PNEUMATIC DRIVING IN MATERIAL HANDLING SYSTEMS

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Abstract. Pneumatics is one of the most used systems in these days. Today equipment and system use this type of actuating because it is a very safe, economic and ease to implement. Another advantage that recommends this type of actuating is the reduced loss of heat during the actuating process. Material handling systems are characterised by repetitive movements, speed and displacement control and precision, requirements that recommend pneumatics driving. The present paper is focused on pneumatics used in material handling system, underling the limitation or the specific application of concrete actuators.

Keywords: material handling, Matlab, pneumatics, simulation

1. Introduction

The operating rate of workstations corresponds to the production rate of the plant. This basic principle of automated mass production has shaped the appearance of modern factories: a continuous flow of products that moves as if by magic from one station to the next, before being despatched at the end of the production process.

A wide range of industrial applications require substances, objects, or components to be moved from one location to another. A further typical requirement is the application of a force to locate, hold, shape, or compresses a component or material. These tasks can be achieved using a prime mover, with rotary motion being provided, for example by an electric motor and linear motion by screw jacks, rack and pinions, and solenoids. Liquids and gases can also be used to convey energy from one location to another and as a result produce rotary and linear motions and apply forces. Fluid based systems using a liquid as the transmission media are known as hydraulic, and those using a gas are known as pneumatic [1].

The pneumatic cylinder has a significant role as a linear drive unit, due to its [2]:
– relatively low cost;
– ease of installation;
– simple and robust construction;
– ready availability in various sizes and stroke lengths.

The pneumatic cylinder has the following general characteristics:
– diameters: 2.5 to 320 mm;
– stroke lengths: 1 to 2000 mm;
– available forces: 2 to 45 kN at 6 bar pressure;
– piston speed: 0.1 to 1.5 m/s.

Not always the new tendencies in technical application are the most appropriate. Sometimes, the “fashion” is used only because the firms want to be considered modern. The present paper validates, through simulation, the application for which some concrete pneumatic components are appropriate.

2. Material handling driving characteristics

According to the literature [3], mechatronic drive solutions can be divided into twelve groups. These groups are focused based on main function that appears in material handling solutions. Thus:

1) Transport function determines the following drives solutions:
– *conveyor drives* are stationary systems for the transport of material;
– *travelling drives* move with the vehicle and the material to be conveyed;
– *hoist drives* move objects against the force of gravity;
– *positioning drives* place work pieces and tools at precisely defined positions;
– *coordinated drives* for robots and materials handling move objects in space using multi-axis kinematics.

2) Continuous operation or fast cycles in production lines use:
– *synchronised drives* move materials in a production line;
– *winding drives* feed the process with materials which have been wound up to form a coil in order to save space or rewind them at the end of the process;
– *intermittent drives* for cross cutters and flying saws single out the materials on a process line;
– *drives for electronic cams* are used for a large number of non-linear motions for machining steps.

3) Change the work piece function determines:
– *drives for forming processes* are used, for example, on presses and extruder;
– *main drives and tool drives* drive entire machines

as principal drives or execute metal-cutting machining processes.

4) Conveyance of liquid and gaseous function implies:

– *drives for pumps and fans,* which are used for conveying liquids and gases and are often found in process engineering, in the infrastructure of buildings and factories, as well as in auxiliary units of production machines and systems.

Because the present papers is focused on pneumatic actuating used in material handling, in the following there are presented the main parameter for the equipment that may use pneumatic instead electric drive. Thus, based on literature [3], there are presented (Table 1) the parameters for some conveyors, travelling equipment, hoists. The parameters regard the power, speed and throughput offered by the actual systems.

Table 1. Parameters for existing material handling equipment [3]

