Design and Development of Hydraulic Control Valve Test Bench

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NOV 2021

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A thesis submitted in partial fulfillment of the requirements for the degree of MS Mechanical Engineering

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I certify that this research work titled "Design and Development of Hydraulic Control Valve Test Bench" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged/referred.

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Signature of Student

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Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which Your setup in my mind to improve it. Indeed, I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout in every department of my life.

I would also like to express special thanks to my supervisor **DR. RIAZ AHMAD MUFTI** for his help throughout my thesis and for **Tribology** and **Advanced Instrumentation and Experimental Methods** courses which he has taught me. I can safely say that I haven't learned any other engineering subject in such depth than the ones which he has taught.

I would also like to pay special thanks to **Dr. Jawad Aslam, Dr. Mian Ashfaq Ali** and **Fazal Badshah** for his tremendous support and cooperation. Each time I got stuck in something, he came up with the solution. Without his help I wouldn’t have been able to complete my thesis. I appreciate his patience and guidance throughout the whole thesis.

I would also like to thank **Dr. Rehan Zahid** for being on my thesis guidance and evaluation committee and express my special thanks to **Aaras Bhatti** for his help.

Finally, I would like to express my gratitude to all the individuals especially **Muhammad Riza, Arslan Rahat Sultan** and **Talha Yousaf** who have rendered valuable assistance to my study.

Dedicated to my exceptional parents and adored siblings whose tremendous support and cooperation led me to this wonderful accomplishment.

Abstract

The tractor manufacturing automotive industry, particularly in under-developed countries like Pakistan, incorporate a conventional method of using discrete weights of up to 1800kg for assuring the quality of the hydraulic control valve that is used in the hydraulic lifting unit of the tractors. These Hydraulic control valve, if tested manually, requires significant human effort for the handling the loads. Moreover, it also exposes the workers to a greater safety hazard since the probability of an accident due to heavy load handling is high. Adding to this, using manual technique for the quality assurance test compromises the accuracy of the test since discrete weight cannot give a continuous output reading. Our project is an industrial solution for the local tractor manufacturing industries based in Pakistan to incorporate the modern technological techniques for simulating the load on the hydraulic control valve for the quality assurance test. The designed testing rig for the hydraulic control valve of tractors will provide a convenient method to reduce the workload on the workers to a greater margin since the setup can be handled by a single operator. The testing rig has been integrated with user-friendly GUI display to offer more flexibility to the operator while carrying out the test. This project holds a promising future for the tractor manufacturing industry who are motivated to promote the internationally standardized manufacturing and quality testing techniques within the organization to compete at the international market for increasing their exports.

Key Words: *Hydraulics, Hydraulic Distributor, Tractors(automotive), Hydraulic Control Valve*

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Chapter 01: Introduction

Pakistan is an agricultural country in which the agriculture sector contributes significantly in the economic progress. As per the Economic Survey of Pakistan 2020-21 conducted by the Ministry of Finance of Pakistan, the importance of agriculture sector can be realized from the fact that this sector contributed 19.2% to the GDP of Pakistan. Hence, a significant progress in this sector correlates with the economic boost for Pakistan. [1]

One of the most promising agricultural machinery that plays a pivotal role in the promotion of agriculture sector is ‘tractor’. Tractors, which first emerged during the 19th century, was invented by Richard Trevithick. This agricultural machinery, which has significantly evolved during the years, has proven to be a powerful invention for increasing the agricultural output. In this technologically advanced world, the modernization of agriculture industry in Pakistan has paced up in order to ensure food security to the rising population of Pakistan and to compete at the international market to increase the exports of the country that can eventually help to attain the positive balance of trade. [2]

During these years, the purpose of tractors has remained unaltered but due to the top-notch research and development in the automotive industry, the technological advancements have led to the improved quality, functionality and efficiency of the tractors. [3]

