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Development and Testing of Hydraulic 'Bharath Valve' to Control Multiple Actuators

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Abstract: ***The Research is entitled "Design, Fabrication and Performance Testing of Directional Control Valve for Control of Multiple Actuators". An indexing unit is a direction control valve used in Hydraulic system. This device shall be named 'Bharath Valve' (US10180190), as is the name of its Inventor. This valve can control more than one number of actuators. This valve consists of a hollow outer cylinder and inner cylinder. The inner cylinder fits in the hollow portion of outer cylinder; this inner cylinder is operated manually. The rotation of the inner cylinder inside the outer cylinder changes the direction of flow of liquid through the valve this control the movements of actuator. This Indexing valve can become a highly advantageous replacement of the conventional Spool valves that are used for controlling the actuator. In the present scenario one spool valve can control only one actuator thus the number spool valves used in a hydraulic system is equal to the number of actuators. However 'Bharath' valve can control more than one number of actuators, this in turn makes the number of system components less and also reduces the overall cost of hydraulic system. Even the controlling of movement of actuators can be easy. A computer interface if given can make this valve versatile and a very cheap alternative to the existing valves, taking number of components, construction, friction and efficiency into account. This research proves that 'Bharath' valve has more advantages than that of existing ones and some of the advantages are listed below,***

- ***One valve can control more than one actuators thus reduces the number of valves.***
- ***Construction of this indexing valve is simpler and parts involved in friction is less.***
- ***Reduction in the cost of manufacturing is highly significant.***
- ***This valve makes it possible to actuate the desired cylinder keeping the other at rest.***
- ***The modification in operating actuators of system can be easily changed by operating ON/OFF flow valve connected to the inlets of Indexing valve.***

Keywords: Bharath Valve, Hydraulic Indexing valve, spool valve, rotary valve, pump, motor, hydraulic actuators, efficiency etc.

I. INTRODUCTION

1.1 Spool valve

For picking and placing an item manually it is done by the human brain which signals concerned muscles to perform the activity. However, in an hydraulic system for similar activities, actuators are used. Actuator is a component of a machine that is responsible for controlling a mechanism or system. Actuator control mechanism or system by converting hydraulic energy into mechanical energy. Since in hydraulic system oil is medium for operation pump is used to supply oil in the system for perform required operation by converting mechanical power into hydraulic energy and the mechanical power is provided by the prime mover i.e. motor coupled to the pump. Hydraulic systems that are used consist of spool valves that control the direction of flow of liquid to the actuators. A spool is a cylindrical valve element that opens and closes ports when moved axially within the valve bore.

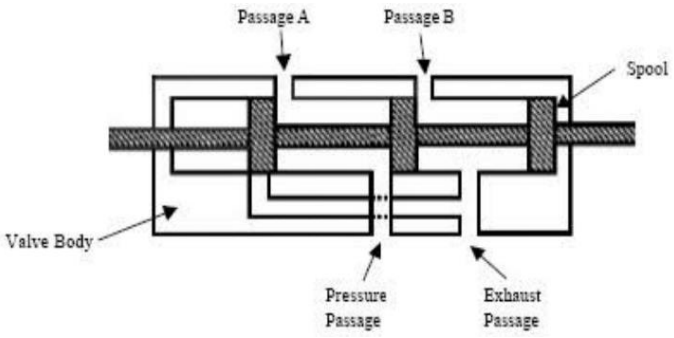

Fig 1 Spool valve

The disadvantages of spool valves are

- Design and construction is complex.
- Parts involved in friction are more thus short product life.
- Higher cost and maintenance.

But at present one spool valve can control only one actuator which has been the practice since decades. Here it is proposed to design a system which is simpler than the spool valve in construction and to design a direction control valve i.e. indexing unit to operate multiple actuators keeping the desired actuators at rest. Hydraulic spool valves are 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 a spool-valve 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.

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1.2 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.

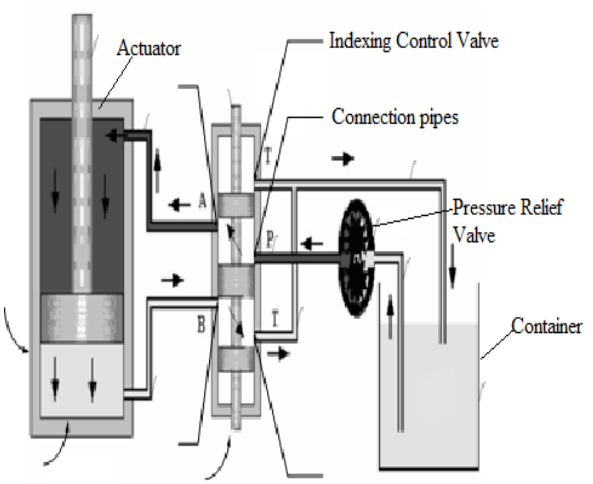


Fig 2 Hydraulic system using indexing control valve

1.3 Hydraulic actuators [4]

A hydraulic actuator consists of a cylinder that uses hydraulic power to facilitate mechanical operation, 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.

