

Survey on Actuators Used in Automation

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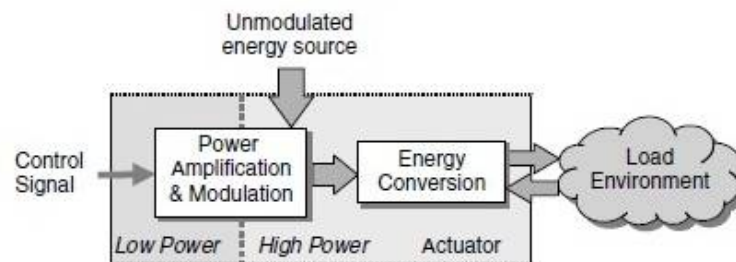
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ABSTRACT: Actuators play a vital role in automation process. Actuators can probably a last element of an automation system which provides physical result. There are different types of actuators which have different capabilities, shape and size and have its own unique function to carry out required process efficiently. Hence from perspective of automation it is important to know about different type of actuators and compare among them to know about their unique features/characteristics, their advantages and disadvantages for different condition and their application areas to select most suitable actuating system to obtain most efficient automation system.

KEYWORDS: Actuators, Automation, Hydraulics, Pneumatics, Electromechanical

I. INTRODUCTION

In automation process a device which provides desire result on load environment is called as actuator. Basically actuator is device which converts any form of energy into mechanical motion. Typically it is energy conversion device which leads to energy transduction into an action. Fig.1 below shows components of actuating system.



Source: *Mechatronics-handbook, Robert H. Bishop, the University of Texas at Austin, Texas, Chpt 20, Fig 20.2*

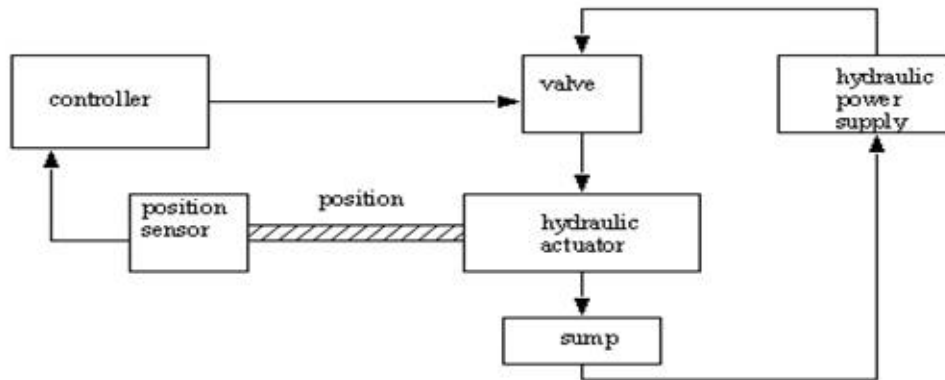
Actuator is combination of energy conversion element along with power amplification & modulation element which carried- out energy conversion with the help of control signal which is a low power in nature (usually signal from controller) and un-modulated energy source which is usually high power in nature. All components together produce a mechanical motion to obtain desire output. Methods and materials used for the survey are literature reviews and papers and some of the books related to automation. In automation domain following four types of actuators are widely used.

Hydraulic actuating system,
Pneumatic actuating system,
Electromechanical actuating system &
Mechanical actuating system

II. RELATED WORK

Hydraulic actuating system:

It uses fluid power to produce mechanical force. Fluid power is technology that deals with the generation, control and transmission of forces responsible for movement of mechanical element. Hydraulics is based on Pascal's law which states that when there is an increase in pressure at any point in a confined fluid, there is an equal increase at every other point in the container. In simple words intensity of pressure in fluid is equal in all direction. Fig.2 shows simple block diagram of hydraulic actuating system consist of sensors, controller, actuating components which is given blow in detail.



Source: <http://www.thelearningpit.com/hj/plcs23.asp>

Hydraulic actuators is popularly used in automation system as an actuator because of its high power capacity, best power to weight ratio and good speed of response. In addition to these it can handle the payload without significant power consumption. However economical factor and use of hydraulic system in high temperature circumstances limits its area of application. A biggest advantage of this system is that it can handle large load with minimum efforts.

Let's have an eye on components that basic hydraulic actuator system consist of

- **Pump**– It is hydraulic power generation system. It pressurized fluid to the level required by an actuating system.
- **Valve** - It controls the direction, pressure, flow rate of hydraulic fluid basically it act as a regulating system.
- **Actuator**- It converts the fluid pressure into mechanical movement either linear or rotary.
- **Pipes** – Used to connect various elements of actuating system with each other.
- **Accumulator, reservoir and filter** – Filter is used to filter the hydraulic fluid to prevent damage to system components by contaminants and the reservoir & accumulator is use for storage purposes.
- **Sensors** – Sensors are crucial part of any automation process, it provide some kind of feedback signal to evaluate the end result by controller.
- **Control device** – It control whole actuating system by providing signals.(Microcontroller or PLC are popularly used)

Pressurized fluid from pump is regulated by valve as per the requirement which will further converted into mechanical motion by an actuator. Microcontroller and sensors provide close loop control of an actuating system to ensure that only desired results is obtained. Working pressure of hydraulic system is between 150 to 300 bars.

