

Design and Fabrication of Directional Control Valve to Operate Multiple Actuators

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CHAPTER 1 1. INTRODUCTION

1.1 Spool-type valve

In manual pick-and-place operations, objects are handled using human strength and coordination controlled by brain. In contrast, hydraulic systems perform these tasks using mechanical components, eliminating need for direct human effort.

In such systems, actuators act like artificial arms that produce motion. An actuator is a device that enables movement by converting energy into mechanical action. In hydraulic applications, it transforms the energy of pressurized fluid into force and motion required to carry out tasks such as lifting or positioning.

Hydraulic systems use oil as the working fluid. A pump is responsible for circulating this fluid and generating pressure by converting mechanical input into hydraulic energy. This input is supplied by a prime mover, typically an electric motor connected to the pump.

To control how fluid moves within the system, directional control valves are used. Among them, spool valves are common. These valves contain a cylindrical internal element that slides within a precisely machined chamber. As it shifts position, it opens and closes different flow paths, thereby directing fluid toward actuators and controlling their movement.

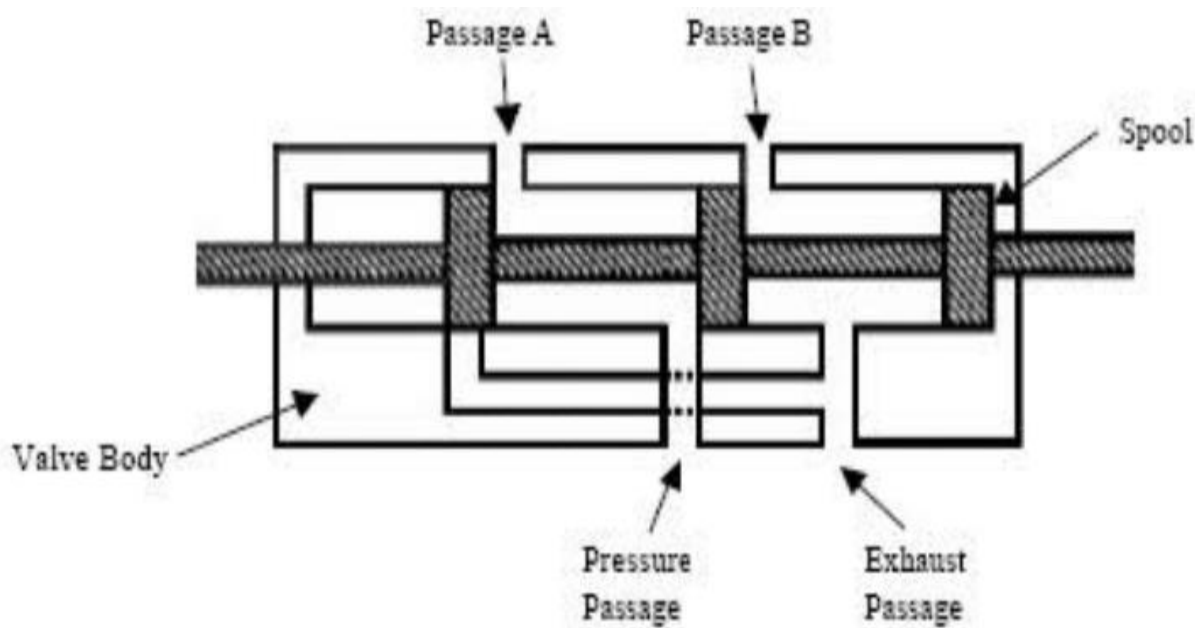


Fig 1.1 Spool-type Valve

In traditional hydraulic arrangements, a single spool valve is typically limited to controlling only one actuator at any given time; a custom has persisted in its original for many years. This restriction reduces system flexibility when multiple actuators need to be managed within same setup.

To address this limitation, a new approach is proposed that focuses on simplifying valve design while enhancing its functionality. The concept involves developing an alternative directional control mechanism, such as an indexing unit, capable of selectively operating multiple actuators. This system would allow specific actuators to be activated as needed, while others remain idle without interference.

By adopting this, system-wide enhancements are possible efficiency, reduced complexity, and better control over multiple operations using a single, more versatile mechanism.

Spool-type valves are commonly employed in hydraulic systems to control fluid power a long range of mechanical engineering applications. For proper operation, internal element of gate must be accurately positioned using an actuating mechanism. This mechanism is tasked with overseeing shifting internal component to regulate fluid flow as required.

While moving internal element, actuating system must overcome various opposing load acting on it. These forces are mainly caused by both internal force and flow liquid traversing internal chamber valve, which resist the displacement of component.

In such a directional control valve system, a slides linearly inside a precisely machined cavity inside valve housing. By moving back and forth, it alternately opens and blocks different flow passages, there by directing fluid to desired path.

1.2 Directional operate Regulation units serve as indispensable elements within fluid power systems, as they regulate pressure levels, control rate of flow, and determine direction in which the fluid travels. In hydraulic various implementations, units are configured to meet high standards of strength, reliability, and precision demanding operating conditions.

It is important to distinguish between hydraulic and pneumatic systems Hydraulic mechanisms work under high-pressure conditions. And therefore require robust, accurately manufactured valves, often made from strong materials such as steel. On the other hand, pneumatic systems function at lower pressures, allowing use of lighter and more economical materials like aluminium or polymers, which also reduces manufacturing cost.

To study how these systems perform, one must examine the path of working fluid is delivered from a pump (or compressor in pneumatic systems) to an actuator, where it performs useful work. Afterward, it either returns to a storage tank or is released into surrounding environment. A basic circuit diagram helps illustrate this flow process clearly.

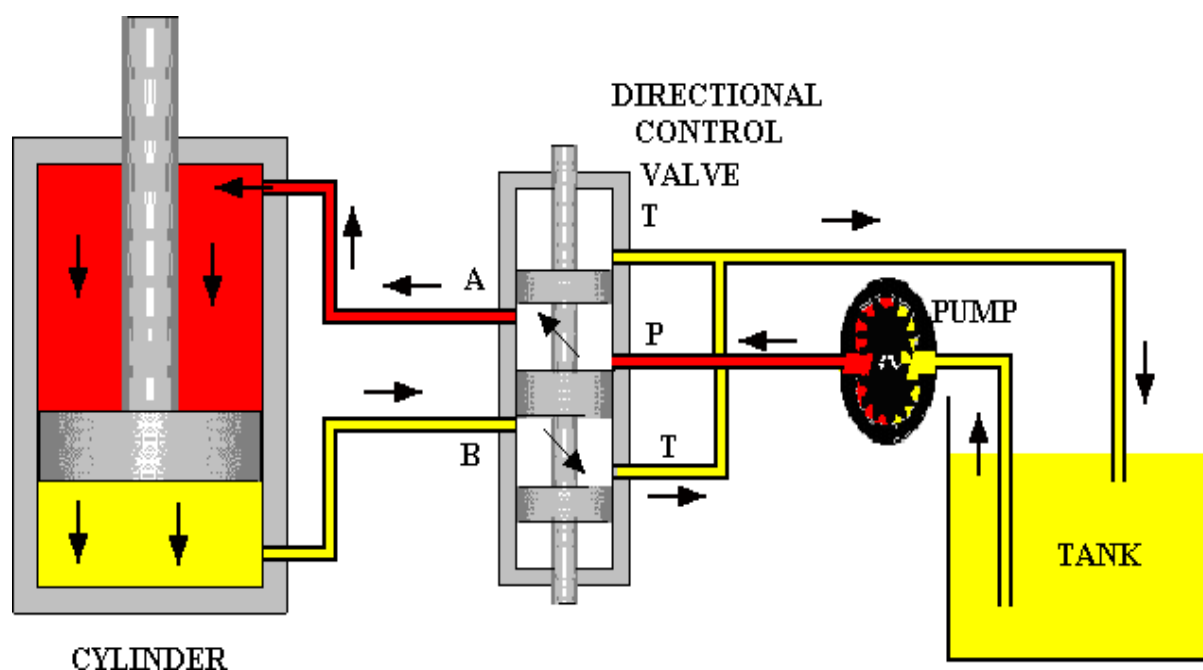


Fig 1.2 Hydraulic system containing Directional operate valve

A directional control valve is created to route fluid coming flowing from the pump toward one of two outlets, commonly labelled to either port A or port B; simultaneously, the fluid leaving actuator chamber is directed through another passage back to reservoir.

These valves are categorized dependent upon total quantity of external connections they possess and different positions they can assume during operation, which together define their functionality and control capability.

The primary function of path-selection regulators is to alter flow path followed by working fluid within a system. By guiding the fluid into actuator chamber, they enable activation and movement of components such as cylinders. In addition to controlling motion, these valves also serve to start or stop fluid signals and are commonly used in basic signal control functions within pneumatic systems.

1.3 Hydraulic actuators

A fluid-driven motion controller is a device that produces motion by utilizing energy of pressurized fluid. It converts hydraulic energy into practical mechanical output, output allowing a system to perform work. The motion generated by such actuators can be either linear or rotational, depending on their design.

Typically, A linear fluid-power motor is made up annular tubular structure component casing with an internal cavity. Inside this space, a piston moves back and forth under influence of fluid pressure, generating the required force and displacement for operation.



Fig 1.3 Hydraulic actuator

CHAPTER 2

2. LITERATURE SURVEY:

This study focuses on limitations associated with spool-type as well as rotary valves. To assist analysis and development of improved solutions, relevant references have been consulted and are presented for further understanding and validation of work.

In reference [1], a study by Elena Ponomareva examines both hydraulic and pneumatic actuators, highlighting their advantages, limitations, and different design variations. The work also discusses three main types of drive systems commonly used in modern applications: electric, pneumatic, and hydraulic..

In reference [2], work by Constantinos Mavroidis, Charles Pfeiffer, and Michael Mosley focuses on conventional actuator systems. Their study explains the operating principles of fluid-power architecture, air-driven, and motor-driven

positioning units. Comprehensive details descriptions and oretical foundations of actuators are broadly available in standard robotics.

A study cited in reference [3], conducted by **Mohammad Pournazeri, Amir Khajepour**, introduces an effective electro-hydraulic camless valve train system. Their research emphasizes enhancing system performance through variable-speed operation, allowing improved control and higher efficiency. Additionally, fuel consumption can be optimized by refining torque transmission and release through flexible adjustment of valve timing, duration, plus upward actuation. For majority of currently available electro-hydraulic dynamic valve-timing frameworks, the target displacement height during each. the power stroke sequence is fulfilled through precisely controlling the opening duration of solenoid valve. In reference [4], research conducted by Mark Beasley examines the problem of valve stiction in hydraulic systems and proposes a solution based on eliminating soft contaminants. The study identifies performance degradation as result of slow servo valve response, primarily attributable to intensified frictional drag from oxidation residues (varnish). These deposits narrow radial tolerance within slider assembly and its bore, restricting motion and ultimately reducing system efficiency.

In reference [5], research by **Song Liu and Bin Yao** presents programmable valves as an effective approach to addressing the through-pass dead band problem within electronically-governed fluid power networks. This study demonstrates that performance closed-centre proportional directional control valves and servo valves can be enhanced by minimizing dead band, leading to improved responsiveness and more precise system control.

This study proposes a redesigned valve configuration to eliminate the dead band effect commonly found in conventional systems. The solution involves use programmable valves, which consist of small arrangement of five distinct and separately regulated poppet-type cartridge valves working together to improve response and control accuracy.

In reference [6], a study by **Alessandro De Luca and Raffaella Mattone** presents a method for identifying faults in robotic actuators.. The study also focuses on techniques for effective fault detection and isolation to improve system reliability.

In reference [7], a review by **Akira Sasaki and Takashi Yamamoto** examines research related to hydraulic lock in spool-type valves. The study identifies two primary areas of investigation: one focusing on uneven the distribution of pressure around spool, along with t other addressing issues caused by contamination within hydraulic fluid. In addition, review discusses secondary research directions that further explore the causes and effects of hydraulic locking in such systems.

In reference [8], A study conducted by **Hao Tian and James D. Van** investigates design enhancements of rotational flow-diverter used in hydraulic engines. Their findings indicate that engine efficiency is significantly affected by valve-related parameters, including timing characteristics, internal fluid migration and kinetic resistance between moving parts interacting with force and return ports. To enhance performance, the authors propose a new clearance-sealed cylindrical rotary valve, specifically developed for use in linkage-driven hydraulic piston engines.

A major concern within hydraulic systems is maintaining proper containment and regulation of working fluid inside the actuation system mechanism. Leakage not only reduces system efficiency fluid, which may result in damage to internal components and surfaces over time. Hydraulic fluid is both flammable and maintained under high pressure, making leaks or ruptures potentially hazardous to equipment. Such conditions can also contribute to issues like cavitation's, which may damage system components and reduce operational reliability.To divide conventional sliding spool valve into separate modular sections that can be assembled in different configurations. Allowing performance evaluation through simulation to understand how these design variations influence behavior and efficiency of hydraulic system.

This approach enables user to determine the most suitable valve design, leading to improved efficiency.

In electro-hydraulic adjustable valve-timing architectures, achieving control gain with during each individual combustion sequence essential for proper performance. However, due to relatively delayed response time of these valves, maintaining precise control becomes challenging, particularly at higher engine speeds.

Furthermore, proposed lift control method has been preliminarily implemented by modifying existing electro-hydraulic variable valve system model, allowing initial evaluation of its performance.

Air leakage in rotary valves continues to be a recurring problem. When not adequately managed, escaping air tends to travel upward via a gravity-fed conduit attached to feeder, which can adversely impact overall system performance.

Internal Spool Leakage describes slow and unintended displacement of a load from its set position over time, regardless of lack of any control input. A sliding-column regulator system is often built by assembling multiple sections into a manifold assembly (for example, sections a series of five individual ports). This valve bank governs the vast majority of machine's hydraulic operations and is generally controlled through manual means, such as hand levers or foot pedals.

CHAPTER 3 PROBLEM STATEMENT

3.1 Objective of the work:

- Considering issues identified above, operation of current system can be analysed in detail to understand its limitations. Based on this analysis, efforts can be directed toward developing an improved solution. A new device may be designed and manufactured with high precision, aiming to effectively address and overcome previously mentioned problems.
- Explain the fundamental concepts of hydraulics and outline working mechanism of a hydraulic system, including how fluid pressure is generated, transmitted, and used to perform mechanical work.
- Identify the limitations associated with traditional spool-type valves and design an improved valve system capable of managing multiple actuators at the same time.

Investigate and develop methods to address issues arising from pressure variations within valve caused by differences in land areas, aiming to improve performance and stability.

Hydraulic actuator using a internal shuttle element valve: A fluid-driven motion controlled is made up of a cylindrical chamber designed to harness energy from pressurized fluid. This energy is converted into mechanical motion, enabling the system to perform work such as raising, pressing, or positioning components.

