Lecture 37

PNEUMATICS ACTUATORS

Learning Objectives

Upon completion of this chapter, Student should be able to

- Explain the meaning of Pneumatic Actuator
- Classify the various types of Pneumatic actuators
- Explain the working of various pneumatic actuators
- Understand the importance of cushioning
- Study the seals used in the Pneumatic actuators
- Understand the working of rodless cylinders
- List advantages and disadvantages of various cylinder mounting
- Study the effect of buckling in cylinders
- Explain the various lever systems used with pneumatic cylinders
- List the various applications of different lever systems using actuators
- Explain the working of limited angle rotary actuators.
- Explain the working and application of air motors

1.1 PNEUMATICS ACTUATORS

Pneumatic actuators are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work. In other words, Actuators are used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston. The pressurised air from the compressor is supplied to reservoir. The pressurised air from storage is supplied to pneumatic actuator to do work.

The air cylinder is a simple and efficient device for providing linear thrust or straight line motions with a rapid speed of response. Friction losses are low, seldom exceeds 5 % with a cylinder in good condition, and cylinders are particularly suitable for single purpose applications and /or where rapid movement is required. They are also suitable for use under conditions which preclude the employment of hydraulic cylinders that is at high ambient temperature of up to 200 ℃ to 250 ℃

Their chief limitation is that the elastic nature of the compressed air makes them unsuitable for powering movement where absolutely steady forces or motions are required applied against a fluctuating load, or where extreme accuracy of feed is necessary. The air cylinder is also inherently limited in thrust output by the relatively low supply pressure so that production of high output forces can only be achieved by a large size of the cylinders.

1.2 TYPES OF PNEUMATICS ACTUATORS

Pneumatic cylinders can be used to get linear, rotary and oscillatory motion. There are three types of pneumatic actuator: they are

i) Linear Actuator or Pneumatic cylinders
ii) Rotary Actuator or Air motors
iii) Limited angle Actuators

1.2.1 Types of Pneumatic cylinders /Linear actuators

Pneumatic cylinders are devices for converting the air pressure into linear mechanical force and motion. The pneumatic cylinders are basically used for single purpose application such as clamping, stamping, transferring, branching, allocating, ejecting, metering, tilting, bending, turning and many other applications.

The different classification scheme of the pneumatic cylinders are given below

1. Based on application for which air cylinders are used

i) Light duty air cylinders

ii) Medium duty air cylinders

iii) Heavy duty air cylinders

2. Based on the cylinder action

i) Single acting cylinder

ii) Double acting cylinder

- Single rod type double acting cylinder
- Double rod type double acting cylinder

3. Based on cylinder's movement

i) Rotating type air cylinder

ii) Non rotating type air cylinder

4. Based on the cylinder's design

i) Telescopic cylinder

ii) Tandem cylinder

iii) Rod less cylinder

- Cable cylinder,
- Sealing band Cylinder with slotted cylinder barrel
- Cylinder with Magnetically Coupled Slide

iv) Impact cylinder

v) Duplex cylinders

vi) Cylinders with sensors

1.2.1.1 Based on application for which air cylinders are used

Air cylinders can be classified according to their intended use, as light duty, medium duty or heavy duty types. In the main this merely governs the strength of the cylinder, and thus typical choice of material of construction and the form of construction. Comparison is given in Table 1.1. It should be noted that classification by duty does not necessarily affect the output performance of the cylinder, as bore size for bore size; identical cylinder diameter will give the same thrust on the same line pressure, regardless of whether the cylinder is rated for light, medium or heavy duty. This form of rating , however, normally precludes the use of light classification for cylinders of large size (and thus high thrust) ; and medium classification for cylinders of even large size and very high thrust outputs.

All plastic construction has the advantage of being inherently free from corrosion and similar troubles but, in general is limited to smaller cylinder sizes and light duty applications. As originally introduced they were intended to provide low cost cylinders for light duty work , and where rigidity of the unit was not an important factor. The development of all-plastic cylinders for higher duties tends to nullify any cost advantage and the types has not, as yet, achieved any particular prominence, although the potentialities remain for corrosion- resistant duties.

Force limitation with air cylinders are purely matter of size and cost. Since line pressures available are usually very much lower than pressure common in hydraulic circuits, air cylinder must be very much larger in diameter than the hydraulic cylinders for the same thrust performance. Where a very high force is required the cost of the suitable size of air cylinder may work out at more than the cost of a complete hydraulic system to do the same job. In addition the cost of the compressed air feed such cylinders could also be prohibitive.

Table 1.1: Materials of construction for light, medium and heavy duty cylinders

Components	Type of cylinder		
	Light duty	**Medium duty**	**Heavy duty**
Cylinder tubes	Hard drawn seamless aluminium or brass tubes Plastics	Hard drawn seamless brass tubes Aluminium , brass, iron or steel castings	Hard drawn seamless tubing , brass , bronze, iron or steel casting
End covers	Aluminium alloy castings Fabricated aluminium , brass , bronze	Aluminium brass, bronze, iron or steel castings, fabricated brass, bronze,	High tensile castings
Pistons	Aluminium alloy castings	Aluminium alloy castings, Brass, cast iron	Aluminium alloy castings, Brass, cast iron
Piston rods	EN 8 or similar steel ground and polished or chrome plated	EN 8 steel, ground and polished or chrome plated. Ground and polished stainless steel	Ground and polished stainless steel
Mounting brackets	Aluminium alloy casting	Aluminium,brass,iron castings	High tensile castings or fabricated

1.2.1.2 Based on the cylinder action

Based on cylinder action we can classify the cylinders as single acting and double acting. Single acting cylinders have single air inlet line. Double acting cylinders have two air inlet lines. Advantages of double acting cylinders over single acting cylinders are

1. In single acting cylinder, compressed air is fed only on one side. Hence this cylinder can produce work only in one direction. But the compressed air moves the piston in two directions in double acting cylinder, so they work in both directions
2. In a single acting cylinder, the stroke length is limited by the compressed length of the spring. But in principle , the stroke length is unlimited in a double acting cylinder
3. While the piston moves forward in a single acting cylinder, air has to overcome the pressure of the spring and hence some power is lost before the actual stroke of the piston starts. But this problem is not present in a double acting cylinder.

A) **Single acting cylinders.**

Single acting cylinder has one working port. Forward motion of the piston is obtained by supplying compressed air to working port. Return motion of piston is obtained by spring placed on the rod side of the cylinder. Schematic diagram of single acting cylinder is shown in Figure 1.1

Single acting cylinders are used where force is required to be exerted only in one direction. Such as clamping, feeding, sorting, locking, ejecting, braking etc.,

Single acting cylinder is usually available in short stroke lengths [maximum length up to 80 mm] due to the natural length of the spring. Single Acting Cylinder exert force only in one direction. Single acting cylinders require only about half the air volume consumed by a double acting cylinder for one operating cycle.

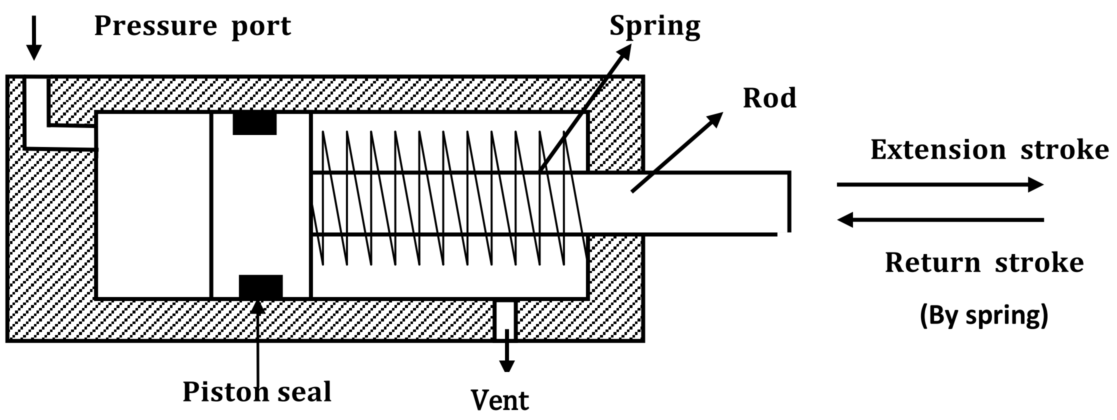


Figure 1.1 Construction features of single acting cylinder

There are varying designs of single acting cylinders including:

1. Diaphragm cylinder
2. Rolling diaphragm cylinder
3. Gravity return single acting cylinder
4. Spring return single acting cylinder

i) Diaphragm cylinder

This is the simplest form of single acting cylinder. In diaphragm cylinder , piston is replaced by a diaphragm is replaced by a diaphragm of hard rubber, plastic or metal clamped between the two halves of a metal casing expanded to form a wide, flat enclosure. Schematic diagram of diaphragm cylinder is shown in Figure 1.2.The operating stem which takes place of the piston rod in diaphragm cylinder can also be designed as a surface element so as to act directly as a clamping surface for example. Only short operating strokes can be executed by a diaphragm cylinder, up to a maximum of 50 mm. This makes the diaphragm type of cylinder particularly adaptable to clamping operations. Return stroke is accomplished by a spring built into the assembly or by the tension of diaphragm itself in the case of very short stroke. Diaphragm cylinders are used for short stoke application like clamping, riveting, lifting, embossing and riveting

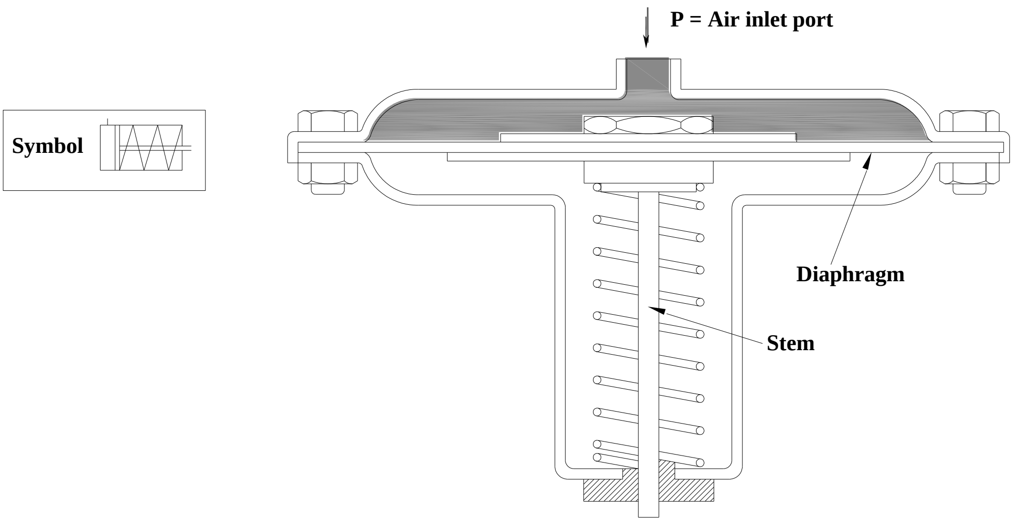


Figure 1.2 Construction features of diaphragm cylinder

ii) Rolling diaphragm cylinder

They are similar to diaphragm cylinders. Schematic diagram of Rolling diaphragm cylinder is shown in Figure 1.3.They too contain a diaphragm instead of piston, which is this instance rolls out along the inner walls of the cylinder when air pressure is applied to the device, thereby causing the operating stem to move outwards. Compared with the standard diaphragm type, a rolling diaphragm cylinder is capable of executing appreciably longer operating strokes (averaging from 50 mm to 800mm) . Separate guiding of stem is not normally provided in these designs, since the component being actuated by the cylinder usually cannot break out of set limits of motion. Any off-center displacement is compensated by the rolling diaphragm with no loss of power. Materials used for rolling diaphragms in present –day designs ensure good durability under normal operating conditions. On the other hand, even very small cracks or cuts in the diaphragm will generally lead to early failure because if high stresses are imposed on the flexible material as it unrolls at each stroke. If the actuator needs to be dismantled for any reason, it must accordingly be inspected carefully for any burrs or sharp edges inside. Metal cuttings also constitute a hazard if they are able to enter the cylinder housing.

