IJIRMET ISSN (Online): 2456-0448
International Journal Of Innovative Research In Management, Engineering And Technology
Vol. 2, Issue 4, April 2017

Design of Hydraulic Test Manifold for Testing the Primary Flight Actuators

[1] Dr. R. Kiruba Shankar, [2] V. Shyam chander
[1] [2] Department of Mechatronics Engineering, Kongu Engineering College,Perundurai, India,
[2] shyamchander92@gmail.com

Abstract: ***The hydraulic manifold gathers the valves in one place and allows making connections between them. The hydraulic manifold block compact nature is a great advantage, as it decreases in the number of connections and therefore leakage risks. The valve assembly time in the hydraulic manifold is relatively less compared to the conventional type. The type of material used for the hydraulic manifold block affects weight, working pressure and price. Cast iron, steel and aluminum are among the most widely used material chose according to the varying requirement. The solid manifold block is drilled for fluid flow path according to the valve specification then internal thread is machined to house the cartridge valve in the specific cavities directly into the manifold block. Generally, only the control part is apparent. The cartridge valve is small in size comparing to the ordinary conventional valve. The hydraulic test manifold will give efficient usage and compact floor space occupancy.***

I. INTRODUCTION

Hydraulic Control panel is the heart of the primary flight actuator test rig which provides conditional supply of Hy-Jet oil for actuating the primary flight actuator and also the load cylinder which simulate the load acting on the primary flight actuator in real time circumstance. The Hy-Jet oil is used in aeronautic field of application due to its chemical property. Test conducted on flight actuator are endurance test and acceptance test. The endurance test followed by number of sequences and procedure to check the overall performance. The acceptance test will validate the flight actuator didn't have any damage at any stage of process. For each and every step of operation and process the hydraulic control panel supplies fluid according to command which predetermined by the user. The hydraulic control panel which using up to today is designed in a traditional way of hydraulic design, my project is about studying the existing hydraulic control panel and analysing it to process out better hydraulic circuit. The existing hydraulic control panel as some compromises on maintains, oil leakage and huge floor space occupies. To come out with better design of hydraulic control panel the hydraulic test manifold is designed. The hydraulic test manifold has better circuit design and cartridge valve is used instead of ordinary slip-in valves and hydraulic manifold block is used. The hydraulic manifold block plays a major role in the project due to its compact structure and rigid property.

HYDRAULIC CONTROL PANEL

Hydraulic control panel description

Hydraulic Control Panel (HCP) is used to simulate the pressure required to activate the flight primary actuators or Unit under Test (UUT). Hydraulic Control Panels have been engineered to meet the complex demands of operational specifications. Unlike a motor-operated control valve, the control panel allows field adjustment of the valve operating times so that the valve can be set to match the surge characteristics of the piping system. The controls are panel mounted and pre-wired to a terminal strip of the test rig and the rear view of all valve and accessories pipe connection are shown in figure 1.

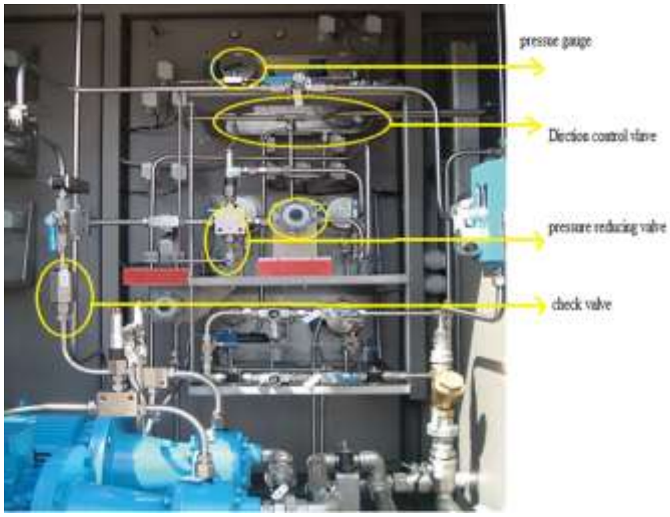

Figure 1 Rear view of Hydraulic Control Panel

Description of hydraulic control panel are shown in the table 1, the description lists out the features of hydraulic control pane and what are the options in the hydraulic control panel like the types of sources, cost and also the additional features present in the hydraulic control panel.