• Spool-type hydraulic gate are category of flow-routing mechanisms utilised to manage the motion and functioning of pressurized liquid drive units. Typically, a internal shuttle element is patterned to actuate a single actuator at a time. The aims to prototype and implement a precision flow-management device that can simultaneously operate multiple actuators. The current framework is formally presented for patent consideration, emphasizing its novelty and its importance as an active area of research.

3.2 Methodology (Proposed work)

- **Identification**

In modern hydraulic systems, spool-type gate are commonly leveraged for to govern course taken by. Fluid flow toward actuators. However, a key limitation of this arrangement is that each valve is typically capable of operating only one actuator at a time, which restricts overall system flexibility and efficiency

- **Definition of Issue:**

As quantity of motion controllers within a fluidic network grows, additional linear-displacement manifolds represent needed accordingly. This results in increased capital requirements in addition to greater complexity, along with a higher overall count of components within the system configuration.

- **Synthesis:**

The proposed design consists of two primary parts: an internal chamber and an external chamber. The internal chamber is coupled to a incremental pulse-driven drive alongside is located inside the outer chamber. The outer chamber is provided several drilled channels that connect to actuator ports, the pressure supply line, and return line storage tank. The inner chamber is also designed with specific openings and flow passages. By rotating or positioning the inner chamber, these openings align with those in outer chamber, allowing controlled distribution of fluid to required ports.

- **Analysis:**

In the first position, openings of the inner and outer chambers align with each other, establishing a flow path. In this configuration, pressurized fluid from the supply port is directed to one side of actuator, causing it to move forward. Simultaneously, fluid from opposite side within actuator is discharged back into the reservoir. When discrete-step actuator rotates, it inner chamber to turn accordingly. As result, openings in the inner chamber align with different flow

channels in outer chamber. In new position, pressurized fluid is directed to opposite side of actuator, causing reverse motion, while fluid from other side is returned to storage tank.

With further rotation of stepper motor, alignment shifts again, allowing the fluid flow to be redirected toward another actuator. During this process, the previously activated actuator maintains its position, while next actuator begins its operation.

Initially, the ports and flow passages were arranged across length of valve. Although increasing valve length allowed control of more actuators, it resulted in higher material usage and made the structure difficult to support and handle.

To overcome these drawbacks, design was modified by positioning openings along circumference (diameter) of valve instead of its length. This change reduces material consumption, improves compactness, and makes valve easier to manufacture and maintain while still enabling efficient operation of multiple actuators.

- **Evaluation:**

The performance of developed system must be tested under varying fluid pressures, different diameters, and multiple operating conditions. This stage serves as final verification to ensure that design functions effectively and meets intended requirements.

The developed flow direction control valve consists of two main parts: an external hollow cylinder and an inside rotating cylinder. The outside cylinder is designed with passages that serve as pressure inlet, return (tank) outlet, and connections to both sides of actuator. The inside cylinder fits precisely within outer casing and contains a set of openings and slots.

When the inside cylinder is positioned in its first alignment relative to outside cylinder, force inlet is attached to one side of actuator, while opposite side is linked to return port. This configuration produces forward motion of piston.

When inner cylinder rotates to another position, the connections are reversed. The pressure supply is directed to opposite side of actuator, and previously pressurized side is attached to tank, resulting in return moving of piston.

3.3 Material selection

Mild Steel (EN8 Carbon Steel)

EN8 is a medium carbon steel known for offering higher strength and toughness compared to mild steel. It can be heat treated to achieve improved hardness and mechanical properties. Additionally, this material has good machinability, making it suitable for a wide range of engineering applications.

EN-8 steel can also be surface hardened using processes such as induction hardening, which enhances its resistance to wear. In its heat-treated condition, material exhibits a uniform metallurgical structure.

Mild Steel Properties

Table: 3.1 Mild Steel Chemical Composition

Standard	Grade	C Carbon	Mn Manganese	P Phosphorous	S Sulphur	Si Silicon
BS 970	EN8/080M40	0.360.44	0.60-1.00	0.05	0.005	0.10-0.40

Table: 3.2 Mild Steel Mechanical Properties and Hardness

Heat Treatment	Tensile Strength Rm	Yield Strength Rm	Rp 0.2	A min on	Impact		Hardness
				5.65√So	Izod	KCV J	
	MPa	MPa	MPa		Ft.lb		
N Normalizing	550	280	—	16	15	16	152/207
H Hardening	510	245	—	17	—	—	146/197
Q Quenching	625/775	385	355	16	25	28	179/229
R Rolling	700/850	465	450	16	25	28	201/255

Oil Seal (Nitrile Butadiene Rubber Oil Seal) (NBR)



Fig 3.1 NBR Oil seal

TWO PAIRS OF NITRILE BUTADIENE OIL SEAL



Fig 3.2 Two pairs of Nitrile Butadiene Oil Seal

3.4 Construction

The research entitled “Design, Fabrication and Performance Testing of Directional valve for operate of multiple Actuators” is based on concept of US patent US 10180190 titled “Method, system, apparatus and device for directional flow operate of fluids and gases” granted to Professor Dr. G. R. Bharath Sai Kumar Ph.D on Jan 15, 2019.

Components Used

The system is made up of following essential components:

- Hydraulic actuators
- Indexing (directional control) valve
- Fluid storage tank (reservoir)
- Hydraulic
- Pump
- Electric motor (drive unit)
- Pipes and connectors for fluid flow
- Hydraulic oil as the working medium

Tank (Reservoir)

The tank is used to store hydraulic fluid required for system operation. In addition to storage, it performs several important functions:

- It helps in cooling fluid by dissipating heat to surrounding environment.
- It allows impurities and contaminants present in oil to settle at bottom, improving fluid quality.
- It supplies additional fluid to maintain required oil level in system, compensating for any losses due to leakage or usage.

Hydraulic Actuation Systems;

Hydraulic Drive Actuators is a component of a system responsible for producing motion or controlling a mechanism. In hydraulic systems, actuators function by converting energy of pressurized fluid into mechanical force and movement, enabling operation of various machine components.

Pump

A pump serves as the primary power-generating unit in a hydraulic system. It transforms mechanical input energy into hydraulic energy by pressurizing and moving fluid through system.

Motor

The motor functions as primary driving unit of system converting electrical energy into mechanical power. This mechanical energy is then transmitted to hydraulic pump, allowing it to operate and circulate fluid throughout system efficiently.

Indexing Unit

The indexing system is composed of two main parts an outside hollow cylinder and inside rotating cylinder. The external cylinder is designed with multiple ports, including a pressure inlet, a return (tank) outlet, and connections to both sides of actuation device chamber.

The inside cylinder is precisely fitted within outside cylinder and is offered with a combination of openings and slots. These features are arranged in a specific pattern to control fluid flow. The outer cylinder contains a series of holes positioned at equal angular intervals, typically spaced at 36 degrees from each other.

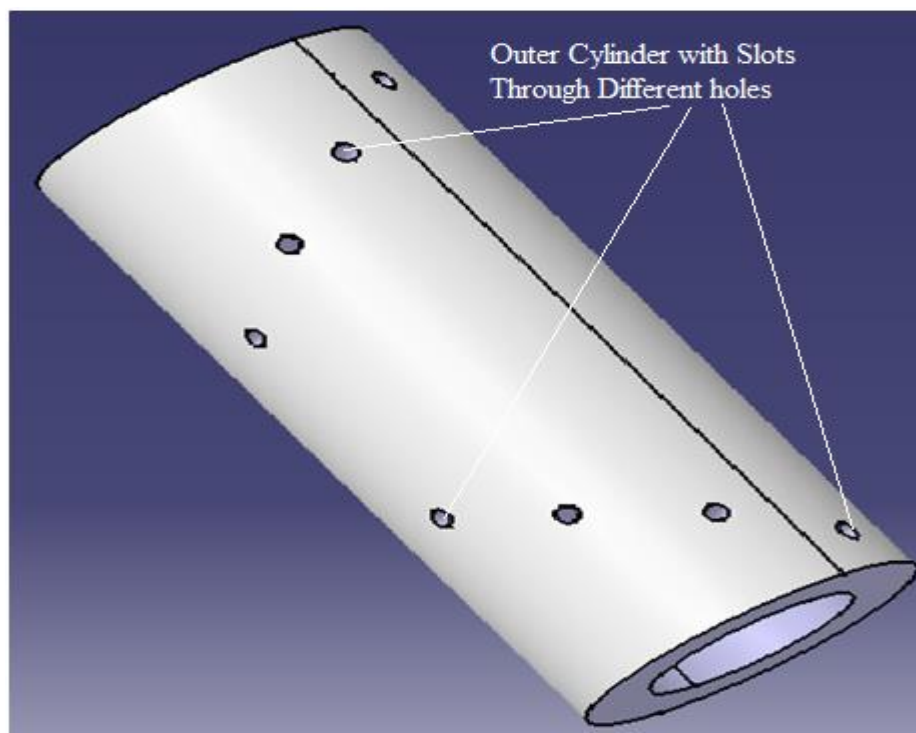


Fig 3.3 external cylinder

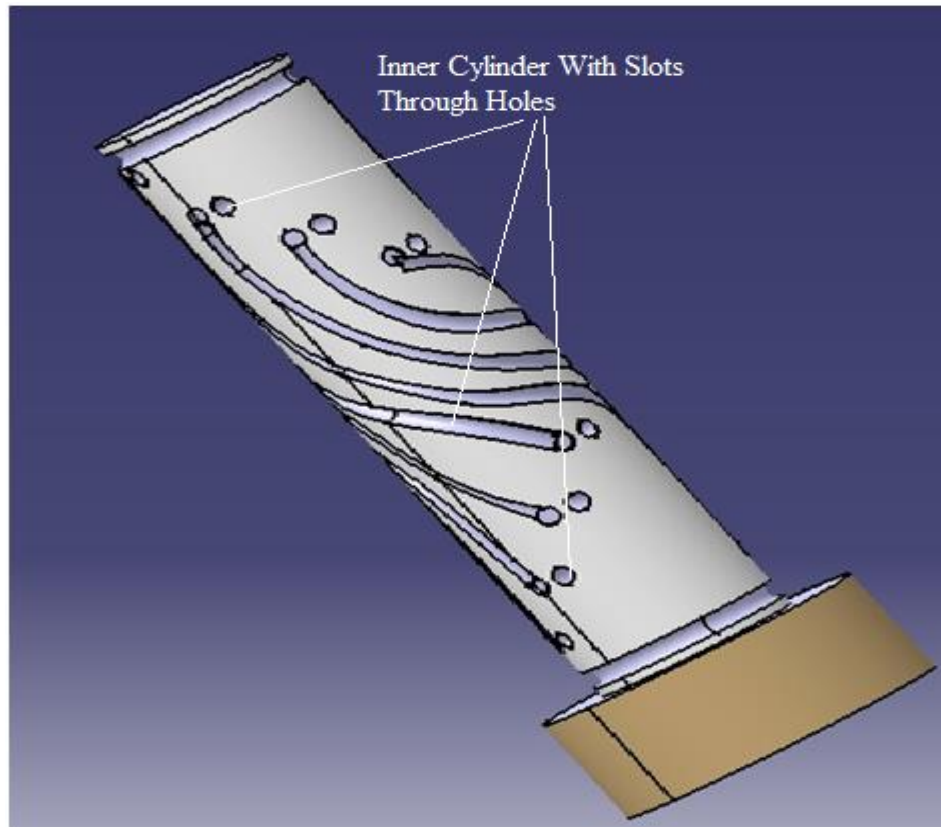


Fig 3.4 Inner cylinder

3.5 Actual Components



Fig 3.5A Hydraulic cylinder



Fig 3.5B indexing valve



Fig 3.5C Pump



Fig 3.5D Tank



Fig 3.5E Motor



Fig 3.5F Hose pipe

3.6 Model design specifications

Hydraulic Actuator Specifications

- External diameter of the actuator: 26 mm
- Diameter of the piston rod: 10 mm
- Diameter of the piston: 18 mm
- Cylinder mounting type: Eye mount or clevis mount

Indexing Valve Specifications

- Outer diameter of the external cylinder: 73 mm
- Internal diameter of the external cylinder / Diameter of the internal cylinder: 45 mm
- The length of the internal cylinder: 214 mm
- The Length of the external cylinder: 184 mm
- Diameter of holes and slots: 5 mm

Hose pipe

Connection from Pump to Indexing Unit:

- Hose type: Oil-resistant synthetic rubber
- Reinforcement: Single braid of high-tensile steel wire
- Outer cover: Synthetic rubber resistant to abrasion and weather conditions
- Operating temperature range: -40°C to $+100^{\circ}\text{C}$ (maximum up to $+120^{\circ}\text{C}$)
- Inner diameter: 3/8 inch
- Outer diameter: 17.4 mm
- Weight: 0.31 kg per .4 Tank Specifications
- Material: Sheet metal

- Dimensions: 30 cm × 25 cm × 25 cm 8.5 Motor Specifications
- Type: Three-phase motor
- Power rating: 0.5 hp
- Operating speed: 1440 rpm

3.7 Pump Specifications

- Pump type: Hydraulic gear pump
- Maximum operating pressure: 200 kg/cm²

Work Carried

- Further investigations have been carried out on indexing control valves designed for operating multiple actuators. This work primarily focuses on developing detailed drawings and sketches of indexing valve utilizing CATIA for accurate modelling and design.

3.8 Design Drawings

3.8.1 CATIA Model of Internal Cylinder

Subsequent empirical probing was finalized on indexing control valves designed for operation of multiple actuators. Within this specific developmental stage of work, particular meticulous focus is directed toward creating detailed models and technical drawings of inner cylinder of the indexing valve using CATIA. This modeling approach ensures accuracy in geometry, proper alignment of ports and slots, and effective visualization of design before fabrication.

CATIA models of the indexing control valve:

The CATIA-based models of indexing regulation valve include internal cylinder, external cylinder, oil seals, and complete assembly. Variations in design profile contingent upon quantity of slot openings is also analyzed and presented.

3.8.2 Proposed Internal Cylinder

The proposed design of internal cylinder is lustrated in Fig9.1 This methodology was developed using CATIA and includes multiple slots arranged with an indexing angle of 180°, which helps in controlling directional flow of fluid within valve system.