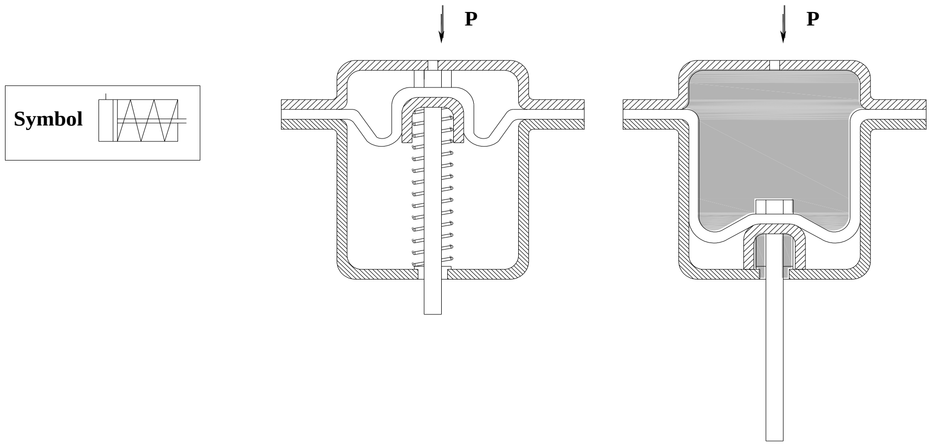


Figure 1.3 Construction features of rolling diaphragm cylinder

iii) Gravity Return Single Acting Cylinder

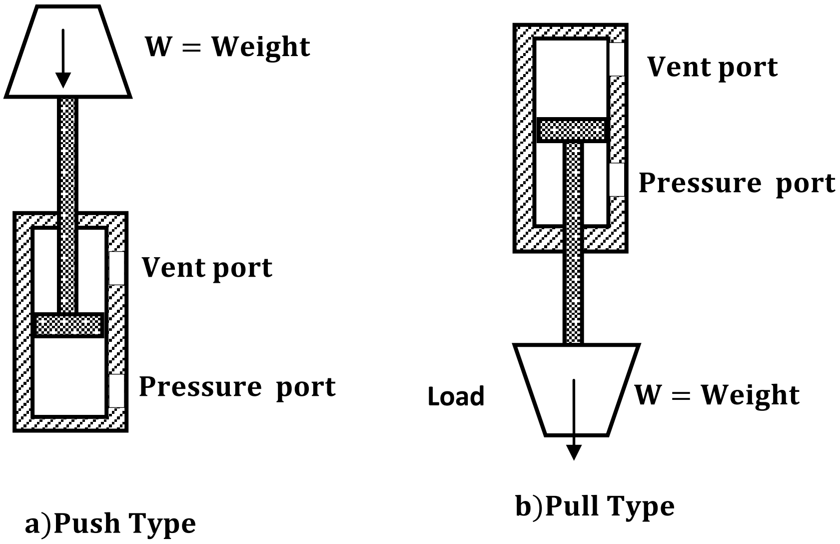


Figure 1.4 Gravity return Single Acting Cylinder

Figure 1.4 shows gravity return type single acting cylinders. In a push type (a), the cylinder extends to lift a weight against the force of gravity by applying oil pressure at the blank end. The oil is passed through blank end port or pressure port. The rod end port or vent port is open to atmosphere so that air can flow freely in and out of the rod end of the cylinder. To retract the cylinder, the pressure is simply removed from the piston by connecting the pressure port to the tank. This allows the weight of the load to push the fluid out of the cylinder back to tank.

In pull type gravity return type single acting cylinder the cylinder (b) lifts the weight by retracting. The blank end port is the pressure port and blind end port is now the vent port. This cylinder will automatically extend whenever the pressure port is connected to the tank.

iv) Spring Return Single Acting Cylinder

Spring return single acting cylinder is shown in Figure 1.5 in part (a) push type the pressure is sent through pressure port situated at blank end of the cylinder. When the pressure is released, the spring automatically returns the cylinder to the fully retracted position. The vent port is open to atmosphere so that air can flow freely in and out of the rod end of the cylinder.

Part (b) shows a spring return single acting cylinder. In this design cylinder retracts when the pressure port is connected to the pump flow and extend whenever the pressure port is connected to the tank. Here pressure port is situated at rod end of the cylinder.

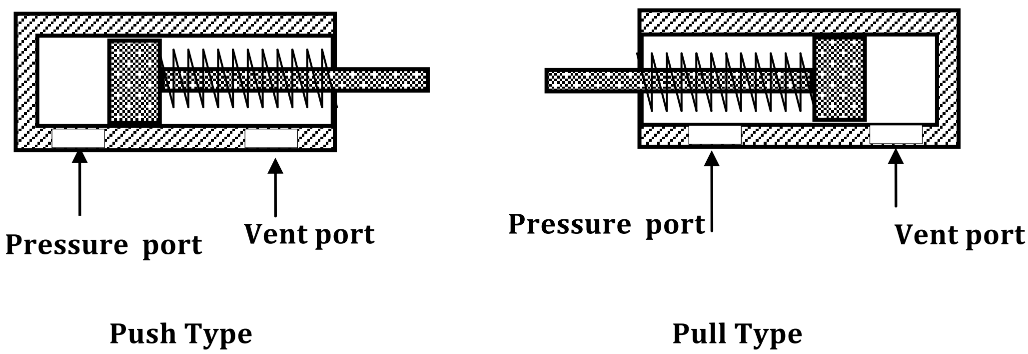


Figure 1.5 Push and Pull type Single Acting Cylinder

B) Double acting cylinders.

Schematic diagram of double acting cylinder is shown in Figure 1.6. Double Acting Cylinders are equipped with two working ports- one on the piston side and the other on the rod side. To achieve forward motion of the cylinder, compressed air is admitted on the piston side and the rod side is connected to exhaust. During return motion supply air admitted at the rod side while the piston side volume is connected to the exhaust. Force is exerted by the piston both during forward and return motion of cylinder. Double acting cylinders are available in diameters from few mm to around 300 mm and stroke lengths of few mm up to 2 meters

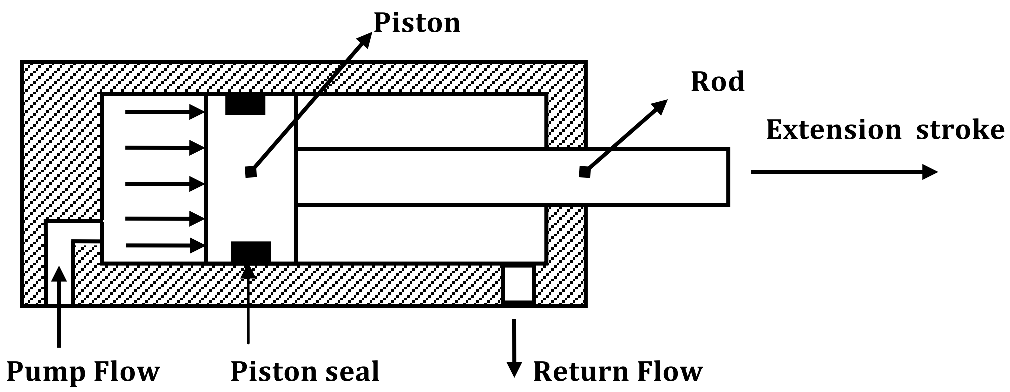


Figure 1.6 Double acting cylinder

Construction of Double acting cylinder

The construction features of double acting cylinder are shown in Figure 1.7. The construction of double acting cylinder is similar to that of a single cylinder. However, there is no return spring. In double acting cylinder, air pressure can be applied to either side (supply and exhaust) of the piston, thereby providing a pneumatic force in both directions. The double acting cylinders are mostly commonly used in the application where larger stroke length is required.

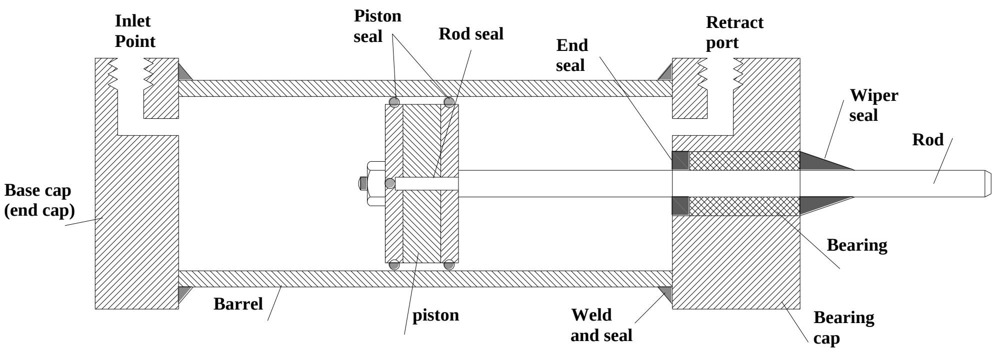


Figure 1.7 Construction features of double acting cylinder

The seven parts of the double acting cylinder are

1. Base cap with port connection
2. Bearing cap with port connection
3. Cylinder barrel
4. Piston
5. Piston rod
6. Scrapper rings
7. Seals

The **base cap** and **bearing cap** are made of cast material, aluminium or malleable cast iron. The two caps can be fastened to the cylinder barrel by tie rods, threads or flanges.

Cylinder barrel is usually made of seamless drawn steel tube to increase the life of the sealing components, the bearing surfaces of the cylinder are precision machined,. For special applications, the cylinder barrel can be made of aluminium, brass or steel tube with hard chromed bearing surface. These special designs are used where operation is infrequent or where there are corrosive influences.

The piston rod It is preferably made from heat treated steel. A certain percentage of chrome in the steel protects against rusting. Generally the threads are rolled to reduce the danger of fracture.

Piston seals are provided in between piston and barrel to avoid leakage. A **sealing ring** is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and may be made of sintered bronze or plastic coated metal.

In front of this bearing bush is a scrapper ring.(wiper ring). It prevents dust and dirt particles from entering the cylinder space. Bellows are therefore not normally required.

The materials for the double cup packing sealing are

Perbunan, for -20 ℃ to + 80℃

Viton, for -20 ℃ to +190℃

Teflon for -80 ℃ to +200℃

O rings are normally used for static sealing.

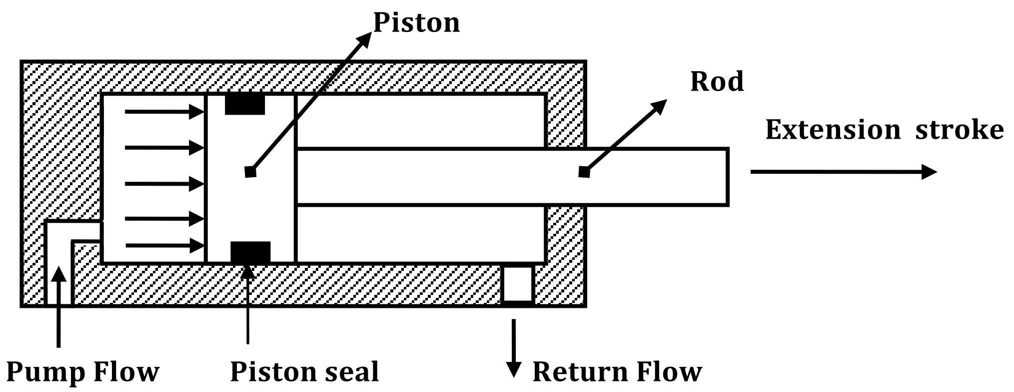
Construction of Double acting cylinder

There are two types of double acting cylinders.

i) Double acting cylinder with piston rod on one side.
ii) Double acting cylinder with piston rod on both sides

i) Double acting cylinder with piston rod on one side.

Figure 1.8 shows the operation of a double acting cylinder with piston rod on one side. To extend the cylinder, pump flow is sent to the blank end port as in Figure 1.8 (a). Fluid from the rod end port returns to the reservoir. To retract the cylinder, the pump flow is sent to the rod end port and fluid from the blank end port returns to the tank as in Figure 1.8 (b).



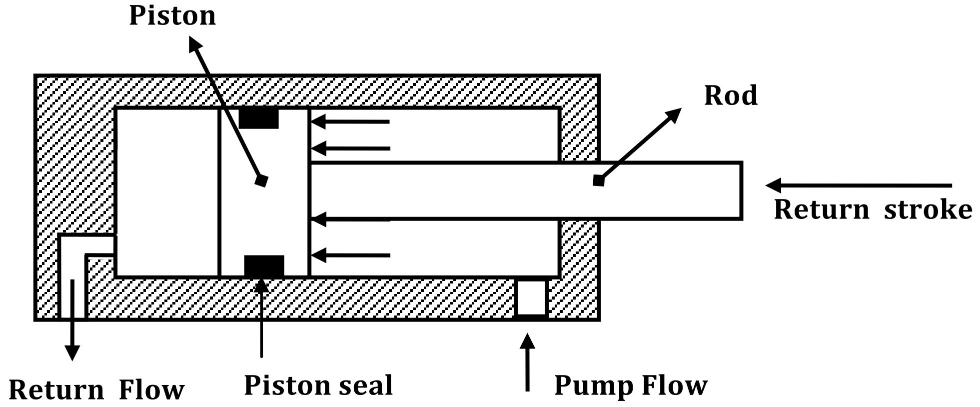


Figure 1.8 Double Acting Cylinder with piston rod on one side

ii) Double acting cylinder with piston rod on both sides

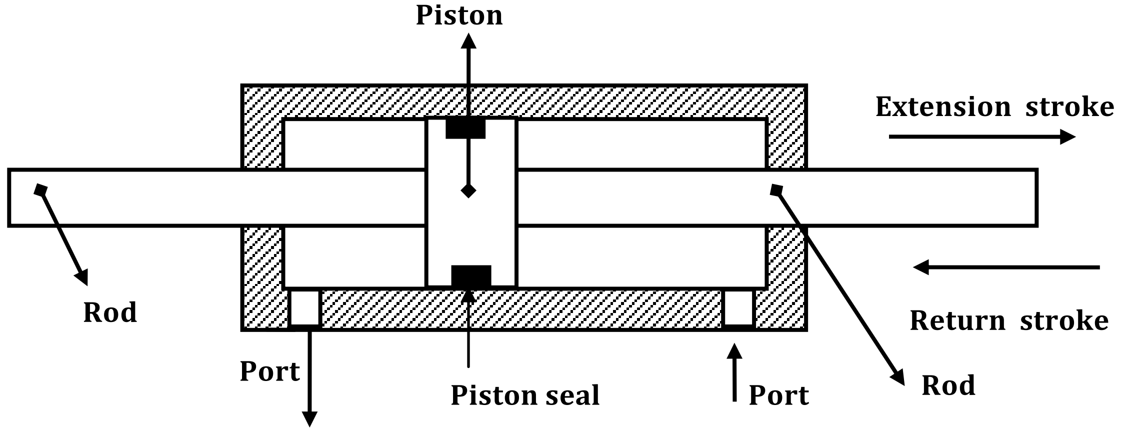


Figure 1.9 Double Acting Cylinder with piston rod on both side

A double acting cylinder with piston rod on both sides (Figure 1.9) is a cylinder with rod extending from both ends. This cylinder can be used in an application where work can be done by both ends of the cylinder, thereby making the cylinder more productive. Double rod cylinders can withstand higher side loads because they have an extra bearing one on each rod to withstand the loading. Double rod cylinders are used when there is bending load and accurate alignment and maximum strength is required. A further advantage is that rod is precisely located and may be used to guide the machine member coupled to it, dispensing with external guides or bearing in many cases, most standard production models are available either in single rod or double rod configuration A disadvantage of double rod configuration is that there is a reduction in maximum thrust due to the blanking effect of the rod cross section on the piston area and a slightly larger size of cylinder is required for a given duty. The thus will be the same on the ingoing stroke as that of a single rod double acting cylinder.