Equipment	**Speed**	**Material conveyed**	**Throughput**	**Power/ drive [kW]**
CONVEYORS				
Bulk materials				
Belt conveyors	≤ 4m/s	–	≤ 1,600 t/h	≤ 200
Chain bucket elevator	Chains: 0.5–1.5m/s Belt: 0.6–4m/s	–	≤ 1,700 m^3/h	≤ 100
Chain conveyors	0.5–1.5m/s	–	≤ 1,000 t/h	≤ 130
Unit loads (bins b, pallets p)				
Chain conveyors	0.1–0.5m/s	p: ≤ 1,250 kg	≤ 1,200 p/h	≤ 2.2
Belt conveyors	0.5–2.0 (6.0)m/s	b: ≤ 50 kg; p: ≤ 1,250 kg	≤ 1,000 b/h ≤ 1,000 p/h	≤ 3
Belt ejectors	0.1–0.9 m/s	b: ≤ 50 kg	≤ 2,000 b/h	≤ 0.25
Pop-up ejectors	0.5–1.2m/s	b: ≤ 50 kg	≤ 3,500 b/h	≤ 0.25
Tilt tray conveyors	0.5–2.5m/s	≤ 60 kg	≤ 12,000 pcs./h	≤ 3
TRAVELLING EQUIPMENT				
Rail vehicles	100 m/min	100 t		≤ 150
Monorail overhead conveyors	130 m/min	5 t		5
Overhead cranes and gantry cranes	200 m/min	≤ 200 t		≤ 500
HOIST				
Storage and retrieval units	120 m/min	10 t		5–150
Cranes/winches	200 m/min	150 t		1–120
Belt lifters	110 m/min	2.2 t		10–37
Platforms	120 m/min	1.5 t		5–22
Elevating platforms	10 m/min	10 t		2–15

3. Pneumatic actuating and material handling systems

The most used pneumatic actuator in material handling applications is the pneumatic cylinder, especially the double-acting cylinder.

In the last years, researchers, tried to prove that a replacement of the cylinder is the pneumatic muscle, that may be used in almost all application dominated by the pneumatic cylinder.

The present paper presents, based on simulations done in Matlab-Simscape, some possible material handling applications for both pneumatic cylinder and muscle.

3.1. Double-acting pneumatic cylinder

Simulation diagram of a double-acting pneumatic cylinder is presented in Figure 1. The simulations were done based on data sheet for DSNU-20-100-PPV-A cylinder from Festo [4].

The inputs were pressures into the chambers (Figure 2) and outputs were considered the position, speed and force.

There were done three types of simulations for three different functioning situations (input signal characteristic): idling function, loaded at constant 100 N and loaded at variable force (0 to 100 N).

These situations are characteristics to material handling systems. For example: for dosing function (Figure 3) the load either exists or not; for local storage function (Figure 4) the load increase from zero to maximum.

The system reacts instantaneously as effect of the inputs signals: piston advances when chamber A is fed (at 1 s time) and retracts when chamber B is fed (at 4 s time). The results of the simulations are presented in Table 2.