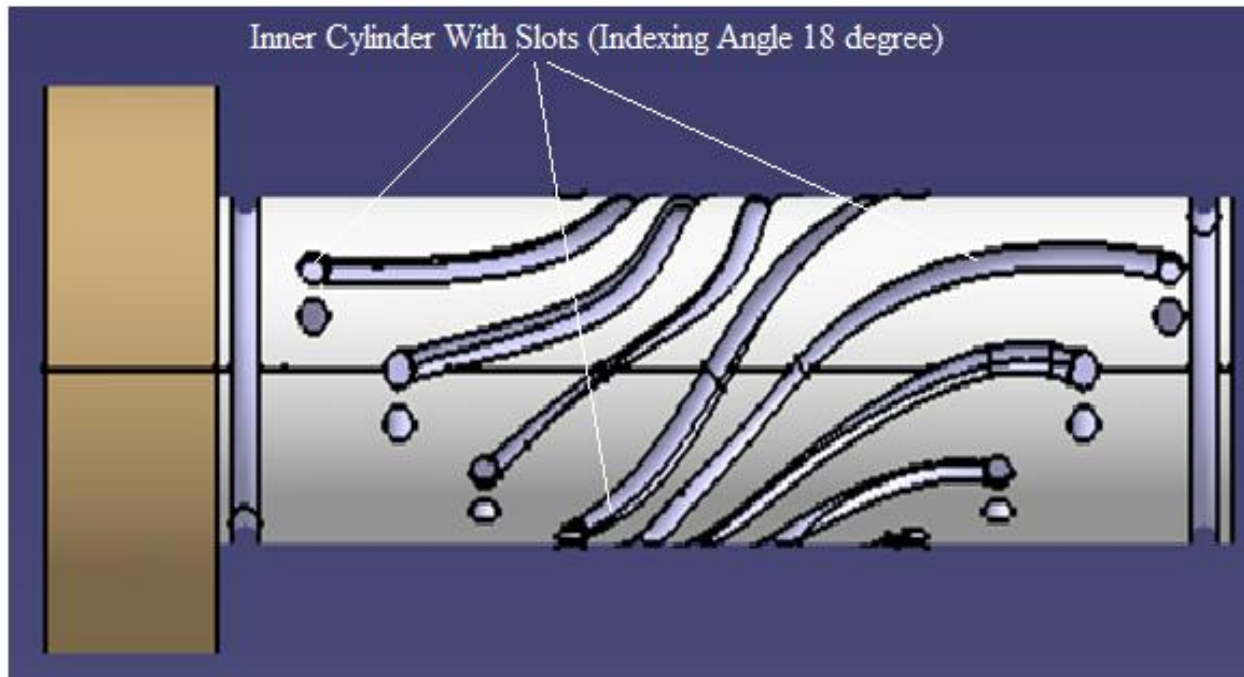


Fig 3.6 CATIA model of Internal Cylinder (It consists of slots with an indexing angle of 180°)

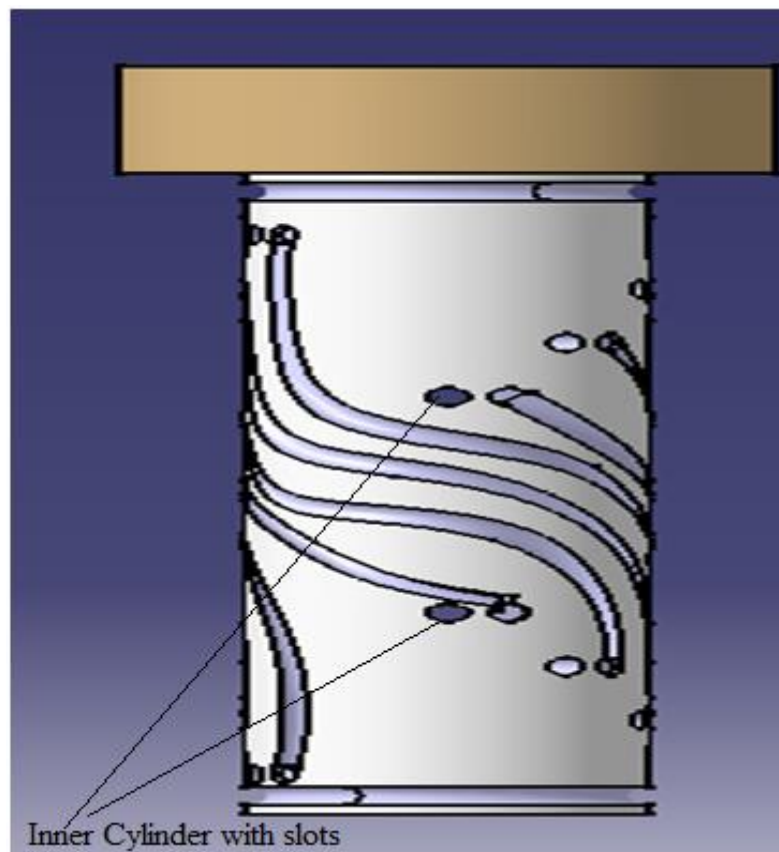


Fig 3.7 Internal cylinder

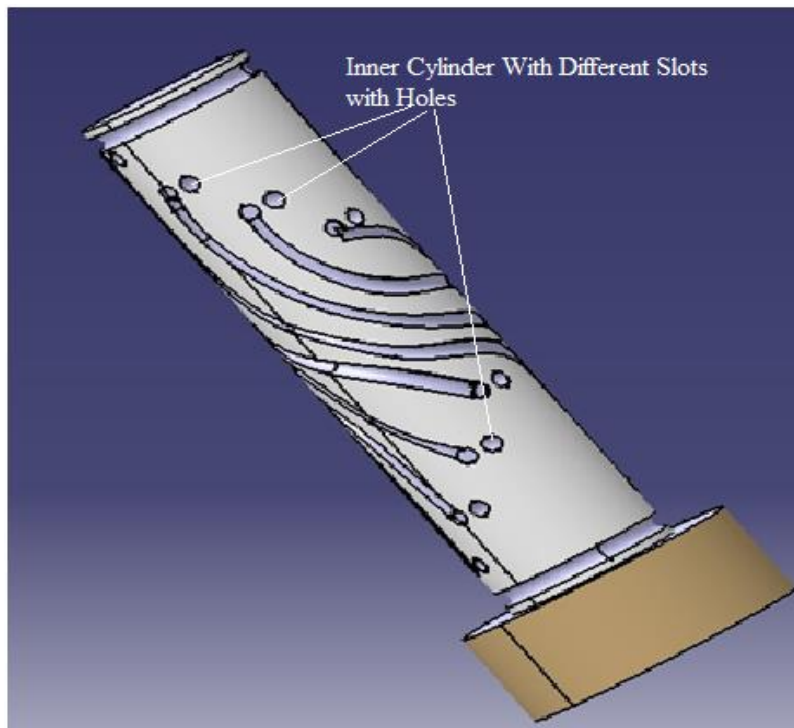


Fig 3.8 Drawings different views of internal cylinder

Different Views of Internal Cylinder

The internal cylinder is represented through multiple orthographic and 3D perspectives to provide enhanced clarity regarding its geometry and design features. These views include:

- Front view
- Top view
- Left side view
- Isometric view

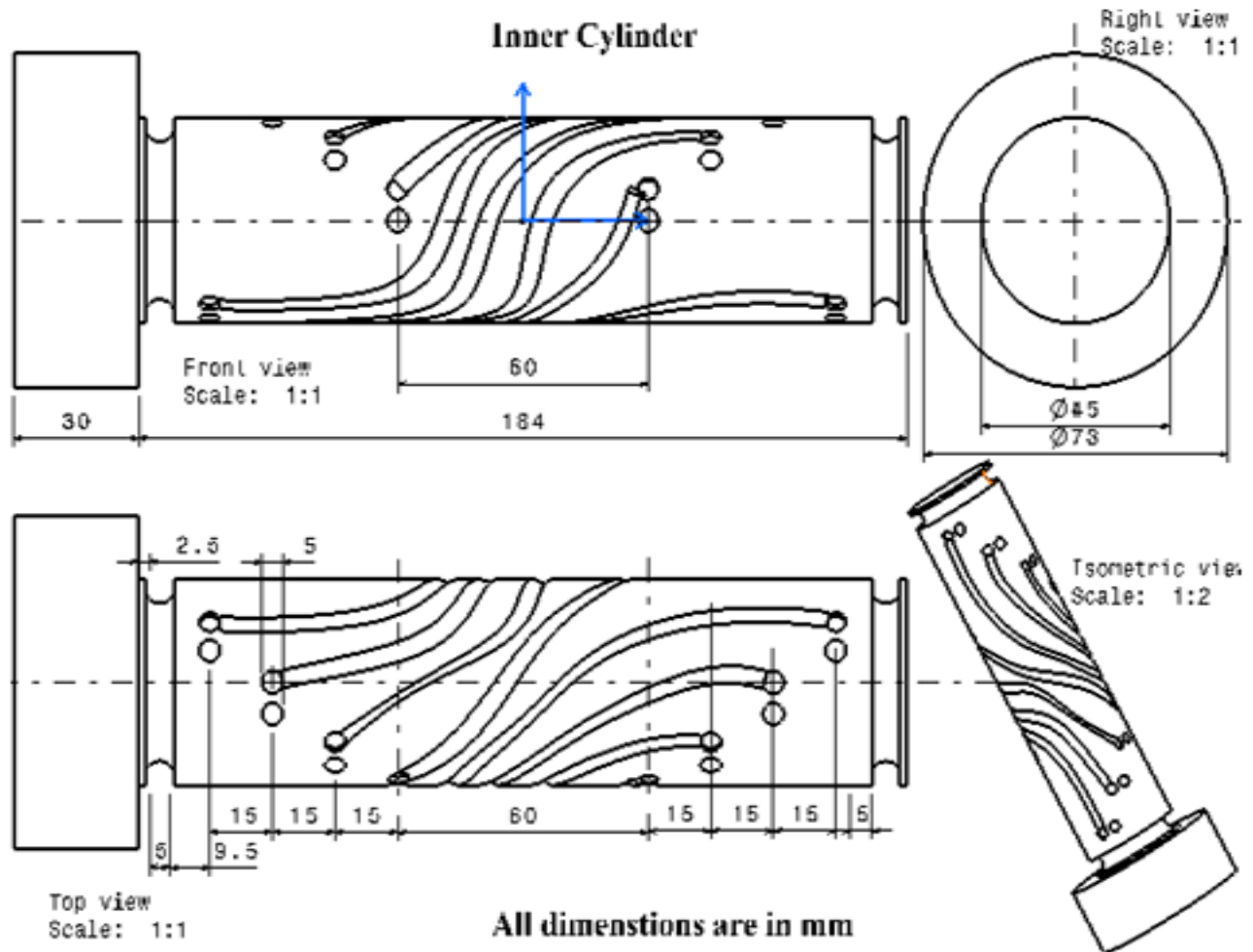


Fig 3.9 All the above different views of Internal Cylinder

3.8.3 External Cylinder

The proposed external cylinder model is shown in Figure 9.4. It has been developed using CATIA and includes multiple holes arranged at angular pitch for 360°. This design ensures proper alignment with internal cylinder for controlled fluid distribution in system.

