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PNEUMATIC APPLIED TO LOGISTIC SYSTEMS

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Abstract: Material handling and logistics are expensive operation which comprise of 10% to 80% of the product cost and this percentage tends to rise for inexpensive or commodity products. Since material handling and logistic operations often involves a substantial amount of direct labor and labor is expensive, designer engineer were very supportive of automation. This paper present several pneumatic actuators used in logistic systems.

1. INTRODUCTION

Today, the most important property of the medium air is the simple conversion of pressure to force and translational displacement using a piston in a circular bore. Pneumatic applications using compressed air as the control medium have many physical characteristics advantages such as safety, ease of maintenance. They are far superior in there resistance to contamination in a variety of environments; from highly corrosive to the cleanest pharmaceutical manufacturing environments. Another, advantage in some applications is that air devices create no sparks in explosive atmospheres. They can also be used under wet conditions with no electrical shock hazard.

2. PNEUMATIC CYLINDERS

Cylinders convert pneumatic energy to mechanical work. They usually consist of a movable element such as a piston and piston rod, or plunger, operating within a cylindrical bore. Cylinders are often double-sided, pressurized air can work on both sides of the piston to extend or retract it, and they have mostly a single-ended piston rod.

A typical design is shown in fig. 1.The piston rod is case hardened and chrome plated while the barrel is made of stainless steel or of an aluminum profile. Most cylinders

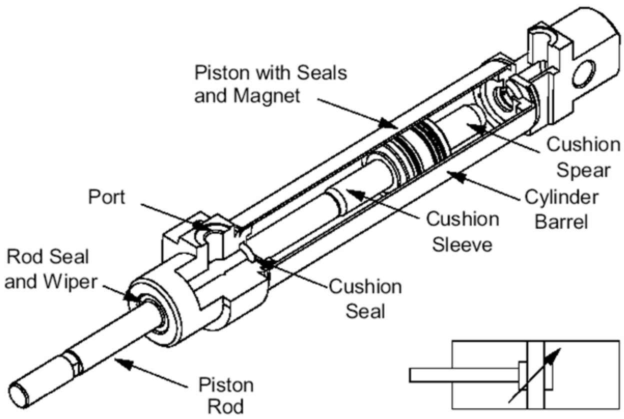

Fig. 1 Cut-away view of single rod cylinder and symbol

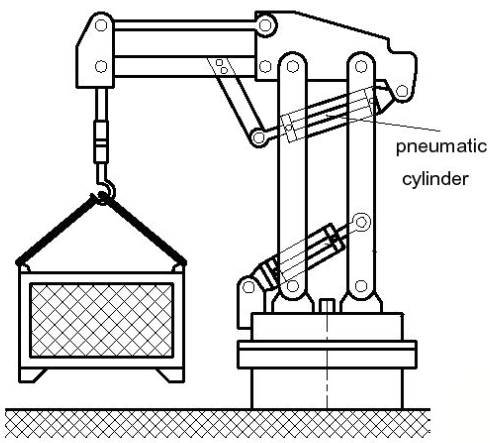

Fig. 2 Elevator mechanism (Festo)

have a band of magnetic material around the circumference of the piston and are fitted with a non-magnetic cylinder barrel. The magnetic field will travel with the piston as the piston rod moves in and out. Some means of stroke cushioning, gradual deceleration of the piston near to the end of its stroke are provided by cushioning rings in the end position or elaborate pneumatic valve systems. The symbol in Fig. 1 shows barrel, piston and rod. The arrow and the two rectangles beside the piston symbolize the adjustable cushioning. Pneumatic cylinders are very well suited to rapidly accelerate a mass to a high speed, e.g. 1 m/s. At the end of the cylinder stroke this mass has to be decelerated gently to prevent damage from the load and the machine, and avoid excessive noise. [7]

An example of elevation systems with pneumatic cylinders is presented in figure 2.

3. NON-STANDARD LINEAR ACTUATORS

3.1. Multi-Position and Tandem Cylinders: A simple way to move a load to a number of fixed reliable positions is to mount two or more cylinders together and fully in stroke or outstroke them in all possible combinations. Manufacturers typically offer these mountings for some of their cylinder lines. The disadvantage is that the cylinder barrels are not fixed but moving. This increases the load mass and requires a solid mechanical design and the use of flexible tubing. An alternative are custom built *multi-position cylinders* (fig.3) where the pistons are integrated in one barrel.