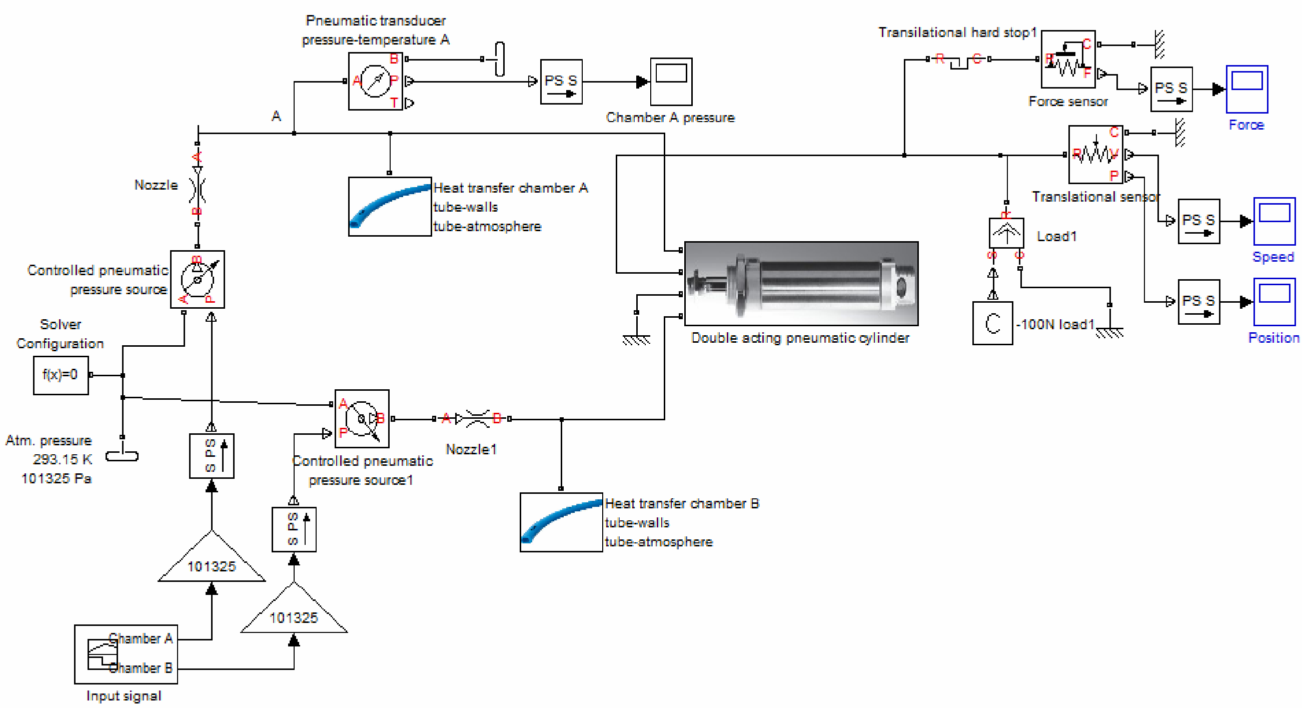

Figure 1. Simulation diagram of double-acting pneumatic cylinder

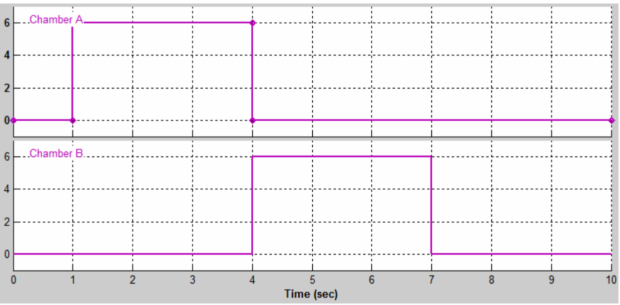

Figure 2. Input signals (pressure in the two chambers of the cylinder)

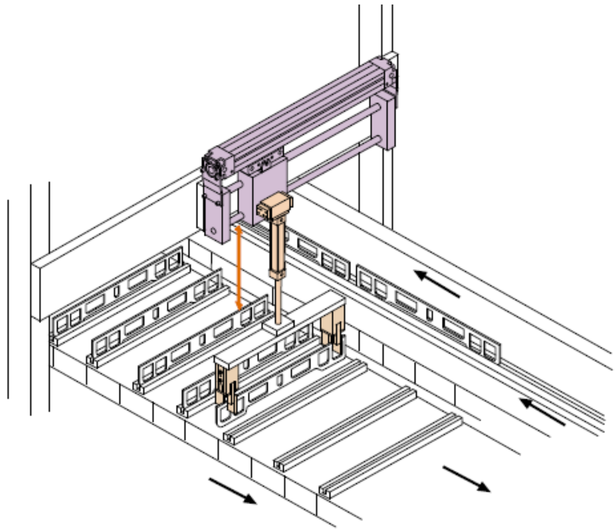

Figure 3. Pick-and-place system – load is either zero or maximum, equal to the mass of manipulated object [5]

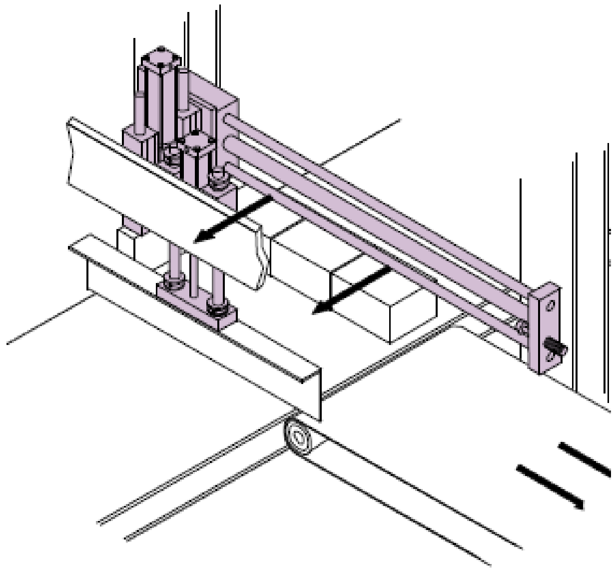

Figure 4. Accumulating function – load varies from zero to maximum [5]

3.2. Pneumatic muscle

Simulation diagram of a pneumatic muscle is presented in Figure 5. The simulations were done based on data sheet for MAS-20-750N-AA-MC-O-ER-BG pneumatic muscle from Festo [6].

