A SPOOL TYPE DIRECTIONAL CONTROL VALVE TO CONTROL AN ACTUATOR - A REVIEW

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Abstract: To control mechanical systems via hydraulic components, actuator need directional control valve i.e. the main function of directional control valve is to operate the actuator whether it is spool valve or rotary valve. Based on the capacity the selection of the valve can takes place? Nowadays one directional control valve can control only one actuator but our idea is to implement that existing device to control number of actuators using single directional control valve.

Key words: **Directional control valves, actuators, spool valve, rotary valve etc.**

I. INTRODUCTION

A. Directional control valve

Valves are necessary to control the pressure, flow rate and direction of the fluid. Hydraulic valves are made to a high standard of quality and robustness. The diagram shows a few of the vast range of hydraulic valves available. We should remember always that hydraulic systems are high pressure systems and pneumatic systems are low pressure systems. Hydraulic valves are made of strong materials (e.g. steel) and are precision manufactured. Pneumatic valves are made from cheaper materials (e.g. aluminum and polymer) and are cheaper to manufacture. We will start by considering how the fluid is directed from the pump/compressor to the actuator and back to the tank/atmosphere. Consider the basic circuit below.

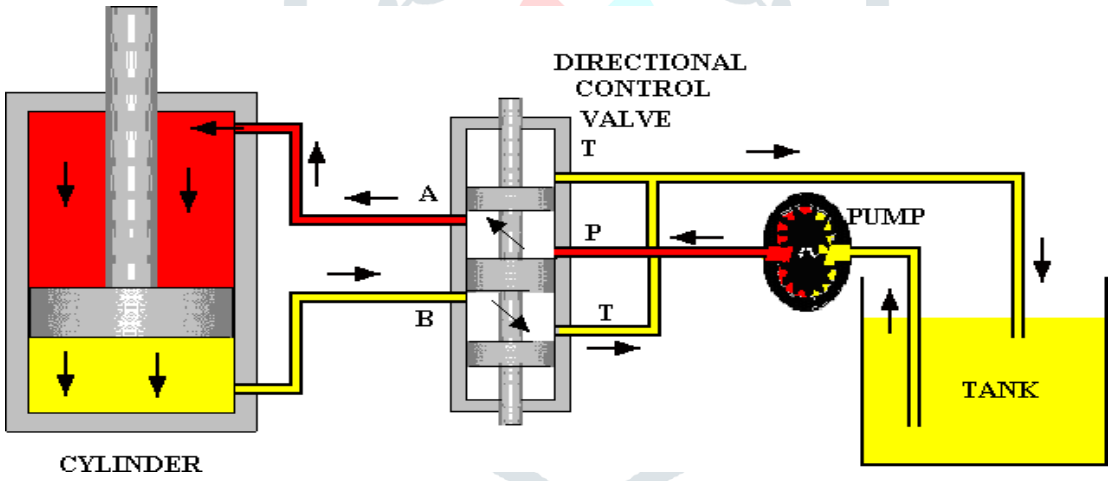


Fig. 1 Hydraulic System with Directional control valve [1, 4]

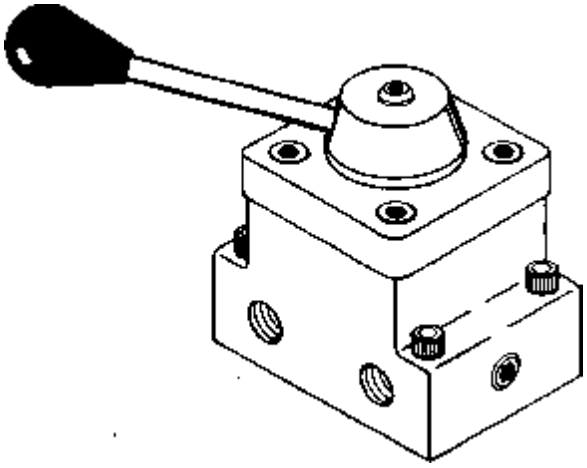
The directional control valve must direct the flow from the pump either to port A or port B. The oil being exhausted by the cylinder must be directed from the other port back to tank. The number of ports (external connections) and the number of positions describe such valves. Directional Control valves are mainly used to change the direction of flow path of working medium. They are used for admitting working medium to the cylinder for actuation of the cylinder. Also used to start or stop the pneumatic signal as well as for signal processing.