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Source: <https://www.boschrexroth.com/en/us/products/product-groups/industrial-hydraulics/motors/index>

(a)



Source: <http://energyhydraulic.in/home/productslist/5>

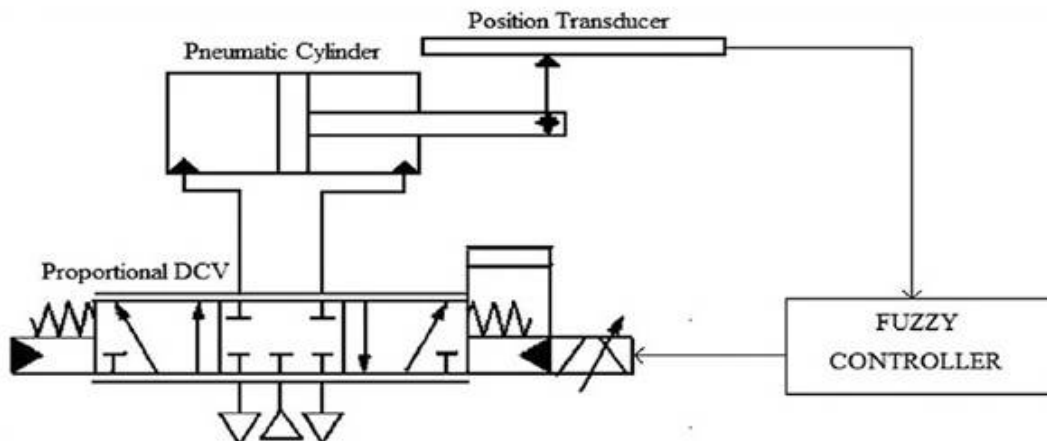
(b)

Figure 3 show (a) hydraulic motor and (b) Hydraulic double acting cylinder used in hydraulic actuating system.

Pneumatic actuating system:

It is similar to hydraulic actuator system, except instead of hydraulic fluid compressed air is used to transmit the power between various elements. Pneumatic actuators are widely used in automation field because of its low weight and compact size. Control of pneumatics system is slightly difficult as compare to hydraulic system because of compressed air governing equations of pneumatics are nonlinear in nature and are more used in automation industry as discrete device such as gripper.

Pneumatic actuator has low power capability somewhat less than 10 bars as compare to hydraulic system. However its low cost availability, compact size, minimum maintenance and application areas of extreme temperature make it more attractive than hydraulic system. Fig.4 shows circuit diagram of pneumatic actuating system used in automation process.



Source: <http://www.onlinejet.net/article.asp?issn=09768580;year=2014;volume=4;issue=2;page=115;epage=118;aulast=Saravanakumar>

The function and construction of pneumatic actuator are similar to the hydraulic one, even it consists of some different components which is follows

- **Compressor** – It act as power sources for pneumatic system.
- **Air treatment unit** – It consist of FRL unit which comprises of filter to filter the compressed air, a pressure regulator to regulate a flow of compressed air and a lubricator to lubricate air.
- **Valve** – It controls the direction and regulates the air flowing to actuating system.

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- **Actuator** – It convert the pneumatic force or compressed air pressure into mechanical fore or movement.
- **Pipes** – Used to connect various elements of actuating system with each other.
- **Sensors** – It act as feedback element for a controller in pneumatic system.
- **Controller** – Monitors whole system to provide required output.

Compressed air from compressor is delivered to FRL unit which allow the filtration and regulation of supply pressure to actuating element through a valve which further converted into linear or rotary motion by a pneumatic cylinder or pneumatic motor respectively.



Source: <http://hydraulicspneumatics.com/cylinders-amp-actuators/sorting-out-air-motors>

(a)



Source: <http://www.mfgnewsweb.com/archives/4/37449/MaterialHandling-AGVs-Storage-InvCtrl-nov12/Gripper-for-a-Variety-of-Gripping-Diameters.aspx>

(b)

Figure 5 of (a) pneumatic motor and (b) Pneumatic gripper used as pneumatic actuation.

Electromechanical actuating system:

This type of actuators converts electrical energy into mechanical energy. There are different ways to achieve this conversion. One of the popular method which is used by many electromechanical actuators is by generating magnetic field in which “when current carrying conductor is placed in magnetic field it experiences mechanical force” - *Lorentz's Law of Electromagnetic Force*. This generated force will further converted into mechanical motion.