In Pakistan, there are two major tractor manufacturing companies, Tractor industries who have immense potential to increase the exports of tractors by adopting internationally standardized manufacturing and quality assurance techniques. The number of tractors manufactured each year in Pakistan is approximately 52,000. But the actual value keeps fluctuating from year to year depending on the demand. [4]

Figure 1: Stats of Tractors Production per year

The tractor sales are dependent upon couple of factors which includes good monsoon, growth in agriculture sector, a bountiful harvest and remunerative price of farm produce. Despite the good monsoon season in Pakistan and other various neighboring countries, it can be seen in Figure 1. that after hitting the peak value in 2018, the number of tractors manufactured has steeply declined for 2019 fiscal year. In the past few years, a lot of work has been globally done to deliver the best quality in the most economical price. While India and China have remained the two largest tractor manufacturing countries, Pakistan has been forced to allow the import of tractors due to low prices and high quality. Hence, Pakistan's tractors manufacturing industry has a huge milestone to achieve by employing the standardised quality assurance techniques and equipment. [1]

One of the major components of the tractor is hydraulic distributor and hydraulic control valve. This component has a key role in the hydraulic lifting unit of the tractor. Hydraulic control valve opens, close or change the direction of the working fluid in the hydraulic system. This device, which undergoes multiple manufacturing process, is locally manufactured in Pakistan. The manufacturing of Hydraulic control valve requires the casting and machining processes. Unfortunately, there is no accurate testing unit to carry out the quality assurance or endurance testing of the manufactured or repaired hydraulic distributor control valve. In order to maintain the functionality of the tractor, it is important to carry out the hydraulic testing of the Hydraulic Distributor control valve before it is mounted on the tractor. The malfunctioning of this component can shut down the hydraulic lifting unit and will put all the efforts of a farmer to halt. [5]

Pakistan's tractor manufacturing industry needs to mechanize the quality assurance methods for the hydraulic testing of the hydraulic distributor control valve during the process of raising, lowering or neutrally balancing the hydraulic lift at a certain angle. It is time to utilize every resource at disposal to revolutionize the tractor industry by designing and manufacturing a hydraulic bench for the quality testing of locally manufactured hydraulic distributor control valves for ensuring the higher accuracy in controlling the lift that will eventually allow the end user to improve the effectiveness of the tractor in the agriculture industry.

1.1 Motivation

This project has been offered by leading Tractors Industry who have taken the lead in providing top quality products at cheapest rate. This project is an industrial oriented project which provides me with an opportunity to go beyond classroom learning experience and tackle real-time industrial problems.

Currently, the conventional technique, requiring manual loads of up to 1300 kg, is used to measure the pressure that can be handled by the hydraulic distributor control valve of tractors. This conventional technique requires a lot of manpower and effort to handle the load. This technique also possesses a safety risk as manual load of this huge amount can cause serious injuries due to operator error or defective design and manufacture. Hence it is important to design and manufacture a testing bench that provides a safe and highly user-friendly work experience.

Moreover, it is also worth of being highlighted that due to the manual operation technique that has been adopted, the accuracy of the testing setup is also compromised. Manual techniques can lead to significant human error during data collection. As a result, the credibility of the conclusions derived from the testing is a trade-off. This project aims to reduce the human effort and to provide a technologically advanced and convenient method for testing the quality of the Hydraulic Distributor control valve to ensure that the results obtained are accurate and reliable.

1.2 Problem Statement

In Pakistan, hydraulic distributor control valves are tested using manual loads requiring discrete weights and manpower. In these conditions we cannot apply variable loads of our desired requirement. The scope of this project is to simulate variable loadings using hydraulic pressure and test the hydraulic circuit of the distributor during the raising, neutral and lowering operation of the hydraulic lift unit of tractor.