B. Hydraulic actuators [4]

A hydraulic actuator consists of a cylinder that uses hydraulic power to facilitate mechanicaloperation, converts hydraulic power into useful mechanical work. The mechanical motion produced may be linear or rotary. The hydraulic cylinder consists of a hollow cylindrical tube along which a piston can slide.

C. Rotary valves [4]

In hydraulic motor applications, the cylinder valves are of great importance. The transition speed, timing, leakage, and friction of the valves impact the efficiency, flow ripple, and reliability of the system. The majority of variable displacement hydraulic piston motors are of the axial piston architecture, in which the piston block rotates relative to a stationary valve plate. For an adjustable linkage pump/motor currently under development the piston chambers remain stationary and thus an alternative valve solution is needed. The fluid in the motor cylinder flows through a continuously rotating valve rotor to pressure and tank ports, located radially outwards from the rotor. The radial flow design allows precise control of the clearance between the rotor and valve sleeve. A rotary valve consists simply of a rotor closely fitted in a valve body. Passages in the rotor connect or block the ports in the valve body to provide the desired flow paths. A rotary valve can control only one actuator.



The diagram shows a cross section through 4/3 valve. When the element is rotated about its axis, the passages A, B, P and T are connected as shown.

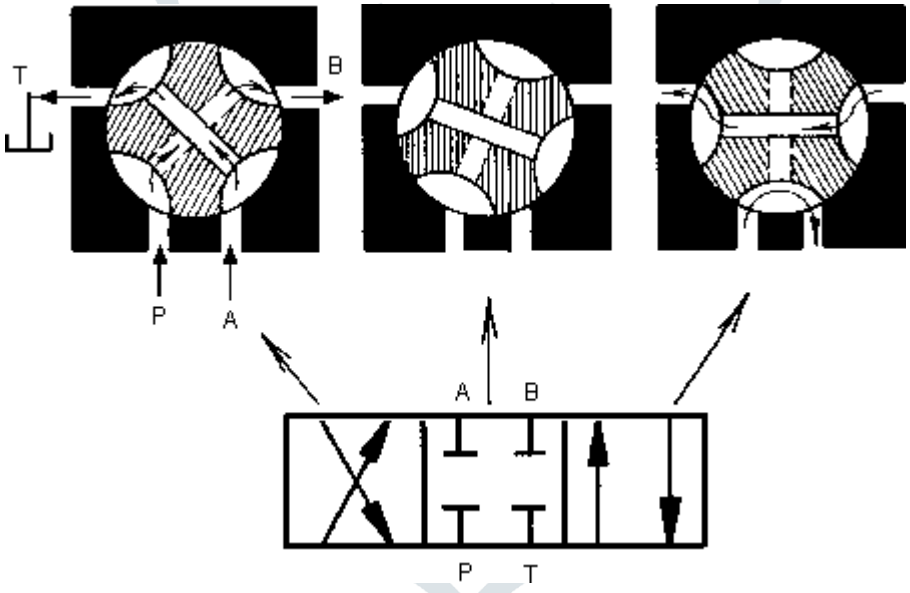


Fig 2 Rotary valve assembly

D. Spool valves [1, 3 , 4]

Hydraulic spool valves are Directional Control Valves (DCV) used for controlling hydraulic Power for a wide number of mechanical engineering applications. In order for the hydraulic Spool valve to accomplish its objective, its position must be controlled by an actuation device. As the actuation device attempts to move the spool, it must overcome the forces that act on the Spool valve, which result from the momentum of the fluid passing through the valve itself. In the Spool type directional valve a cylindrical spool moves back and forth in a machined bore in the Valve body. The port connections in the body are interconnected through annular grooves in the Spool or blocked by the raised portions of the spool called lands. Changes in valve operation are achieved by utilizing spools with different land patterns, with the same valve body.

i) *Classification of Directional control valve*

(a) *Two way two position directional control valve*

Gate valve is example of 2W/2P directional control valve which either turns on or off the flow in normal or working position depending on need of application.