Table 1 HCP Description

Description	**HCP**
Control Pressure	Yes
Dual source	Yes
Soft Start	Yes
Emergency Stop	Yes
Leakage point	More
Accumulator	Yes
Envelope	Large
Cost	Expensive

Components of hydraulic control panel are given in table 2 the detail list of components in the hydraulic control panel and the quantity of the valve used is accounted. The usage of check valve for safety reason is also taken in account due to validate the new design approach of hydraulic control panel.

Table 2 List of components

Component	Quantity
Test Article (UUT)	1
Load System	1
Directional control valve	2
Pressure control valves	2
Solenoid valves	6
Accumulator	2
Needle valves	6
Check valve	8

Note:
Maximum UUT supply pressure = 5046.0 psi (348 bar)
Maximum Load supply pressure = 1957.5 psi (135 bar)
Maximum UUT flow rate = 20 gpm
Maximum load flow rate = 20 gpm

Schematic of Hydraulic

The hydraulic circuit of hydraulic control panel is shown in figure 2. It was designed in Automation Studio 5.0 the solenoid operated directional control valve 2 (dcv) in the beginning of the circuit with a throttle valve is used for soft circuit which means in order to prevent the proportional valve from the high pressure while starting the system initially. The purpose of accumulator is to avoid the pressure fluctuation in the pressure line which will affect the performance of the hydraulic control panel.

IJIRMET ISSN (Online): 2456-0448
International Journal Of Innovative Research In Management, Engineering And Technology
Vol. 2, Issue 4, April 2017

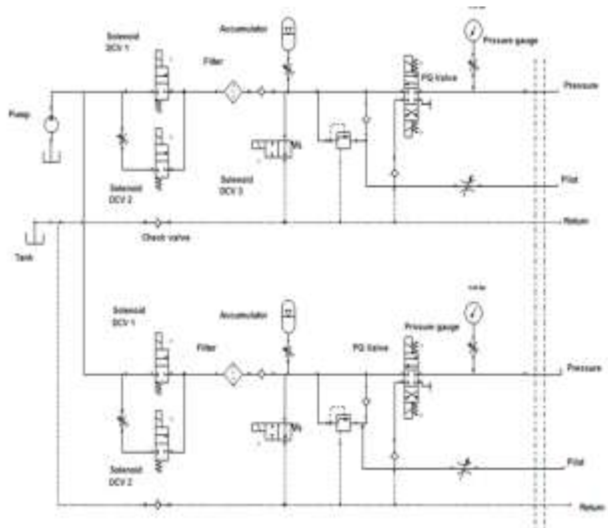

Figure 2 Hydraulic Control Panel Circuit

The solenoid actuated spring off set directional control valve which named dcv 3 in the hydraulic control panel circuit diagram is used to release the pressure accumulated in the accumulator of the pressure line when any maintenance work is need to be proceed if the solenoid valve is not actuated and the pressure in the accumulator is not released means there is a chance of accident due to sudden release of high pressure fluid. The pressure and return port are connected to the appropriate actuator cylinder ports.

The simulation of the hydraulic circuit is done and showed in the figure 3 the simulation is done for the soul purpose of getting visual understanding of the circuit function and to get idea in what way we can optimize the hydraulic control panel. The cylinder extraction condition and the retraction condition is simulated using PLC program in Automation Studio 5.0 and timer circuit and what will be the valve position of each valve during the extraction and retraction condition are plotted. It helps in getting a deep understanding of functioning of each valve and it's important in the operation. The solenoid valve in the circuit which next to the source is to prevent sudden hit by pressurized fluid to the spool of hydraulic system.