Fig 3 Hydraulic actuator

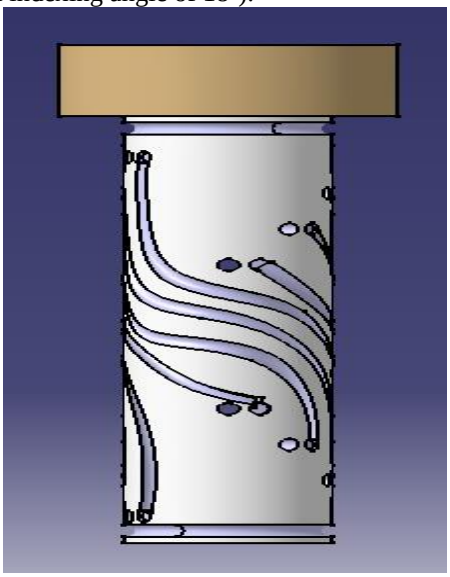
II. OBJECTIVE OF THE WORK

- 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 take up the problem in spool valve and to develop a valve to control several actuators simultaneously.
- To seek solutions to the problems faced by the variation in pressure inside the valve owing to differential land areas.
- 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 design and develop a control valve to control several actuators simultaneously.
- This idea has been applied for patent which in itself a field of research.

III. DESIGN DRAWINGS

3.1 CATIA Model of Inner cylinder

Research work has been carried out further that are related to Indexing control valve used to control multiple actuators. In this regard we are focussing on Indexing control valve drawing and sketches using CATIA Modelling software. Indexing control valve CATIA models: The inner cylinder, outer cylinder, oil seal, assembly of indexing control valve and changes in profile with number of slots are described as follows; 3.1 Proposed Inner Cylinder is depicted in figure 4 used CATIA modelling software multiple slots with indexing angle 18^0. Fig 4 CATIA model of inner cylinder (It consist of slots with indexing angle of 18^0).



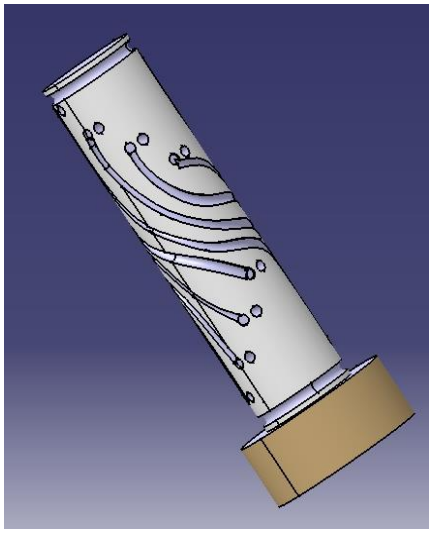


Fig 4 Drawing of Inner cylinder

Different views of inner cylinder namely: front view, top view, left view and isometric view is depicted in fig 5

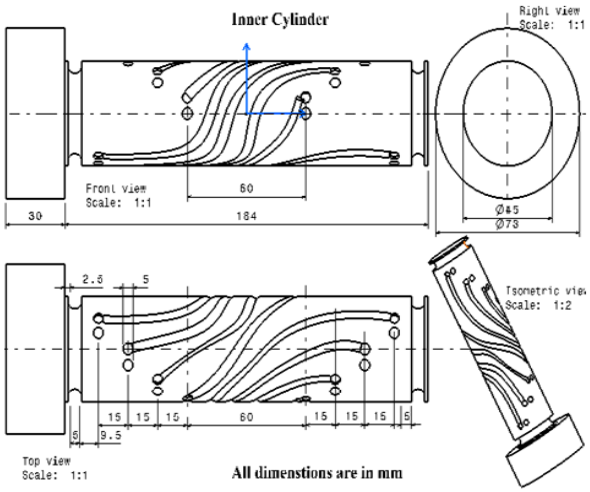
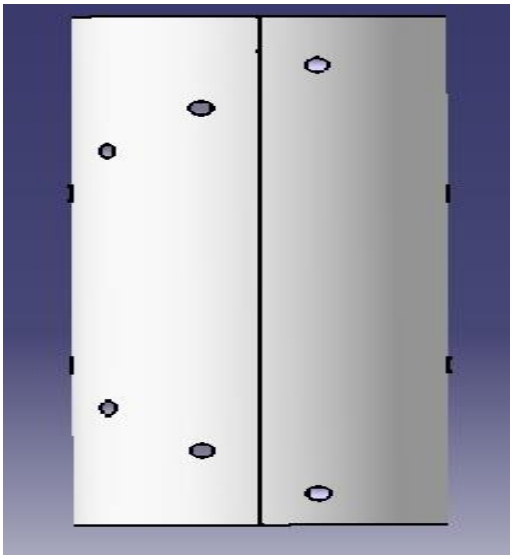


Fig 5 all views of Inner cylinder

3.2 Outer cylinder

(a) Proposed Outer Cylinder is depicted in fig 6 used CATIA modelling software multiple holes with indexing angle 36^0.



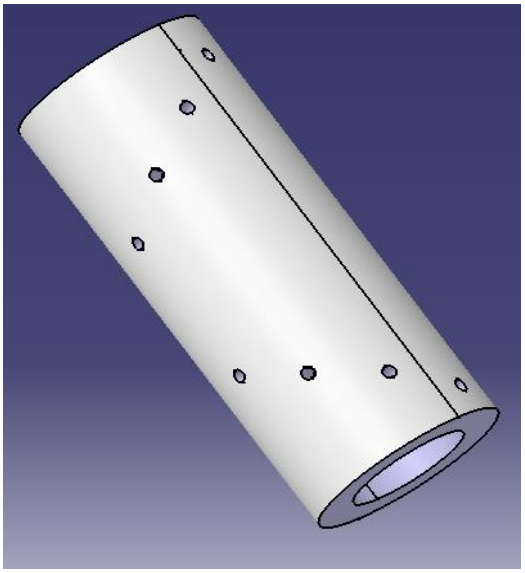


Fig 6 Different views of outer cylinder

(b) Different views of outer cylinder namely: front view, top view, left view and isometric view is depicted in fig 7