The inputs were pressure (constant at 6 bar) and load (variable from 0 to 1000 N) and the outputs were the position, speed and force. To validate the simulation it can be analysed the displacement that varies between –0.04 m and 0.02 m, equivalent to a 60 mm stroke. For the simulated muscle, according to the data sheet the nominal length is 247 mm and the stroke (which is maximum 25% from nominal length) will be maximum 61.5 mm. or the situation of variable load the results of the simulations are:

– positioning times for inflating and deflating situations: t_{pi} = 26.1 ms and t_{pd} = 40.2 ms;
– rise-drop times: t_r= 50.1 ms and t_d = 67.1 ms;
– complete inflating/deflating times: t_{ci} =50.1 ms and t_{cd} = 113.2 ms.

4. Conclusion

There are many comparing points of view regarding the two actuating systems: stiffness, stroke, costs, force, speed, etc. In the present paper there are compared from stroke, dynamic parameters of simulation and force point of view.

Thus, in Table 3 are presented characteristics of the two actuating systems: the advance/ retreat times and strokes. Even if, from force point of view the results are in favour of the muscle, the dynamic behaviour for the maximum force is less performing (higher increase times, higher overshoot).

Table 2. Simulation results for three functional situations

IDLE FUNCTIONING	
maximum displacement	100 mm
advance time, $t_{advance}$	71.8 s
retreat time, $t_{retreat}$	112.5 s
advance speed, $v_{advance}$	1.54 m/s
retreat speed, $v_{retreat}$	1.369 m/s
advance force, $F_{advance}$	190.5 N
retreat force, $F_{retreat}$	179 N
CONSTANT LOAD: 100 N	
maximum displacement	100 mm
advance time, $t_{advance}$	78.8 s
retreat time, $t_{retreat}$	136 s
advance speed, $v_{advance}$	0.8 m/s
retreat speed, $v_{retreat}$	1.715 m/s
advance force, $F_{advance}$	91 N
retreat force, $F_{retreat}$	279 N
VARIABLE LOAD: 0 – 100 N	
maximum displacement	100 mm
advance time, $t_{advance}$	72.4 s
retreat time, $t_{retreat}$	112 s
advance speed, $v_{advance}$	1.52 m/s
retreat speed, $v_{retreat}$	1.389 m/s
advance force, $F_{advance}$	$188_{t=1.09} – 91_{t=4}$ N
retreat force, $F_{retreat}$	$183_{t=4.125} – 279_{t=7}$ N