1.3 Objectives

The deliverables of this project are:

- Designing a testing bench capable of performing standardized quality control tests for the manufactured and repaired hydraulic distributor control valves.
- A system, where operator can apply variable loads.
- Fabrication and assembly of a testing rig with hydraulic circuit.
- Carrying out a test run through simulation of a load equivalent to a max. of 1300 kg at a maximum operating pressure of 130 bar.

Chapter 02: Literature Review

2.1 Hydraulic Control Valve

The hydraulic control valve is a device that controls the pressure in the line and regulates the flow of oil from the pump to the lift. It has three different modes of operation: raising, lowering, and neutral. When the lever is operated by an operator, a feedback mechanism regulates the switching and operation of various modes. As shown in figure below. [6]

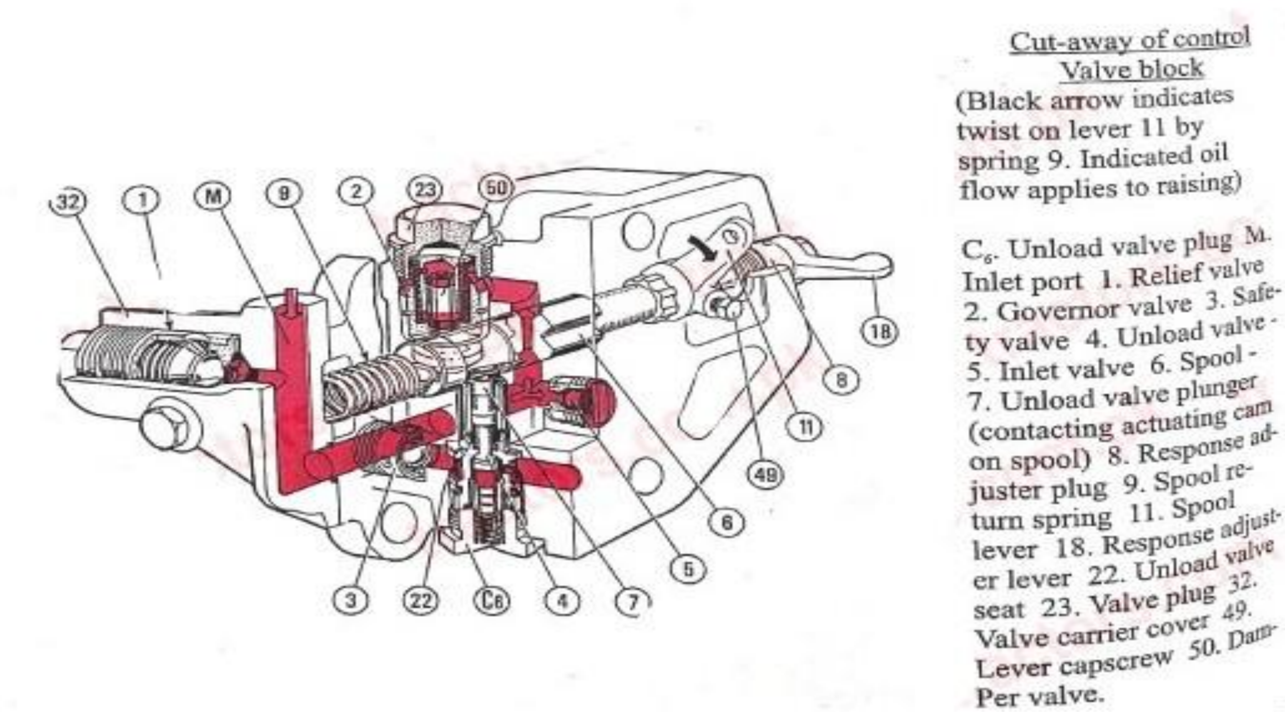


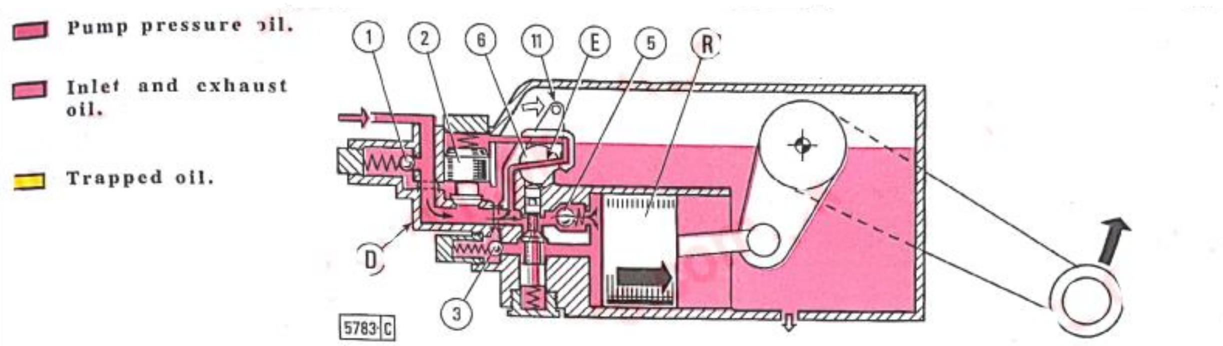
Figure 1a: Hydraulic Control Valve [6]

The direction of the oil is controlled by the spool (6) position which changes with the lever operated by operator. Spool return spring (9) is used inside the valve base to return the spool to its neutral position. Either oil will drain to tank or go to cylinder to apply pressure on the piston.