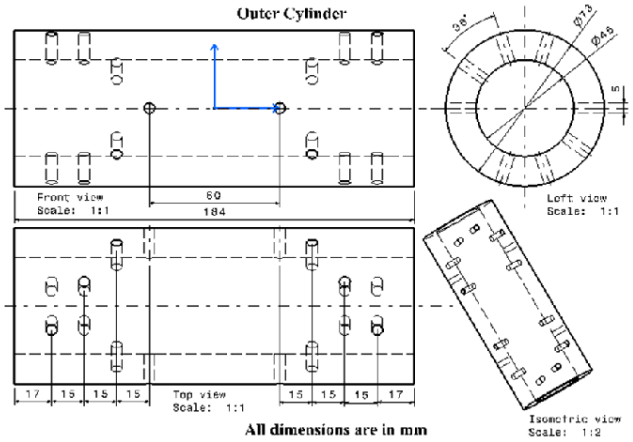
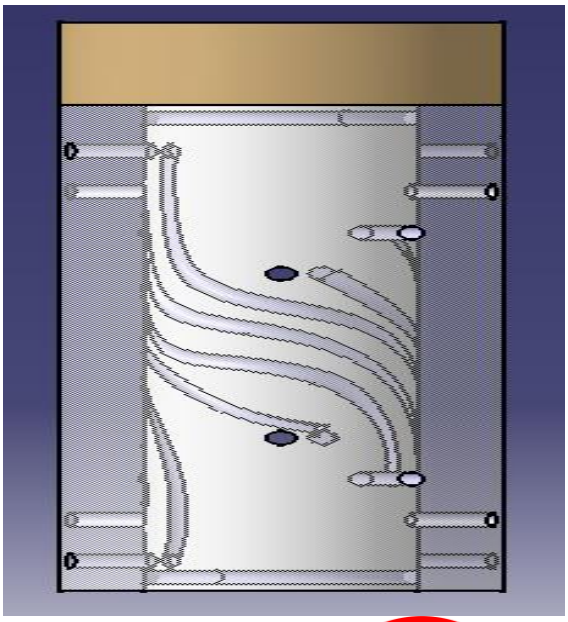


Fig 7 all views of outer cylinder

3.3 Drawing of Indexing valve assembly



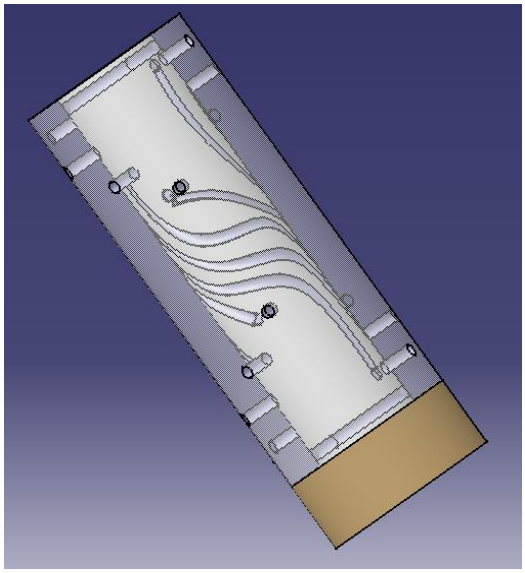


Fig 8 Drawing of Indexing valve assembly

3.4 Different views of indexing valve assembly

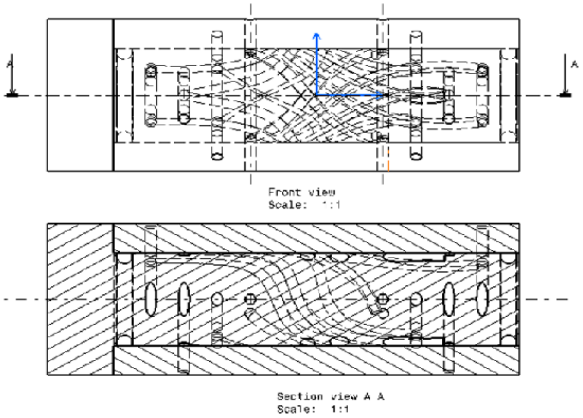


Fig 9 all different views of indexing valve assembly

IV. CONSTRUCTION AND FABRICATION OF DIFFERENT ASSEMBLY PARTS OF INDEXING CONTROL VALVE

4.1 Fabrication of Hydraulic Actuator

Step 1: Hydraulic actuator

Outer dia. of Actuator = 26mm
Piston Rod dia. = 10mm
Piston dia. = 18mm
Type of Cylinder Mounting= Eye or Clevis mount

Fig 10 Hydraulic Actuator

Fig 11 Hydraulic cylinder actuator

4.2 Fabrication of Indexing control valve

Step 2: Indexing control valve

Outer Diameter of outer cylinder = 73mm
Inner diameter of outer cylinder = Diameter of inner cylinder = 45mm
Length of inner cylinder =214mm
Length of outer cylinder = 184mm
Diameter of holes and slots = 5mm