(b) *Four way two position directional control valve*

The 4 way 2 position valves have four connections to it and two valve positions one of them is normally open.

II. LITERATURE SURVEY

Relative to our research which is based on the problems encountered in spool valves and rotary valves. The following references are made for the better purposes.

Elena Ponomareva. who's paper deals with a Hydraulic and pneumatic actuators, about their advantages and disadvantages, about their types and variants of design. Three types of drives are basically used now: electric, pneumatic and hydraulic.

Constantinos Mavroidis, Charles Pfeiffer and Michael Mosley. who's paper deals with a Conventional actuators. To study the principle of operation of Hydraulic, Pneumatic and Electric actuators. Detailed description of these actuators can be found in many robotics and haptics textbooks.

Mohammad Pournazeri, Amir Khajepour, Amir Fazeli. who's paper deals with An Efficient Lift Control Technique in Electro hydraulic Cam less Valve train Using Variable Speed Hydraulic Pump. Significant improvement in fuel consumption, torque delivery and emission could be achieved through flexible control of the valve timings, duration and lift. In most existing electro hydraulic variable valve actuation systems, the desired valve lift within every engine cycle is achieved by accurately controlling of the solenoid-valve opening interval;

Mark Beesley, Fortum O & M (UK) LTD. who's paper deals with a Valve Stiction Problem Cured by Soft Particle Removal in hydraulic system. The pressure loss was attributed to slow servovalve operation, caused by increased friction due to oxidation buildup (varnish) and the subsequent reduction of clearance between valve spool and bore.

Song Liu and Bin Yao.who's paper deals with a Programmable Valves: a Solution to Bypass Dead band Problem of Electro-Hydraulic Systems. The closed-center PDC/servo valves have overlapped spools to prevent internal leakage so that the system can hold a position even when the power is off. However, the over-lapped spools also introduce dead bands, which are sandwiched by plant dynamics and valve dynamics. In this paper, the sandwiched dead band problem is bypassed by new valve con_guration.the programmable valves, a unique combination of five independently controlled poppet type cartridge valves.

Alessandro De Luca Raffaella Mattone.who's paper deals with an Identification scheme for Robot actuator Faults. A scheme for identifying the time profile of actuator faults that may affect a robot manipulator. Fault detection and isolation.

Akira Sasaki Takashi Yamamoto.who's paper deals with a Review of studies of Hydraulic lock. There were two main streams and two side streams of studies of hydraulic lock with spool type valves. One of the main types involved studies of the non-uniform pressure distribution around a valve spool, and the other involved those due to contamination of the oil.

Hao Tian, James D. Van de Ven. who's paper deals with a geometric optimization of a hydraulic motor rotary valve. The performance of a hydraulic motor is strongly influenced by the timing, leakage, and friction of the valves connecting to the pressure and tank ports. For the application of a linkage-based hydraulic piston motor, a novel clearance sealed cylindrical rotary valve is introduced.

Noah D. Manring, Shusen Zhang. who's paper deals with a Pressure Transient Flow Forces for Hydraulic Spool Valves.

Mohammad Pournazeri, Amir Khajepour, Amir Fazeli.who's paper deals with an efficient lift control technique in electro-hydraulic cam-less valve train using variable speed Hydraulic pump. In most existing electro hydraulic variable valve actuation systems, the desired valve lift within every engine cycle is achieved by accurately controlling of the solenoid valve opening interval.