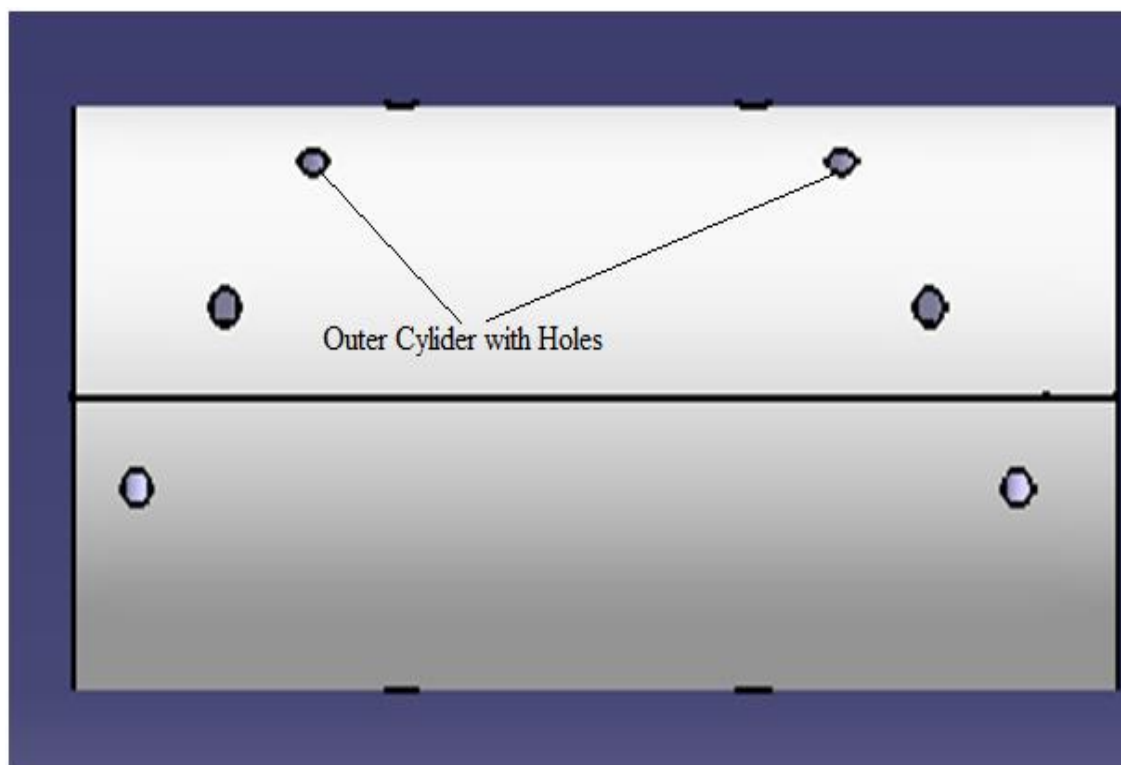


Fig 3.10 CATIA Model of external cylinder

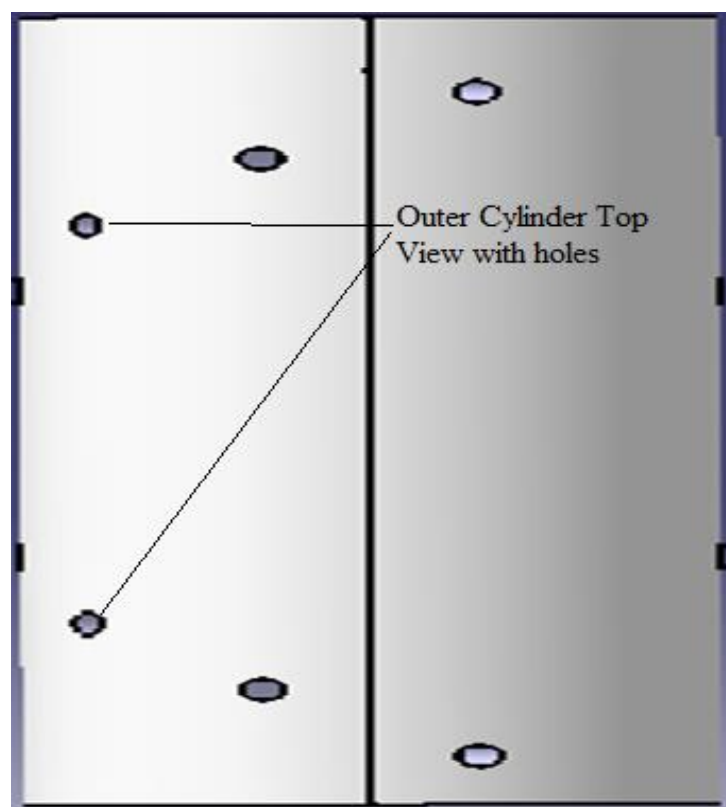
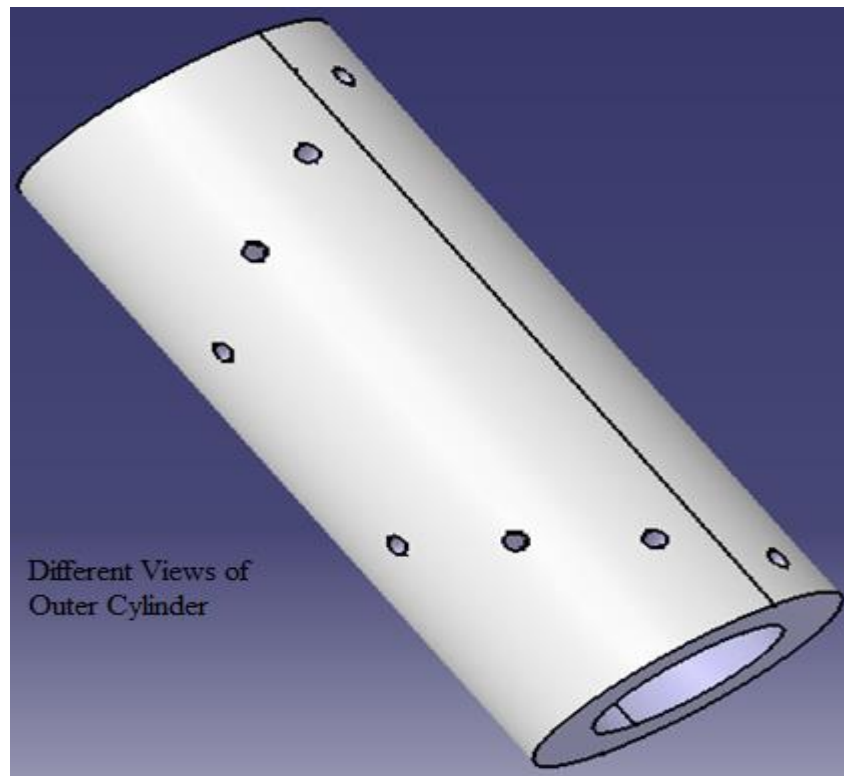


Fig 3.11 Different views of external cylinder



All the above different views of external Cylinder is depicted in Fig 3.12

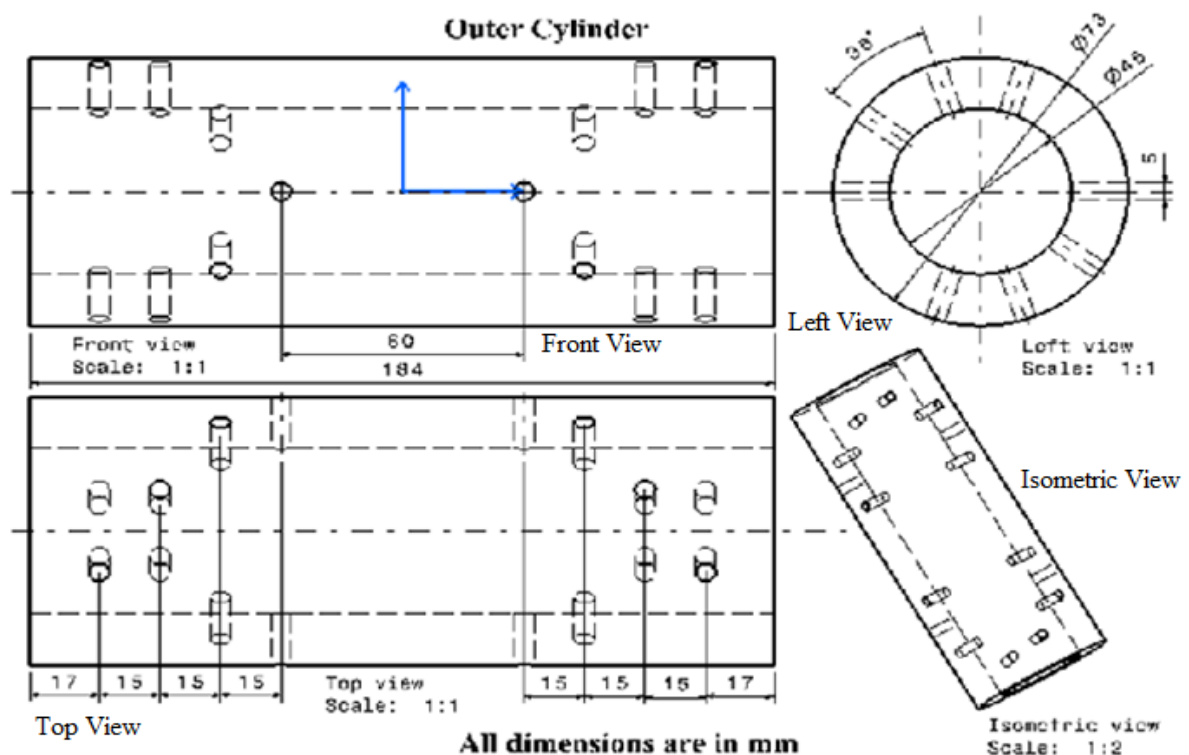


Fig 3.13 All views of external Cylinder

3.8.4 CATIA Model of Indexing Valve assembly

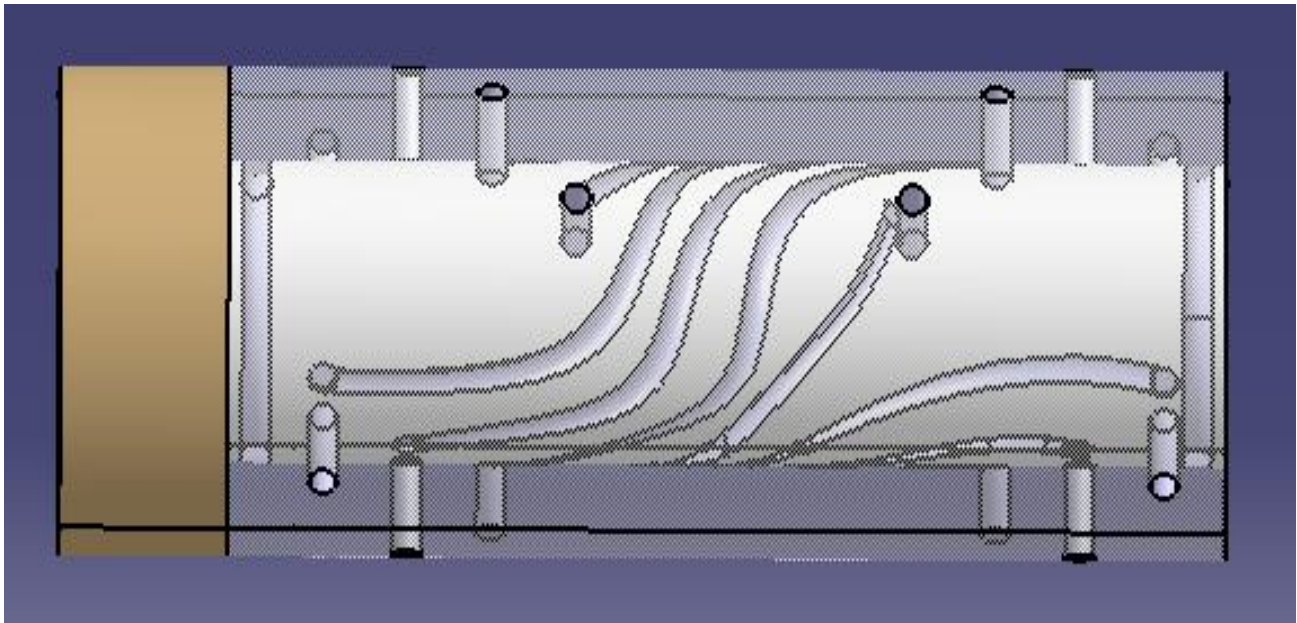


Fig 3.14 CATIA Model of Indexing Valve assembly

3.8.5 Comparative layouts of the step-wise metering module

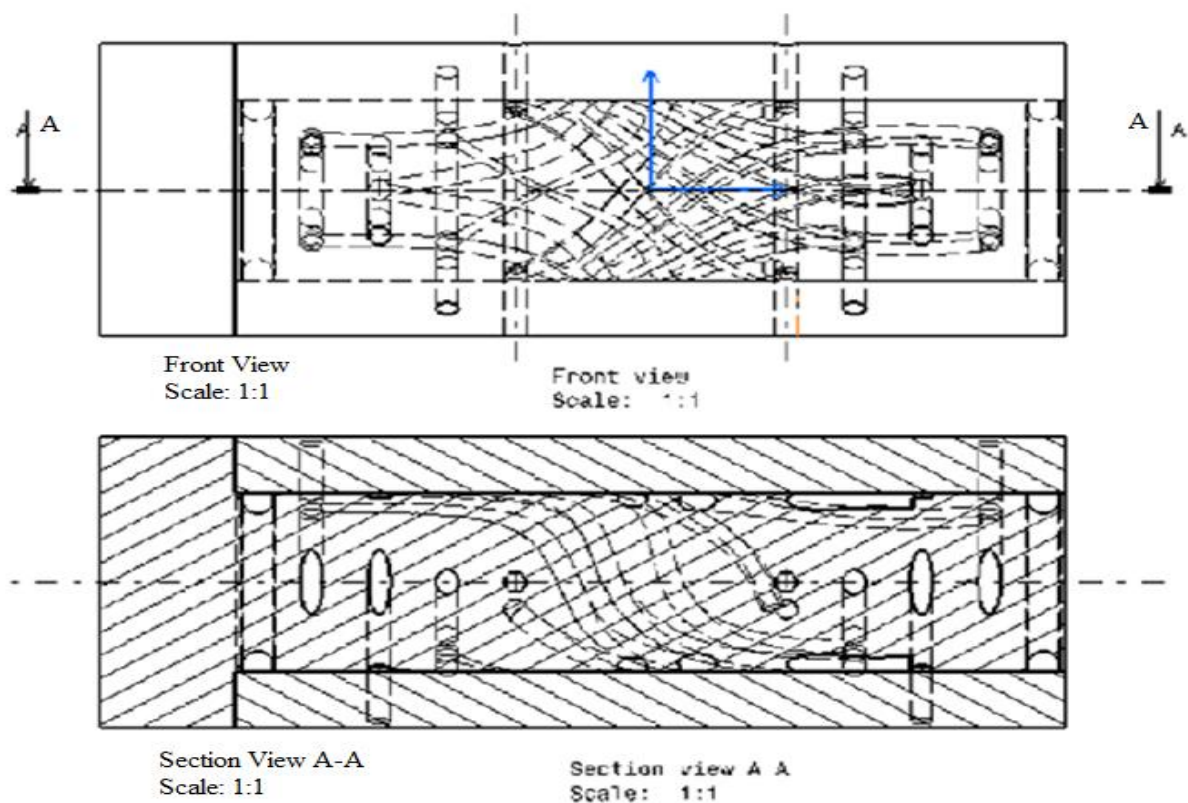


Fig 3.15 Entirely distinct views (Front View and Section View) belonging to the step-wise regulation unit

CHAPTER 04

METHODOLOGY

4.1 Prototyping Varied Sub-assemblies of a Step-wise Metering Mechanism

Step 1: Hydraulic Actuator

The hydraulic actuator is fabricated with the following specifications:

- Outer diameter of actuator: 26 mm
- Piston rod diameter: 10 mm
- Piston diameter: 18 mm
- Cylinder mounting type annular lug or the U-shaped bracket mounting arrangement



Fig 4.1 Fluid-powered motion initiator



Fig 4.2 Pressurized piston-and-bore assembly

4.2 Prototyping the Phase-sequenced Flow Controller

Step 2: Sequential Flow Regulation Unit

The A successive-position flow diverter is fabricated with the following design specifications:

- external diameter of external cylinder: 73 mm
- Internal diameter of external cylinder / internal cylinder diameter: 45 mm
- Length of internal cylinder: 214 mm
- Length of external cylinder: 184 mm
- Span of the circular openings and elongated recesses : 5 mm