One of the biggest advantages of electromechanical actuator is that it provides flexibility to control it from remote location. Also they have a very high speed of response, low cost, easy maintenance, accurate control and clean energy source makes it highly acceptable by a various automation industry. Some basic types of electromechanical actuators includes

Solenoid – It is simplest electromechanical actuator which operates on electromagnetic principal. It consists of coil as solenoid, magnetic plunger in center of coil and a frame. When coil is energized movable plunger will experience a mechanical force due to magnetic field produce between coil and plunger. It is capable of producing both types of actuation motion linear as well as rotary.

Electric motor- Electric motors has wide applications in the industrial as well as in automation sector and popularly used in robotics application because of its high speed of response, finer speed control capability. The magnetic field of stator interacts with magnetic field of rotor to produce rotating torque. There are two basic types of electric motor - AC & DC motor which consist of basic element such as

- **Stator**– It is stationery outer part of motor made up of permanent magnet or coli winding.
- **Rotor** – It is rotating part of motor made up of permanent magnet or ferromagnetic coil.
- **Armature**–Rotor winding that generates rotor magnetic field.
- **Filed coil** – Part of stator which generates stator magnetic field.
- **Air gap** – Small gap between stator and rotor where two magnetic fields interact with each other to generate mechanical torque.

In Today's scenario piezoelectric actuator is gaining more attention of modern automation industry because of its compact size and large force producing capabilities.

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Piezoelectric actuators

Piezoelectric material is crystal type of material which produces a voltage under the mechanical stress. This property of piezoelectric material is called as piezoelectric effect. And reversal of this effect i.e. producing mechanical deformation/movement by applying electrical voltage can be used to produce mechanical actuation. Piezoelectric actuators are more popularly used for MEMS (micro-electromechanical system) application because of some outstanding feature such as low power consumption, response time below millisecond, grater life cycle, several environment compatibility (such as vacuum, high temperature etc.) and precise movements. There are two types of piezoelectric material – ceramic and polymers which are used for actuation and sensor application respectively.



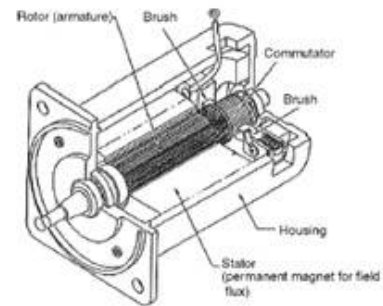
Source:
<http://www.solenoidactuator.org/>

(a)



Source: <http://www.pi-usa.us/products/PiezoActuators/>

(b)



Source: "Mechatronics-handbook",
Robert H. Bishop, the University of
Texas at Austin, Texas, Figure no
20.1, Page no.533

(c)

Figure 6 (a) solenoid Actuator, (b) piezoelectric actuator, along with the (c) basic construction of electric motor.

Mechanical actuating system:

This type of actuators is used to transform one type of motion into another type of motion such as linear to rotary and widely preferred for secondary actuators for simple motion conversion. It uses the rigid links, gears, pulleys, chain and belts to convey one form of motion to another. Examples of mechanical actuators are rack and pinion, cam and follower, slider crank mechanism. Belts and chain drives are used to transmission of torque from one pulley to another pulley when they are at measurable distance. Gears are used where variation in torque is required or to transform rotation motion from one plane to another plane of action. Even though different mechanical actuators are available to produce different motion because of their high cost, low efficiency and less precise control because of friction they are less preferred in automation field. And also they are difficult to implement in complex motion condition.

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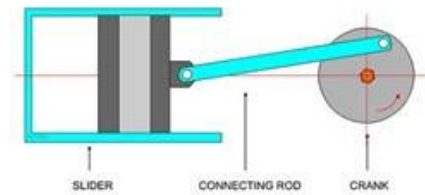
Source:<http://wdc65xx.com/thexxc-elr8academy/lessons/what-are-actuators-and-different-types-of-actuators/>

(a)



Source:
<http://rayharvey.org/index.php/2010/03/rack-and-pinion-steering/>

(b)



Source:<http://raindrops.in/simha007/embed/540fe1554251dfe0119db05f>

(c)

Figure 7 (a) worm and worm wheel (b) rack and pinion (c) slider crank mechanism.

III. CONCLUSION

We have seen the different types of actuators with different characteristic and their importance's in automation field and we derived following comparison given in below in a table no 1. This compares the actuating systems on the basis of their important characteristics to select most efficient actuating system for an automation process.

Table no 1- comparison of actuators used in automation system.

Criteria	Mechanical actuators	Electromechanical actuators	Pneumatics actuators	Hydraulics actuators
I/O energy source	Electric Motor, IC Engines.	Water/gas turbine	Presser tank/Compressor.	IC engines, electric motor, Hydraulic Pump
Energy transmission Element	Gears, shafts, levers.	Electric cables	Pipes & hoses	Pipe & hoses
Speed of response	Fair	Best	Good	Good
Control	Fair	Best	Fair	Good
Cost	High cost	Very cheap	Cheap	Very costly
Output motion	Liner/rotary	Mostly Rotary	Liner/rotary	Liner/rotary

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