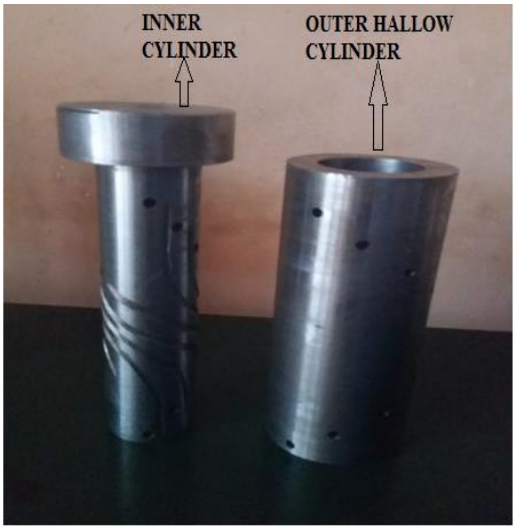


Fig 12 Fabricated products of inner and outer cylinder

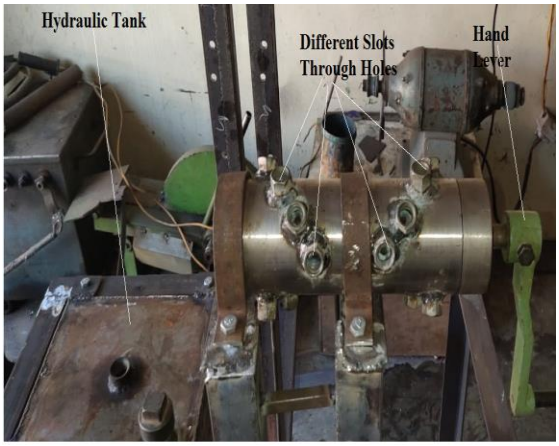


Fig 13 Fabricated part of indexing unit

4.3 Fabrication of Hose pipes

Step 3: Hose pipes
Connected from Pump to Indexing unit
Tube Type: Oil resistant synthetic rubber
Reinforcement: One high tensile steel wire braid
Cover: Abrasion and weather resistant synthetic rubber
Temperature Range: -40°C to +100°C (+120°C max)
Inner diameter = 3/8”
Outer diameter = 17.4mm
Weight = 0.31 kg/m
Hose pipe connected from Indexing unit to Actuator
Diameter= 8.5 mm

Fig 14 Hose pipe connected from Pump to Indexing unit to Actuators

Fig 15 Hose pipe

Fig 16 Hose pipes connected from indexing unit to actuators

4.4 Fabrication of Holding Frame and Tank

Step 4: Holding frame and tank
Material type: Sheet metal
Dimension: 30 cm x 25cm x 25 cm

Fig 17 Fabricated Frame and tank for indexing valve assembly

Fig 17 Fabricated part of hydraulic tank

4.5 Motor Specification

Step 5: Motor
Phase type: 3 phase
Power = 1/2 hp
Speed =1440 Rpm

Fig 18 Motor

4.6 Pump specification

Step 6: Pump

Type = Hydraulic Gear Pump

Max pressure= 200 kg/cm^2

Fig 19 Pump

4.7 Fabrication of complete model of assembly of indexing control valve

Step 7: Complete assembly of model

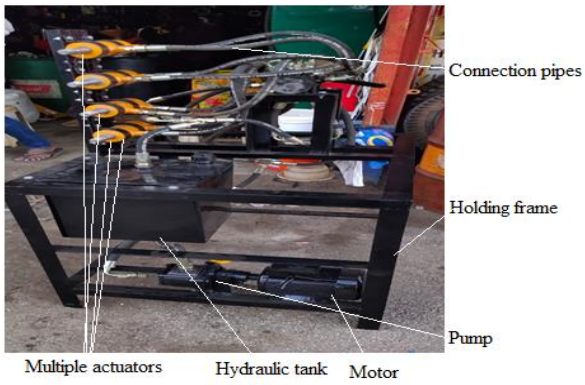


Fig 20 Complete Fabricated assembly of model of indexing valve

4.8 The following fig. indicates the CATIA model of assembly

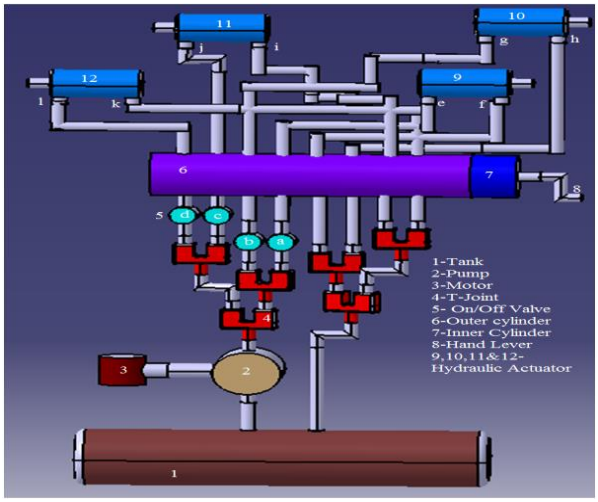


Fig 21 CATIA model of Assembly

V. WORKING OF INDEXING CONTROL UNIT

Case (i): For One Actuator

For better understanding of this project the working of indexing unit for one actuator is discussed below.