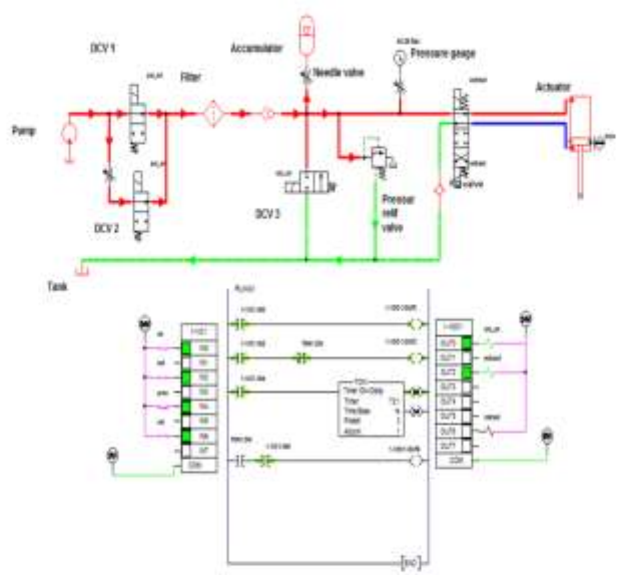

Figure 3 HCP circuit simulations

IJIRMET
ISSN (Online): 2456-0448
International Journal Of Innovative Research In Management, Engineering And Technology
Vol. 2, Issue 4, April 2017

The simulation is done by using PLC program with timer circuit. When the cylinder end reaches the bottom the proximity sensor will trigger the timer circuit. The timer on delay is set for three seconds. The detail procedure is as follows. When we close the first switch in the PLC diagram the solenoid valve is actuated.

The retraction stroke supply is normally close. When the extraction supply is closed the actuator move towards the bottom. When the cylinder reaches the bottom the proximity sensor will start the timer. The timer will count for three seconds and will activate the normally open switch to close. The timer will also open the connection of the extraction stroke. Now the cylinder will retract to the top. The pressure and the flow given in the simulation are 5000 psi and 20 gpm. The valve of pressure and flow for the hydraulic cylinder is taken from the simulation and it was compared to the proposed hydraulic circuit.

HYDRAULIC TEST MANIFOLD

Hydraulic circuit optimization

Hydraulic Test Manifold (HTM) is designed with coming up with better circuit design and hydraulic manifold block. The check valve and solenoid valve which included for the purpose of safety and additional future is reduced in the hydraulic test manifold design without any compromise in the performance factor. The flow is controlled by proportional valve the solenoid valve in circuit is for direction control and in hydraulic control panel we used six solenoid valves and

here we use only four solenoid valve. Figure 4 shows the hydraulic circuit design of the hydraulic test manifold.