Brian J. MacLachlan, Niell Elvin, Carl Blaurock, N. Jared Keegan.who's paper deals with a Piezoelectric valve actuator for flexible diesel operation. The piezoelectric actuator and spool coupling mechanism were the two main areas of development under this program. Detailed actuator design centred on meeting two primary objectives. The first objective was to maximize anticipated actuator stiffness. Second, the stroke requirement had to be met, with an additional goal of optimizing the device efficiency. To maximize the actuator's work efficiency, it should act against a load of equal stiffness.

Bill Bigge Inman R. Harvey.who's paper deals with a Programmable Springs Developing Compliant Actuators for Autonomous Robots. Developing real robots that can exploit these dynamics requires the use of actuators that can react to the environment, exhibiting behaviour that varies from high stiffness to complete compliance or zero impedance. We will outline our design for an electric actuator, called a programmable spring, which can be configured to emulate many complex sprung and zero impedance systems within its range of movement and mechanical limits. This design forms the basis for a prototype actuator intended as a cost effective 'off the shelf' component for robotics development.

Marko Simic-Mihael Debevec-Niko Herakovic.who's paper deals with a Modelling of Hydraulic Spool-Valves with Specially Designed Metering Edges. This paper presents a new approach for modelling and simulation of hydraulic spool valves by using the already known simple mathematical expressions for describing the sliding spool geometry. The main objective of the research is to divide the hydraulic sliding spool into functional elements which can be described analytically.

Jerry E. Pratt, Benjamin T. Krupp.who's paper deals with a Series Elastic Actuators for legged robots. Series Elastic Actuators provide many benefits in force control of robots in unconstrained environments. These benefits include high force fidelity, extremely low impedance, low friction, and good force control bandwidth. Series Elastic Actuators employ a novel mechanical design architecture which goes against the common machine design principal of "stiffer is better".

Maher Yahya Salloom.who's paper deals with a Intelligent Magneto-Rheological Fluid Directional Control Valve There are many configurations of directional control valve. Directional control valve has complex construction, such as moving spool to control the direction of actuator and desired speed. Magneto-rheological (MR) fluid is one of controllable fluids. Utilizing the MR fluid properties, direct interface can be realized between magnetic field and fluid power without the need for moving parts like spool in directional control valves.

Sang-Gyum Kim, Jung-Ha Kim, and Woon-Sung Lee.who's paper deals with a Hydraulic System Design and Vehicle Dynamic Modeling for the Development of a Tire Roller. We describe a hydraulic system design and vehicle dynamic modeling for development of tire roller traction, an essential aspect in the system analysis of tire rollers.

Martin VASINA, Lumir HRUZIK.who's paper deals with a "INVESTIGATION OF DYNAMIC PROPERTIES OF HYDRAULIC SYSTEMS".

Hydraulic systems are applied in many branches of industry. It is necessary to take into account a lot of criterions for a future realization of these systems. Dynamic properties belong to one of important design criterions. Pressure or flow pulses have a negative influence on dynamic loading of hydraulic elements and system tightness.

Noah D. Manring, Shusen Zhang.who's paper deals with a Pressure Transient Flow Forces for Hydraulic Spool Valves. Experimentally investigate the significance of the pressure transient flow force acting on hydraulic spool valves.

D. GORDIC, M. BABIC, D. MILOVANOVIC, S. SAVIC.who's paper deals with a Spool valve leakage behavior. A four-way axial spool servo valve has such a design that flows through its restrictions can be presented by means of a hydraulic bridge. The characteristics analytically describe the fluid flow through spool orifices in the most of working regimes.

Perry Y. Li. who's paper deals with a Dynamic Redesign of a Flow Control Servo-valve using a Pressure Control Pilot. The dynamic performance of an unconventional two-spool flow control servo valve using a pressure control pilot is analyzed. Such valves are less expensive than typical servo-valves but also tend to be limited in their dynamic performance.

