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"DESIGN & DEMONSTRATION OF HYDRAULIC CIRCUIT FOR COUNTER BALANCING AND SEQUENCING VALVE"

Dr. Suprit Malagi[1], Dr. R.M. Galagali[2], Sainath Kalkutkar[3], Prajwal Banajawad[4], Prajwal Gasti[5], Prof. Vishwanath M. Khadakbhavi[6]

[1] Faculty, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
[2] HOD, Mechanical Engineering department, S.G. Balekundri Institute of Technology, Belagavi, Karnataka, India
[3] Student, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
[4] Student, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
[5] Student, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
[6] Student, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
[7] Project Coordinator, Mechanical Engineering department, S.G. Balekundri Institute of Technology Belagavi Karnataka, India
Email ID: sainathkalkutkar1437@gmail.com

ABSTRACT:

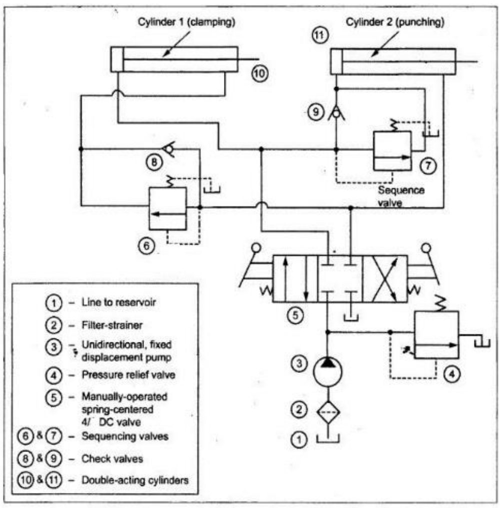
The objective of this project is to design, develop, and experimentally demonstrate a hydraulic circuit incorporating a counterbalance valve and a sequencing valve for controlled actuation in fluid-power systems. Counterbalance valves are used to prevent uncontrolled motion of actuators under gravitational or overrunning loads, while sequencing valves ensure that multiple actuators operate in a predetermined order. In this work, a complete hydraulic circuit was designed using standard industrial components, followed by simulation and laboratory implementation. The counterbalance valve was optimized to provide stable lowering control and load-holding capability, whereas the sequence valve ensured reliable timing between primary and secondary actuator operations. Experimental results validated the circuit's performance, demonstrating improved safety, smooth motion control, and reliable sequencing under varying load and pressure conditions. This study highlights the importance of integrating control valves in hydraulic systems to

enhance operational precision, safety, and efficiency in industrial and mobile application.

INTRODUCTION

Fluid power systems, specifically hydraulics, are integral to modern industrial automation, construction, aerospace, and manufacturing. These systems utilize pressurized incompressible fluids (typically oil) to transmit power, offering distinct advantages such as high force-to-weight ratio, rigidity, and precise control over linear and rotary motion. The operation, maintenance, and troubleshooting of hydraulic systems require a strong foundational understanding of fluid mechanics, system components, and circuit design principles. However, a gap often exists between theoretical knowledge acquired in the classroom and the practical application required in the industry. Training equipment, such as a Hydraulic Trainer Kit, serves as a crucial bridge, allowing engineering students to assemble, visualize, and test fundamental and advanced hydraulic circuits in a controlled, safe. Hydraulic systems are widely used in industries for lifting, clamping, pressing, and automated operations, owing to their high-power density, precision control, and reliability. In many applications, safety, controlled motion, and sequence of operations are critical factors that must be managed effectively