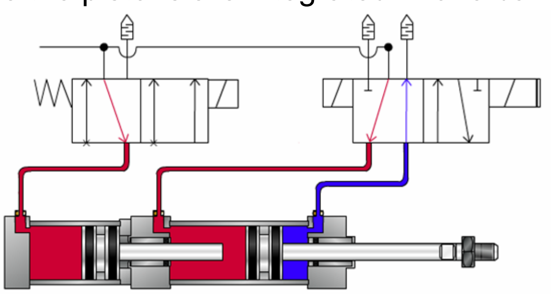

Fig. 3 Three position cylinder

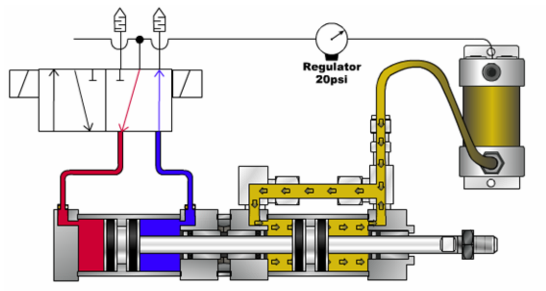

Fig. 4 Tandem cylinder

Tandem cylinders (fig.4) are used when the available space for width and height of the cylinder and the pressure is not sufficient to reach the required force. Then two pistons can be mounted on one common piston rod to almost double the rod force. In contrast to a multi-position cylinder, only two ports are necessary. Some manufacturers offer tandem cylinders where the pistons are not mechanically coupled; the extending chambers are connected to one port, the retracting chamber at the rod side is connected to the second port while the other retracting chamber is open to the atmosphere. [7]

3.2. Rodless Cylinders

3.2.1. Split-Seal or Slot Type: this type of rodless cylinder has a slot the full length of the barrel which allows the carriage and the load to be rigidly connected to the piston (fig.5). Long sealing strips, which can be made of stainless steel with a thickness of 0.2 mm, on the inside and outside of the cylinder tube prevent loss of air and ingress of dust.

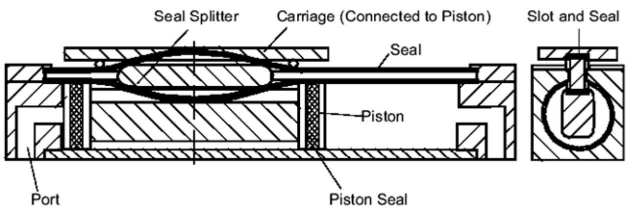

Fig. 5 Schematic view of a slot type rodless cylinder

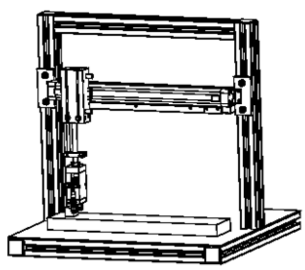

Fig. 6 Rodless cylinder with integrated guiding and vertically transferable gripper

Figure 6 shows a small set-up in the control lab in Soest simulating a pick-and-place

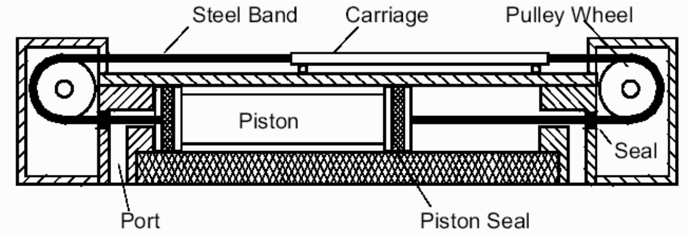

Fig. 7 Schematic view of cable type rodless cylinder

operation. The vertically mounted gripper can be lifted by the compact cylinder that has a non rotational guiding. The rodless cylinder positions the gripper horizontally.

3.2.2. Cable Type: this type of rodless cylinder (fig.7) has a cable or band to transmit mechanical force and motion from the piston to the carriage. The advantage is that there is no full length slot in the barrel which has to be sealed. Instead, only a seal for the cable is required. The direction of motion of the carriage is opposite to the direction of motion of the piston.

