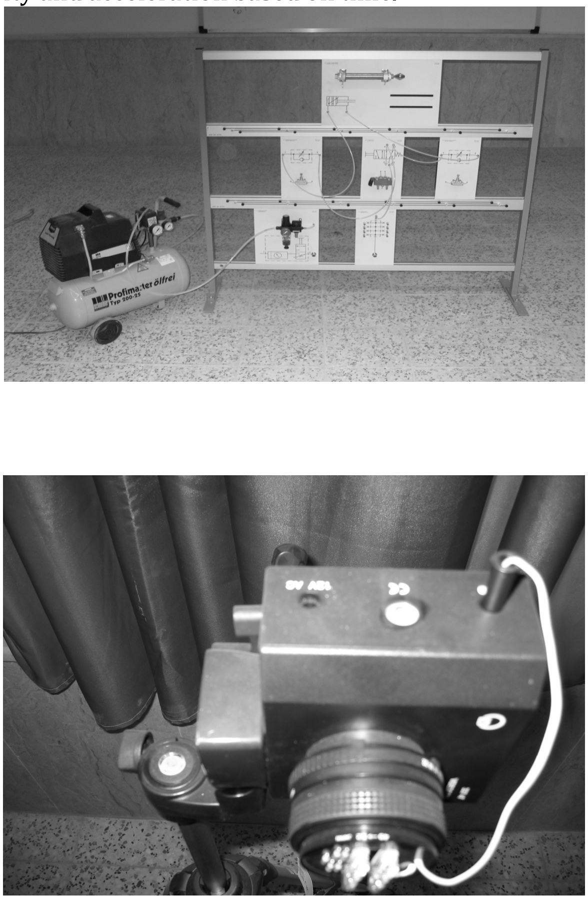


Fig. 3: Panel and Video cam

Procedure

After assemble the pneumatic circuit, the primary settings such as oil sprinkling, pressure, the way of setting the flow control valve(FCV) and balancing the camera of measuring velocity and also setting the proper distance of the camera from the pneumatic cylinder are done. By changing any independent parameter, the dependent parameter are analyzed based on the findings of simulation by the Fluid Sim software and also the obtained information from the velocity sensors. The assembled pneumatic circuit is according to fig. 4.