Fig 1: Circuit diagram of Hydraulic counter balance and sequence valve



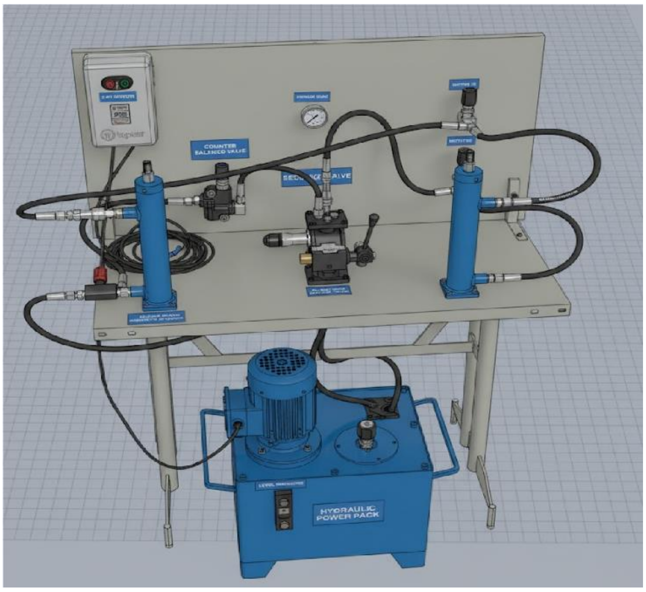


Fig 2: Hydraulic trainer kit

LITERATURE SURVEY OUTCOMES

Theoretical Foundation

- Confirmed Pascal's Law as the core principle for force transmission
- Defined hydraulic fluid requirements (incompressibility, lubricity, viscosity)

Component Specifications

- Double-acting cylinder (DAC) for bidirectional motion demonstration
- Hydraulic power pack (pump, motor, reservoir, relief valve) as energy source
- Counterbalance valve for load holding and controlled descent
- Flow control valves (meter-in/out) for velocity regulation
- Pressure sequence valve (PSV) for operation sequencing

Circuit Principles

- Backpressure maintenance via counterbalance valve prevents load runaway
- Pressure-dependent sequencing logic ensures ordered operations

OBJECTIVES

The main objectives of this project are to design, fabricate, and experimentally validate a modular Hydraulic Trainer Kit that enhances the practical understanding of industrial hydraulic control circuits.

1. Design and Specification: To perform the necessary engineering calculations (force, speed, and flow rate) to select and specify all standard, industry-grade hydraulic components, including the Power Pack, Double Acting Cylinder, and all control valves.

2. Fabrication and Assembly: To construct a stable, ergonomic, and modular trainer workstation using an aluminium profile plate and Quick Release Couplings (QRCs), ensuring components can be safely and easily connected for various circuit configurations.

3. Circuit Implementation & Validation: To successfully assemble and validate the functionality of three core industrial circuits

4. Counter Balance Circuit: To demonstrate controlled lowering of a load by maintaining a constant back pressure on the cylinder, preventing load runaway.

5. Sequencing Circuit: To achieve automatic, pressure-dependent operation of the cylinder using a Pressure Sequence Valve, demonstrating sequential control logic.

6. Secondary Objectives: Safety and Usability: To incorporate essential safety measures, including a Pressure Relief Valve and leak-proof QRCs, to create a safe and user-friendly educational environment.

7. Documentation: To prepare comprehensive circuit schematics, component lists, assembly procedures, and detailed experimental results for educational and future development purposes.

8. Cost Estimation: To develop a detailed budget outlining the material and fabrication costs, ensuring the project is cost effective for laboratory deploy ment.

METHODOLOGY

The methodology for designing and demonstrating the hydraulic circuit for counterbalancing, meter-in/meter-out speed control, and pressure sequencing begins with identifying the functional requirements of each hydraulic operation and understanding their interdependence. Based on these requirements, standard hydraulic components such as a reservoir, filter, pump, pressure relief valve, directional control valve, counterbalance valve, flow control valves, sequencing valve, check valves, and double-acting cylinders are selected. The circuit is first designed theoretically using standard hydraulic symbols and verified for correct flow paths, pressure levels, and safety considerations. The trainer kit is then assembled in a modular manner, allowing flexible interconnections for different circuit configurations. During demonstration, the hydraulic power unit is started and the directional control valve is actuated to initiate cylinder motion. The counterbalance valve ensures controlled load holding and smooth lowering, the meter in/meter-out arrangement regulates cylinder speed, and the sequencing valve allows the second actuator to operate only after the required pressure is reached in the first circuit. System performance is observed through pressure gauges and cylinder motion, and adjustments are made to valve settings to study their effects. This step-by-step approach ensures safe operation while enabling students to clearly understand the working principles and practical applications of each hydraulic control function.