3.2.3. Magnetic Type: this type of rodless cylinder uses the force locking of a magnetic coupling to transmit mechanical force and motion from the piston to the carriage. The advantage is that no seals for the slot in the barrel or for the cable are necessary because the piston chamber and slide are hermetically sealed. [7]

A typical configuration for handling devices made up of modular components is shown in Fig.8. Panels are picked from a stack and transferred to a conveyor. Two linear axes are sufficient for this. In this example, rodless pneumatic cylinders, linked by a cross-member, are used for the horizontal motion. In the case of light small panels, one of the cylinders can be replaced by a linear guide, for example, a roller strip. The suction-cup spider travels in an open rectangular motion cycle. The elements that compose this modular pick-and-place device are: 1-standard cylinder, 2-cross-member, 3-rodless cylinder, 4-suction cup, 5-rack with free support, 6-conveyor system, 7-workpiece.

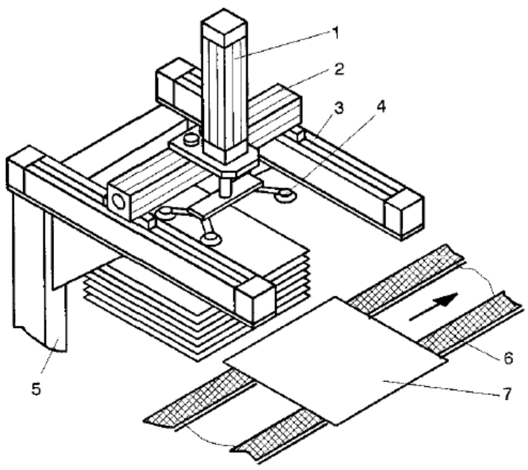

Fig. 8 Modular pick-and-place device (Festo)

3.3. Bellows: are single acting concertina like actuators which extend when inflated. Due to their space saving design they require only a low installation height. They are made of rubber (fig.9) and reinforced with fabric. Bellows have no mechanically moving parts and therefore no friction forces exist. They are maintenance-free even under severe conditions like underwater installation or in a dirty or dusty environment. They are easy to install because the permissible tilt angle between the two end caps is much higher than those for standard cylinders. Bellows are used as mechanical actuators, in vibration isolation systems on stationary machines and as vehicular suspensions. In the second case, the bellows is typically connected through a line of significant length to a reservoir whose pressure is constant. In the latter case, the reservoir pressure can be controlled to account for changing operating conditions.

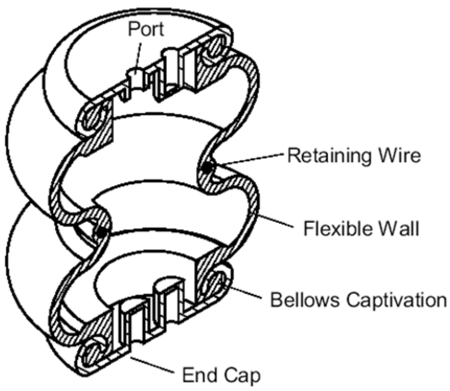

Fig. 9 Cut-away view of a double convolution bellows

3.4. Rolling-Diaphragm Cylinders: While a standard cylinder needs seals to prevent air from venting from one chamber to the other or to the atmosphere, in a rolling-diaphragm cylinder the diaphragm forms a flexible sleeve which rolls from the cylinder wall to the piston wall and back again as the piston moves. Figure 10 shows the design. The rolling action of the diaphragm makes the cylinder almost free of break-away and dynamic friction and thus ideal for applications where a very close control of tension, position or applied force is needed. The diaphragm forms a positive seal that prevents migration of contaminants downstream of the cylinder.