1.2.1.3 Based on the cylinder action

Rotating type of cylinders are used in applications where cylinder body is connected to a rotating member and air connection to the cylinder in a stationary housing. They are not widely used.

Non Rotating type of cylinders are widely used Industries. Cylinder body is connected air connection are mounted stationary housing and piston rod moves and exerts force.

1.2.1.4 Based on the cylinder's design

In industry , differentiation is made between special design of regular cylinder and the special duty cylinders designed for a special purpose that are known by designation of their own. Special design cylinders are basically natural variations of single or double acting cylinders. Variations in special designs derived from standard production of cylinders and merely exchanging selected parts for others of different shapes or material. Special duty cylinders on the other hand are from the start designed to non-standard conditions of service or application. Following section deals with some of commonly used special design and special duty cylinders.

A) Telescopic Cylinder

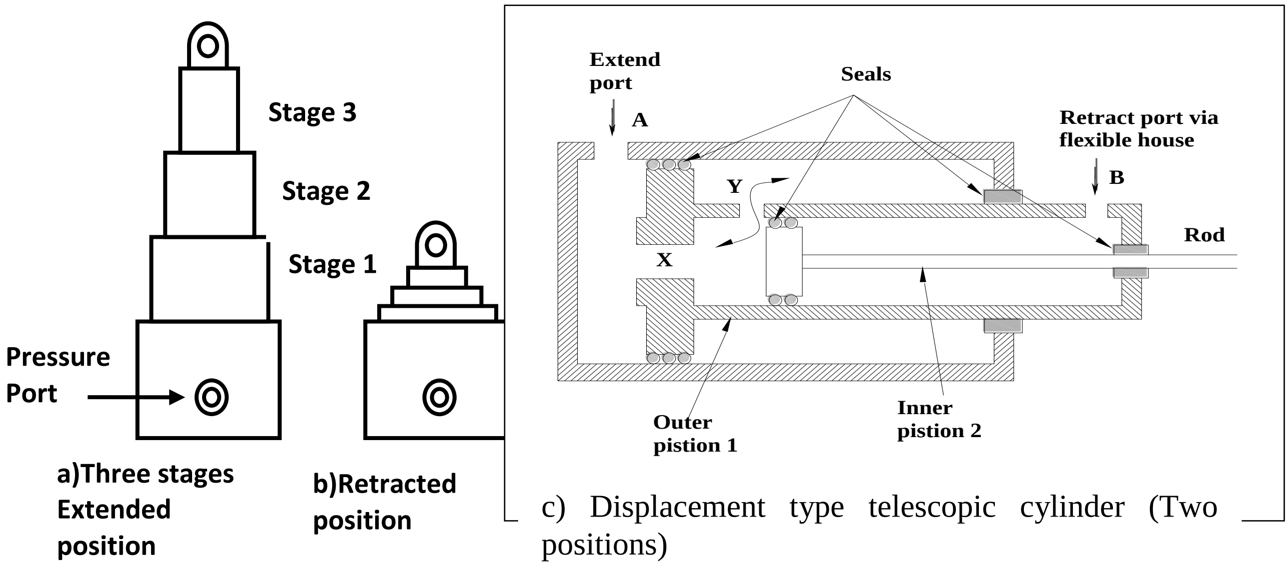


Figure 1.10 Double Acting Cylinder with piston rod on one side

Telescopic cylinder (shown in Figure 1.10 (a) and (b)) is used when long stroke length and short retracted length are required. They extend in stages, each stage consisting of a sleeve that fits inside of the previous stage. Figure 1.10 (c) shows the construction of a typical double acting telescopic cylinder with two pistons (Two stages).

Extension stroke: When the pressure is applied at port A, air flow through port X and Y and pressure is applied on both sides of Piston 1. But difference in areas causes the piston 1 to move to the right. Once the piston 1 fully extends, Inner Piston 2 will extend.

Retraction stroke: To retract, air is applied to port B. Air pressure will act on the annulus of the inner piston 2 and moves inner piston 2 to the left. When the inner piston moves to left and started to close port X, air from port B goes to annular side of the piston 1 via port Y and pushes the piston 1 to the left.

Figure shows the construction of a typical double acting telescopic cylinder with three pistons (three stages)

Forward stroke: when the pressurised air enters the port p, larger ram of diameter A moves first. Since the diameter of Ram A is relatively large, this ram produces large force at the beginning of the lift of the load. (usually in many application, initial inertial is high and larger force is required in the beginning, once initial inertia is overcome, smaller force is required to keep moving the weight). When ram A reaches the end of the stroke, ram B begins to move, providing smaller force. When ram B reaches its end position, Ram C will move outward to complete the stroke.

Retraction stroke: When the pressurised air enters the port T, then it acts on the annular area of Ram A and ram A is retrieved. Once the Ram A is retrieved, pressure continues to act on annular area of Ram B and retrieves Ram B. In similar way, the Ram C is also retrieved.

B) Tandem Cylinder

Schematic diagram of Tandem cylinder is shown in Figure 1.12. Tandem cylinders are two separate double acting air cylinders arranged in line to one cylinder body so that the power generated by the two is added together, thereby approximately doubling the piston output. A tandem cylinder is used in applications where a large amount of force is required from a small-diameter cylinder. Basically, a tandem cylinder is simply two or more separate cylinders stacked end to end in a unit and with all the pistons mounted on a common piton rod. Pressure is applied to both pistons, resulting in increased force because of the larger area. The drawback is that these cylinders must be longer than a standard cylinder of larger flow rate than a standard cylinder to achieve an equal speed because flow must go to both pistons

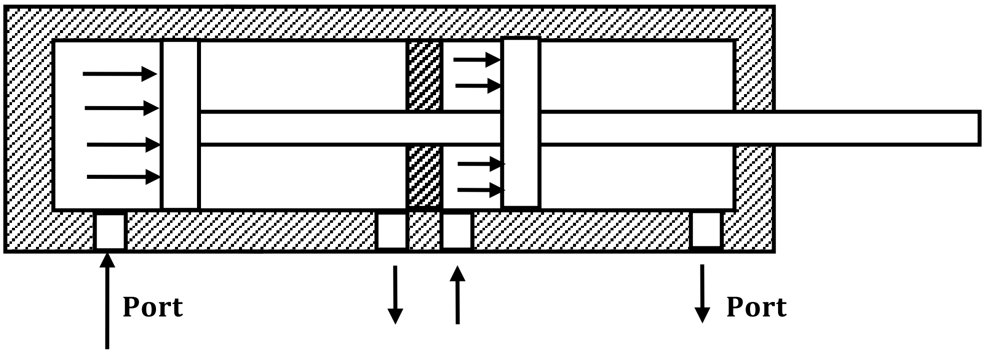


Figure 1.11 Double Acting Cylinder with piston rod on one side

Tandem cylinders are used where large output force is required with appreciable saving in bulk and weight. Tandem cylinders are employed where a small diameter of the assembly is required.

c) Rodless Cylinder

A rod less air cylinder differs from a basic air cylinder in that no piston rod extends outside the cylinder body. Instead, the internal piston is connected to an external carriage, by means of a magnetic or mechanical coupling system

There are three types of rod less cylinders, they are

i) Cable Cylinder
ii) Sealing band Cylinder with slotted cylinder barrel
iii) Cylinder with Magnetically Coupled Slide

i) Cable cylinder:

It is used for very long strokes, up to 2000mm. It consists of nylon jacketed cable which enters the cylinder barrel and is attached to one end of internal cylinder and exits through the gland seal and enters into the other end of the internal cylinder through the another gland seal as shown in the Figure1.12. When compressed air enters the cylinder the piston moves from end-to-end. The cables which are attached to either side of the piston and extend out the ends of the cylinder move as well. Depending on the direction of the piston both the carriage and any on-carriage tooling moves towards one end of the air cylinder or the other.

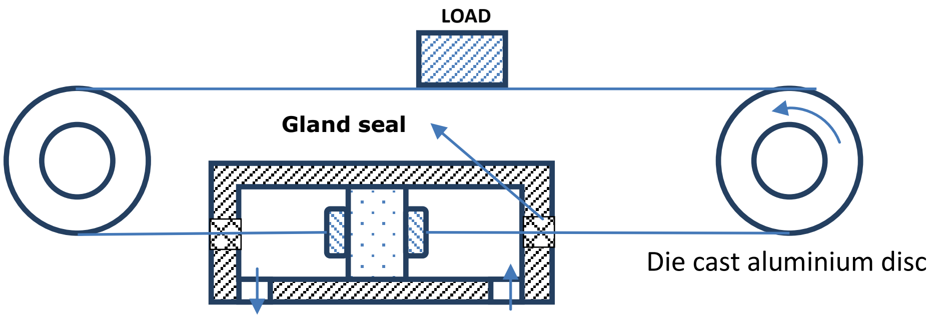


Figure 1.12 Cable cylinder

ii) Sealing band Cylinder with slotted cylinder barrel

Schematic diagram of sealing band cylinder with slotted cylinder barrel is shown in the Figure 1.13. Common components of a band cylinder are:

a. End caps
b. cylinder barrel
c. cylinder piston
d. carriage
e. mechanism for connecting carriage to piston
f. sealing bands / strips

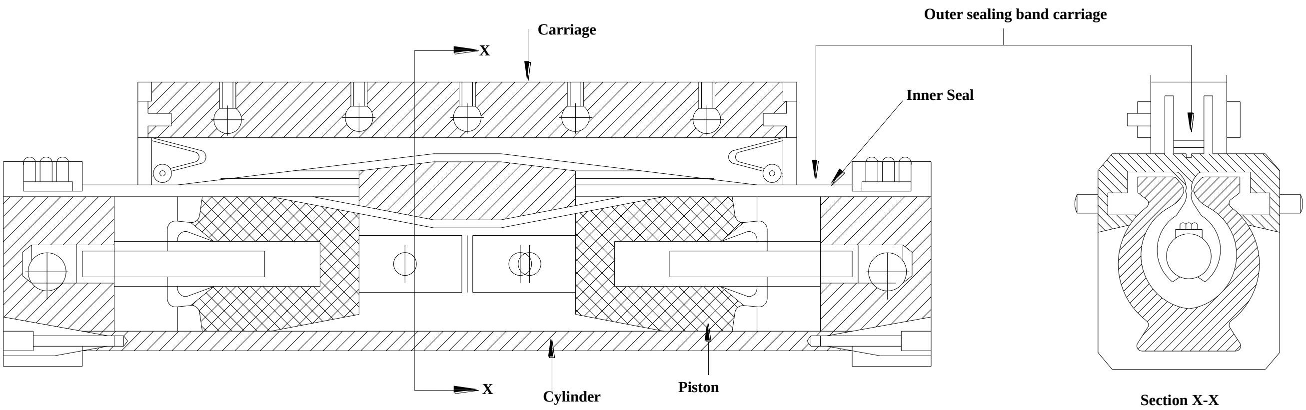


Figure 1.12 Sealing band cylinder with slotted cylinder barrel

As the carriage moves, the two band sealing strips are alternately opened in front and then closed behind of the moving carriage, regardless of the direction of travel. The seals on the pistons inside the cylinder barrel press the inner band seal tight against the barrel of cylinder, preventing air from leaking out.

The carriage on top of the band cylinder will have a wiper assembly at either end which will both remove any debris from the carriage path, and press the top seal tightly against the outside of the slot in the cylinder barrel, stopping any compressed air from escaping there.

iii) Cylinder with Magnetically Coupled Slide

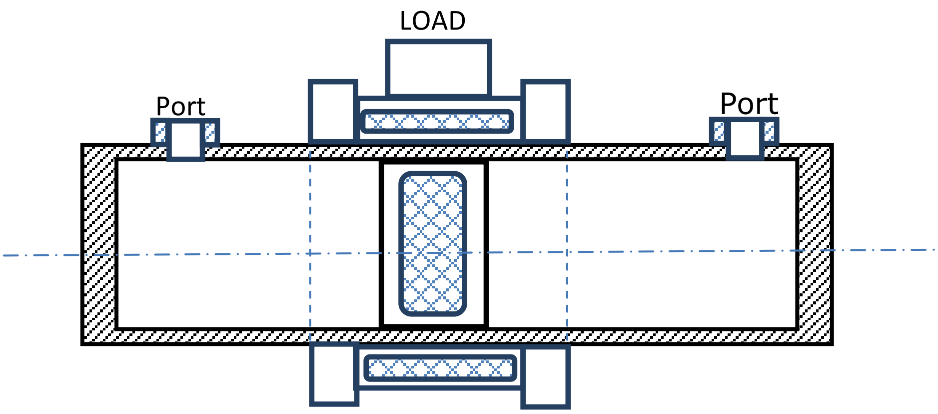


Figure 1.12 Schematic diagram of cylinder with Magnetically Coupled Slide

Figure 1.12 shows the schematic diagram of magnetic piston cylinder. Piston has powerful magnet which bonds the piston inside the cylinder with carriage outside which also contain powerful magnet. The magnetic cylinders are available upto the size of about 40 mm diameter and stroke lengths from 50mm to 4000 mm. They can operate at the speed of about 3000 mm/sec. The major advantages of this type of cylinders are

i) There is no leakage
ii) There is no direct contact of moving elements therefore the wear is less
iii) The orientation of the carriage can be changed easily,

D) Impact cylinders

Impact cylinders are used for high energy applications. Schematic diagram of impact cylinder is shown in Figure 1.13. These comprise, basically a normal pneumatic cylinder allied to a reservoir where by the speed of operation of the cylinder may be raised by some 15 times and the energy rating increases some 200 times without using larger valves or higher air supply pressures. Impact cylinders find particular application for high energy rate forming where, typically, an 200mm bore impact cylinder may accomplish a similar duty to that previously requiring a 50 Ton press.