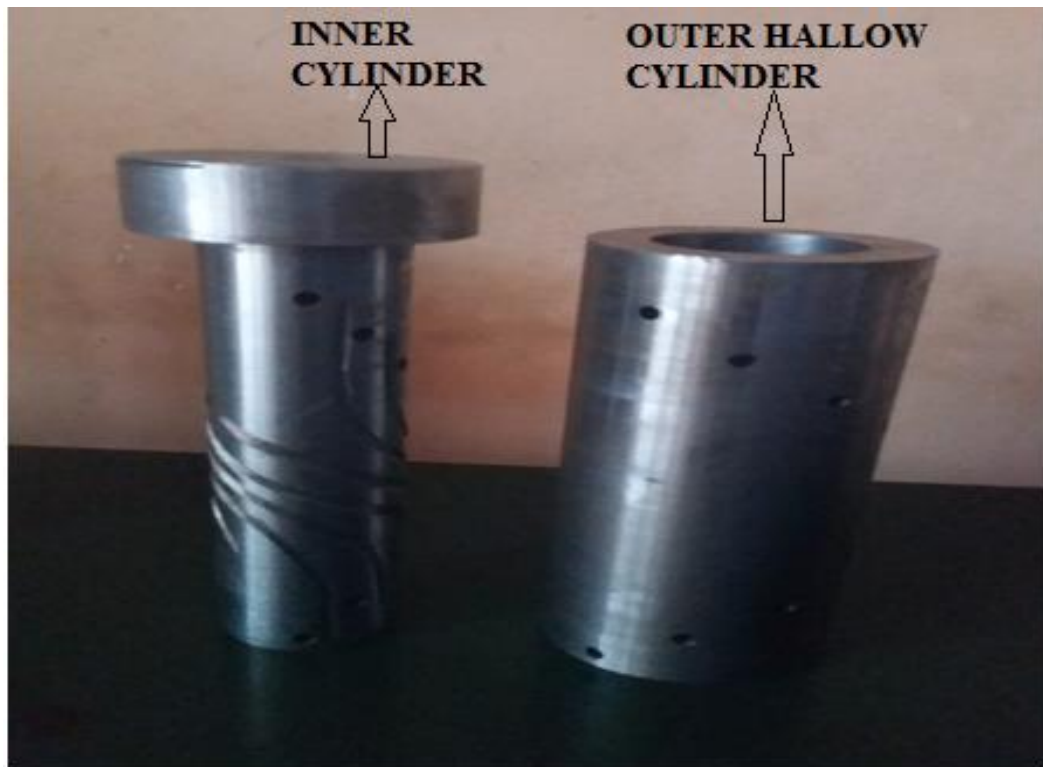


Fig 4.3 The manufactured outputs resulting from internal and external cylinder

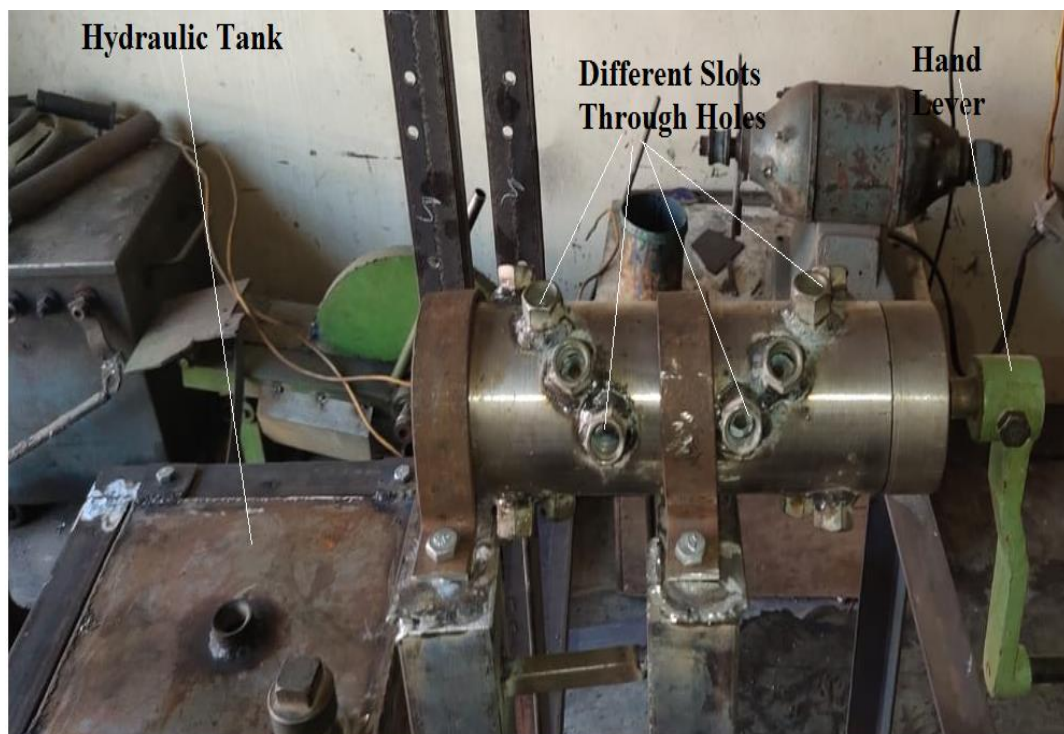


Fig 4.4 Fabricated component assembly of incremental rotation



Assembly of
Indexing control
valve to control
multiple actuators

Fig 4.5 Fluid transmission paths linking circulation hub to increment-logic manifold and on force-delivery module



1-Tank
2-Pump
3-Motor
4-T-Joint
5- On/Off Valve
6-Outer cylinder
7-Inner Cylinder
8-Hand Lever
9, 10, 11 & 12-
Hydraulic Actuator

Fig 4.6 Fluid transmission paths linking the circulation hub to increment-logic manifold and on force-delivery module

Step 4: Support structural chassis and fluid reservoir

The support the structural chassis and fluid reservoir are fabricated using sheet metal. Specifications are as follows:

- Material: Sheet metal
- Dimensions: 30 cm × 25 cm × 25 cm



Fig 4.7 Developed the structural chassis and fluid reservoir for the sequential positioning module



Fig 4.8 Fabricated section of hydraulic tank

4.3 SPECIFICATION OF MOTOR

The motor used system has following specifications:

- Type : Three-phase motor
- Power rating : 0.5 hp
- Rotation Speed: 1440 rpm



Fig 4.9 Motor

4.4 Specification Of The Pump

Step 6: Pump

The pump used a system is specified as follows:

- Type : Hydraulic gear type pump
- Maximum pressure rating: 200 kg/cm²



Fig 4.10 Pump

4.5 Fabrication of complete assembly model of indexing control valve

Step 7: Complete model assembly

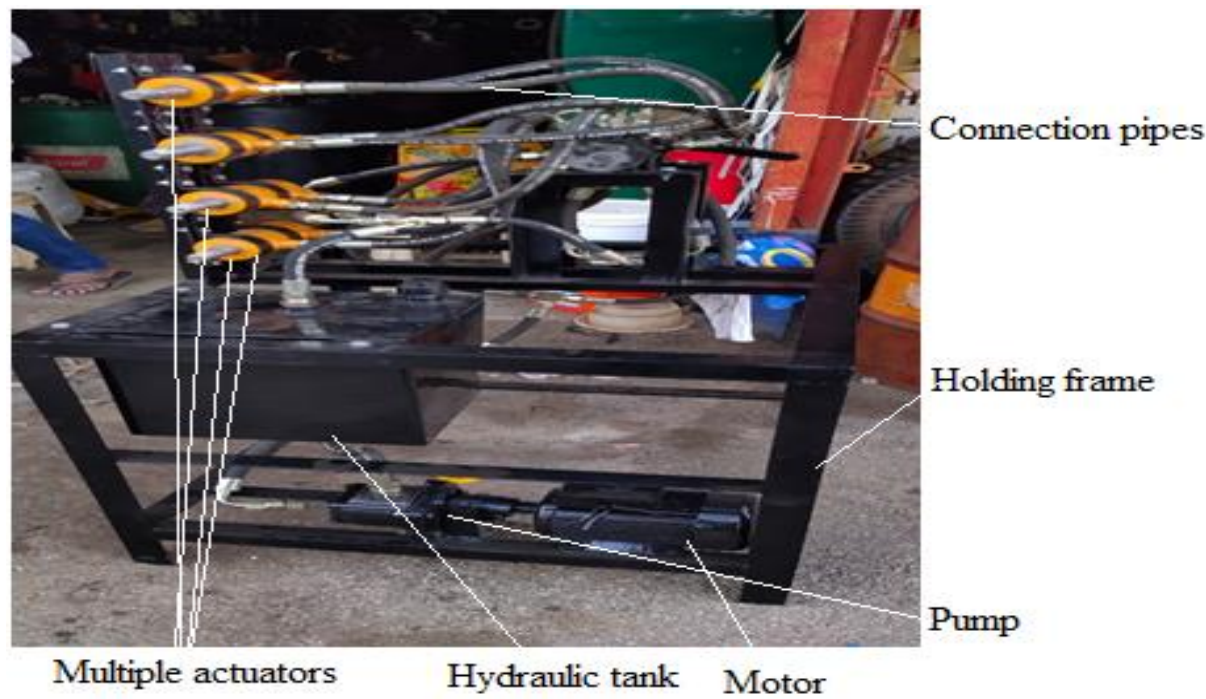


Fig 4.11 Fully Fabricated assembly model of indexing valve

CHAPTER - 5

ASSEMBLY OF MODEL

5.1 Assembly

The supporting structure is fabricated by welding iron bars to form a rigid frame. Components such as sheet metal tank are mounted on this frame using bolts and nuts for secure fastening. The hydraulic pump is coupled to motor through a suitable coupling arrangement; both fixed to frame by welding to ensure stability during operation.

The pump inlet is connected to reservoir using hose pipes, while outlet line supplies pressurized fluid to actuator unit. Since the pump output must be distributed to multiple actuators, T-joints are used to split a single outlet into four separate flow lines. After branching, each line is equipped with a flow control or ON/OFF valve to regulate individual actuator operation. These valves are connected using threaded fittings to allow easy assembly and future modifications.

The return flow from externally cylinder is combined from four lines back into a single line using another set of T-joints. This unified return line is then directed back to tank, completing hydraulic circuit loop.

The main components generally used for complete assembly of following Table

TABLE 5.1: The components used

Name of Component	Number of component used
Actuator	4
Pump	1

Motor (Prime Mover)	1
Indexing unit	1
ON/OFF Valve	4
Tank	1

5.2 A indicates the actual assembly of model of fig

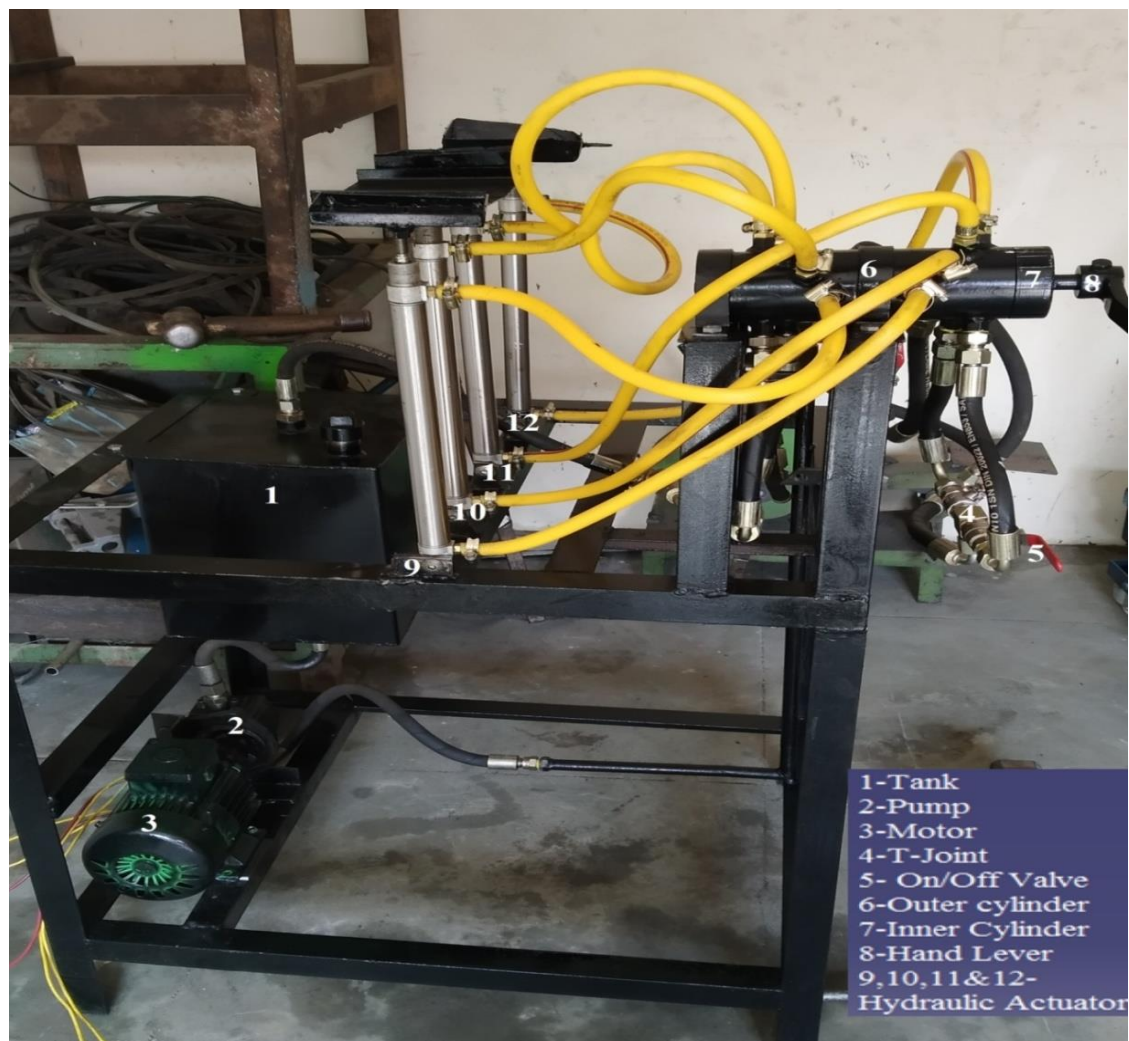


Fig 5.1 Actual Model of Assembly

The main parts of Actual assembly model as following

1. Tank
2. Pump
3. Motor
4. T- Joint

- 5. ON/OFF Valve
- 6. Outer cylinder
- 7. Inner cylinder
- 8. Hand lever
- 9, 10, 11, & 12. Hydraulic cylinder