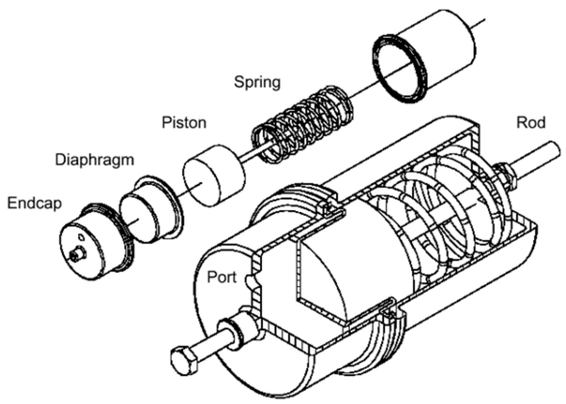

Fig. 10. Cut-away of a rolling-diaphragm cylinder, rod slightly extended

These cylinders are frequently used as pneumatic actuators in food and drug industries because they do not require lubrication and therefore do not exhaust a contaminating oil mist. Rolling-diaphragm cylinders do not generally compete with conventional cylinders because of their relatively slow cycle-rate and short stroke length. While leakage does not appreciably affect the operation of other air cylinders, it could constitute a failure for rolling-diaphragm cylinders. [7]

3.5. Pneumatic Artificial Muscle: pneumatic artificial muscle is a contractile and linear motion engine operated by gas pressure. Its concept is a very simple one: the actuator's core element is a flexible reinforced closed membrane (shell, diaphragm) attached at both ends to fittings along which mechanical power is transferred to a load. As the membrane is inflated or gas is sucked out of it, it bulges outward or is squeezed, respectively. Together with this radial expansion or contraction, the shell contracts axially and thereby exerts a pulling force on its load. The force (tension, load) and motion thus generated by this type of actuator are linear and unidirectional. This contractile operation distinguishes the pneumatic artificial muscle from bellows, which extend upon inflation.

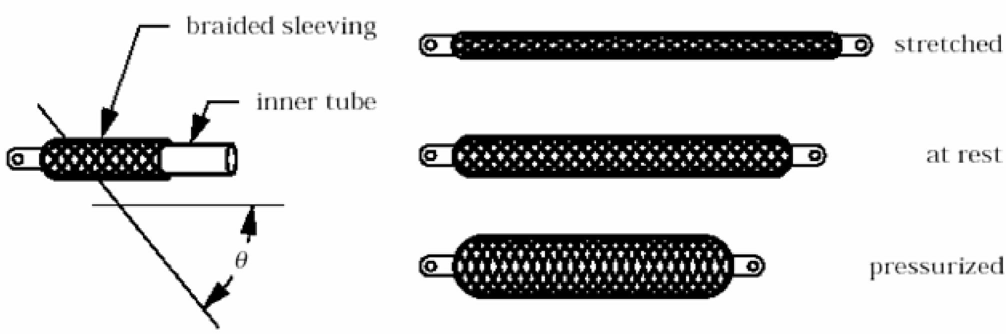

Fig. 11 McKibben type muscle

The type of pneumatic artificial muscle most frequently used and published about at present is the McKibben Muscle. It is a cylindrical braided muscle that has both its tube and its sleeveing connected at both ends to fittings that not only transfer fiber tension but also serve as gas closure. Typical materials used are latex and silicone rubber and Nylon fibers. Fig.11 shows its structure and operation. [2]

Due to a threshold of pressure which depends on the rubber characteristics, these muscles do not function properly at low pressures. To avoid friction and deformation of the

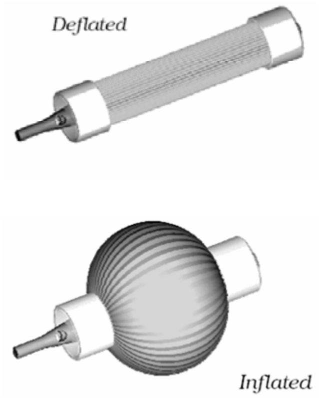

Fig. 12 CAD drawing of the deflated and inflated state of the PPAM


Fig. 13 Inflated state of the second generation PPAM

rubber material, the Pleated Pneumatic Artificial Muscle (PPAM) has been designed by Daerden [1999]. The membrane of this muscle is arranged into radially laid out folds that can unfurl free of radial stress when inflated.

Fig. 12 shows the working principle of the PPAM. The membrane is a fabric made of an aromatic polyamide such as Kevlar to which a thin liner is attached in order to make the membrane airtight. The high tensile longitudinal fibers of the membrane transfer tension, while the folded structure allows the muscle to expand radially. The folded membrane is positioned into two end fittings which close the muscle and provide tubing to inflate and deflate the enclosed volume. The end fittings are constructed with a circular inner teeth structure to position and align each fold of the membrane, while an outer aluminum ring prevents the membrane of expanding at the end fittings. An epoxy resin fixes the membrane to the end fittings.