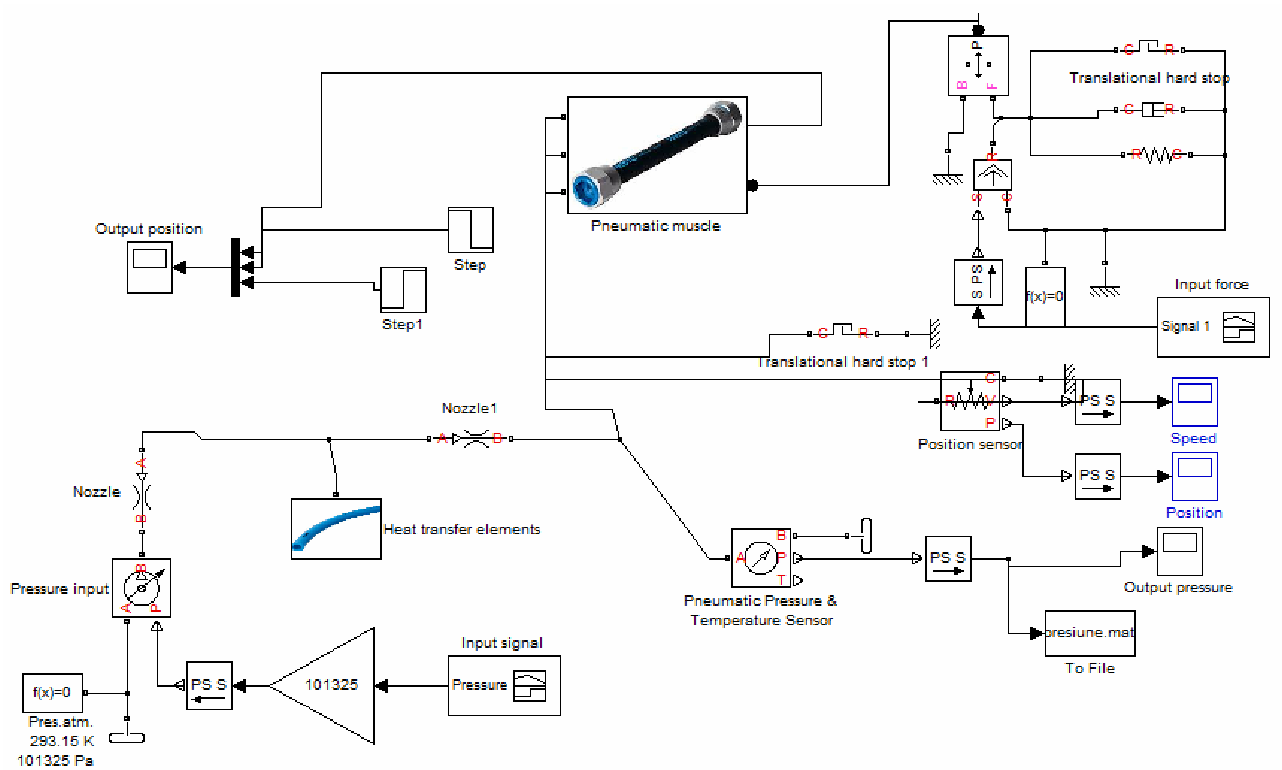

Figure 5. Simulation diagram of a pneumatic muscle

Based on the above values it can be determined work rate for each actuating system and thus, choose the appropriate material handling applications.

Thus, for double-acting pneumatic cylinder there are the following parameters:

– workrate: 5.426 Hz;
– maximum load: 189 N;

– maximum simulated load for which the system is steady-state: 100 N;
– maximum stroke: 100 mm.

Table 3. Advance/retreat times

Actuating system	Time
Double-acting pneumatic cylinder	$t_{advance}$ = 71.8 ms $t_{retreat}$ = 112.5 ms maximum stroke: 100 mm
Pneumatic muscle	$t_{inflating}$ = 26.1 ms $t_{deflating}$ = 40.2 ms maximum stroke: 61.75 mm

For such an actuator an example of material handling application is loading/ feeding systems for machine tools. In Figure 6 is presented such an example for which both advance and retreat movements must be controlled, the advance is high speed movement (is done without piece) and the retreat is the positioning movement (done with the piece) so is low speed one. The system is used in mass and large series production systems.

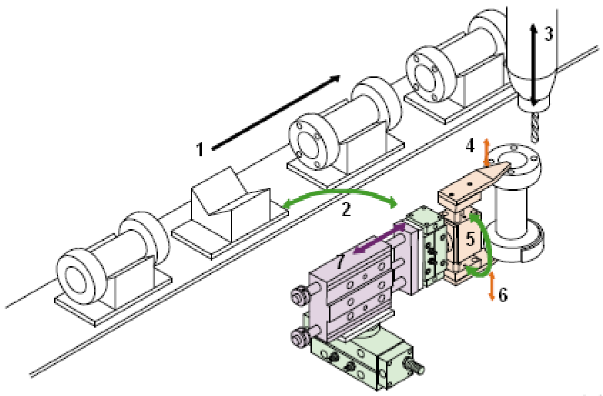

Figure 6. Mass/large series production system actuated by a pneumatic cylinder (movements 4÷7) [5]

In the case of pneumatic muscle the parameters are:
– workrate: 15.083 Hz;
– maximum load: 630 N;
– maximum simulated load for which the system is steady-state: 1000 N;
– maximum stroke: 61.75 mm.

Unfortunately, in this case, because of the high hysteresis, the system is less steady-state than the pneumatic cylinder.

For this actuating system a possible material handling application is that of a system where required force and rate is high, but not a high positioning precision. Such an example is presented in Figure 7 (a punch in mass/ large series production system).

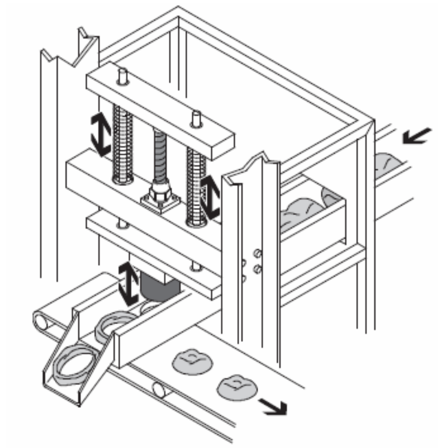

Figure 7. Mass/large series production system actuated by pneumatic muscle [5]

The above results may be improved if there will be implemented the pneumatic control (based on directional valve) and the electronic control (the most used controller being the PID one). Even in these cases, it cannot be concluded that the pneumatic actuating is appropriate for all the systems similar to those from Figures 6 and 7. This is because the pneumatic systems are more difficult to be control (to be able to achieve the desired position on a specific time and the repeatability accuracy of this movement).

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