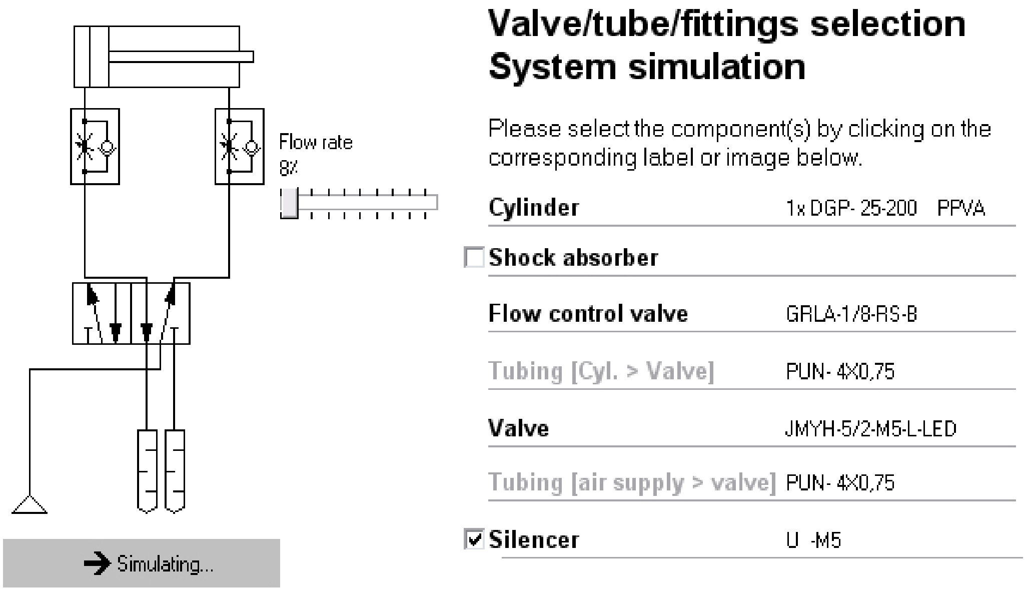


Fig. 4 the software function

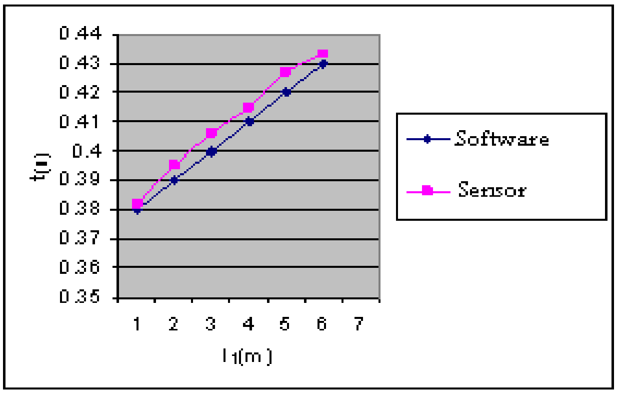
FINDINGS AND DISCUSSION

Surveying the effect of tube length on the functional parameters of pneumatic cylinder

In order to survey the effect of tube length from the unit of producing compressed air to the control valve (L_1) on the functional parameters of pneumatic cylinder for air tubes of different lengths the considered parameters were measured. The specifications of pneumatic circuit used in table I has been indicated. Fig. 5, also shows the diagram of tube length compared to the time of covering the path by pneumatic cylinder. As seen in the fig. 5,as the length increases, the time is also increased slightly. This time increase is because of the increase of air compressibility. Then it is suggested to pay attention to the length L_1 in designing pneumatic circuit in automation systems. In fig. 6 the effect of length L_1 is shown on the average velocity. As the length increase the average velocity decrease slightly. As we can see, the findings of the sensors in both fig. 5 and fig. 6 are lower than those resulted from the software which is because of more air leaking in the practical situation. The effect of cylinder velocity while stroking the cylinder floor (V_i) is also given in fig. 7 As the amount of V_i increase the probability of cylinder piston stroking its floor is highly increased. Then the importance of V_i is because of choosing the cushion in pneumatic cylinders (internal or external). According to fig. 7, as the length L_1 increases the velocity V_i is also increased. This can be justified this way that as L_1 increases the amount of compressed air increases at the beginning of the movement. Then, the compressed air causes pistons to accelerate at the end of the path and consequently the velocity (V_i) increase at the end of the path. Therefore it is advised when a weak cylinder or a cylinder without cushion is used in the automation system, the tube length should not be selected from the collection of preparing and producing the compressed air to the valve of direction control. In fig. 8, the effect of tube length L_1 on the maximum velocity throughout the course of pneumatic cylinder. As is seen, the maximum velocity remains fixed almost in all different lengths L_1. The air used does not show any difference as the tube length increase and almost in all situations the amount of air used has been 0.7221 liter. The reason why the air used is fixed is because the air used does not get out of the control valve of direction.

TABLE I
The specifications of pneumatic circuit for surveying the effect of length L_1

Parametr	MEASURE
L2	1000 mm
L	200 mm
D	40 mm
D1	6 mm
M	10 kg
P	6 bar
Flow rate	% 18
α	0



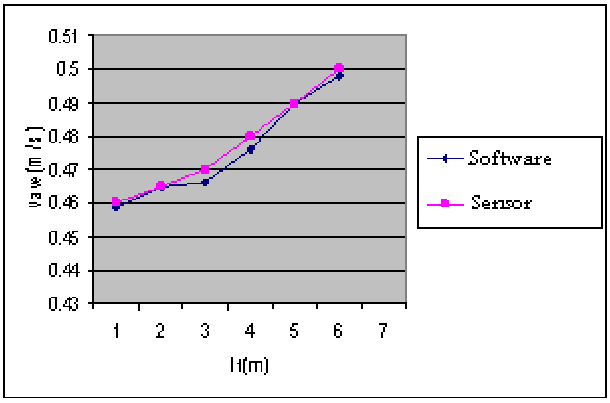


Fig. 5 and 6 The effect of the length L_1; The effect of the length L_1 on the average velocity