Finally, fig. 13 shows a photograph of the new muscle prototype. The muscle is shown in its inflated state. Note the regular unfolding of the flexible membrane while the Kevlar fibers stay positioned at equal distances [1]

One application of the pneumatic artificial muscle is the gripping process. Thus, in the case of the gripper shown in fig. 14, the gripper has a simple mechanical design, of lighter weight than comparable grippers and yet more powerful in retaining an object. The pneumatic artificial muscle is fitted sufficiently close to the centre of rotation of the finger, the short muscle being adequate to execute the clamping motion. The efficiency of the gripper is excellent, since frictional resistance only has to be overcome in the circular pivots of the gripper fingers. This design does not permit opening angles of 90° per finger and different gripper kinematics would need to be selected. The element that compose the gripper are:1- gripper flange; 2-gripper housing; 3-tension spring; 4-gripper finger; 5-gripper jaw; 6-workpiece; 7-pneumatic artificial muscle; 8- rod for motion synchronization; 9- finger stop.[6]

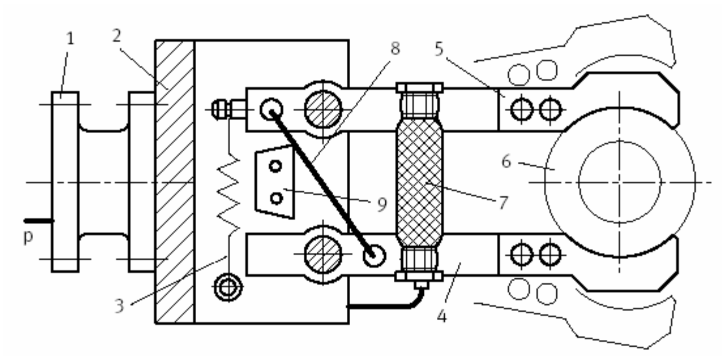

Fig. 14 Simple angle gripper (Festo)

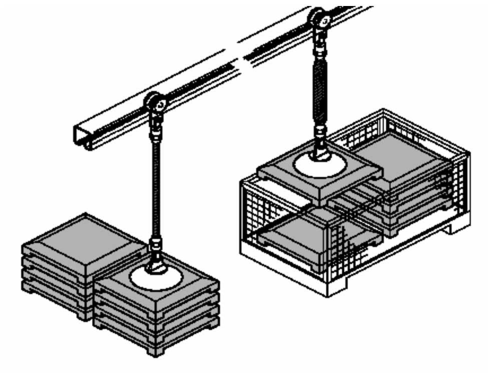
Fig. 15 Positioning systems

Pneumatic artificial muscle can be use for example in simple positioning systems (fig.15). In this case the work pieces can be raised or lowered as required by pressurizing or exhausting the muscle via a hand lever valve.

4. PNEUMATIC ROTARY ACTUATORS

Pneumatic rotary actuators use pressurized air to rotate mechanical components. They are used in applications such as machine loading and unloading, material handling, product assembly, welding, packing, testing and quality control. There are several types of pneumatic rotary actuators. Single rack-and-pinion actuators drive a single rack that rotates the pinion. Double or four piston rack-and-pinion actuators drive racks on both sides of the pinion. Single rotary vane devices are actuated directly by pressurized air. Double rotary vane devices use two chambers of pressurized air to produce increased torque. Multi-motion rotary vane actuators are also available. Indexing or multi-position devices allow multiple position stops along strokes. Rotation angle, the angle to which an actuator can rotate before reaching its travel limit, varies widely among pneumatic rotary actuators. Common rotation angles are 45°, 90°, 120°, 135°, 180°, 225°, 270°, 325°, and 360°. Pneumatic rotary actuators with rotation angles less than 45° or greater than 360° are also available.

The major difference between its cousin the linear actuator is that rotary actuators or commonly called air motors, is the fact that they produce torque. Selecting pneumatic rotary actuators requires an analysis of product features.