5.3 The following fig indicates the Assembly model of CATIA

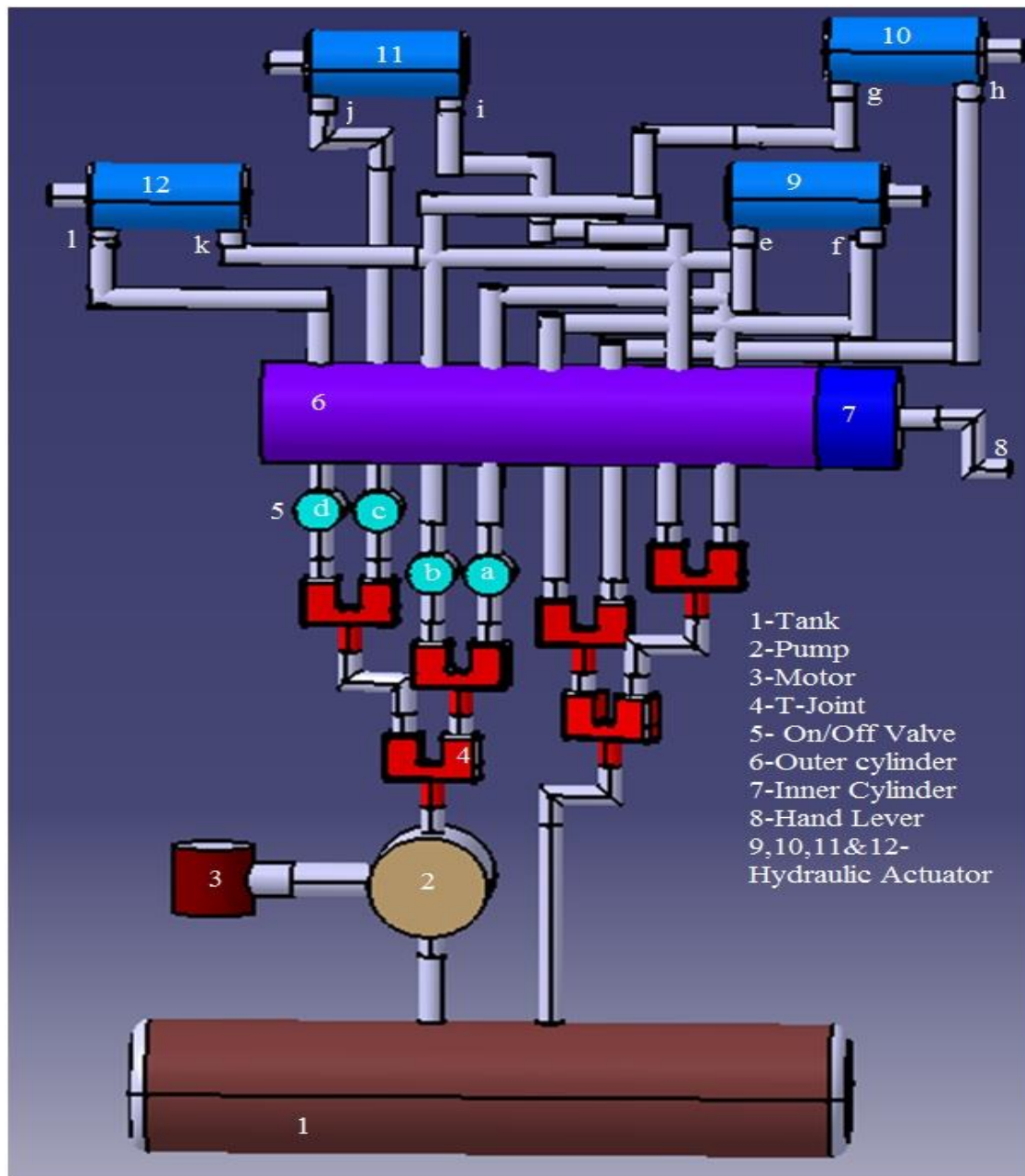


Fig 5.2 CATIA model of Assembly

5.4 The major parts of CATIA model of Assembly as following

1. Tank
2. Pump
3. Motor
4. T- Joint
5. ON/OFF Valve
6. Outer cylinder
7. Inner cylinder
8. Hand lever
- 9, 10, 11, & 12. Hydraulic cylinder

5.5 Changes in Profile with Number of Slots is shown in fig 11.5 with (i) 4 actuators (ii) 3 actuators (iii) 2 actuators

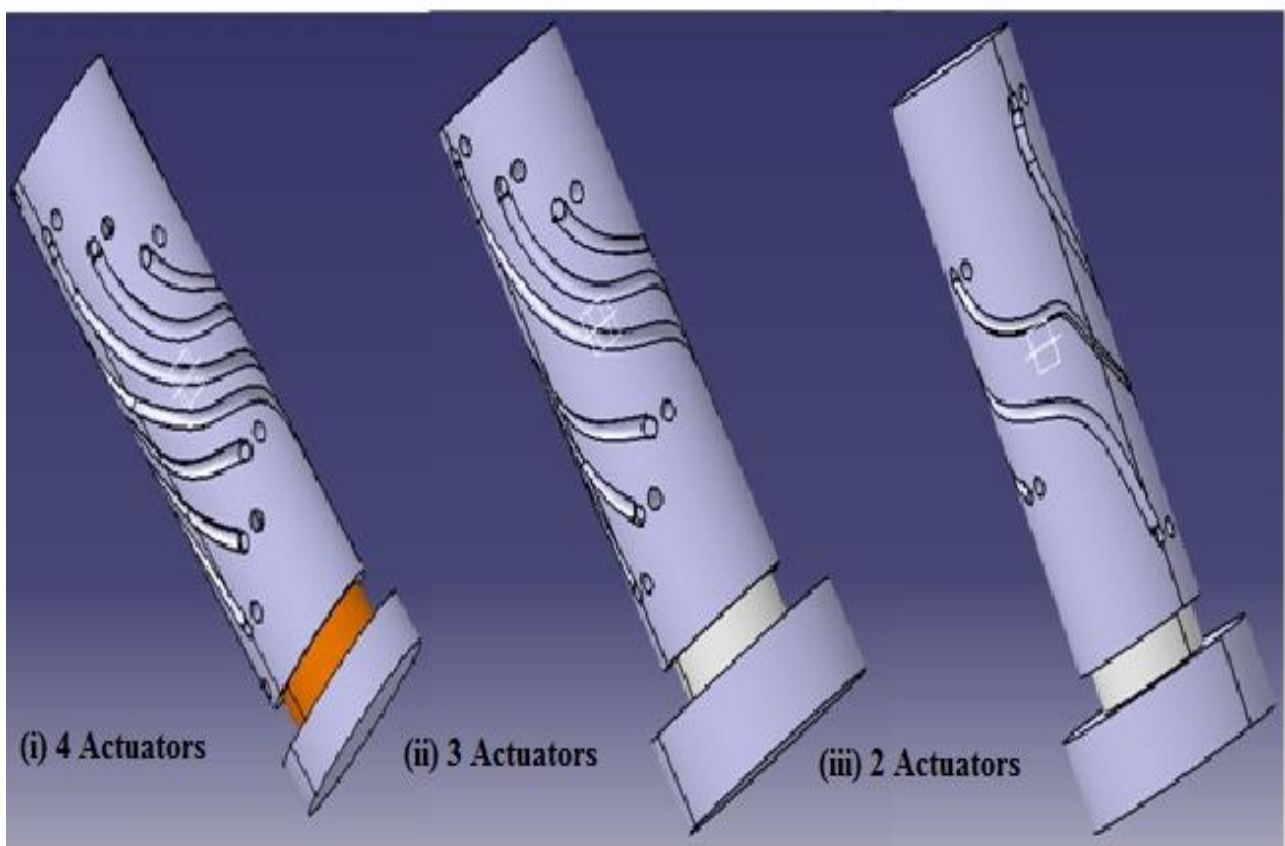


Fig 5.3 Change in Profile with Number of Slots

5.5 Related Work on Operation of Indexing Operate Valve For Multiple Actuators

13.1A Working Operation of Indexing operate valve

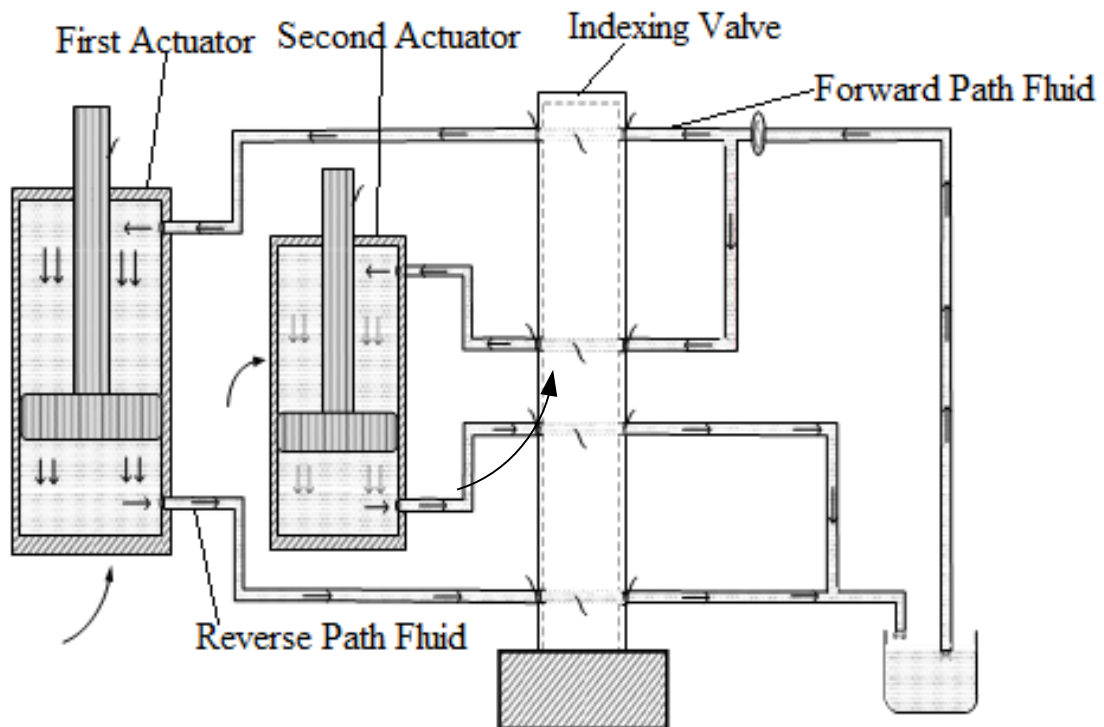


Fig 5.4 Working operation of indexing operate valve to operate multiple actuators

Initially, the internal cylinder is inserted within a hollow cross-section of outer cylinder and is linked to a stepper motor, which provides controlled rotational motion to it. At starting position, inner cylinder is set at 0° , where it aligns in its first relative position with outer cylinder.

In this position, pressure inlet is connected to left actuator port, while return (tank) line is connected to right port. As a result, pressurized fluid from pump flows through pressure port into left section of actuator chamber, causing piston to move forward.

The pressure on left side increases relative to right side, which forces fluid on right side of actuator to flow back to tank through the valve's return port. This pressure imbalance causes actuator to move forward, resulting in extension stroke.

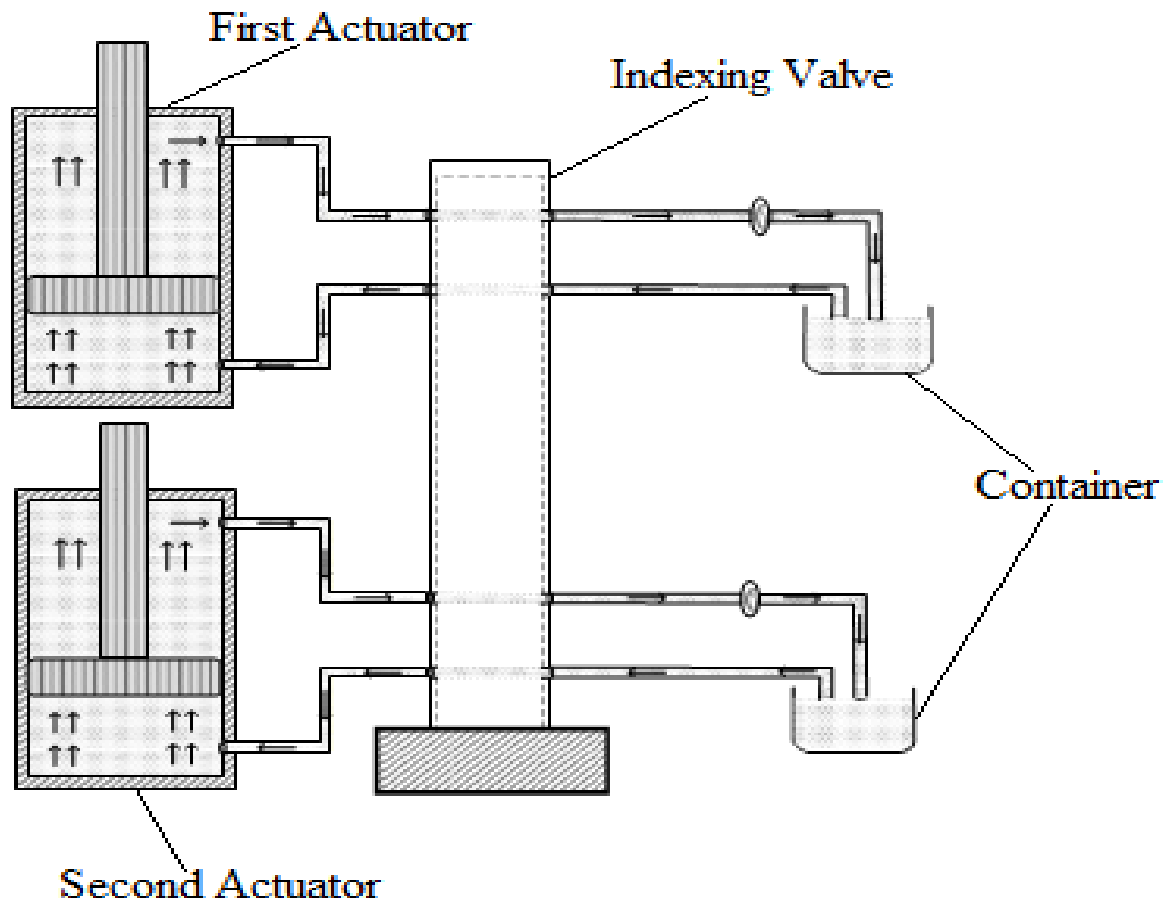


Fig 5.5 First operation of indexing operate valve

When the inner cylinder is rotated by approximately 18° using stepper motor, it reaches an alternate coordinate point relative to external cylinder of valve. In this position, the pressure inlet is connected to the right actuator port, while the tank (return) line is connected to left port.

As a result, high-pressure fluid from pump flows through valve into right section of actuator. Since pressure on left section of piston is lower, pressurized fluid pushes piston towards left, producing return stroke. The fluid displaced from left chamber flows back to tank, thereby completing one full operating cycle.

The indexing unit is rotated to 36° , inner cylinder reaches first relative alignment position with outer cylinder corresponding to second actuator. In this configuration, fluid paths are redirected such that second actuator receives pressurized fluid, resulting in its forward stroke.

At same time, first actuator is isolated from pressure supply and remains in its previous position, effectively staying at rest while second actuator is activated.