Vijaya Sagar Tenali.who's paper deals with a "SIMUALATION OF ELECTRO HYDRAULIC SERVO ACTUATOR". Hydraulic actuators are used in many applications like aircraft flight control, machinery and automobiles etc. This actuator when coupled with a feedback system is called a Servo Actuator.

JANUSZ RAJDA, EDWARD LISOWSKI.who's paper deals with a "FLOW FORCES ACTING ON THE SPOOL OF DIRECTIONAL CONTROL VALVE". The forces acting on the spool during the flow of working liquid stream through the electro-hydraulic pilot operated directional control valve.

Yang Xuelan ,Gong Guofang , Liu Yi ,Min Chaoqing.who's paper deals with a Research on Dynamic Characteristics of the Rotary Valve. An electro-hydraulic vibrator with high frequency, great exciting force and large flow, a new type of rotary valve with four-way commutation was designed. The rotary valve is worked under special environment, so the characteristic of the valve must be studied.

a. From Literature survey general problems identified in spool valves:

One of the larger concerns with hydraulic systems is the containment of the fluid within the actuation system. The leakage can also contaminate the oil and possibly lead to damage the interior surfaces. The hydraulic fluid is flammable and pressurized so leaks could pose an extreme hazard to equipment (Cavitations). To divide the sliding spool of the valve into different modules which can be optionally put together? To design a valve with different metering edges of the spool and to quickly check through simulation how the valve influences the characteristics of a practical hydraulic system. The user can get best possible design of the valve and achieve the best possible performance of the hydraulic system. In most existing electro hydraulic variable valve actuating systems, the desired valve lift within every engine cycle is achieved. However due to slow response time, precision control of these valves is difficult particularly during higher engine speeds. Moreover the new lift control technique is implemented experimentally by reconfiguration of the existing electro hydraulic valve system prototype. The amount of rotary valve air leakage from rotary valves is a perennial problem. Unless this air is controlled it's only escape route is up through the drop tube leading into the feeder. Load drift in spool valves (a continuous slow movement in from one place to other). The spool valve assembled with multiple sections to make a valve bank (A, B, C, D, and E). The valve bank would control all of the hydraulic functions on the machine and would be actuated by foot or hand operated levers. Troubles in spool valves: Dirt in system, restricted drain, Distortion of valve body, Pilot pressure off.

III. CONSTRUCTION

List of components used

Hydraulic Actuators, Valve, Stepper motor, Tank, Pump, Connector (pipes).

Hydraulic Actuators: Actuator is a component of a machine that is responsible for controlling a mechanism or system. Hydraulic actuators control mechanism or system by converting hydraulic energy into mechanical energy.

Spool valve: It can turn the flow of hydraulic fluid from a hydraulic pump to an actuator ON or OFF the route the fluid takes.