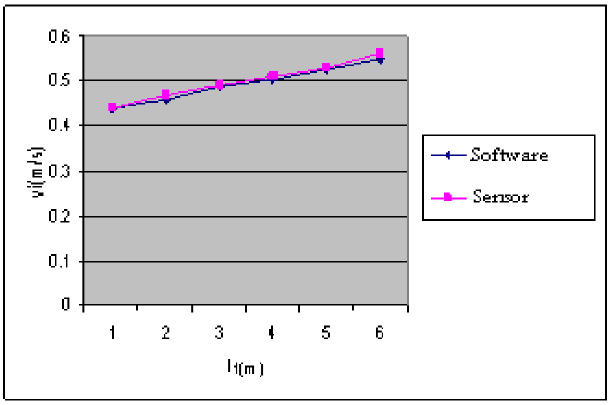


Fig. 7 The effect of the length L_1 on the average velocity V_i

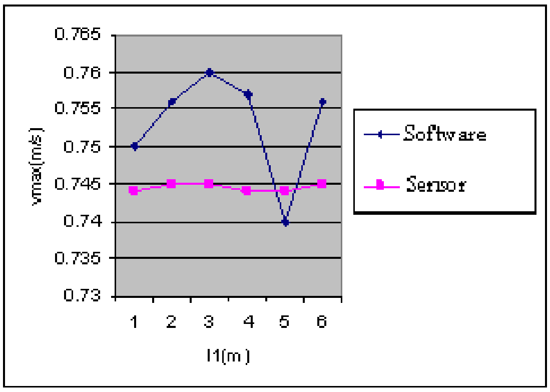


Fig. 8 The effect of the length L_1 on the V_{max}

The effect of tube length from directional control valve on pneumatic actuator

To survey the effect of tube length, from direction control valve (DCV) pneumatic actuator (L_2) on functional parameters of pneumatic cylinder for different lengths of air tube the desired parameters were measured. The findings of this experiment are given in table II. Fig. 9 shows the effect of tube length from the valve to the actuator according to the time of covering the distance. As is seen, with the increase in tube length (L_2) the time needed to cover the path is increased. Of course according to fig. 10, this increase is very slight. Also, compared with fig. 6, the length (L_2) shows less effect compared with L_1. In fig. 10, fig. 11, and fig. 12, the effect of the length L_2 on average velocity, maximum velocity and piston velocity at the end of the path are shown. Regarding the above figures, there is no considerable change in the velocity diagrams and the findings obtained from the simulation by Fluid Sim software show less differences compared with the findings obtained from the sensors. Fig. 13 shows the effect of used air according to L_2. As is seen, with the increase in tube length L_2 the amount of air used (Q) is also increased. With the increase in tube length, the amount of air compressed in the tubes increases and in the process of changing the position of this valve, the compressed air is released completely. It is necessary to mention that with the increase in the length L_1, there is no difference in the amount of air used, Fig. 14 shows the effect of the course on the time of covering the path, and certainly with the increase in the course, the time is also increased frequently. As we can see, in longer courses, we have longer time. In fact, with the increase in stroke, the volume of pneumatic cylinder gets bigger and consequently the amount of air compressed increases and this causes an increase in time. In this experiment, the amount of average velocity, maximum velocity at the end of the path are fixed. They are 0.52 and 0.34 m/s respectively. As most parameters remain fixed the amount of used air increases with the increase in the course. This increase is logical and the increase in the volume of the cylinder is the reason for this increase in the course and this volume is filled and emptied because movement (fig. 15).

TABLE II
The specifications of pneumatic circuit for surveying the effect of length L2

Parametr	MEASURE
L_1	1000 mm
L_2	1 mm
D	40 mm
D_1	6 mm
M	10 kg
P	6 bar
Flow rate	% 18
α	0