5. MULTI-MOTION ACTUATORS

Multi-motion actuators provide independent rotary and linear motion from one output shaft ideal for part transfer, positioning, and orientation. Built-in flow controls and angle adjustments are standard on most sizes. Also, free floating pistons with rack and pinion rotary design eliminates binding for low breakaway and long unit life. Sealed shaft ball bearings on rotary section provide long life and low friction. Simple construction allows easy field reparability. The working principle is presented in fig.16.The main components of the actuator consist of a cylinder and a rack-and-pinion type rotary actuator. Linear motion of the rod D is produced when port 1 or 2 is pressurized. Rotary motion of the rod D is produced when port 3 or 4 is pressurized causing pinion gear A and spline bar B, which are coupled together to rotate coupled piston C.

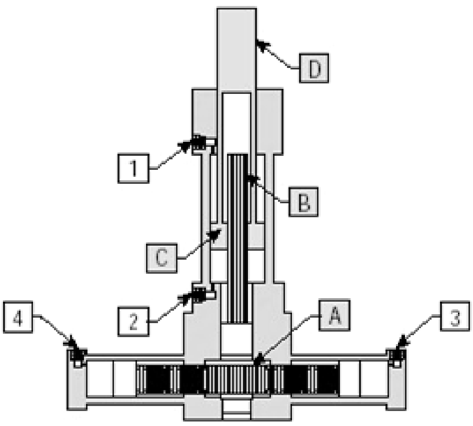

Fig. 16 Multi-motion actuators

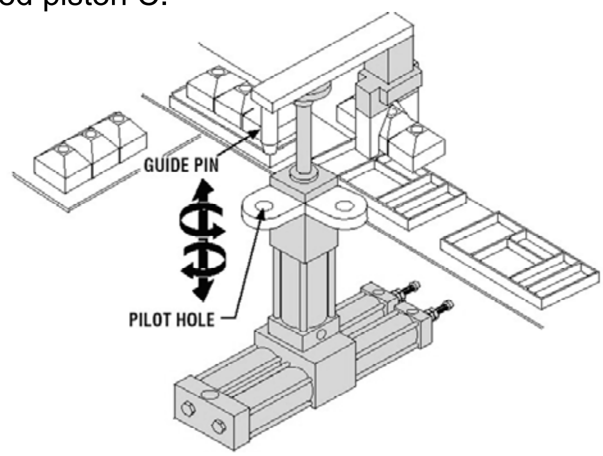

Fig. 17 Multi-motion actuator for transfering

Parts transfer and positioning can be easily accomplished using a multi-motion actuator. The multi-motion actuator presented in fig.17 is transferring parts from one line to another and is locating the part being moved onto a second part. This precise location is being done by use of a customer provided guide pin on the back side of the transfer arm. As the multi-motion retracts, the tapered guide pin engages the pilot hole and ensures a positive rotary position for both the pickup and placement point. This type of guide pinning should always be considered where exact positioning is required. [8]

5. GRIPPERS

A pneumatic gripper is a specific type of pneumatic actuator that typically involves either parallel or angular motion of surfaces that will grip an object.The easier way to describe a gripper is to think of the human hand. Just like a hand, a gripper enables holding, tightening, handling and releasing of an object.Grippers are frequently added to industrial robots in order to allow the robot to interact with others objects. So, we can say that grippers form the link between all kinds of work pieces and the manipulating machine concerned.

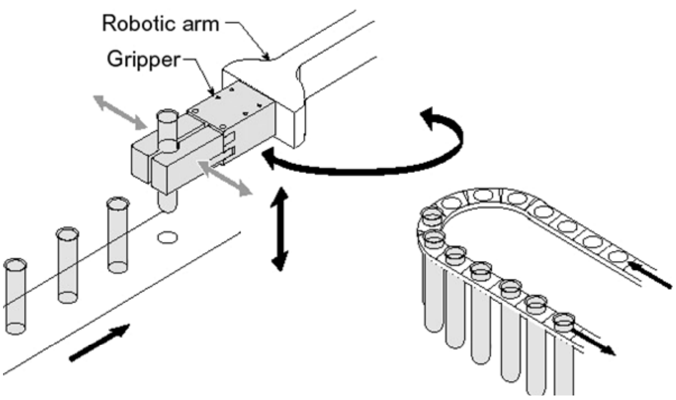

Fig. 18 Angular gripper for pharmaceutical application

In fig.18 is presented an angular gripper for pharmaceutical application. The angular gripper is mounted to the end of a robotic arm. The gripper grips the test tube and moves it to the test station. The angular gripper provides a lighter weight gripper. [8]

