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Pneumatic actuator speed control

(This document is written with rotary actuators in mind; however, many of the principles also apply to linear actuators.)

Speed regulation of pneumatic actuators can be required for many different reasons. These include the prevention of damage caused by sudden surges in pipeline pressure (water hammer), improving the performance of control loops and ensuring that control sequences are carried out in a timely manner.

There are many factors which affect speed of response, all of which vary with actuator type and size.

The most significant factors to affect actuator operating times are:

a) The relationship between output torque and valve torque
b) Supply pressure and capacity of the compressor and its associated piping
c) Air consumption or swept volume of the actuator chambers
d) Double acting or spring return design
e) Flow restrictions both external and internal to the actuator
f) Friction within the actuator

a) The relationship between output torque and valve torque.

It is essential to select an actuator which has sufficient torque to operate the valve but which is not too large, having the potential to shear the valve stem. In the extreme case if the torque of the actuator matches exactly the torque of the valve, the actuator will not move. As the differential increases the speed of operation increases, although the rate of increase is limited by the rate at which of air can be displaced from the actuator.

b) Supply pressure and capacity of the compressor and its associated piping

The torque output available from a double acting actuator (or from the air stroke of a spring return actuator) will increase as supply pressure increases. If the torque requirement exceeds the requirement of the valve (see "a" above) speed should increase with increasing torque.

c) Air consumption or swept volume of the actuator chambers

As actuator size increases the volume of compressed air in the chambers increases. If air is displaced from a range of actuators at a constant rate then smaller units will operate faster than larger ones.

d) Double acting or spring return design

With rack and pinion double acting actuators the swept volume increases in proportion to the increase in torque e.g. an actuator developing 270 Nm of torque @ 5.5bar.g will consume twice the volume of air of an actuator developing 135Nm @ 5.5bar.g.

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If one now considers a spring return actuator, at the start of stroke approximately 60 - 70% of the force generated by the compressed air is required to compress the springs. As a consequence, to develop the same torque as a double acting actuator at the valve stem, the actuator has to be 2.5 - 3.0 times larger with a corresponding increase in air consumption. If air is displaced from a range of actuators at a constant rate then a double acting actuator will operate faster than a spring return actuator with an equivalent seating torque.

e) Flow restrictions both external and internal to the actuator.

Having arrived at an actuator type and size which is appropriate for the valves requirements, the next limiting factor to speed of operation is how quickly compressed air can be evacuated from the actuator chamber(s). The speed at which this happens is affected by the opposing forces acting on the actuator pistons and the size of ports both internal and external to the actuator.

Pressure acting on the piston of a double acting actuator, forcing air from the opposing chambers, is constant throughout the stroke whereas with a spring return actuator the spring force at the end of stroke is usually half the force of that available at the start of stoke. This significant drop of in force reduces the speed of closure dramatically over that of an equivalent double acting unit.

Air entering and leaving an actuator passes through piping, connecting ports and along internal flow channels all of which offer a restriction to flow. Often the internal porting has a greater effect than the size of the connecting ports. E.g. increasing the size of pneumatic connection from G1/4" to G1/2" has little effect if, within the actuator, the passage of flow to the chambers is through 6mm diameter holes. As there are no standards for actuator design other than the mounting and drive format, such features vary from manufacturer to manufacturer and are often not accounted for in a 'standard product'. It is only when a 'high speed' version is requested that such factors are considered.

Valves external to the actuator often contribute significantly to speed of operation. Solenoid control valves can either be located at the actuator (Namur mounted or in an integrated switch solenoid control centre) or remotely in a panel. The air in the piping has to be vented during one of the actuator strokes. As the volume of air in the interconnecting piping is greater when the solenoid is located remotely, the actuators will take longer to operate than if the solenoid is located at the actuator.

f) Friction within the actuator.

All being equal this should have a minimal effect, if any, on the speed of response. However, factors such as dry O-ring seals, excessive side loads on bearings caused by actuator/valve misalignment and tight meshing of rack and pinion gears can all affect speed of operation.

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Increasing actuator speed

Valves external to the actuator often contribute significantly to speed of operation. The flow coefficient (“Cv”) of a solenoid control valve determines the flow rate through both the supply and exhaust ports and has to be selected accordingly. For small to medium sized rack and pinion actuators a “Cv 0.3” is usually adequate, larger units may require a “Cv 0.5” or greater. High “Cv” quick exhaust 'dump valves' can be used with fail safe actuators so that exhausting air from the cylinder is dumped directly to the atmosphere. The resulting decrease in back pressure causes the actuator to move much faster. However, even with a dump valve fitted, the speed may be restricted by the size of port on the spring chamber vent port of the actuator. Too small a vent port may slow the flow of air into the spring chamber causing a vacuum effect which will slow the actuator.

Reducing actuator speed

The simplest method of reducing the speed of a pneumatic actuator is to install a variable orifice flow control valve in the exhaust port(s) of the actuator, of the solenoid control valve or in the exhaust piping. Flow control valves are usually a combination of an adjustable needle valve controlling the flow in one direction and a check valve to allow the full flow of air around the needle valve in the other direction. It is better to regulate the exhaust rather than the inlet flow because varying frictional forces in the valve and actuator may cause jerky, erratic movement, especially at low speeds. Using flow controls in the inlet to the actuator will accentuate the problem due to the slow, uncontrollable build up of air pressure behind the piston. Installing flow control valves in the exhaust port of the actuator will allow the incoming air to build to full pressure, minimising the small frictional fluctuations, thus reducing the tendency for irregular motion.

Different opening and closing times for the same actuator

Combining the techniques detailed above will allow the same actuator to operate at different speeds in each direction. Furthermore it is possible to extend this further with a three position control system. E.g. Actuator might be required to open in less than 3 seconds and then move from open to 50% open in 5 seconds and then from 50% open to closed in 20 seconds.

Conclusion

Taking into account all of the above there is not a precise formula available to determine actuator operating speed. Manufacturers are therefore reluctant to give exact figures and will usually state that times are “typical” and should only be treated as a guide.

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