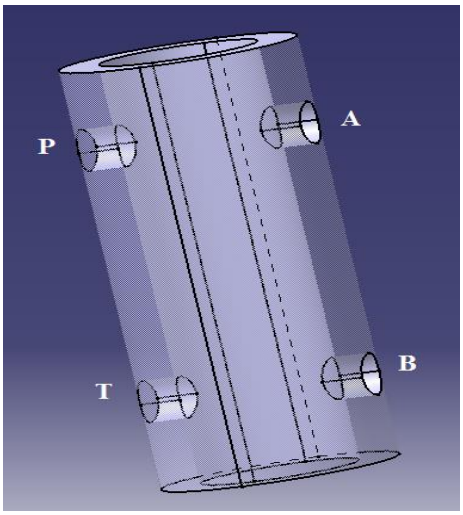


Fig 22a Outer Cylinder for controlling single actuator

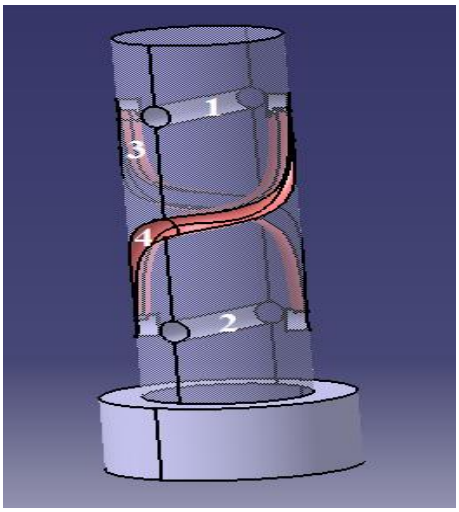


Fig 22b Inner Cylinder for controlling single actuator

The indexing unit consists of fig 23a Outer cylinder and fig 23b Inner cylinder. The hollow cylinder consist through holes for a pressure port connected to pump **P**, a tank port connected to tank for return line **T**, a port connected to blank end of cylinder **A** and one port to rod end of cylinder **B**. The inner cylinder fit to the hollow part of the outer cylinder. It is provided with through holes **1&2** and slots **3&4** on it. When the inner cylinder is in first relative position with the outer cylinder then the holes of Outer cylinder gets in contact with holes of inner cylinder then the high pressure oil from pump through port **P** enters the blank end of the cylinder though the port **A** from through hole **1**. The oil from the rod end flows from port **B** to **T** from through hole **2** this causes forward stroke of actuator.

When the inner cylinder is in second relative position with the outer cylinder then the holes of Outer cylinder gets in contact with slots of inner cylinder then the high pressure oil from pump through port **P** enters the rod end of the cylinder though the port **B** from slot **3**. The oil from the blank end flows from port **A** to **T** through slot **4** this causes return stroke of actuator.

Case (ii): For Multiple Actuators

Before starting the model make sure that at least one On/Off flow valve should be in open position and inner & outer cylinder should be in either relative position 1 or 2 which is done using hand lever. Ref **fig 23a** when the motor **3** is started it makes pump **2** to suck the fluid from the tank **1** now the pressurised fluid enters the T-Joint **4** and now to the On/Off flow check valves **5**. Now when the flow check valves **b**, **c** and **d** are in close position and only flow check valve **a** is in open position then the pressurised fluid flow to the Actuator **9**. If the inner cylinder **7** holes are in contact with the outer cylinder **6** holes then the pressurised fluid flow takes place to the port **e** of the actuator **9** causing forward stroke and the fluid from the actuator **9** is return back to the tank **1** through port **f**. By using the hand lever **8** is the position of inner **7** and outer **6** is changed such that slot of inner cylinder **7** gets in contact with hole of outer cylinder **6** then the pressurised fluid enters the actuator **9** port **f** causing return stroke of actuator **9** and the fluid on blank end of actuator **9** is returned to tank **1** through port **e**. If the flow check valves **a**, **c** and **d** are in close position and only flow check valve **b** is in open position then the pressurised fluid flow to the Actuator **10**. If the inner cylinder **7** holes are in contact with the outer cylinder **6** holes then the pressurised fluid flow takes place to the port **g** of the actuator **10** causing forward stroke and the fluid from the actuator **10** is return back to the tank **1** through port **h**. By using the hand lever **8** is the position of inner cylinder **7** and outer cylinder **6** is changed such that slot of inner cylinder **7** gets in contact with hole of outer cylinder **6** then the pressurised fluid enters the actuator **10** port **h** causing return stroke of actuator **10** and the fluid on blank end of actuator **10** is returned to tank **1** through port **g**. When the flow check valves **a**, **b** and **d** are in close position and only flow check valve **c** is in open position then the pressurised fluid flow to the Actuator **11**. If the inner cylinder **7** holes are in contact with the outer cylinder **6** holes then the pressurised fluid flow takes place to the port **i** of the actuator **11** causing forward stroke and the fluid from the actuator **11** is return back to the tank **1** through port **j**. By using the hand lever **8** is the position of inner cylinder **7** and outer cylinder **6** is changed such that slot of inner cylinder **7** gets in contact with hole of outer cylinder **6** then the pressurised fluid enters the actuator **11** port **j** causing return stroke of actuator **11** and the fluid on blank end of actuator **11** is returned to tank **1** through port **i**. If the flow check valves **a**, **b** and **c** are in close position and only flow check valve **d** is in open position then the pressurised fluid flow to the Actuator **12**. If the inner cylinder **7** holes are in contact with the outer cylinder **6** holes then the pressurised fluid flow takes place to the port **k** of the actuator **12** causing forward stroke and the fluid from the actuator **12** is return back to the tank **1** through port **l**. By using the hand lever **8** is the position of inner cylinder **7** and outer cylinder **6** is changed such that slot of inner cylinder **7** gets in contact with hole of outer cylinder **6** then the pressurised fluid enters the actuator **12** port **l** causing return stroke of actuator **12** and the fluid on blank end of actuator **12** is returned to tank **1** through port **k**. Thus the required sequence of operation of different hydraulic cylinder can be controlled and modified by using On/Off valves and hand lever mechanism.