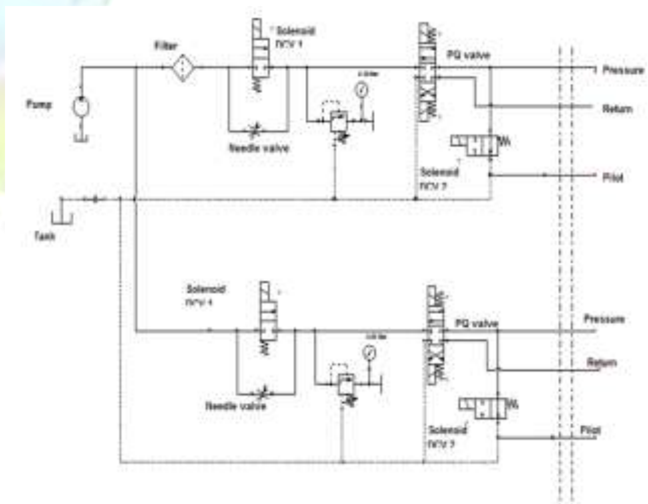

Figure 4 HTM

The simulation of the hydraulic circuit is done and showed in the figure 5 the simulation is done for the soul purpose of getting visual understanding of the circuit function and to know whether the cylinder is actuated with the new proposed design of hydraulic circuit. The cylinder extraction condition and the retraction condition is simulated using PLC program in Automation Studio 5.0 and timer circuit and what will be the valve position of each valve during the extraction and retraction condition are plotted. It helps in getting a deep understanding of functioning of each valve and it's important in the operation. The solenoid valve in the circuit which next to the source is to prevent sudden hit by pressurized fluid to the spool of hydraulic system

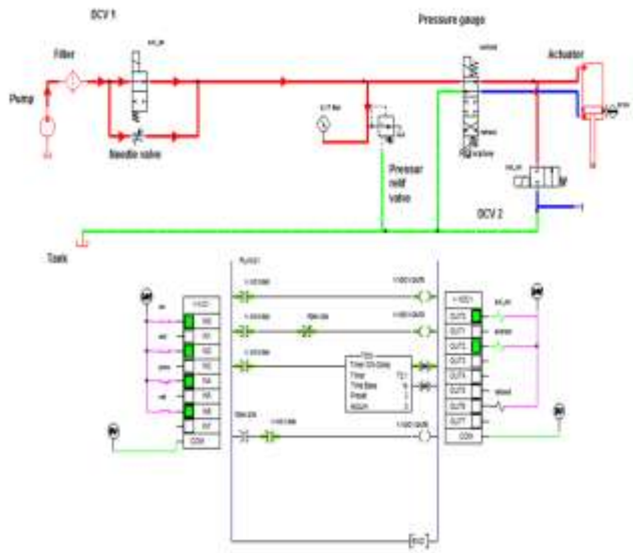

Figure 5 HTM simulation

The simulation procedure is done in the same manner for both hydraulic control panel circuit and hydraulic test manifold which is the proposed circuit design. The PLC program with timer circuit, proximity sensor and switch is operated. When the cylinder end reaches the bottom the proximity sensor will trigger the timer circuit. The timer on delay is set for three seconds. The detail procedure is as follows. When we close the first switch in the PLC diagram the solenoid valve is actuated.

The retraction stroke supply is normally close. The actuator moves towards the bottom when the cylinder extraction supply switch is closed and it is done by manual operation. When the cylinder reaches the bottom the proximity sensor will start the timer. The timer will count for three seconds and will activate the normally open switch to close. The timer will also open the connection of the extraction stroke. Now the cylinder will retract to the top. The pressure and the flow given in the simulation are 5000 psi and 20 gpm.

Design of Hydraulic manifold block

Design of hydraulic manifold blocks is a kind of complex solid special layout problem. Due to the complexity of the manifold blocks layout the position of the valve and its fitting dimensions are marked and made in the way of trial and error for simple design and based on the place of fitting it. Figure 6 and 7 shows the 3 Dimensional and wireframe view of the manifold and figure 8 shows the manufacturing diagram of the hydraulic manifold block. It gathers the valves in one same place and allows making connections between them. Its compact nature is a great advantage, as is the decrease in the number of connections and therefore leakage risks is reasonably reduced. Assembly time is reduced. The type of material to be used should be chosen according the requirement because it affects the weight of the system, working pressure and price. Cast iron, steel and aluminium are among the most widely used material for hydraulic manifold block.