Many styles and sizes of grippers exist so that the correct model can be selected for the application. The choice of gripper type is always determined by the properties of the object to be gripped and the purpose of the handling operation concerned. Some grippers act directly on the object they are gripping based on the force of the air pressure supplied to the gripper, while others will use a mechanism such as a gear or toggle to leverage the amount of force applied to the object being gripped. Grippers can also vary in terms of the opening size, the amount of force that can be applied, and the shape of the gripping surfaces. Pneumatically-driven grippers are robust and technically relatively simple; they are used in large numbers in all branches of industry.

They can be used to pick up everything from very small items (a transistor or chip for an electronic assembly board, for example) to very large items, such as an engine block for a car. New technology, such as video recognition systems, has led to new demands

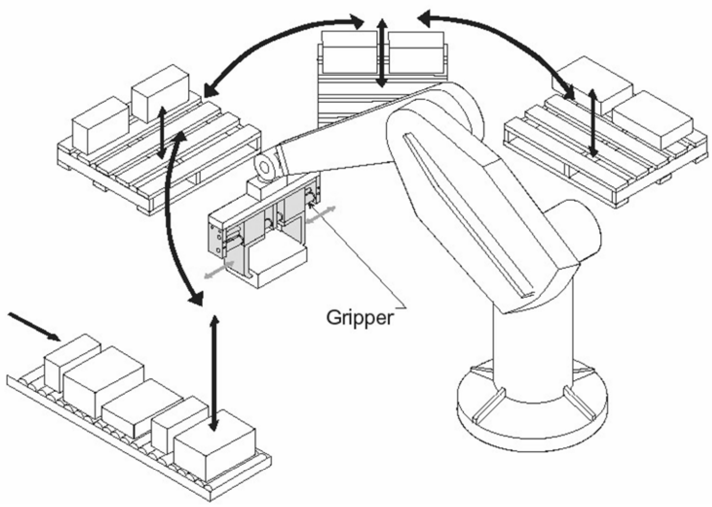

Fig. 19 Gripper for long travel

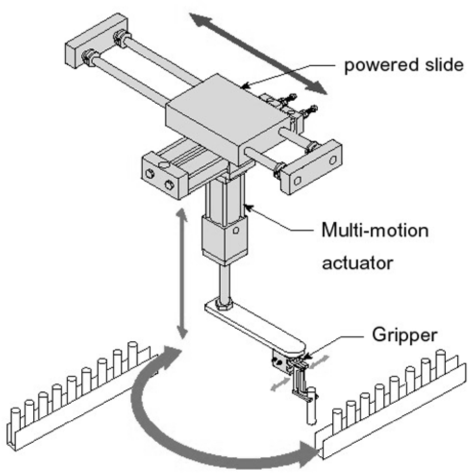

Fig. 20 Pick and place

being placed on gripper systems. One solution is to use several suction cups to pick-up.

The gripper presented in fig.19 is design for long stroke, high force capability. Used as an end effector on an industrial robot the synchronized parallel action automatically centers items for operations such as sorting. The long stroke compensates for items of varying size or position.

Fig. 20 shows that the multi-motion actuators and grippers are used in pick-and-place application for the pharmaceutical industry. He handles and transfer delicate glass containers throughout the filing, mixing and measuring process. The completed containers are loaded onto a pallet and transferred to the next station. [8]

6. CONCLUSIONS:

Pneumatic actuators continue to generate significant research interest due to their unique advantages. They are low-cost, safe, clean, and possess a high power to weight ratio. Pneumatic cylinders produce a small force over a long movement. Pneumatic artificial muscles, on the other hand produce very high forces, but pull relatively short distances. Therefore cylinders and air muscles are used in different ways, and are generally for slightly different applications. Pneumatic artificial muscle is a powerful actuator, which can exert large forces, over a short distance at low air pressures. Air muscles are most effective at the beginning of their stroke (fully extended), giving a high force and good responsive movements. Unlike pneumatic cylinders, air muscles have no 'stiction', and an immediate response. This results in a smooth natural movement.

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