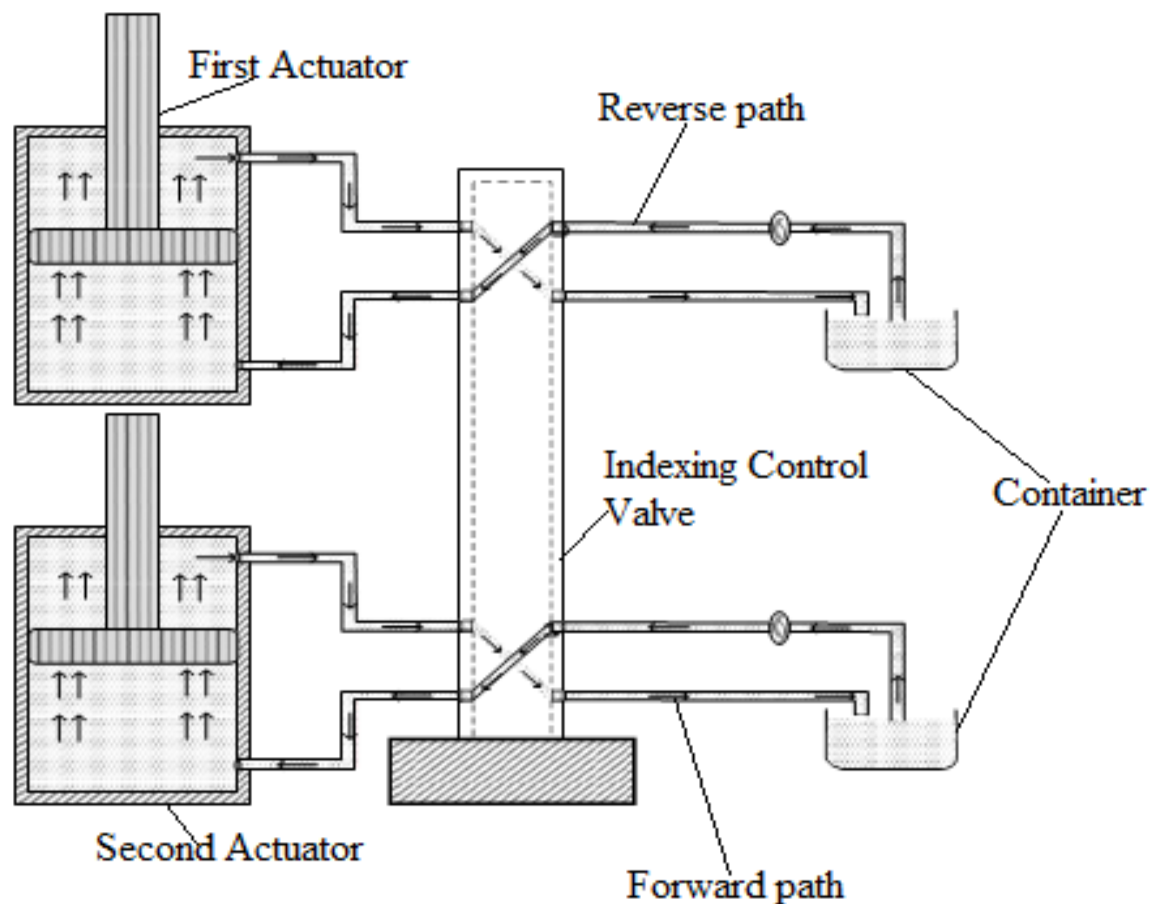


Fig 5.6 Second operation of indexing operate valve

When indexing unit is further rotated to 54° internal cylinder attains alternate coordinate point relative to outer cylinder, corresponding toward auxiliary .actuator. In this configuration, fluid flow is reversed, causing the second actuator to undergo its return at a crank angle of 72° , the internal cylinder aligns in its first relative position with external cylinder corresponding to third actuator. In this state, pressurized fluid is directed to third actuator, producing its forward stroke, while remaining actuators stay inactive.

When indexing unit is further rotated to 90° inner cylinder shifts to its second associated position relative to outer cylinder for the third actuator. This reverses flow direction, causing third actuator to perform its return stroke.

At an indexing angle of 108° , the fourth actuator is supplied with pressurized fluid, resulting in its forward stroke. When unit is rotated further to 126° , flow direction is reversed, causing fourth actuator to complete its return stroke. During these operations, all other actuators remain in their respective positions without movement.

The system also allows flexible operation of actuators in any required sequence. Check valves are incorporated to control and direct fluid flow from pump to selected actuator, while changes in the indexing angle enable activation of different actuators as needed.

This design simplifies operation of hydraulic system compared to conventional valve arrangements. Additionally, it reduces manual intervention required in traditional spool-type valve systems, as entire operation can be controlled through a computer-based interface.

Toward the auxiliary

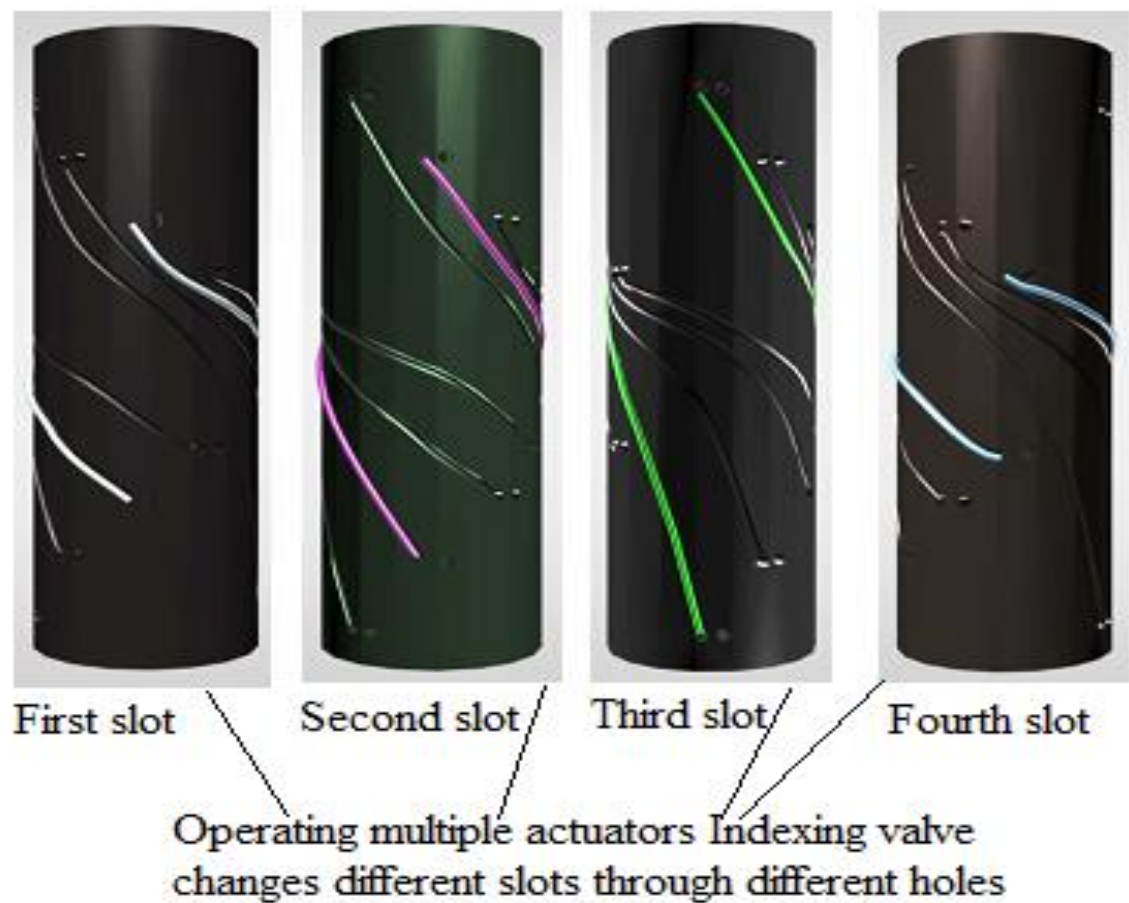


Fig 5.7 Indexing valve changes different slots through different holes

CHAPTER-6

RESULTS AND DISCUSSIONS

6.1 Experimental Outcomes and Analytical Interpretation

TABLE 6.1: Operational Efficiency of the Motion Initiators

mechanical drive unit	Extension duration (in sec)	Retraction interval (in sec)
1	5	8
2	5	9
3	6	10
4	6	12

6.2 Results

6.2.1 Maximum load acting on Piston

Case 1:

Throughout the extension interval:

(I) "Fluidic intensity is derived by dividing the exerted load by the surface span of the reciprocating face.

Maximum load through pump,

$$P = 200 \text{ Kg/cm}^2$$

(II) the cross-sectional breadth of the drive-head

$$A = \pi(\text{Dia of piston})^2/4$$

$$A = \pi(1.8)^2/4 = 2.5446 \text{ square cm}$$

(III) Max. Load acting on piston,

$$F = P \cdot A = 200 \text{ kg/cm} \cdot 2.5446 \text{ cm} = 508.92 \text{ kg}$$

Case 2:

During Return Stroke:

(I) Pressure = Force / Area of piston on which force is acting,

Maximum Pressure through pump,

$$P = 200 \text{ kg/cm}^2$$

(II) Cross-sectional breadth of the bore-conforming plate

$$\text{Area} = \pi((\text{Piston dia})^2 - (\text{Piston rod dia})^2)/4$$

$$\text{Area} = \pi((1.8^2) - (1^2)) / 4 = 1.7592 \text{ kg}$$

$$\text{Area of span} = 1.7592 \text{ kg}$$

(iii) Maximum mechanical load distributed across the drive-head

$$\text{Load} = P \cdot A = 200 \cdot 1.7592 = 351.84 \text{ Kg.}$$

$$\text{Load} = 351.84 \text{ Kg.}$$

6.3 Result Discussions

6.3.1 Result Discussion Case 1:

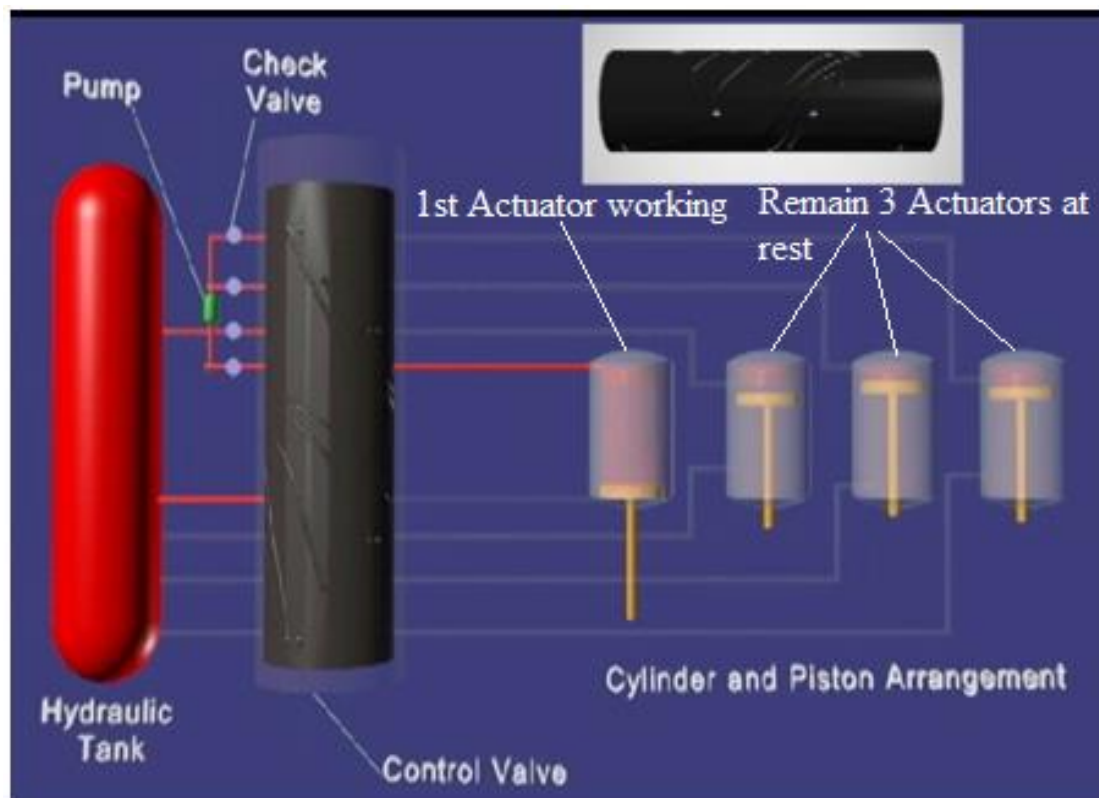


Fig 6.1 Operating 1st actuator remain 3 actuators are at rest

Case 1

In the first angular position, flow control system consists of external hollow cylinder integrated with an indexing mechanism. The external piston housing is equipped with multiple ports, including a pressure inlet, a tank return, and two actuator connection ports located on its surface. The indexing unit includes an inner rotating cylinder, which is precisely fitted inside annulated space of external cylinder.

When internal cylinder positioned its first relative alignment with external cylinder, the primary inlet orifice is interfaced with first actuator port, while reservoir discharge point is joined to second port. When internal cylinder is rotated to its second relative position, connections are reversed pressure supply is directed to second port and tank return is connected to first port.

From a system perspective, arrangement includes an indexing valve, a hydraulic actuator, and a pump. The actuator comprises a piston and piston rod assembly, while pump serves as primary driver for supplying pressurized fluid. The step-wise regulation unit is made up of external cylinder and the rotating internal cylinder.

In one operating condition, the piston moves in one direction when internal cylinder is its initial position and high-pressure fluid is supplied. In another condition, piston moves in the opposite direction when internal cylinder is shifted to second indexed position, reversing flow trajectory of pressurized fluid.

6.3.2 Result Discussion Case 2:

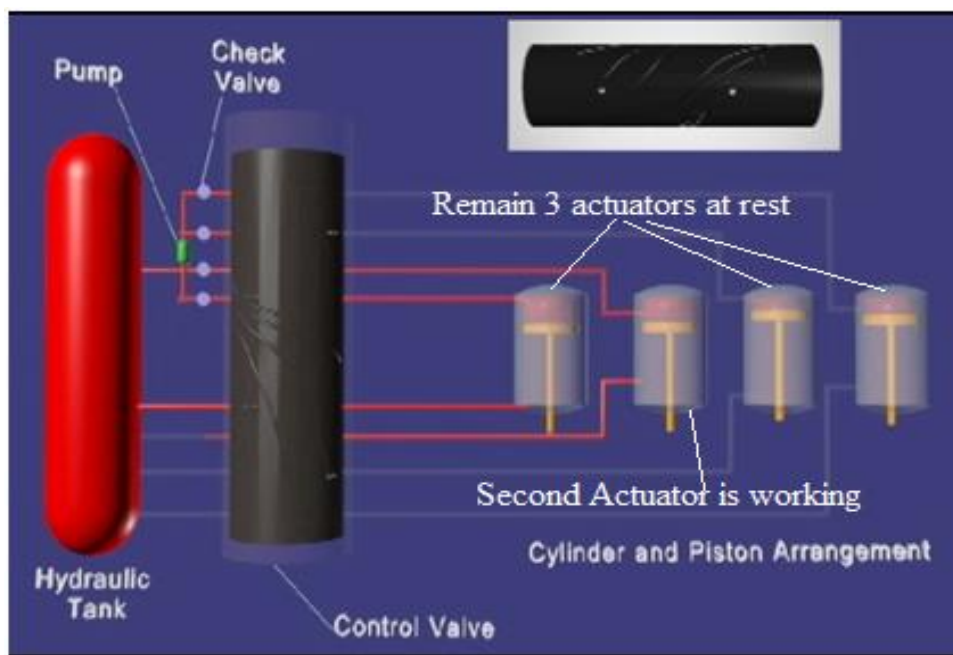


Fig 6.2 Operating 2nd actuator remain 3 motion initiators remain in a static state

Case 2:

Various illustrative configurations are detailed hereafter in connection with supplementary diagrams for better understanding. It should note specific details are provided to ensure a clear explanation of invention. However, person skilled specialists in related domain will acknowledge that concept can be implemented without some of these details, or by using different methods and configurations.