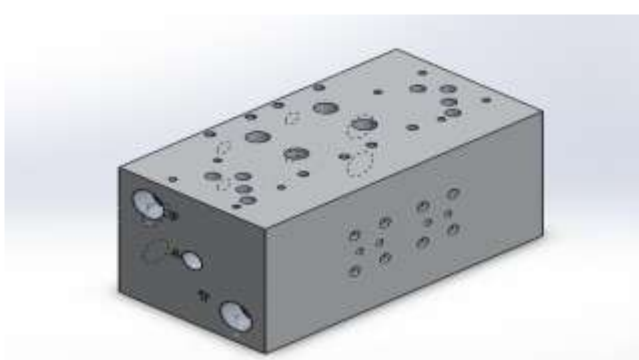

Figure 6 Hydraulic manifold block

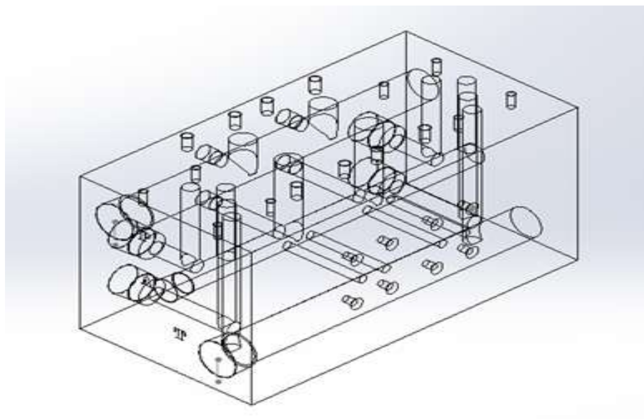

Figure 7 Manifold wireframe view

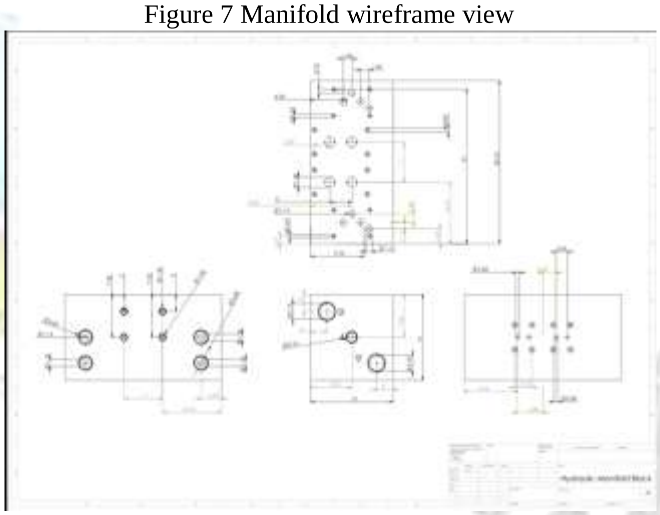

Figure 8 Manifold manufacturing diagram

VALIDATION OF MANIFOLD DESIGN

Manifold assembly

Hydraulic Manifold block 15*15*28.5 cm was drilled according to the pipe length dimension for the particular pressure and flow rate. After drilling the manifold for flow passage a standard internal thread for fitting the cartridge valve is machined in the manifold. The manifold block is designed in Solid Works and dimensions of the drill are given in the technical drawing.

External pipe is fitted to analyse the flow of the manifold block which was shown in the figure 9 the internal fluid path line is shown in the figure 10. The get better result on the flow simulation the internal flow path is analysed. The limitation for analysis is the flow path should be solid structure but the manifold has internal pipe line so the internal paths is analysed separately.