VI. RESULT AND DISCUSSIONS

TABLE 1: Performance of Actuators

Actuator	Forward stroke (in sec)	Return Stroke (in sec)
1	5	8
2	5	9
3	6	10
4	6	12

6.1 Results

6.1a Maximum Force acting on Piston

For Case 1:

During Forward Stroke:

(i) Pressure = Force / Area of piston on which force is acting, Max. Pressure by pump,

P = 200 Kg/cm^2

(ii) Area of piston on which force is acting,

A = π (Dia of piston)^2/4

A = $\pi(1.8)^2$/4 = 2.5446 cm^2

(iii) Max. Force acting on piston,

F = P*A = 200*2.5446=508.92 kg

For Case 2:

During Return Stroke:

(i) Pressure = Force / Area of piston on which force is acting, Max. Pressure by pump,

P= 200 kg/cm^2

(ii) Area of piston on which force is acting,

A= π((Dia Of Piston)^2 – (Dia. of Piston Rod)^2)/4

A= π((1.8^2)-(1^2)) /4 = 1.7592 kg

A = 1.7592 kg

(iii) Max Force acting on piston,

F = P*A =200*1.7592 = 351.84 Kg

F = 351.84 Kg

Result Discussion Case 1:

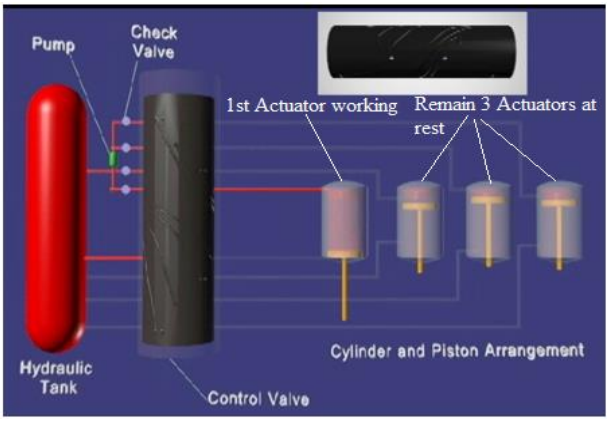


Fig 24 Operating 1st actuator remain 3 actuators are at rest

As figure shows when 1st actuator is working then remaining 3 actuators at rest.

According to first aspect, a flow control valve comprises outer hollow cylinder and an indexing member. The hollow cylinder comprises a pressure port, a tank port, a first port and a second port on the curved surface. The indexing member comprises an inner cylinder, and is fit to the hollow part of the outer cylinder. When the inner cylinder is at a first relative position with the outer cylinder, the pressure port is connected to the first port and tank outlet is connected to the second port. When the inner cylinder is at a second relative position with the outer cylinder, the pressure port is connected to the second port and tank outlet is connected to first port. According to another aspect, a system for controlling a movement of a piston in an actuator may comprise an indexing valve, an actuator and a pump. The actuator comprises piston and piston rod. The indexing valve comprises outer cylinder and indexed inner cylinder. The pump is used to inject pressurized fluid. In one embodiment, piston is moved in one direction by the pressurized fluid when the indexed inner cylinder is at first index. In another embodiment, the piston is moved in other direction by the pressurized fluid when the indexed inner cylinder is at second index position.

Result Discussion Case 2:

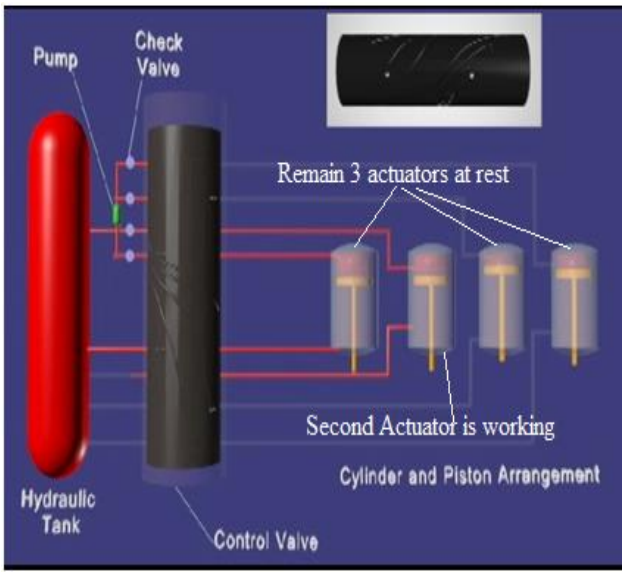


Fig 25 Operating 2nd actuator remain 3 actuators are at rest

Similarly when 2nd actuator is working then remaining 3 actuators at rest. Several embodiments are described below, with reference to diagrams for illustration. It should be understood that numerous specific details are set forth to provide a full understanding of the invention. One skilled in the relevant art, however, will readily recognize that embodiments may be practiced without one or more of the specific details, or with other methods, etc. In other instances, well-known structures or operations are not shown in detail to avoid obscuring the features of the invention. The valve is shown comprising the outer cylinder (or external cylinder) and an indexing member. The outer cylinder comprises four holes and. The indexing member is shown with the index marks (or index) used to indicate the relative position of the outer cylinder and the indexing member. The internal structure of the indexing member as shown there the indexing member comprises the base part and the inner cylinder. The inner cylinder may be a solid cylinder integrally attached to the (solid) base part. In an alternative embodiment, both the base part and the inner cylinder or manufactured on a single solid block. A three dimensional view exposing hollow part of the outer cylinder. The hollow part is configured to accept the inner cylinder of the indexing member. Each hole on the outer cylinder provides a through path from outer surface to inner surface. The outer cylinder is a hollow cylinder having an inner and outer diameter. The diameter of the inner cylinder is adjusted to equal to the inner diameter of the outer cylinder such that the outer cylinder is in precise push fit on to the inner cylinder as. The outer cylinder is sealed on top to prevent leakage.The through and through hole is shown with openings 1 and 2 and the through and second through hole is shown with openings 3 and 4. The through and through holes are drilled through the solid inner cylinder enabling flow of fluid from opening 1 to 2 (or vice-versa) through the hole and from opening 3 to 4 through hole.

Result Discussion Case 3:

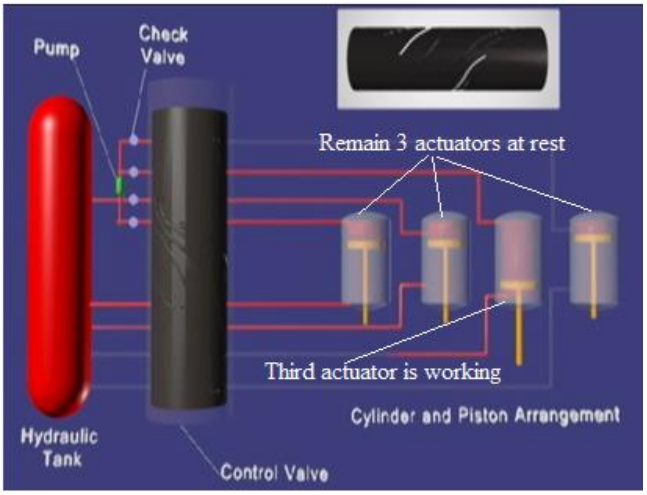


Fig 26 Operating 3rd actuator remain 3 actuators are at rest

Similarly when 3rd actuator is working then remaining 3 actuators at rest. The outer cylinder holes are aligned to the through and through two holes and the outer cylinder holes are aligned with through and through holes. As a result, two straight paths are formed for flow of fluid. Thus, a fluid may enter through outer cylinder hole and flow out of the outer cylinder hole (or vice versa). Similarly, the fluid may enter outer cylinder hole and flow out of the outer cylinder hole (or vice versa). As a result, the first groove connects two holes (providing a path for flow). Similarly, the second groove connects the holes providing another path for fluid flow. Thus, a fluid may enter through outer cylinder hole and flows downwards and out of the outer cylinder hole (or vice versa). A direction control arrangement for operation of the actuator piston in one embodiment. The direction control arrangement is shown comprising fluid tank, pump, indexing valve, and actuator. The pipes connect the fluid tank, pump, indexing valve, and actuator as shown in the figure. The pump sucks the fluid from the fluid tank and forces the pressurized fluid on to the pipe.

When the indexing member is rotated and aligned index with reference mark (first position of the index valve), the pressurized fluid is forced to the piston side of the actuator cylinder through the pipe, outer cylinder holes, through and through hole of the inner cylinder, and pipe. The pressurized fluid forces the piston downwards thereby forcing the fluid in the flat side out of the actuator cylinder. This fluid from the flat side reaches the tank through pipe, outer cylinder holes, through and through hole, and pipe.Thus causing a downward movement of the piston in the actuator, hence achieving the work done in the first position. The operation when the index part is rotated to align the index with reference. Accordingly, the grooves (in dotted line) cross connect the outer cylinder holes there by swapping pressurized fluid to flow in to the flat side of the actuator cylinder. In particular, when the indexing member is rotated and aligned to reference mark (second position of the index valve), the pressurized fluid from pump is forced to the flat side of the actuator cylinder through the pipe, outer cylinder hole and, groove of the inner cylinder, and pipe. The pressurized fluid pushes the piston upwards thereby forcing the liquid in the piston rod side out of the actuator cylinder. The released fluid from piston rod side reaches the tank through pipe, outer cylinder holes, groove, and pipe. This causing an upward movement of the piston in the actuator, hence achieving the work done in the second position.

Due to this arrangement the piston is moved downwards when the index part is rotated to anticlockwise (aligning with reference) and the piston is moved upwards when the index part is rotated anticlockwise (aligning with reference). The up and down movement of the piston is caused by a partial rotational motion of the indexing member. The piston movement is used for causing desired work done such as lifting of heavy weight, moving of heavy weight, digging, for example, the manner in which single indexing valve may be used for actuating multiple actuator in an embodiment of the present disclosure is further described below. an example arrangement for controlling multiple pistons (multiple actuators) using only a single indexing valve. The operation of the flow control arrangement when the multi control index valve is at first position. The valve is shown with two pressure inlets, two tank outlet, two ports, and two ports (these are the holes on the outer cylinder). The 4 ports are configured to control the actuator piston. The multivalve is shown with the through and through holes. The through and through hole connects to pressure inlet and port 1. The through and through hole connects tank outlet to port 2.