If normal cylinders are used for forming operations, the thrust forces of the compressed air are limited. A cylinder producing high kinetic energy is the impact cylinder. In accordance with formula for kinetic energy (KE), the obvious means of obtaining high impact energy is by increasing the velocity.

$$\mathrm{KE} = \frac{1}{2}mv^2$$

$\mathrm{KE} = kinetic\ energy, Nm$

$m = mass\ in\ kg$

$v = speed\ in\ m/s$

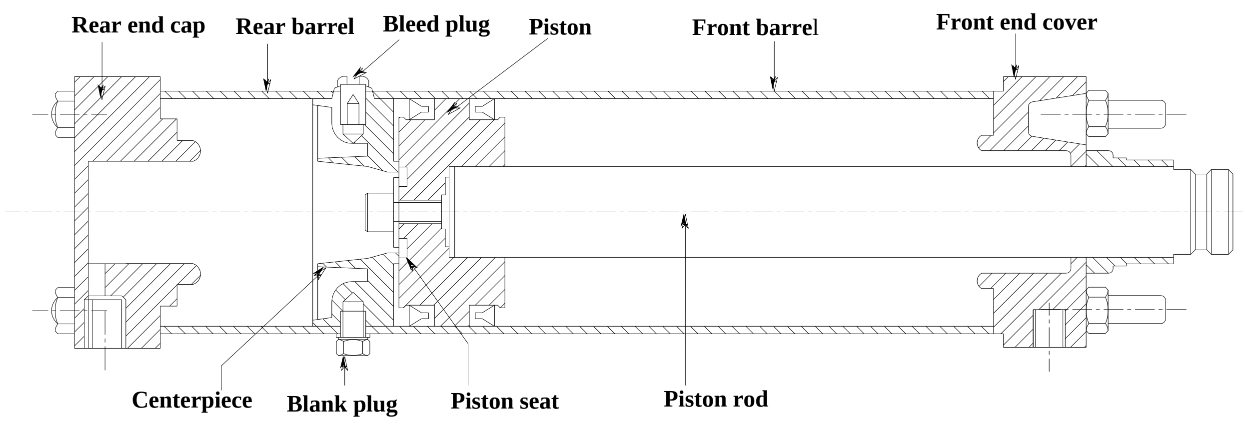


Figure 1.13 Schematic diagram of Impact cylinder

If the forming stroke is large, the velocity diminishes rapidly and hence also the impact energy, This type of cylinder is therefore not suitable for large forming strokes. They are used for stamping, punching, cutting, riveting, beading, embossing etc.

Sequence of operation is shown in the Figure 1.14. To the top end of conventional cylinder is added a reservoir opening into the cylinder proper via a poppet valve (centre piece) controlled by the piston movement. Ratio is the piston area to poppet valve (centre piece) area is of the order of 9:1 so that pressure in the reservoir is balanced by a pressure of approximately 1/9th in the exhaust end of the cylinder.

To charge the cylinder the reservoir is connected to the line with the pressure building up to the line pressure. Movement of the piston is opposed by exhaust pressure until this falls to 1/9th of the line pressure. Forces acting on the top and bottom of piston are then in balance and the piston starts to move away from the poppet seat (centre piece). Immediately the poppet valve is open and the reservoir pressure is applied over the entire whole of the piston area resulting in very rapid acceleration of the piston up to the maximum speed. The energy released by the air suddenly allowed to expand from the reservoir is thus converted into kinetic energy by the piston assembly which delivers an impact blow.

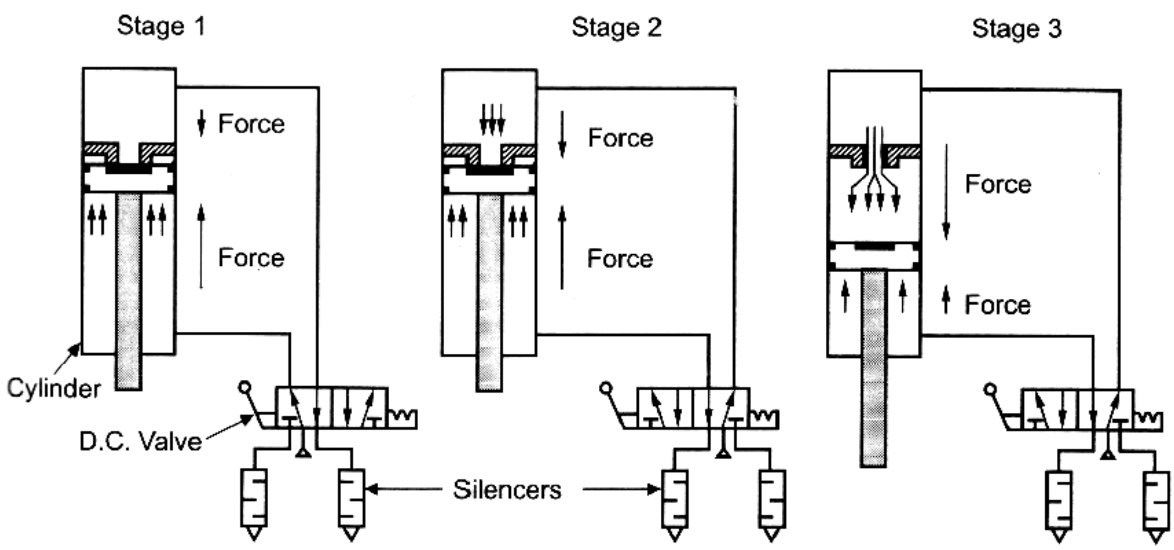


Figure 1.14 Sequence of operation of Impact cylinder

E) Duplex cylinder or opposite thrust or multi position cylinder

A special duty tandem arrangement is also used in duplex cylinder, although in this case the (two) pistons are mounted on separate connecting rods, one operating the other. Each piston is thus capable of independent motion via its own separate air supply control Thus a duplex cylinder may be used for tow motion duties- example clamping a work piece in position y motion of one piston, followed by a shearing, punching, pressing or similar operation powered by the other piston.

Opposed thrust or multi position cylinders are similarly a combination assembly of at least two double acting cylinders in one with the pistons and rods in opposed arrangement. This results in a four position cylinders as shown in Figure 1.15 (b) The characteristic of such opposed thrust cylinders is the availability of more than two definite fixed operating positions. Theoretically it is possible for a multiple number of pistons and rods to be combined into the one cylinder assembly so as to obtain an actuator with six or eight position. Three position cylinders as illustrated in Figure 1.15(a) can be obtained as standardized units. Designs with up to 12 operating positions are possible.

Application

- Filling shelves from a conveyor
- Lever actuation
- Sorting device (accept – reject- rework)

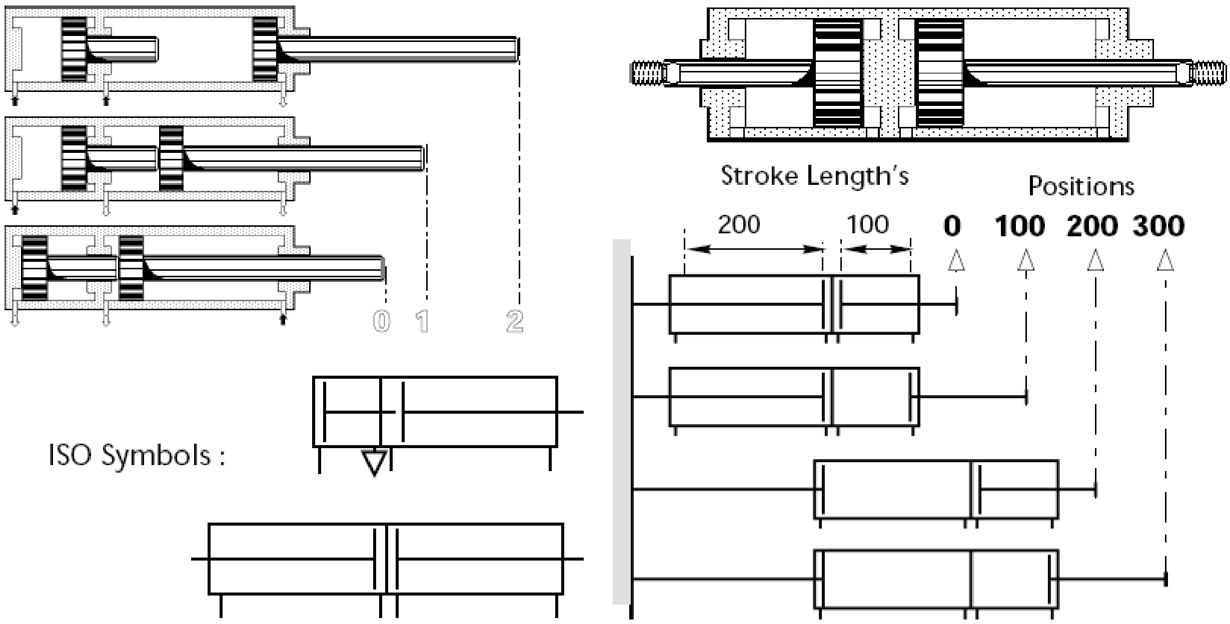


Figure 1.15 Duplex cylinder (a) three position b) four position

F) Position sensor for cylinders

In automation application, it is often required for a signal to be generated when the cylinder piston reaches a particular position along its stroke, so that the control system can initiate the next phase of the operation. This position may be at either end of the stroke or some point intermediate between the ends. There are several ways in which this can be done. Schematic diagram of cylinders with position sensor is shown in Figure 1.16

- The piston rod trips a micro-switch or pneumatic valve
- Pressure threshold sensors respond to a drop in exhaust pressure when the piston stops moving
- Magnetic sensors mounted directly on the cylinder barrel sense the magnetic field created by a permanent magnet incorporated in the piston and trigger reed switch.
- Hall effect sensors triggered by a magnetic piston
- Pneumatic reed valves. Triggered by a magnetic piston
- Miscellaneous such as photoelectric, inductive and capacitive detectors

Magnetic trip switches are the traditional method for position sensing and are still widely used and reliable. Pressure threshold sensor respond less to actual position than to piston velocity, so they are only suitable for detecting the end of the piston travel, they have work unreliably with slow moving pistons. Both of these are gradually being superseded by the two types of magnetic sensors.

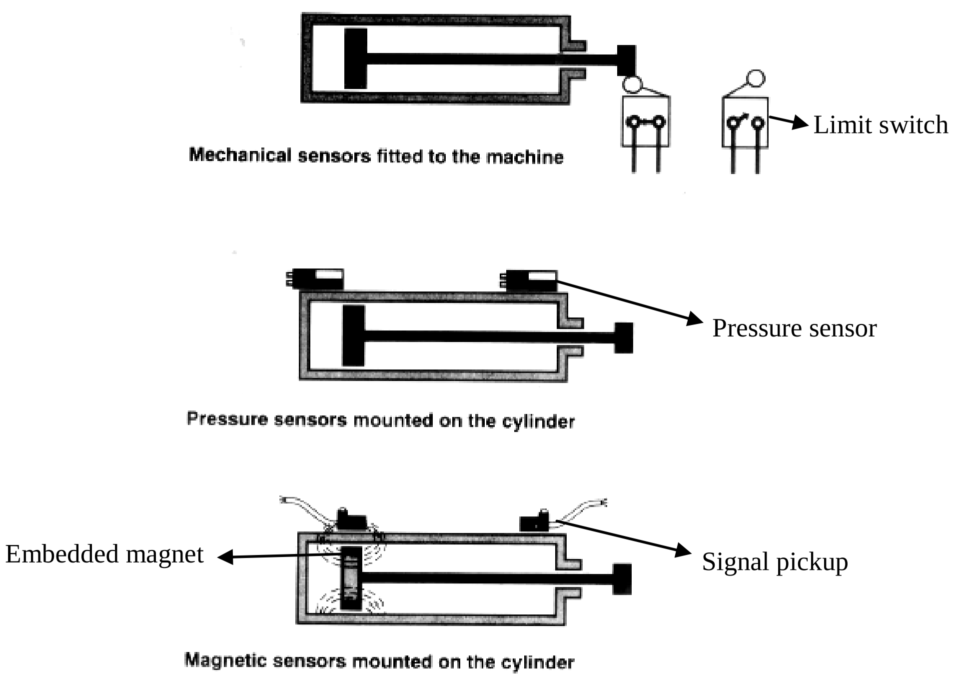


Figure 1.16 Cylinder with sensors (a) Mechanical b) pressure c) magnetic

The other type of sensors which are used are electronic sensor with magnetic detection. They are directly mounted on a magnetic cylinder tube. A permanent magnet is embedded in the piston. This creates a magnetic field. When the piston moves, the magnet actuates the electronic system of the sensor and provides the desired signal. These electronic position sensors work at 10-24 volts. The maximum current is around 150mA. The leakage current is around 10 mA at 24 Volts and internal voltage drop is less than 0.5 Volts for 100 mA. They are capable of working between -10℃ to +60 ℃

1.3 Standard metric cylinders

BS: 5785 1980 gives tables (Table 1.2) of preferred sizes for the cylinder bore and rod diameter of metric cylinders. Most cylinder manufacturers have based their standard range of metric cylinders on these recommendations, offering two rod sizes for each cylinder bore.