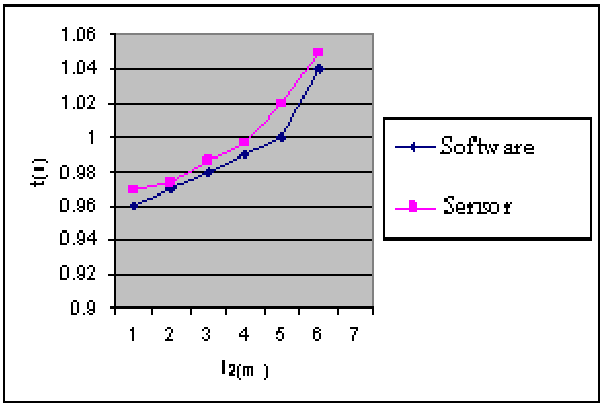


Fig. 9 The effect of the length L_2 on the Time

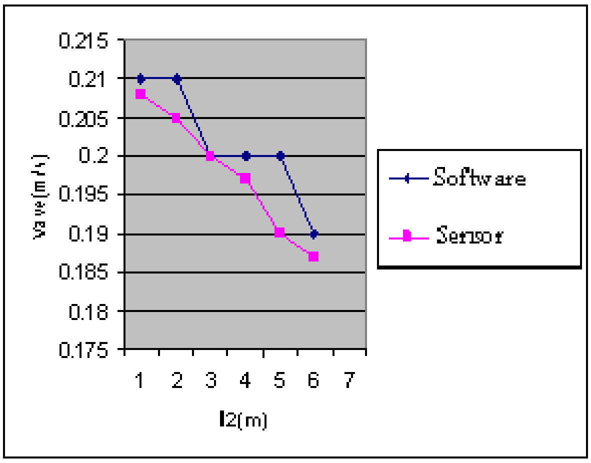


Fig. 10 The effect of the length L_2 on the average velocity

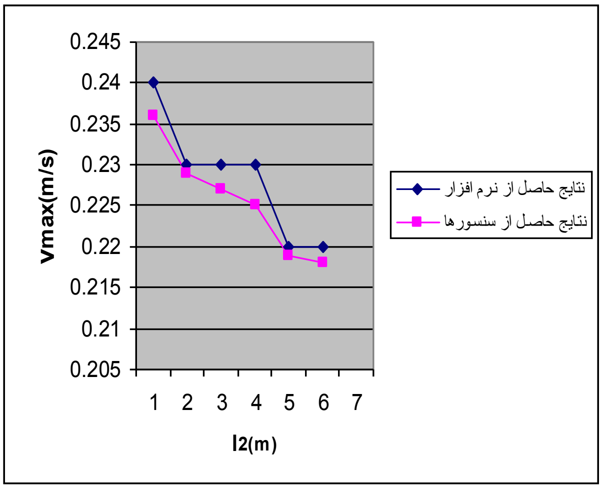


Fig. 11 The effect of the length L_2 on the V_{max}

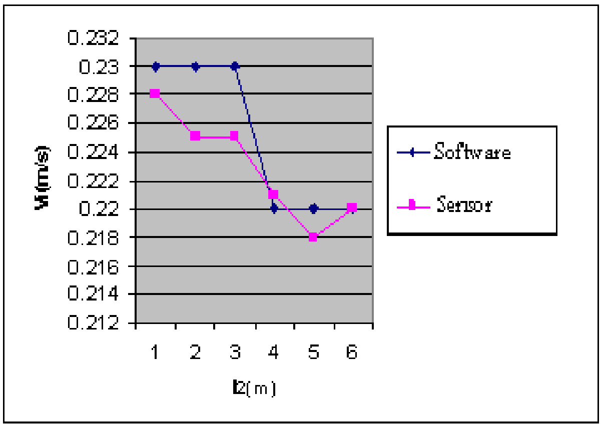


Fig. 12 The effect of the length L_2 on the V_i

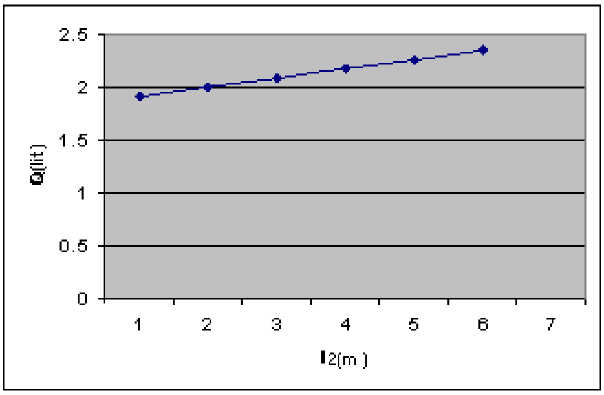


Fig. 13 The effect of length L_2 on the amount of air used

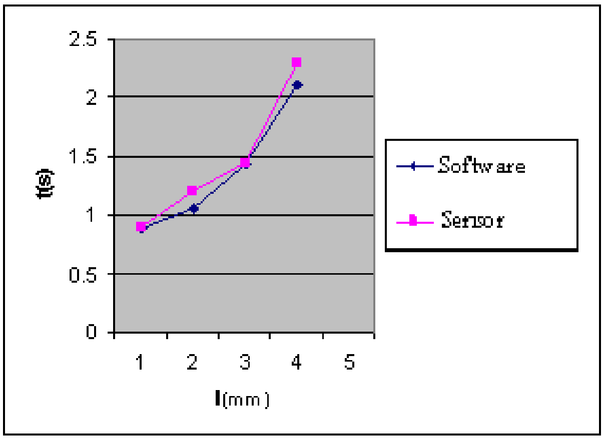


Fig. 14 the effect of the course on the time of covering the path

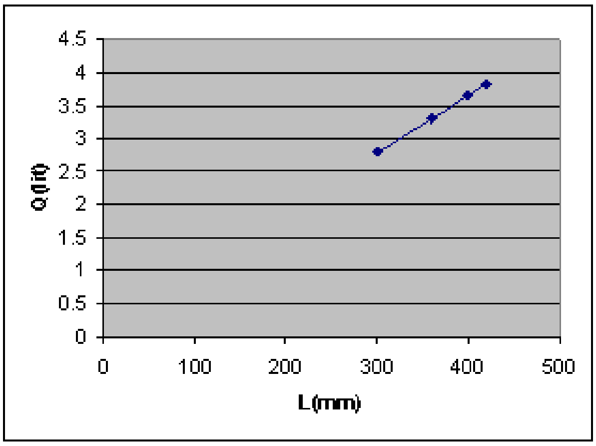


Fig. 15 The effect of the course on the amount of air used

CONCLUSION

As seen in the fig. 5,as the length increases, the time is also increased slightly. This time increase is because of the increase of air compressibility. Then it is suggested to pay attention to the length L_1 in designing pneumatic circuit in automation systems. As the length increase the average velocity decrease slightly. As we can see, the findings of the sensors are lower than those resulted from the software which is because of more air leaking in the practical situation. As the amount of V_i increase the probability of cylinder piston stroking its floor is highly increased. Then the importance of V_i is because of choosing the cushion in pneumatic cylinders (internal or external). According to exprimentals. as the length L_1 increases the velocity V_i is also increased. This can be justified this way that as L_1 increases the amount of compressed air increases at the beginning of the movement. Then, the compressed air causes pistons to accelerate at the end of the path and consequently the velocity (V_i) increase at the end of the path. Therefore it is advised when a weak cylinder or a cylinder without cushion is used in the automation system, the tube length should not be selected from the collection of preparing and producing the compressed air to the valve of direction control. As is seen, the maximum velocity remains fixed almost in all different lengths L_1. The air used does not show any difference as the tube length increase and almost in all situations the amount of air used has been 0.7221 liter. The reason why the air used is fixed is because the air used does not get out of the control valve of direction.