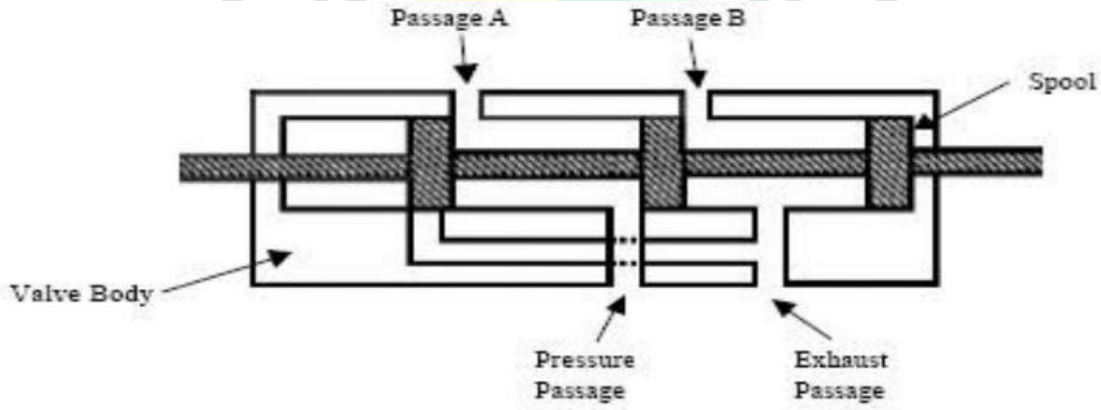


Fig 3 Spool valve

Pump: A hydraulic pump is a mechanical source of power that converts mechanical power into hydraulic energy.

Stepper motor: Stepper motor is a special type of electric motor that moves in precisely defined increments of rotor position. The size of the increments measured in degrees and can vary depending on the application. Due to precise control, stepper motors are commonly used in medical, satellites, robotic and control applications.

Classification of stepper motor:

- Variable Reluctance Motor (VRM)
- Permanent Magnet Stepper Motor(PMSM)
- Hybrid Stepper Motor(HSM)

Variable Reluctance Motor (VRM): It consists of a soft iron multi-toothed rotor and a wound stator. When the stator windings are energized with DC current, the poles become magnetized rotation occurs when the rotor teeth are attracted to the energized stator poles

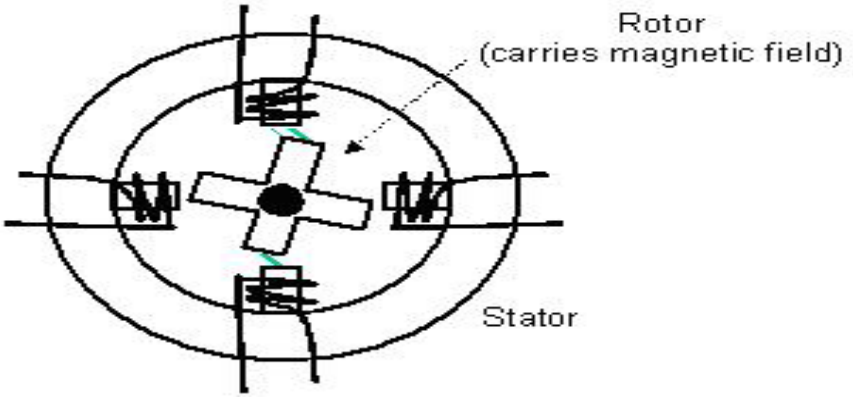


Fig 4 Variable reluctance Stepper motor

Permanent Magnet Stepper Motor (PMSM): The rotor no longer has teeth as with the VRM. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft.