A number of combinations have a piston rod to piston diameter ratio in the region of 0.7, which gives an annulus area of approximately one-half the full bore area. This area ratio is of use in regenerative circuits to give similar values of speed and thrust on both the extension and retraction strokes.

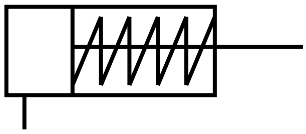
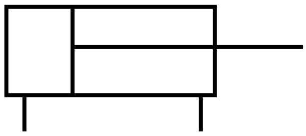
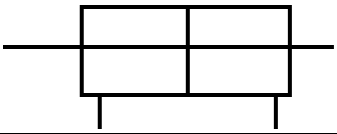
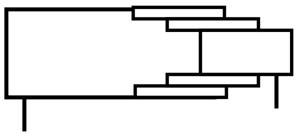
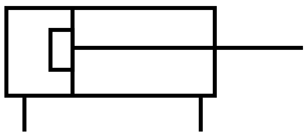
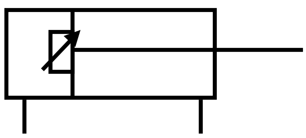
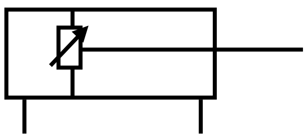
1.3.1 Graphical Symbols for cylinders.

There are several symbol systems and conventions in use around the world for pneumatic cylinders. Most official recognized by standard bodies, commonly used is ISO 1219-1. Table 1.3 gives the symbols for most commonly cylinders in industry.

Table: 1.2 Standard cylinder sizes

Piston Diameter(mm)		40	50	63	80	100	125	140	160	180	200	220	250	280	320
Piston Rod	small	20	28	36	45	56	70	90	100	110	125	140	160	180	200
Diameter(mm)	large	28	36	45	56	70	90	100	110	125	140	160	180	200	220

Table 1.3 Graphical symbols of cylinders

Sl No	Graphical Symbols	Explanation
1		**Single acting cylinder with unspecified return:** Air pushes the piston in one direction and the piston is return is unspecified. External dock or lever may push
2		**Single acting cylinder with spring return.** Air pushes the piston in one direction and piston returns by spring on rod side
3		**Double acting cylinder –single piston rod:** the force exerted by compressed air moves the piston in both direction.
4.		**Double acting cylinder –double piston rod**It has piston rods extending from both ends of the cylinder. It produces equal force and speed on both sides of the cylinder
1.		**Telescopic cylinder –double acting** is used where space is constraint. It is used for long stroke application like in pneumatic cranes, dump trucks, lift fork trucks, dipper wagon
7.		**Double acting cylinder –** fixed cushion on one side, Cushioning is used in the end position to prevent sudden impact which otherwise may damage parts**.**
8		**Double acting cylinder – variable cushion on one side–** fixed cushion on one side, cushioning is variable in one direction by adjusting the orifice opening.
9		**Double acting cylinder – variable cushion on both sides–** fixed cushion on one side, cushioning is variablein both direction.

5.4 Cylinder mountings.

The way in which the cylinder is mounted influences service life, maintenance frequency and success of the entire installation. Poor mounting design can cause excessive side loads and stresses which will bring about early failure of some vital component. There are three main categories of cylinder mounting. The selection of these mountings depends on the application and machine configuration.

1. Fixed Centreline mountings
2. Pivoted centreline mountings
3. Fixed non centreline mountings

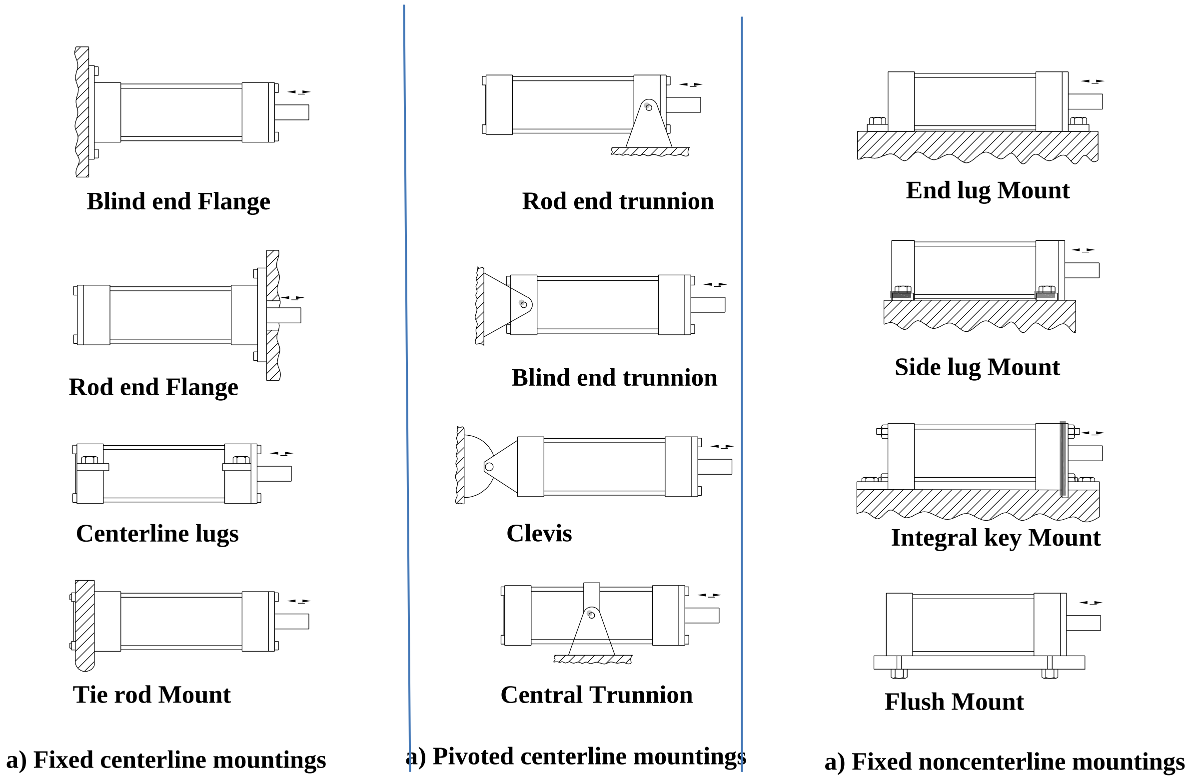


Figure 1.17 Types of mounting a) Fixed centreline b) Pivoted centreline c) Fixed noncenterline

Figure 1.17 shows all three types of mountings.

Fixed Centreline mountings: In this mounting, the cylinder is supported along its centre line. The mounting bolts are thus subjected to shear or simple stress. This mounting needs accurate alignment. Misalignment is not tolerable.

Pivot centreline mounting: Many applications need rotational degree of freedom for a cylinder as it reciprocates. The pivot mounting can be clevis type or trunnion type. This mounting permits rotational freedom in one plane. If universal joint is used, greater degrees of freedom are possible.

Fixed non centreline mounting: This mounting of cylinder introduces torque under loaded condition. The cylinder may rotate or bend about its mounting bolt when loaded. The stress level on the cylinder is higher as compared to the centre line mounting.

Following points should be considered while mounting the cylinder

1. Cylinders with centreline mountings tend to lean under load.
2. Cylinder with non-centreline mounting generally require strong machine frames to resist bending moments

3. If the motion of the machine part acted on by the cylinder rod movement is essentially linear, a fixed mounted cylinder should be used.
4. If the cylinder has a long stroke, a pivoted mounted cylinder may be required to prevent the piston rod buckling. Where long stroke and fixed mounting are necessary , support is needed to prevent vibration and excessive sag
5. The mounting selection depends on the resulting force (compression or tension) in the cylinder rod. The blind end or cap flange mounting is best for compressive loads. The rod end or head flange mounting is best where the rod is in tension
6. Alignment problem are always critical. If misalignment can occur between the cylinder and machine part it moves, it is necessary to compensate for this in the selection of cylinder mounting. For example, a simple centreline pivot mounting will compensate for misalignment if it occurs in only one plane. Where misalignment can occur in more than one plane, the cylinder must be fitted with a universal (ball and socket) pivot joint. It is important that both ends of the pivot mounted cylinder should be supplied with flexible connections.

1.4.1 Piston rod buckling

The piston rod in a pneumatic cylinder will act as a strut when it is subjected to a compressive load or it exerts a thrust. Therefore the rod must be of sufficient diameter to prevent buckling. Euler's strut theory is used to calculate a suitable piston rod diameter to withstand buckling. Euler's formula states that

$$k = \frac{\pi^2 EI}{L^2}$$

Where K = buckling load (kg),

E = modulus of elasticity (kg/cm^2) (2.1 ×10^6 kg/$cm^2$for steel),

I = second moment of area of the piston rod (cm^4) ($\pi d^2/64$ for a solid rod of diameter d cm), an L = free (equivalent) buckling length (cm) depending on the method of fixing the cylinder and piston rod. The values of L for various configuration is shown in Figure 1.19

The maximum safe working thrust or load F on the piston rod is given by

F = k /S,

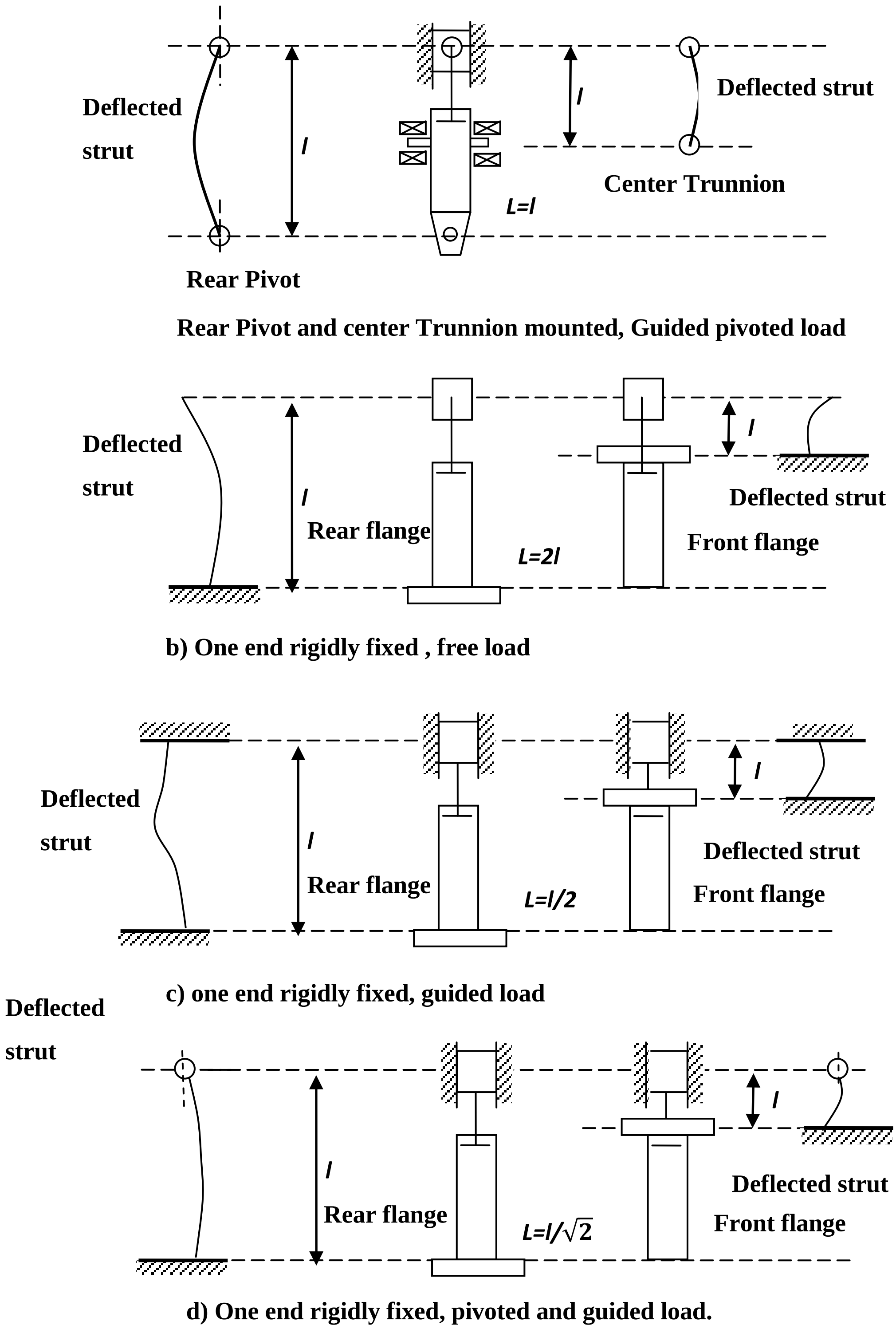


Figure 1.19 Relationship between piston rod, free buckling length and method of fixing

Where S is a factor of safety which is usually taken as 3.1. The free or equivalent buckling length L depends on the method of fixing the piston rod end and the cylinder, and on the maximum distance between the fixing points, i.e. the cylinder fully extended. In cases where the cylinder is rigidly fixed or pivoted at both ends there is a possibility of excessive side loading occurring. The effect of side loading can be reduced by using a stop tube inside the cylinder body to increase the minimum distance between the nose and the piston bearings. Schematic diagram is shown in Figure 1.20. The longer the stop tube, the lower will be the reaction force on the piston owing to the given value of side load. Obviously the stop tube reduces the effective cylinder stroke

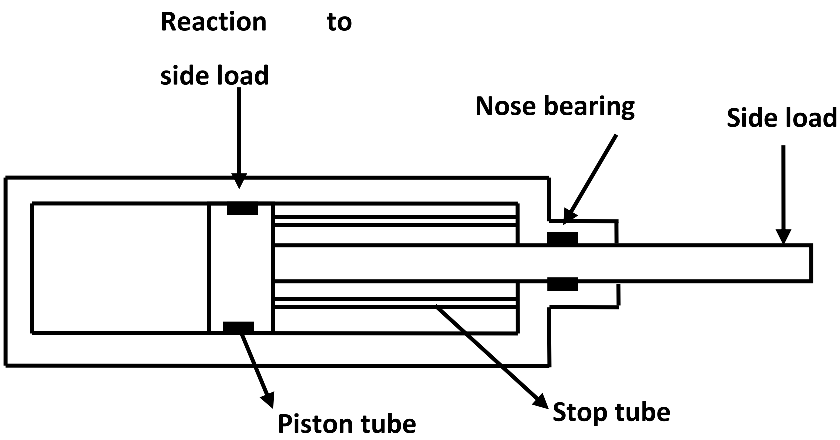


Figure 1.20 Use of stop tube to minimize side loading.