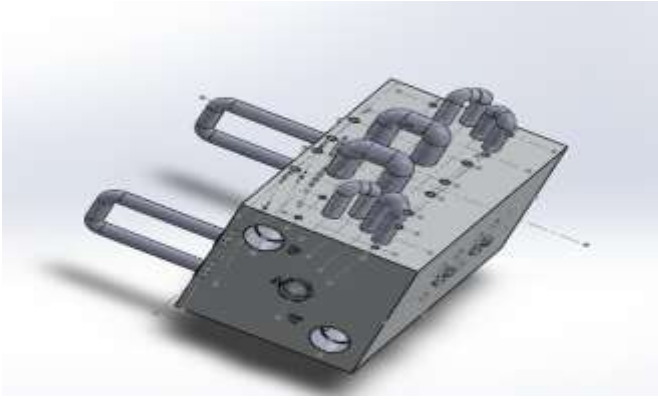

Figure 9 Manifold with external pipe fitting

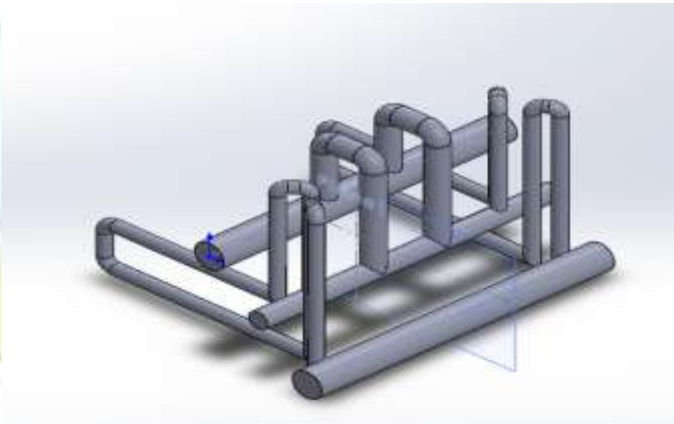

Figure 10 Internal fluid paths

Meshing and boundary condition

The designed manifold block is uploaded in the Ansys workbench and CFX flow analysis is done. The model is meshed to get better result the nodes are 96214 and elements are 457366. We need to choose the domain physics by selecting the required feature. The physics chosen for this analysis is given in the table 3. Port is set as input and port T set as output.

Table 3 Domain physics

Type	**Fluid(water)**
Domain Motion	Stationary
Heat Transfer Model	Isothermal
Fluid Temperature	25 degree Celsius
Turbulence Model	K epsilon
Turbulent Wall Functions	Scalable

Velocity and pressure contour

The velocity contour in the manifold path line is shown in the figure 11 the velocity throughout the path is evenly distributed and there is no any velocity drop in the flow path. The pressure contour is shown in the figure 12 the pressure builds up in the pressure line is high then it was distributed evenly in the flow path and the main reason is the tank line dimension is greater when we compare to pressure line.

The result is analysed by taking the difference between the maximum pressure and minimum pressure in the flow path and the difference between them is very small so there is no pressure drop in the flow path the same procedure is followed for the velocity contour also the maximum and minimum velocity is taken and the difference is calculated, we got very low velocity difference it shows that there is no any kind of velocity drop and these analysis is shown in the table

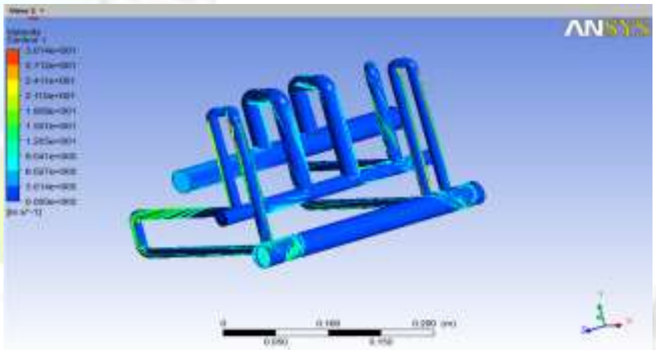

Figure 11 velocity contour

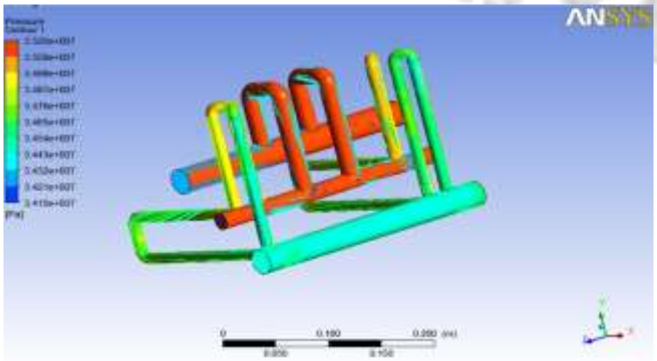

Figure 12 Pressure contour

RESULT

The performance results are presented in table 4 and table 5. The pressure variation and the velocity variation obtained by the CFD analysis shows the variation is very minimum so that the pressure and velocity distribution in the flow path is even and there is no fluctuation in the flow path. The circuit design in the automation studio shows the proposed hydraulic test manifold circuit is functioning well without compromising the performance level.