The directional valve assembly is composed of an external cylinder and an indexing mechanism unit. The outer cylinder is provided with four ports, arranged such that each specific junction is assigned a corresponding radically opposite port; the external cylinder is identified using a reference mark for clarity in representation.

When the reference mark is aligned with reference position, one port aligns and connects with corresponding mating port.

As an alternative option, indexing member can also be fabricated using different material selections and design considerations, such as varying wall thickness or introducing hollow sections, depending on desired functional requirements and application.

A three-dimensional view of the external cylinder is shown, highlighting its hollow internal region. This hollow region is designed to accommodate internal cylinder of indexing unit. Each port provided on external cylinder forms a passage that connects external surface to internal bore, allowing controlled fluid flow.

An example structure of internal cylinder is illustrated separately below for better understanding of its design and function.

A three-dimensional view of indexing element is presented to illustrate the structure of internal cylinder. As shown, the internal cylinder includes a combination of grooves, channels, and through-holes. These grooves, including both straight and curved profiles, are precisely machined on cylindrical outer surface of internal component.

Each groove consists of two terminal ends. These ends are positioned so that one end of each groove is position one side of cylinder; the opposite end lies on the reverse side and is not visible in the current view. In this arrangement, opposite ends of grooves are located radically opposite to each other. Similarly, the second groove is positioned in the same manner, with its ends also aligned in a radically opposite configuration.

When outer cylinder is assembled over the inner cylinder, these grooves collectively form enclosed passageways. This arrangement creates sealed flow channels that allow controlled movement of fluids or gases through indexing valve system.

The through-holes are indicated by openings labelled 1 and 2, while the second set of through-holes is represented by openings 3 and 4. These holes are drilled fully through the solid inner cylinder, allowing fluid flow between the connected ports. Accordingly, fluid can pass from opening 1 to opening 2 (or in the reverse direction) through one passage, and similarly open from 3 to opening 4 through the second passage.

When datum point located at indexing component aligns with reference mark on external cylinder, the ports of outer cylinder coincide with when index mark on indexing component through-holes labelled 1, 2, 3, and 4. In this position, fluid entering a particular port is directed through corresponding internal passage and exits through its paired outlet port. Similarly, fluid entering second set of ports follows same mechanism, flowing through internal channel and discharging through opposite opening, thereby maintaining controlled flow distribution.

When index mark on indexing member is aligned with reference position, the ports of external cylinder match precisely with internal grooves. In this condition, fluid entering one port is guided through a downward flow path along groove and exits through corresponding outlet port, or flows in reverse direction depending on pressure conditions. Likewise, fluid entering adjacent port travels upward through next groove and discharges through its paired outlet.

In this way, direction of fluid flow is altered simply by shifting indexing position from one alignment to another. The detailed mechanism of how flow direction changes with each indexing position is explained further in following section.

6.3.3 Result Discussion Case 3:

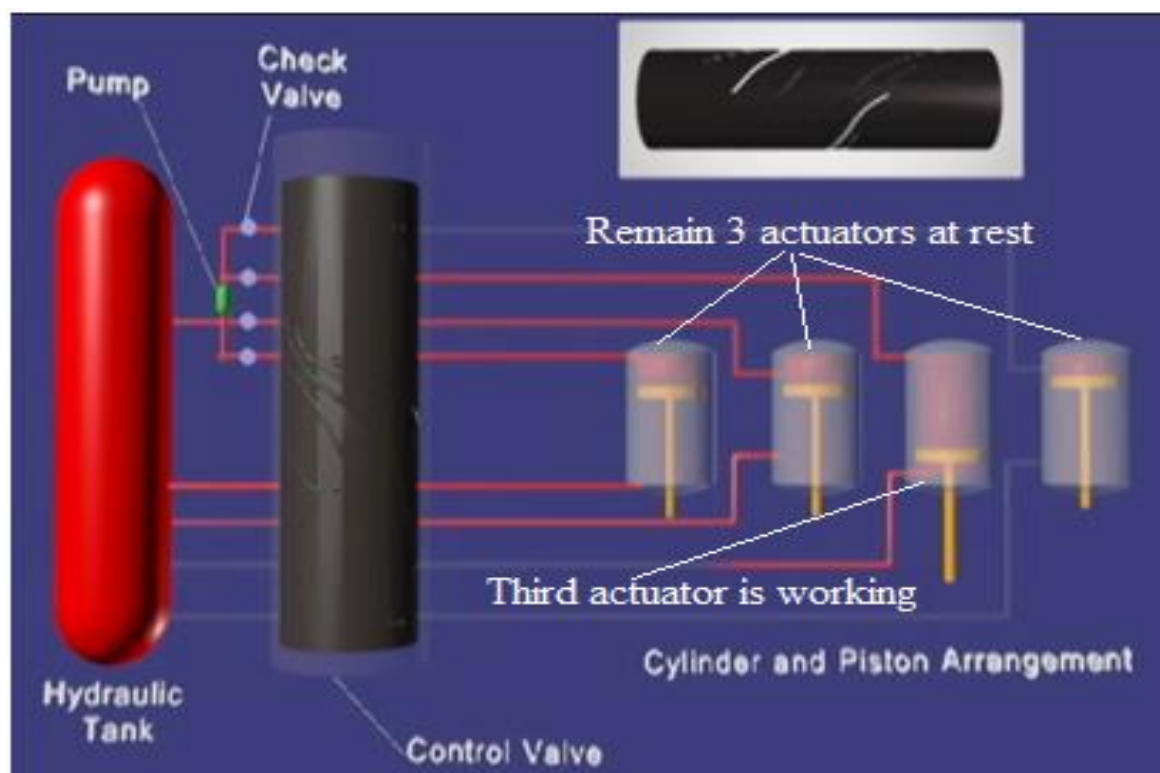


Fig 6.3 Operating 3rd actuator remain 3 actuators are at rest

Case 3:

The valve operation illustrating flow transition in one embodiment is shown when the index mark is aligned with the reference position. In this configuration, the outer cylinder ports align with the internal through-holes, resulting in direct matching between corresponding passages. This alignment creates two straight flow channels for the movement of fluid.

As a result, fluid entering one port of the outer cylinder is directed through internal passage and exits through the corresponding outlet port, or it may flow in the reverse direction depending on system conditions. Similarly, fluid entering the second port follows an identical path through its respective channel and exits through the paired outlet, enabling controlled bidirectional flow.

When the index mark is aligned with the reference position, the flow arrangement is such that external cylinder ports coincide with terminal ends of the internal grooves. In this condition, the external cylinder orifices maintain exact concentricity with both end points of internal passages.

As a result, the first groove forms direct passage connecting two ports creating a continuous flow path. Similarly, the second groove establishes another independent flow route between its corresponding ports. Due to this configuration, fluid entering one port of the outer cylinder can move downward through the groove and exit through

A directional control system for operating an actuator piston is illustrated in one embodiment. The system includes a fluid reservoir (tank), a pump, an indexing valve, and actuator. Units are integrated through pipelines as shown in system diagram representation.

In operation, pump draws hydraulic fluid from tank and delivers it into the system under pressure. This pressurized fluid is then supplied through pipe network to indexing valve, which directs flow toward actuator as required for controlled piston movement.

When the indexing member is rotated and aligned with the reference mark (first operating position of the index valve), pressurized fluid is delivered to piston side of actuator cylinder through pipeline, external cylinder ports, internal through-holes of internal cylinder, and connecting pipe.

This high-pressure fluid pushes the piston downward, while simultaneously forcing fluid present on opposite (rod) actuator side toward be displaced outward. The displaced fluid from the rod side chamber returns to reservoir through pipe network, passing via external cylinder ports and internal flow passages.

As a result, the piston moves downward, completing the forward working stroke in the first to the flat side of the actuator cylinder. In particular when the indexing member is rotated operating position.

When the index section is rotated and aligned with the reference mark (second operating position of the index valve), the internal grooves (shown in dashed lines) interconnect different outer cylinder ports, thereby redirecting flow of pressurized fluid.

In this configuration, pressurized fluid supplied by pump is supplied to rod end (flat side) of motion device cylinder through the pipeline, outer cylinder port, inner cylinder groove, and connecting pipe. The high-pressure fluid pushes the piston upward, simultaneously forcing the fluid present on the piston side exiting actuator cylinder.

The displaced fluid from the piston side is returned to reservoir through the pipe system, passing via the outer cylinder ports, grooves, and return line.

This results in an upward movement of the piston, thereby completing the working stroke in the second operating position.

With this configuration, the piston moves downward when the indexing component is rotated in a single direction (anticlockwise) and aligned with the reference position, while it moves upward when rotated in the opposite direction and aligned with the reference again. Thus, upward with downward motion in the piston is achieved through controlled partial rotation of indexing member.

This reciprocating piston movement can be utilized to perform useful mechanical work, such as lifting heavy loads, shifting materials, or excavation operations. Furthermore, the following section explains how a single indexing valve can be used to drive multiple actuators in one example embodiment of the present system.

An example configuration for controlling multiple actuator pistons using a single indexing valve is described. This arrangement explains the flow behaviour when the multi-operation indexing valve is in its first position.

The valve consists of two pressure inlet ports, two tank (return) outlets, and four actuator connection ports formed on the outer cylinder. These four ports are arranged to control the operation of multiple actuator pistons. The indexing unit contains through-holes that guide and distribute fluid flow within the system.

6.3.4 Result and Discussion; Case 4



Fig 6.4 4th actuator Operating remain 3 actuators remain at rest

Case 4:

When the indexing unit is in its initial state, the pump supplies pressurized fluid through the pressure inlet and connected pipelines. The pressurized fluid is routed to piston rod side of cylinder through Port 1, which is linked to that chamber. As a result, pressurized fluid enters the piston rod side and generates force on the piston, causing it to move in the downward direction and complete the required stroke in this operating condition.

The fluid present in flat (piston) side of actuator is discharged back to reservoir through Port 2, which is link to that chamber. The return flow is guided through the outlet lines and directed into the tank for recirculation.

The tank outlets are properly linked to the main reservoir to ensure continuous fluid recovery and system balance.

The process by which pistons are subsequently driven upward by changing indexing position is explained in following section.

The operation of the multi-operational indexing valve in its second position is described as follows. In this configuration, the valve's internal grooves (as shown in the diagram) are realigned to modify the flow paths between ports.

The first groove section establishes a connection between the pressure inlet and Port 2. Third groove links from the tank outlet to Port 1, fourth groove also assists in completing the return flow path associated with Port 1.

This rearrangement of internal flow passages changes the direction of pressurized fluid delivery, enabling reversal of actuator motion.

In this configuration pressurized fluid is delivered via Port 2 into flat (piston) side of respective actuators. This high-pressure input causes both pistons to move upward simultaneously.

Thus, multiple pistons can be operated simultaneously using one indexing valve although the present description illustrates operation two pistons, the same principle can be extended to control a more actuators without departing from the fundamental concept of invention. A three-dimensional case of multi-operation gate is illustrated using an external cylinder that contains three groups of openings, where each group consists of four ports or holes. Each group is designed to control a single actuator.

Within each set, one opening functions as the pressure inlet, the next serves as the tank (return) outlet, while the remaining two openings act Port 1 together with Port 2 respectively for actuator connections. In this way, each pair of ports within a group is used to control operation one actuator.

Similarly, another set of four openings can be used to operate a second actuator. In this arrangement, the first opening functions as the pressure inlet, the second opening serves as the tank (return) outlet, while the third and fourth openings act Port 1 together with Port 2 respectively.

CHAPTER - 7

SCOPE OF THE CURRENT WORK

- At present, single spool-type valve is capable of operating only one actuator, a practice that followed for many years. In this work, it is proposed to develop a simpler alternative system compared to conventional spool-type valves, in terms of construction and operation. The proposed directional control mechanism (indexing unit) is designed to operate multiple actuators while keeping the remaining actuators in their idle or non-operating state as required.
- Further studies have been under taken on indexing control valves designed for operating several actuators. In this case context, the work focuses on developing detailed drawings and design sketches of the indexing valve using CATIA for accurate modeling, visualization, and analysis system.
- The developed indexing control valve is capable of operating multiple actuators either sequentially or independently, and its construction is comparatively simpler of conventional directional control valves. This method can be adapted for different sizes and varying a required number of actuators as many actuators as required increases, the overall dimensions such as length and the valve diameter also increases accordingly. Additionally, more number of actuators that controlled depends on indexing angle assigned to each actuator position.

CHAPTER - 8

SCOPE FOR FUTURE WORK

- The indexing valve designed for operating four actuators has been successfully developed. This configuration has the potential to replace conventional spool-type valves and significantly reduce total number of gate units in a hydraulic power unit. Hence, the overall system cost can be lowered along with a reduction in component count.
- The gate is initially designed to control four actuators. By degreasing spacing across the slots and optimizing arrangement of through-holes on internal cylinder is feasible to extend design to operate greater total actuators. This valve cannot limit to hydraulic applications alone; it can also be adapted for use pneumatic systems for similar directional flow control purposes. Through research, practical experience, and creative design approaches, effective solutions to identified issues have been successfully developed and demonstrated.
- This gate is not limited to hydraulic applications; it can also be effectively utilized for controlling pneumatic systems as well.
- A functional prototype an indexing mechanism valve, capable of operating single or multiple actuators, has been successfully designed and fabricated.
- In future work, the indexing unit, actuators, and connecting pipes can be fabricated using composite and smart materials in order to achieve reduced weight, improved performance, and lower manufacturing cost.

CHAPTER - 9

CONCLUSIONS

- The review of existing studies shows that most previous research focused on hydraulic actuators and directional control valves focused on systems where a single valve operates a single actuator.
- The developed system helps reduce overall cost, space requirement, maintenance effort, and manpower, while also improving the operating speed in the hydraulic system the proposed work has been illustrated using four actuators as a representative case of multiple actuator operation. In future developments, the system can be extended to control multiple actuators through a computer-based interface. Through research, practical experience, and creative design approaches practical solutions have been developed to address the identified problems successfully.

COST ESTIMATION

Table 9.1: Cost Estimation

Component Name	Quantity.	Amount in (Rs)
Hydraulic Actuator	4	12000/-
Hydraulic Pump	1	6000/-
Motor (Prime Mover)	1	8000/-
Indexing system	1	6500/-
Connectivity	—	10000/-
Frame assembly and Tank	—	4000/-
Total cost		46500/-

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