1.5 Cylinder seals

Seals are used in cylinders to prevent the losses caused by leakage and to make the effective use of the compressed air energy medium. Important characteristics needed for seals are

1. Long life
2. Low friction
3. Resistance to heat
4. Stability of form
5. Higher range of working pressure
6. Higher Range of temperature
7. Mechanical strength

1.1.1 Classification

1. Static seals

2. Dynamic seals

Static seals are used to provide a sealing between the stationary parts of a cylinder. For example, end cap and barrel. O ring is most commonly used static seal. O rings are used for small cylinders.

Dynamic seals are used provided for surfaces which are moving. Dynamic seals are used provided for surfaces which are moving. Cup seals and Z seals are commonly used dynamics seals.

There are a variety of seals required within a pneumatic cylinder. Single acting cylinders use less number of seals. Double acting seals use at least five different types of seals as shown in Figure 1.21

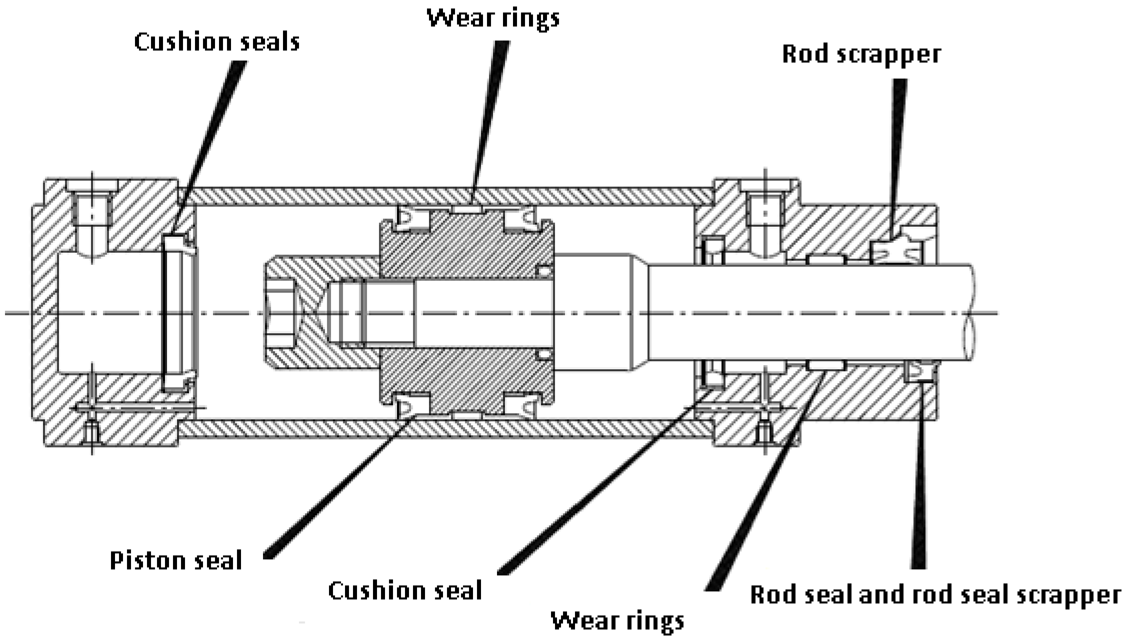


Figure 1.21 Different types of seals used in pneumatic cylinders

1. Cushion seals
2. Wear ring
3. Piston seals
4. Barrel seals
5. Piston rod/wiper seal

Cushion seals: Cushioning protects a cylinder and its load by absorbing energy at the end of the stroke. When the piston moves to the left of pneumatic cylinder, the air on the left side of the piston in the left chamber must be exhausted to allow full travel of the piston and rod. In a cushioned cylinder, this air cannot escape from the port by virtue of the cushion seals which seals against the piston rod. The only escape path is through the cushion orifice, which is normally a small hole. When the piston reaches the cushion seal, the piston travel is slow down due to cushioning of the air. Thus the cushion seals perform a dual role of a seal and non-return valve.

Wear ring is a open band fixed around the piston. It is made from a hard plastic material normally Teflon compounded with polyphenylene sulphide or good quality bearing bronze to provide best wear resistance and excellent bearing support. Wear ring also guards the rod against scoring by piston.

Piston seal: An O-ring piston seal is used for small bore sizes. For medium and large bore double acting cylinders cup seals are used. They are cheap and easy to fit but may be easily damaged by dirt.

Barrel seal: O-ring piston seal is used as barrel seal. It is used in the near the end caps and it is tight fit in the grooves location

Piston rod seal/ Wiper seal.

A piston rod seals, also known as wiper seal, is used for harsh environment. This seals acts as pressure seal and wiper seal. The external body of this seal is a pressure-tight fit within the bearing housing. Cleaning action of the seal removes abrasive particles that can settle on the rod during the outward stroke of the cylinder or due to some other operations

5.6 End cushioning in pneumatic cylinders

The inherent capability of all air cylinders to perform rapid reciprocating motion also supplies a disadvantage in that considerable kinetic energy is dissipated in the form of shock at the completion of the stoke. This can set up severe stresses in cylinders itself or end covers, or on frame work of the machines to which it is attached. This can be overcome by providing cushioning to produce gradual deceleration of the piston as it approaches the end of its stroke. Schematic diagram is shown in **Figure 1.22**

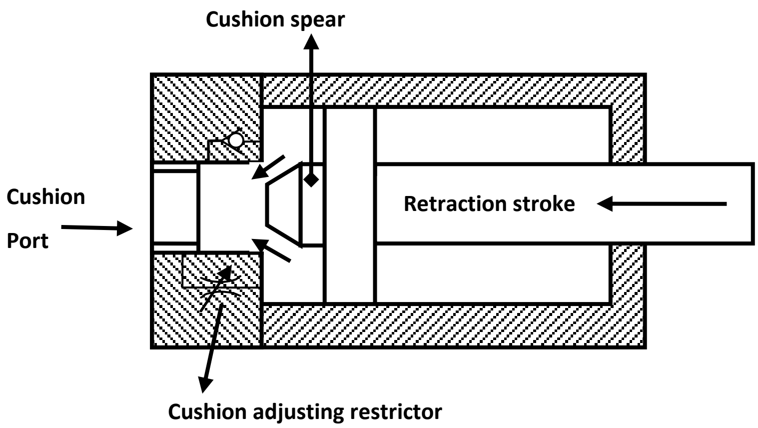


Figure 1.22 Operation of cylinder cushions.

Need for cushioning when the pressurised air is supplied at the inlet port of the cylinder, piston accelerates and travels inside the cylinder. Piston has to be slowed down at the end of the stroke to prevent excessive impact on the end caps. These shock loads arise not only from the fluid pressure, but also from the kinetic energy of the moving parts of the cylinder and load. These end travel shock loads can be reduced by decelerating the piston at the end of stroke by cushioning.

For the prevention of shock due to stopping loads at the end of the piston stroke, cushion devices are used. Cushions may be applied at either end or both ends. They operate on the principle that as the cylinder piston approaches at the end of stroke exhaust fluid is forced to go through an adjustable needle valve which is set to control the escaping fluid at the given rate. This allows the deceleration characteristics to be adjusted for different loads. When the cylinder piston is actuated, fluid enters the cylinder port and flows through the little check valve so that entire piston area can be utilized to produce force and motion.

There are two types of cushioning is possible in pneumatic cylinder

1. Fixed cushioning
2. Adjustable cushioning

Fixed cushioning: This type of cushioning is used for small bore cylinder. These cylinders make use of synthetic rubber buffers to give a simple fixed cushion effect. These shock absorbent disks placed into the end-covers suction the impact of the piston. Schematic diagram is shown in Figure 1.23

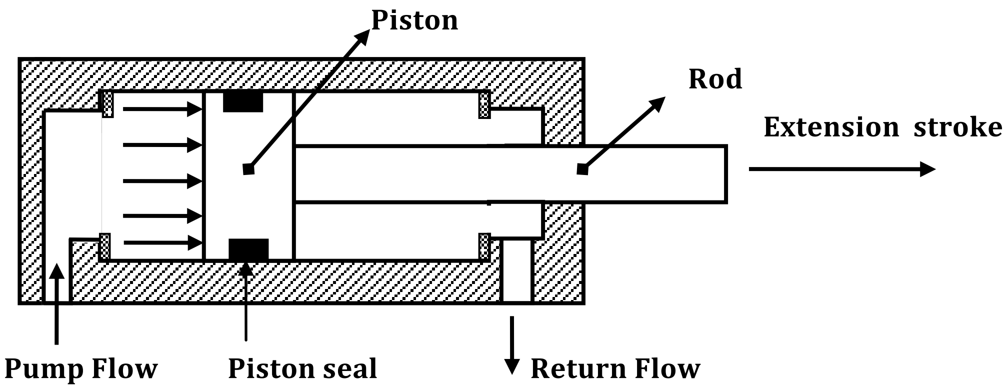


Figure 1.23 Operation of cylinder cushions

Adjustable cushioning: As a rule, cushions are applied to cylinders whose piston speed exceeds 0.1 m/s. Cushion can be applied at one end or both ends of the cylinder. Adjustable cushioning is possible with two methods

1. Using the cushion seal
2. Using the piston with the plunger

Using the cushion seal: Cushioning using cushion seal was explained earlier in cylinder seal section 1.1.1.In a cushioned cylinder, this air cannot escape from the port by virtue of the cushion seals which seals against the piston rod. The only escape path is through the cushion orifice, which is normally a small hole. When the piston reaches the cushion seal, the piston travel is slow down due to cushioning of the air

Using the piston with plunger and cap: In this type exhaust air is unrestricted until the plunger enters the cap. The exhaust flow route is through deceleration valve which reduces the end of travel speed. The needle valve is adjustable to allow the deceleration rate. Schematic diagram of the construction of cylinder cushion is shown in Figure 1.24

Construction and working:

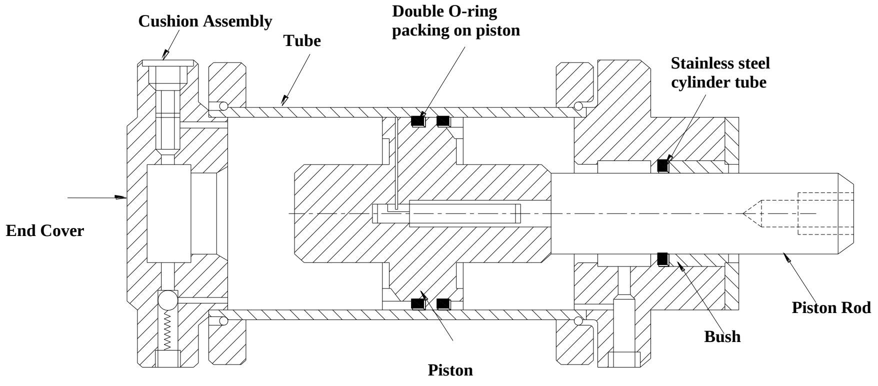


Figure 1.24 construction of cylinder cushions

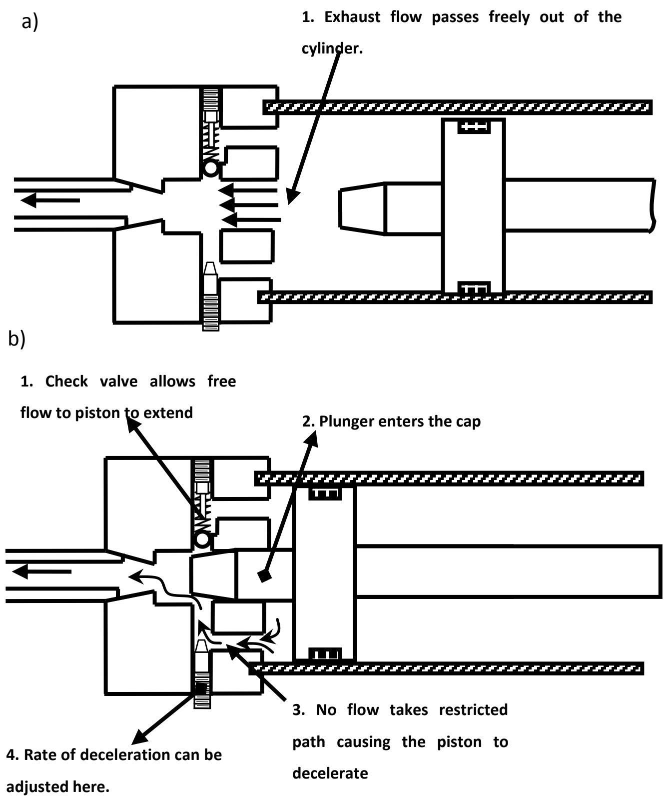


Figure 1.25 Operation of cylinder cushions a) normal position b) end position

A typical cylinder cushioning operation arrangement is shown in the figure 1.25(a) and 1.25(b)

As the piston approaches the end of its stroke, the plunger enters the end cap port and thus blocks the free flow. Now the fluid is trapped between the piston and end cap. This fluid can escape only by passing through the adjustable restrictor, as shown in the Figure 1.25(b). This fluid flow through the restricted flow path causes the piston to decelerate. The rate of deceleration of the piston can be controlled by adjustable needle valve. A non-return valve or check valve is provided to allow free flow of fluid to the cylinder quickly during the return stroke.