As is seen, with the increase in tube length (L_2) the time needed to cover the path is increased. Of course according to fig. 10, this increase is very slight. Also, compared with fig. 6, the length (L_2) shows less effect compared with L_1. In fig. 10, fig. 11, and fig. 12, the effect of the length L_2 on average velocity, maximum velocity and piston velocity at the end of the path are shown. Regarding the above figures, there is no considerable change in the velocity diagrams and the findings obtained from the simulation by Fluid Sim software show less differences compared with the findings obtained from the sensors. Fig. 13 shows the effect of used air according to L_2. As is seen, with the increase in tube length L_2 the amount of air used (Q) is also increased. With the increase in tube length, the amount of air compressed in the tubes increases and in the process of changing the position of this valve, the compressed air is released completely. It is necessary to mention that with the increase in the length L_1, there is no difference in the amount of air used, Fig. 14 shows the effect of the course on the time of covering the path, and certainly with the increase in the course, the time is also increased frequently. As we can see, in longer courses, we have longer time. In fact, with the increase in stroke, the volume of pneumatic cylinder gets bigger and consequently the amount of air compressed increases and this causes an increase in time. In this experiment, the amount of average velocity, maximum velocity at the end of the path is fixed. They are 0.52 and 0.34 m/s respectively. As most parameters remain fixed the amount of used air increases with the increase in the course. This increase is logical and the increase in the volume of the cylinder is the reason for this increase in the course and this volume is filled and emptied because movement (fig. 15).

REFERENCES

1. Kosaki, T.; Sano, M.(2000). Analytical and experimental study of chaotic oscillation in a pneumatic cylinder. www.sys.cs.hiroshima cu.ac.jp.
2. Belforte G.; RAPARELLI,T.; Velardocchia, M.(1993). Study of the behavior of lip seals in pneumatic actuators. J. Tribologists and Lubrication Enginners, Vol. 49, No. 10, pp.775-780.
3. Schroeder, L. E.; Singh, R.(1993). Experimental study of friction in a pneumatic actuator at cinstant velocity. ASME J. Dynamic systems, Measurement, and Control, Vol. 115, pp.575-577.
4. Kawakami, Y,; Noguchi, H.; Kawai, S.(1990). Some Considerations on the High-Speed Driving of Pneumatic Cylinders. Journal of JHPS, Vol. 21, No. 3, pp. 124-130.
5. Ott, E.(1981). Strange attractors and chaotic motions of dynamical systems. Reviews of Modern Physics, Vol. 53, No, 4, pp. 655-671.
6. Wolf, A,; Swift, J.B.;Swinny, H.L.(1985). Determining Lyapunov exponents from a time series. Physica, Vol. 16D, pp. 285-317.