RESULT

i. A **hydraulic circuit was successfully designed and demonstrated** to achieve **safe load holding and controlled motion** using a **counterbalance valve and sequencing valve**.
ii. The **counterbalance valve effectively prevented load free-fall**, ensuring **smooth and safe lowering of the load** under varying operating conditions.
iii. The **sequencing valve ensured proper order of operations**, allowing one actuator to complete its motion before the next actuator was activated.
iv. The designed circuit-maintained **system stability** by controlling back pressure and eliminating sudden jerks during load movement.
v. The project demonstrated **efficient pressure control**, reducing the risk of actuator damage and improving overall system safety.
vi. The hydraulic system **operated reliably at the designed pressure and flow rate**, confirming the correctness of component selection.
vii. The circuit showed **improved operational safety**, especially in applications involving vertical loads such as lifts, presses, and cranes.
viii. Experimental results matched the **theoretical calculations**, validating the design methodology used.
ix. The project proved that **counterbalance and sequencing valves are essential** for applications requiring load control and sequential operation.
x. The developed setup can be **used as a learning model** for understanding industrial hydraulic systems

CONCLUSION

The objective of designing, developing, and validating a Hydraulic Trainer Kit capable of demonstrating the Counter Balance, Meter-in/Meter-out, and Sequencing circuits has been successfully achieved. The project effectively bridged the gap between theoretical understanding of fluid power and its practical application.

1. Design and Assembly: The project successfully specified and integrated a reliable Power Pack and a Double Acting Hydraulic Cylinder with a modular component mounting system. The use of industry-standard quick-release couplings (QRCs) proved essential for safe, quick, and didactic circuit construction.

2. Functional Validation: o The Counter Balance circuit, utilizing a Pilot-Operated Check Valve, was successfully validated, preventing the simulated load from uncontrolled descent and ensuring stable motion. o The Sequencing circuit, employing a Pressure Sequence Valve, functioned as designed, ensuring the cylinder stroke initiated only upon reaching the pre-set pressure, proving the principle of pressure-dependent automatic operation. In conclusion, the developed Hydraulic Trainer Kit is a robust and valuable educational asset that meets all the initial project objectives, providing engineering students with a practical platform to experiment with and master fundamental hydraulic control principles.

FUTURE SCOPE

While the present trainer kit is functionally complete, several enhancements can be integrated to increase its utility and align it with advanced industrial practices:

1. Electro-Hydraulic Control Integration: The current kit is primarily manually operated. Future development should incorporate Solenoid-Operated Directional Control Valves and a low voltage Relay/Switching Module. This would allow for the study of electrical control methods and enable the implementation of complex interlock and safety logic.

2. PLC Automation: Integrating a Programmable Logic Controller (PLC) would enable the demonstration of fully automatic, multi-cycle sequencing operations. Students could learn to program ladder logic to control the solenoid valves, simulating real-world manufacturing processes.

3. Advanced Circuit Modules: New modules could be added to expand the range of experiments, including: o Pressure Reducing Circuits: To operate different parts of the system at varying pressures.

4. Regenerative Circuits: To increase the speed of the cylinder extension without increasing pump flow.

5. Data Acquisition System (DAS): Implementing pressure transducers and flow sensors connected to a DAS would allow for real-time monitoring and recording of system parameters. This would enhance the accuracy of experimental data and provide students with a deeper analytical understanding of transient hydraulic behaviour.

6. Transparent Components: Incorporating cut sections or transparent working models of key valves and the cylinder would allow students to visualize t he internal fluid flow and component operation during system function.

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