1.7 CYLINDER FORCE, VELOCITY AND POWER

The output force (F) and piston velocity (V) of double acting cylinders are not the same for extension and retraction strokes.

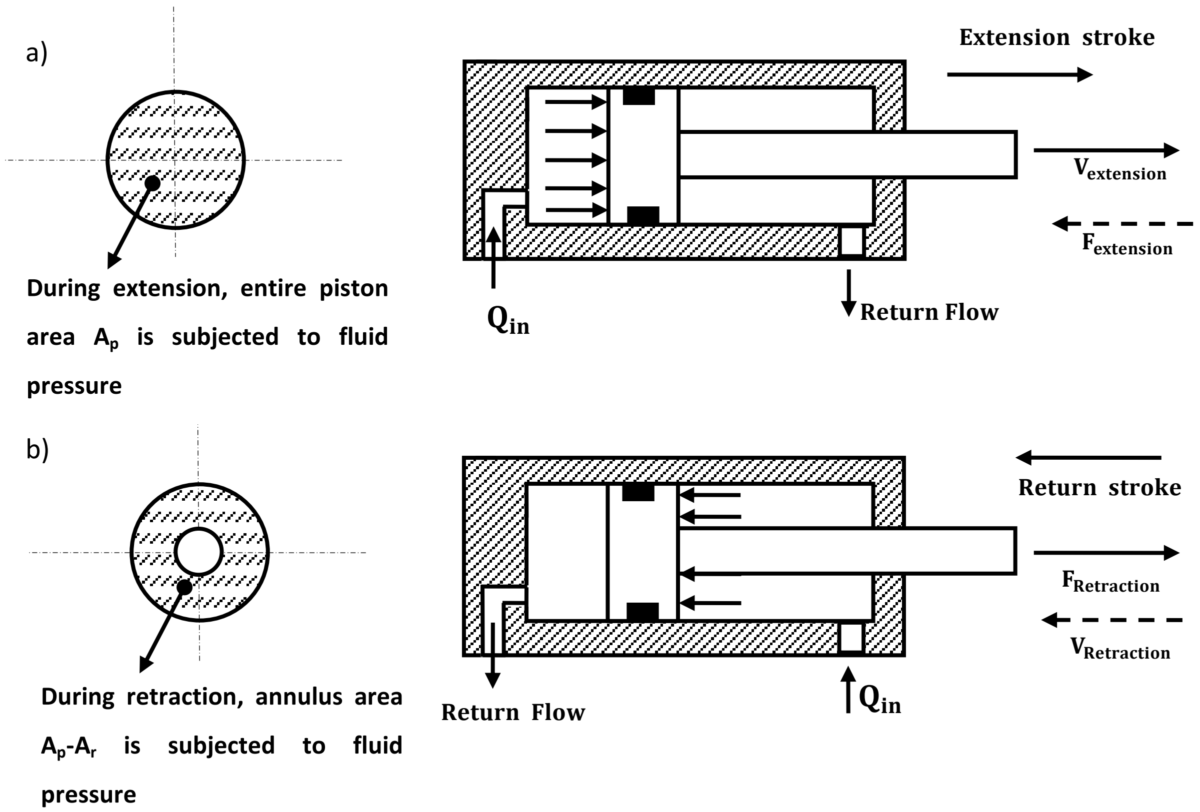


Figure 1.26 Effective areas during extension and retraction strokes

During the extension stroke shown in Figure 1.26(a), the fluid pressure acts on the entire circular piston area Ap. During the retraction stroke, the fluid enters the rod end side and the fluid pressure acts on the smaller annular area between rod and cylinder bore (A_p- A_r) as shown by the shaded area in Figure 1.26 (b). A_r is the area of the piston rod. Due to the difference in the cross sectional area, the velocity of piston changes. Since A_p is greater than (A_p-A_r), the retraction velocity (V_{ret}) is greater than the extension velocity (V_e) for the same flow rate.

During the extension stroke, fluid pressure acts on the entire piston area (A_r), while during retraction stroke, the fluid pressure acts on the annular area (A_p-A_r). This difference in area accounts for difference in output forces during extension and retraction strokes. Since (A_r) is greater than (A_p-A_r), the extension force is greater than the retraction force for the same operating pressure.

Force and Velocity during Extension stroke

$v_{ext} = \frac{Q_{in}}{A_p}$ ----------------------(1)

$F_{ext} = p \times A_p$ -------------------------(2)

Force and Velocity during Retraction stroke

$v_{ext} = \frac{Q_{in}}{A_p - A_r}$---------------------(3)

$F_{ext} = p \times (A_p - A_r)$ -----------------------------(4)

Power developed by a pneumatic cylinder (both in extension and retraction)

$Power = Force \times velocity = F \times V$ -----------(5)

In metric units, the kW power developed for either extension or retraction stroke is

$Power\ (kW) = v_p \left(\frac{m}{s}\right) \times F(kN) = Q_{in}(\frac{m^3}{s}) \times p(kPa)$ --------(6)

Power during extension

$P_{ext} = F_{ext} \times V_{ext} = p \times A_p x \frac{Q_{in}}{A_p} = p \times Q_{in} ------(7)$

Power during retraction

$P_{ret} = F_{ret} \times V_{ret} = p \times (A_p - A_r) \times \frac{Q_{in}}{A_p - A_r} = p \times Q_{in} --(8)$

Comparing equations (A) and (B), we can conclude that the powers during extension and retraction strokes are same.

1.8 ACCELERATION AND DECELERATION OF CYLINDER LOADS

Acceleration

To calculate the acceleration of cylinder loads, the equations of motion must be understood.

Let

u = initial velocity

v = velocity after a time *t*

s = distance moved during time *t*

a = acceleration during time *t*.

The standard equations of motion are:

$v = u + at$ --------------------(9)

$v^2 = u^2 + 2as$ -----------------(10)

$s = ut + 1/2\, at^2$-----------------(11)

and

$s = ½ (u + v)\, t$

The force F to accelerate a weight W horizontally with an acceleration a is given by

Force = mass × acceleration

F = (W/g) a

Where g is the acceleration due to gravity and is $9.81\ {}^{m}/_{s^2}$. The force P required to overcome friction is given by P = μW, where μ is the coefficient of friction.

Note: Dynamic cylinder thrust

In dynamic applications the load inertia, seal friction, load friction, etc. must be allowed for in calculating the dynamic thrust.

As a first approximation, the dynamic thrust can be taken as 0.9 times the static thrust. (It must be realized that this is only an approximation and can be considerably in error, dependent on load conditions and associated circuitry.)

Cylinder seal friction varies with seal and cylinder design. The pressure required to overcome seal friction is not readily available from the majority of cylinder manufacturers. The seal friction breakout pressure can be taken as 5 bar for calculation purposes. It will reduce when the piston starts to move. The pressure required to overcome seal friction will reduce as the cylinder bore size increases and will vary according to seal design.

Example 1: A pneumatic cylinder is required to move a 1000 N load 150mm in 0.5s. What is the output power?

Solution

Velocity,

$V = {}^{d}/_{t} = {}^{0.15}/_{0.5}$=0.3m/s

Power,

$P = F \times V = 10^3 \times 0.3$=300W = 0.3 kW

Example 2: A pneumatic cylinder is required to extend at a minimum speed of 0.75 m/s in a system with a flow rate of 50 LPM. What cylinder size is required?

Solution

$$Q = 50lpm = \frac{50}{1000} {}^{m^3}/_{min} = \frac{50}{1000\times60} = 8.33 \times 10^{-4}\, {}^{m^3}/_{s}$$

$$Q = A_p \times v$$

$$8.33 \times 10^{-4} = \frac{\pi}{4} d_p^2 \times 0.75$$

Solving we get $d_p = 37.6\, mm$

Example 3: An 8 cm diameter pneumatic cylinder has a 4 cm diameter rod. If the cylinder receives flow at 100 LPM and 6 bar, find the (a) Extension and retraction speeds (b) Extension and retraction load carrying capacities.

Solution

Qin=100 LPM=100/(1000×60)=1/600 (m^3/s)

d_p= diameter of cylinder= 8 cm = 8 x 10^{-2} m

d_r = diameter of piston rod= 4cm = 4x10^{-2} m

p = 6 bar =6x10^5 N/rn^2 or Pa

(a) $V_{ext} = \frac{Q_{in}}{A_p} = \frac{1/600}{\pi d_p^2/4} = 0.3315 m/s$

(b) $V_{ret} = \frac{Q_{in}}{(A_p - A_r)} = \frac{1/600}{\pi(d_p^2 - d_r^2)/4} = 0.442 m / s$

(c) $F_{ext} = p \times a_p = 6 \times 10^5 \frac{\pi(8\times10^{-2})^2}{4} = 2513.3$ N

(d) $F_{ret} = p \times (A_p - A_r) = \frac{5\times10^5\times\pi\left[(8\times10^{-2})^2 - (4\times10^{-2})^2\right]}{4} = 1885\text{N} = 1.89\text{kN}$

1.11 Rotary Actuators

Rotary Actuators are used to achieve angular motion. Rotary actuators are devices which produce high torque output and have a limited rotary movement. Standard rotations are 90°, 180°, and 270°. Rotary actuators are mainly available in three designs.

i) Vane type limited rotation motors

- Single vane rotation motor
- Double vane rotation motor

ii) Rotary Actuator of Rack and Pinion Type

iii) Helix spine rotary actuator

1.11.1 Vane type actuators

Where the torque and motion is all produced in a rotary sense, the construction limits the rotation to less than one rotation.

Piston type actuators are essentially linear actuators mechanically connected to translate the linear force to produce an output torque and rotational movement. These devices are capable of providing an output motion of one revolution or more but not continuous rotation.

Both type give bi-directional output motion, and most produce the same torque in both senses. Also output torque is generally constant throughout the stroke. There is no linkages and lost motion associated with cylinder- crank rod arrangement.

While the most often used actuators for pneumatic drives are cylinders for translational movements, there are many applications that require a turning or twisting movement of up to 360 degrees. Examples are turning components over in a drilling jig, providing a wrist action on a pick-and-place device or operating process valves. They are used in bench grinders, agitators, mixers, feeders, hoists, vibrators, pipe threaders etc.

i) Single Vane limited rotation actuators

The single vane actuator consists of a cylindrical housing, through which passes a central shaft to which the vane is rigidly attached. The housing has shoe or a stopper fixed to internal diameter of housing as shown in the Figure 1.43(a), thus dividing the interior space into two chambers. Pressurised air enters through port A and rotates the vane in the clockwise direction and air in the other chamber moves out of the port B. Similarly, when the air pressure is applied to the port B, the vane rotates in anti-clockwise direction and air in the other chamber moves out of the port A. Design geometry normally limits the rotary movement of a single vane actuator to about 280 maximum

ii) Double vane limited rotation actuators

It is possible to modify the design to have two vanes fixed to the output shaft 180 ° apart and two fixed stoppers in the casing providing two separate operating halves each with two chambers as shown in Figure 1.43(b). This gives twice the maximum torque output of a single vane device for the same supply pressure. Obviously the maximum angle of rotation is reduced and because of second stopper only 100° is usually possible.