Table 4 Pressure variation

Path	Minimal pressure[Pa]	Maximum pressure[Pa]	pressure variation[Pa]
streamline	3.42E+07	3.52E+07	9.93E+05
input	3.52E+07	3.52E+07	3.68E+02
output	3.45E+07	3.45E+07	6.21E+04
pipe	3.41E+07	3.52E+07	1.10E+06

Table 5 Velocity variation

Path	Minimal velocity[m/s]	Maximum velocity[m/s]	velocity variation[m/s]
streamline	1.45E-01	3.09E+01	3.07E+01
input	4.93E+00	5.00E+00	7.39E-02
output	6.24E+00	1.28E+01	6.52E+00
pipe	2.17E-02	3.22E+01	3.21E+01

DISCUSSION

Thus the project is used for testing of primary flight actuator the manifold design makes big contribution in saving floor space where we can accommodate more testing rig. The periodic maintenance is required in hydraulic control panel, if not the system will malfunction and it will push us to force shutdown the test for maintenance. If an issue acquired due to some damage of valve or some sort of leakage, then the duration for trouble shooting will be an hour but if any damage occurred in the manifold will be a big issues and takes lot of time to troubleshoot it. And once the manifold got any physical damage then it cannot be reused.

References

Rathore, Narendra. "Design of Hydraulic Circuit and Hydraulic Loss Calculation for Pre-Installation Check of Landing Gear Jack Accessories." International Journal of Innovative and Emerging Research in Engineering Volume 2, Issue 11, 2015.

Rathore, Narendra, and M. R. Ramesh. "Design of Universal Test Rig and Virtual Experimentation of Hydraulic Circuit for Testing of Line Replacement Units." (2015): 1326-1321.

Lu, Lu, and Bin Yao. "Energy-saving adaptive robust control of a hydraulic manipulator using five cartridge valves with an accumulator." IEEE Transactions on Industrial Electronics 61.12 (2014): 7046-7054.

Klapka, Milan, Josef Nevrlý, and Tomáš Panácek. "EXPERIMENTAL RIG FOR SIMULATION OF HYDROMECHANICAL SYSTEM WITH ENERGY REGENERATION." Engineering MECHANICS 21.5 (2014): 305-309.

Pan, Min, et al. "Theoretical and experimental studies of a switched inertance hydraulic system." Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering 228.1 (2014): 12-25.

Eltantawie, Manar Abd Elhakim. "Design, Manufacture and Simulate a Hydraulic Bending Press." International Journal of Mechanical Engineering and Robotics Research 2.1 (2013): 1-9.

Chen, Yong Qing, et al. "Simulation Research on the Basic Platform."Applied Mechanics and Materials. Vol. 345. Trans Tech Publications, 2013.

Pan, Min, Nigel Johnston, and Andrew Hillis. "Active control of pressure pulsation in a switched inertance hydraulic system." Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering (2013): 227(7) 610–620.

Noor, M. M. and Wandel, Andrew P. and Yusaf, Talal (2013) Detail guide for CFD on the simulation of biogas combustion in bluff-body mild burner. In: 2nd International Conference of Mechanical Engineering Research (ICMER 2013): Green Technology for Sustainable Environment, 1-3 Jul 2013, Pahang, Malaysia.

Salah, Taher, and Saad Kassem. "Development and manufacure of a universal hydraulic test rig for proportional and servo valves and cylinders."Engineering and Technology (ICET), 2012 International Conference on. IEEE, 2012.