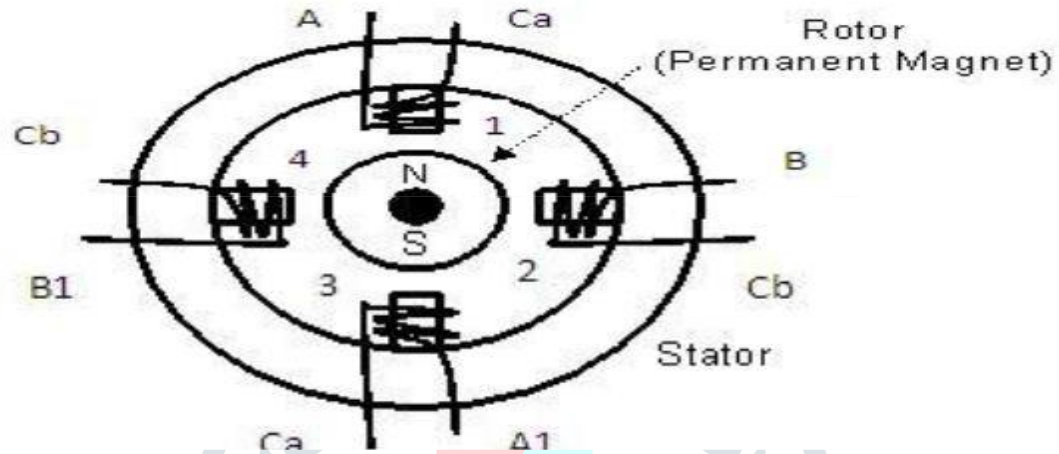


Fig 5 permanent magnet stepper motor

Hybrid Stepper Motor (HSM): The term 'hybrid' is derived from the fact that motor is operated with the combined principles of the permanent magnet and variable reluctance motors in order to achieve small step length and high torque in spite of motor size.

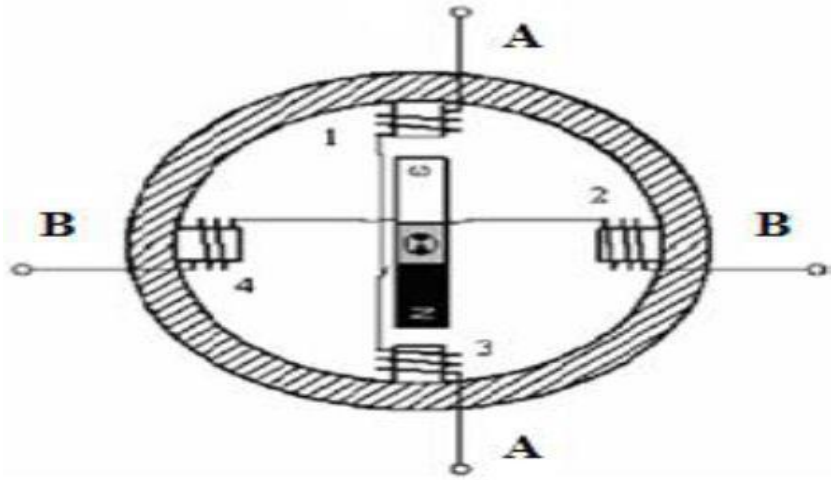


Fig 6 Hybrid Stepper motor

IV. OBJECTIVES

Keeping the above identified problems in mind the working of the existing device could be studied and an attempt could be made to solve the above problems. A device could be possibly designed and fabricated with utmost precision and which would provide solutions leading to solve the above identified problems. Discuss hydraulic principles; describe how a hydraulic system operates. To seek solutions to the problems faced by the variation in pressure inside the valve owing to differential land areas. Keeping the above identified problems in mind the working of the existing device could be studied and an attempt could be made to solve the above problems. A device could be possibly designed and fabricated with utmost precision and which would provide solutions leading to solve the above identified problems. Discuss hydraulic principles; describe how an hydraulic system operates. Hydraulic Actuator with Spool Valve: A Hydraulic actuator consists of a cylinder that uses hydraulic energy to facilitate mechanical operation and converts that energy into motion. Hydraulic spool valves are directional control valves used for controlling hydraulic actuators. A spool valve can control only one actuator. The objective of the proposed work is to control several actuators simultaneously.

V. METHODOLOGY

To study the operations and working of spool valves used for different applications and ranges of pressure with which they are operated. To study the mechanical properties of various materials to select suitable materials and try to develop a solution/device to seek solutions to the problems identified earlier regarding spool valves.

VI. POSSIBLE OUTCOME

With research, experience and creativity, solutions to the identified problems could be demonstrated successfully.

VII. CONCLUSION

The literature survey reveals that most of the earlier work on hydraulic actuators and DC valve was carried out using single valve controlling single actuator. This paper provides an elaborate explanation of working of our proposed work with a novel idea of controlling two or more actuators using single indexing spool valve.

VIII. SCOPE OF FUTURE WORK

In future to implement that existing device, we will work for controlling four actuators using single directional control valve through computer interface.

IX. ACKNOWLEDGEMENT

I am highly grateful to my guide and co-guide for providing guidance and encouraging me throughout the course of this Research work.

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