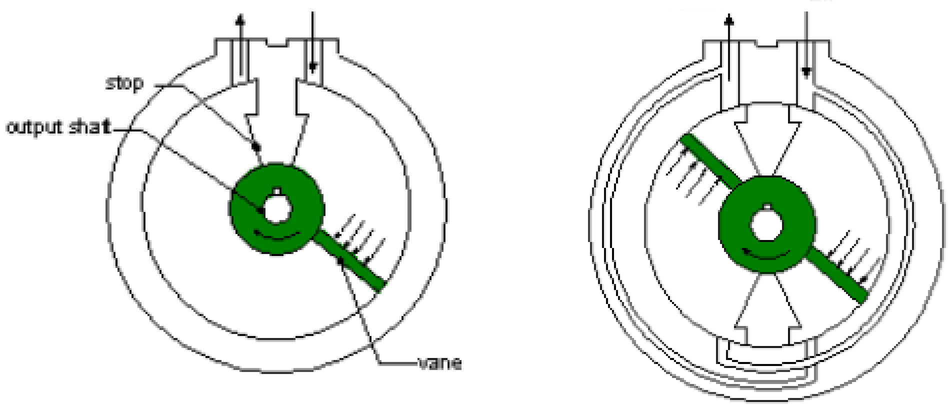
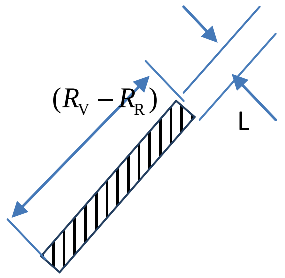


Figure 1.43 Vane actuators a) single vane b) double vane

iii) ANALYSIS OF TORQUE CAPACIT OF SINGLE VANE LIMITED ROTATION ACTUATOR

R_R = Outer radius of the output shaft (m)
R_V = Outer radius of the vane (m)
L = Width of the vane (m)
p = Hydraulic pressure (Pa)
F = Hydraulic force acting on the vane (N)
A = Surface area of vane in contact with oil (m^2)
T = Torque capacity (N m)



The force on the vane equals the pressure times the vane surface area:

$$F = pA = p(R_V - R_R)L$$

The torque equals the vane force times the mean radius of the vane:

$$T = p(R_V - R_R)L\frac{R_V + R_R}{2}$$

On rearranging, we have

$$T = p(R^2_V - R^2_R)L \text{ ----- (1)}$$

A second equation for torque can be developed by noting the following relationship for volumetric displacement V_D :

$$V_D = \pi(R^2_V - R^2_R)L \quad \text{----- (2)}$$

Combining equation 1 and 2 yields

$$T = \frac{p \times V_D}{2\pi} \text{ ------- (3)}$$

For a two vane actuator the theoretical torque is twice that for a single vane. For the given design and style of vane actuator the torque rating is directly proportional to the maximum supply pressure. The volume displacement of a single vane actuator is given by

$$Q = \emptyset\ (R_V^2 - R_R^2) \times \frac{L}{8}$$

Where ∅ is rotary movement in radians

From this speed of rotation ω (rad/s) can be calculated for a supplied flow rate Q(mL/s) with the width and both diameters expressed in cm as

$$\omega = \frac{8Q}{L(R_V^2 - R_R^2)}$$

Although the total volume in a two vane actuator will be the same for the same body size, its speed will be halved for the same flow rate because two chambers must be filled. If necessary, speed can be controlled by throttling or by fitting orifice plugs controlling inflow or outflow. The most critical feature of the vane actuator is the length requiring sealing around the vane between the end faces and the internal bore of the casing. Since this a moving seal there is usual compromise between good sealing with low leakage and resulting higher friction. The sealing surface with the bore is also at the largest radius and operating at the higher sliding speed. Seals are usually pressure activated and may give a nonlinear torque relation with the pressure. In addition to the vane seal, further seals are required on the shaft where it emerges from the body of the actuator and between the shaft and the fixed stopper. The problem of leakage may also be evident where the actuator has to be locked with the load held by a pressurized fluid column as in a linear cylinder. The lock will not be positive due to internal leakage unless provision is made to supply extra fluid to compensate for the leakage. The shaft support may be plain bearing, roller bearing or needle roller type. Friction is responsible for the difference between the starting torque and dynamic torque. Starting torque can be estimated as 80% of the dynamic torque. Overall efficiency of vane actuator is between 70 % to 90%.

1.11.2 Rotary Actuator of Rack and Pinion Type

Schematic diagram of rotary actuator of rack and pinion type is shown in Figure 1.44. They are special duty rotary actuators. It has a high torque and small installation dimensions. The actuator has double pistons, which transmit the turning moment to the output shaft. The toothed piston rods act on the output shaft in a rack-and-pinion type arrangement. Each piston and toothed rod is of integral construction. The rack-and pinion type arrangement gives an even turning moment throughout the rotation movement. The drive shaft is robustly supported in bushings of self-lubricating type. There are key-ways on the output end of the shaft, while the opposite end of the shaft has a stub that can be used to accommodate end-position indication, or to facilitate hand operation of the actuator. The turning limits of the rotary actuator should be determined by external stop lugs, in order to protect the unit from the effects of excessive load inertia. Compressed air is fed into the piston chambers via a connection plate and drilled galleries in the central part and end covers. This rotary actuator has a cylinder block of natural anodized aluminum, with end covers of black anodized aluminum. The unit is available in 5 different sizes, covering a turning-moment range of 20 to 200 Nm. As standard, all sizes are available with a turning angle of either 90° or 180°. Three dimensional view of Rack and pinion type is shown in Figure 1.45

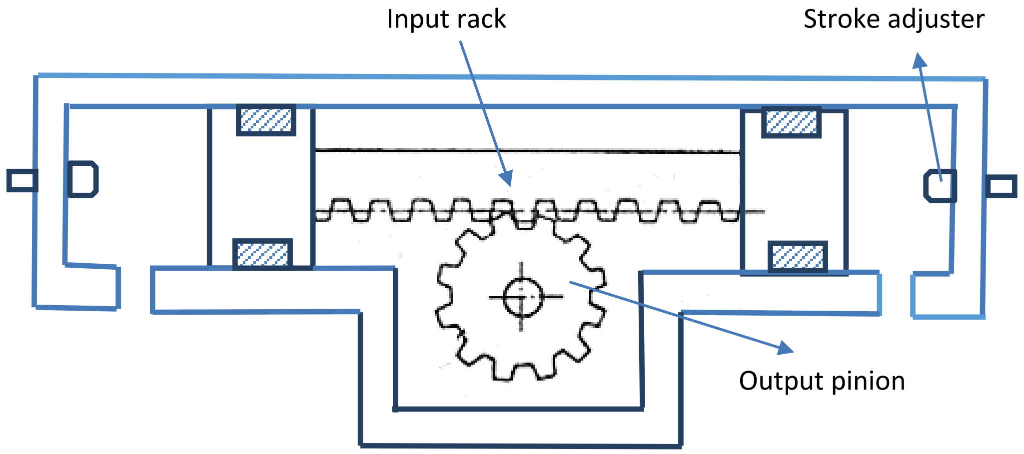


Figure 1.44 Rotary Actuator of Rack and Pinion Type (single rack)

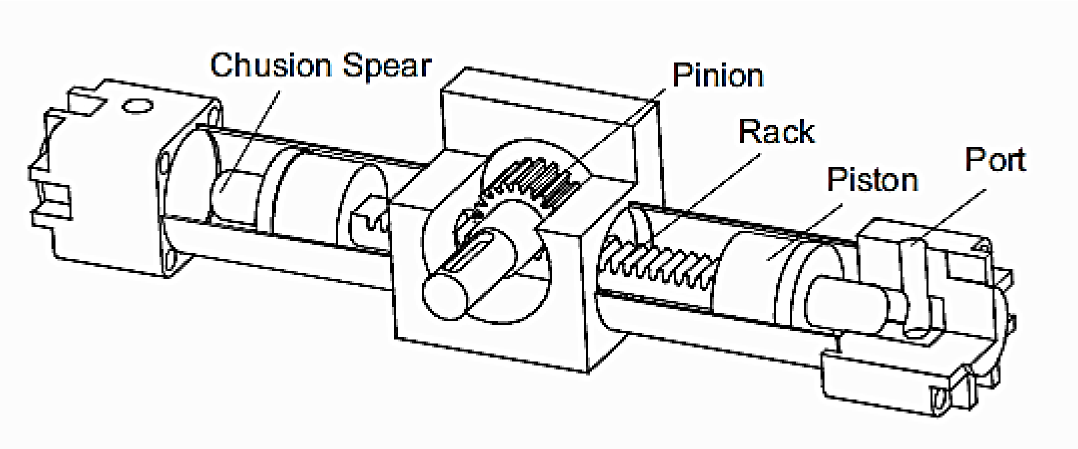


Figure 1.45 Three dimensional view of Rotary Actuator of Rack and Pinion Type

Torque can be doubled by adding another actuator as shown in the Figure 1.46

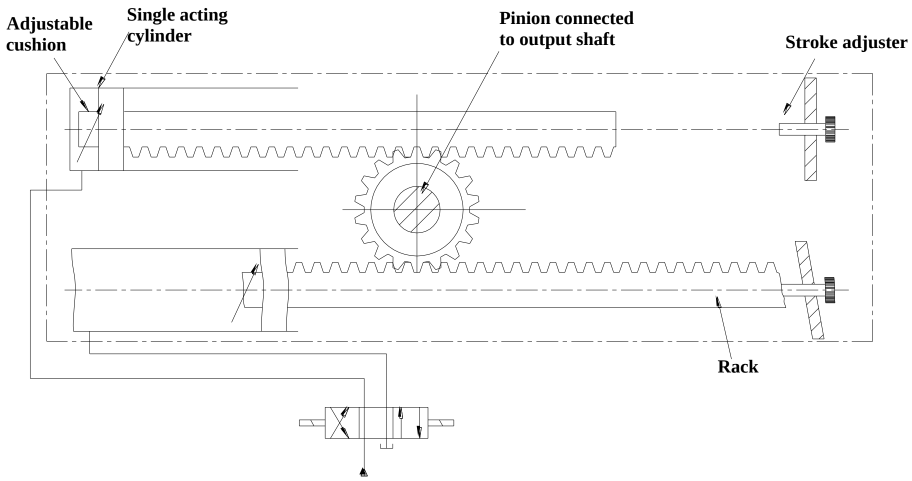


Figure 1.46 Rotary Actuator of Rack and Pinion Type (two rack)

5.11.3 Helix spine rotary actuator

Figure 1.47 shows a simplified cutaway view of a spiral-shaft rotary actuator. Thespiral-shaft rotary actuator has a keyed, non-rotating piston with a hollow rod. The hollow rod has a set of internal spiral grooves that mesh with the spiral shaft. The spiral-grooved shaft only has rotational movement and extends through the housing as an output shaft. With fluid piped to the CW port, the output shaft turns clockwise. With fluid piped to the CCW port, the output shaft turns counter clockwise

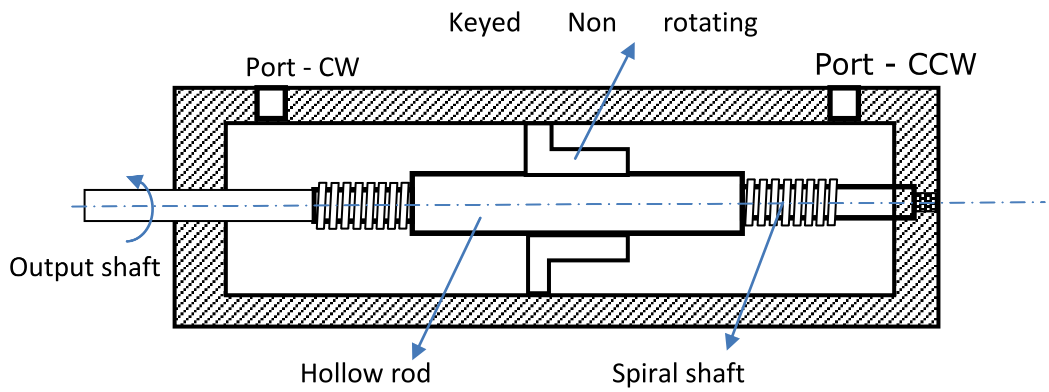


Figure 1.47 Helix spine rotary actuator

Objective Type Questions

1. Single acting cylinders can produce work in -------------- direction
2. In--------------------- type of cylinder, the force on the piston rod is almost doubled.
3. Telescopic cylinders are normally used for ---------------- stroke lengths
4. In first order lever system, fixed hinge point is located ----------- the cylinder and loading point

1. Cylinder with -------mounting generally require strong machine frames to resist bending moments

6. The single acting cylinder converts the compressed air energy into ------in the form of force and linear movement in one direction only.

7. Pneumatic ------ element convert the energy in the compressed air into force and motion. The pneumatic drive elements can move in a linear, reciprocating or rotating motion.

8. Typically, the piston can have diameters of as much as ---- mm

9.------- acting cylinders are used in the assembling and packing automated lines to move, lift, feed, eject, press or push objects or to clamp parts. Practically, they are suitable for oil- free operation.

10. The compressed air is applied only on the bottom side of the piston that is why the cylinder can move loads or perform mechanical work in a forward motion only and that the effective force is reduced by the ---------

11.The working speed of piston is in the range of 50 to ----- mm/s

12 In -----------type of cylinder , it is equipped with a compressible chamber with flexible sides that can be expanded to draw air in and compressed to force the air out

13.An alternative construction is a single acting cylinder, spring ------- with a spring in the piston area causing the piston to extend. Such pistons are used in the automotive industry and these are mounted in the air brakes for vehicles and trains

14.Another special form of single-acting cylinders is -------return spring in which the piston's return stroke is caused by external forces or by its own weight.

11.Short stroke cylinders are used when short strokes are required together with high ------

State True or False

1. Telescopic cylinder is used when long stroke length and short retracted length are required.

2.. Compared to first class lever, Second-class lever also results in a smaller load stroke for a given cylinder stroke

3 For a second-class lever system the cylinder rod pin lies between the load road pin and fixed-hinge pin of the lever.

4. In first order lever system, the loading point is in between the cylinder and the hinge point.

1. In pneumatic cylinders dynamic thrust can be taken as 0.1 times the static thrust

Review Questions

1. What is the function of a pneumatic actuator?

2. How can you classify the pneumatic actuators?

3. How do hydraulic actuators differ from pneumatic actuators?

4. What is the function of a pneumatic cylinder?

1. Explain the working of double acting double rod cylinder with a neat sketch

6. Explain the working of tandem and telescopic cylinders with a neat sketch

7. Mention few applications of pneumatic cylinders

8. Differentiate between single acting and double acting cylinder

9. What are the main advantages of magnetic cylinder?

Answers

Fill in the Blanks

1. only one
2. Tandem
3. long
4. in-between
1. non-centreline
6. mechanical energy
7. drive
8. 100mm
9. single
10. return spring
11. 500
12. diaphragm
13.extend
14. without
11. forces

State True or False

1. True
2. True
3. False
4. False
1. False