Result Discussion Case 4:

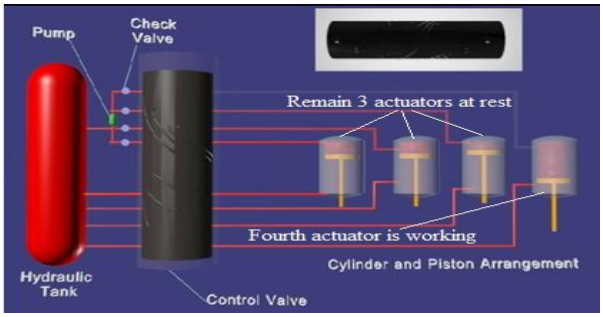


Fig 27 Operating 4th actuator remain 3 actuators are at rest

Similarly when 4th actuator is working then remaining 3 actuators at rest. When the index is in first position the pressurized fluid is forced to the pressure inlet and through pipes and respectively. The pressurized fluid enters the piston rod side of the actuator through the port 1 connected to the piston rod side of the actuator. The pressurized fluid also enters the piston rod side of the actuator through the port 1 connected to the piston rod side of the actuator, thus, forcing the piston and downwards. The fluid in the flat side of the actuator is released to the tank through the port 2 connected to flat side of the actuator. Similarly, fluid in the flat side of the actuator is released to the tank through the port 2 connected to flat side of the actuator. The tank outlets are connected to the tank. The manner in which the pistons may be pushed upward by changing the index is further described below.The operation of the multi control indexing valve when the indexing is changed to the second position. As shown there, the multi control valve is shown with the grooves. The first groove connects to pressure inlet and port 2. The third groove connects tank outlet to port 1, and the fourth groove connects tank outlet to port 1. Accordingly, the pressurized fluid is forced through the Port 2 into the flat side of the two actuators respectively and thereby forcing the pistons upwards. The fluid forced from the piston rod side of the two actuators respectively is forced to the tank through two ports. Thus, the multiple pistons are simultaneously actuated using single indexing valve. Though the description is provided for two piston control, the valve may be implemented to control more number of pistons or actuators without deviating from the spirit of the invention. A three dimensional example construction of the multiple control valves is an example outer cylinder with three sets of openings (each set comprising 4 openings/holes). The openings may be used to control one actuator, in that, hole may be used as pressure inlet, the next hole may be used for tank outlet, the second hole may be used as port 2 and the next hole may be used for port 1. Thus, two holes may be connected to first actuator. Similarly, the 4 openings may be used to control one actuator, in that, the first hole may be used as pressure inlet, the second hole may be used for tank outlet, the third hole may be used as port 2 and the last hole may be used as port 1. Thus, the two holes may be connected to second actuator.

VII. SCOPE OF PRESENT WORK

- At present one spool valve can control only one actuator which has been the practice since decades. Here it is proposed to design a system which is simpler than the spool valve in construction and to design a direction control valve i.e. indexing unit to operate multiple actuators keeping the desired actuators at rest.
- 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 design and develop a control valve to control several actuators simultaneously.
- The research entitled “Design, Fabrication and Performance Testing of Directional valve for control of multiple Actuators” is based on concept of US patent US 10180190 titled “Method, system, apparatus and device for directional flow control of fluids and gases”.

- Research work has been carried out further that are related to Indexing control valve use to control multiple actuators. In this regard here we focusing on Indexing control valve drawing and sketches using CATIA Modelling software.
- The indexing valve fabricated can control multiple numbers of actuators at a time or individually and even the construction of this valve is simple compared to conventional direction control valve. This concept can be used for varied sizes and varied number of actuators. As the number of actuator increase the diameter and distance end to end of the valve increases. And the maximum number of actuators controlled can also depend on the angle of indexing given for each actuator.
- The Indexing valve can control multiple actuators at a time; the control valve is of Rotary type because the valve is rotated in circular motion and simple in design. As the number of actuators increases the number of slot increases thus the diameter and length of the valve cylinder increases and reduces the space between the slots.

VIII. SCOPE OF FUTURE WORK

- The design of indexing valve for controlling 4 actuators is successfully designed; this valve design can replace conventional spool valves and also reduces the number of spool valves in a hydraulic system. This valve can even reduce the cost of system and also reduces the number of valves in a system. This enhances the speed of the system; reduce maintenance of the system and to get more efficiency of the system.
- Our valve is designed for 4 actuators by reducing the gap between slots and through holes on the inner cylinder we can even control more number of actuators. This valve is not only applicable for hydraulic system it can be even used to control pneumatic systems also.
- With research, experience and creativity, solutions to the identified problems could be demonstrated successfully.
- In future we will work with multiple actuators through computer interface the main movement of inner cylinder is though stepper motor, which can be easily varied through programming and even computer interface.
- In addition we will explore the current work by varying pressure and cylinder diameter.
- This valve is not only applicable for hydraulic system it can be even used to control pneumatic systems also.
- Design and fabricate a working prototype of the Indexing control valve to operate one or multiple actuators could be developed successfully.
- In future we will manufacture the indexing unit, actuators and connection pipes by using composite materials and smart materials to get light weight, better performance and low cost for fabrication.

IX. CONCLUSIONS

- 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 research work provides an elaborate explanation of working of our proposed work with a novel idea of controlling multiple actuators using single indexing spool valve.
- The proposed work reduces system cost, required space, maintenance cost, manpower and increased speed.
- Work has been explained using 4 actuators i.e., multiple actuators. In future we will work with multiple actuators through computer interface. In addition we will explore the current work by varying pressure and cylinder diameter.
- With research, experience and creativity possible solutions could be suggested to solve the above problems successfully.

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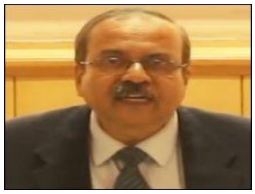

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