2.2 Working of Hydraulic Distributor

Raising Position:

In Raising position, the pressurized oil is forced into the cylinder as the spool turns, governor valve is kept closed by pressurized oil going through cross drilling (E). oil flows through valve (5) to the cylinder and the pressure pushes the piston downward, which results in the raising moment of the arm.



S. Oil flow when raising

As spool (6) turns incoming oil pressure is directed to the upper chamber of governor (2) through cross drilling (E). As the upper area of the governor is larger than that on the lower side, the valve is kept closed. Oil pressure is thus directed to the cylinder through valve (5).

Figure 1:Oil flow in Raising Position [6]

Neutral Position:

In neutral position the governor valve is opened and the pressure is released via (F), and piston cylinder is sealed, no oil goes IN or goes OUT. Oil pressure held the governor valve open. Arms stays still in neutral position.

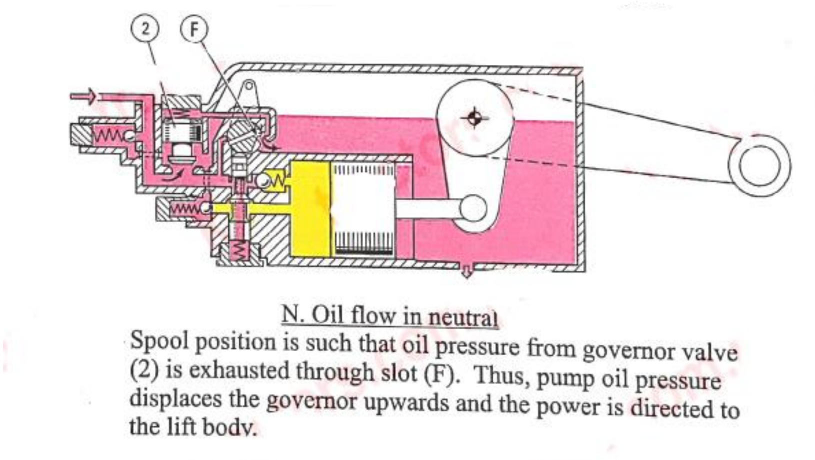


Figure 2: Oil Flow in Neutral Position [6]

Lowering Position:

In lowering position, the cylinder piston pushes the oil out from the cylinder via valve (4) which opens due to the movement of spool cam (G) and all the oil from the cylinder is exhausted to the tank via drain, as a result the arms comes down.

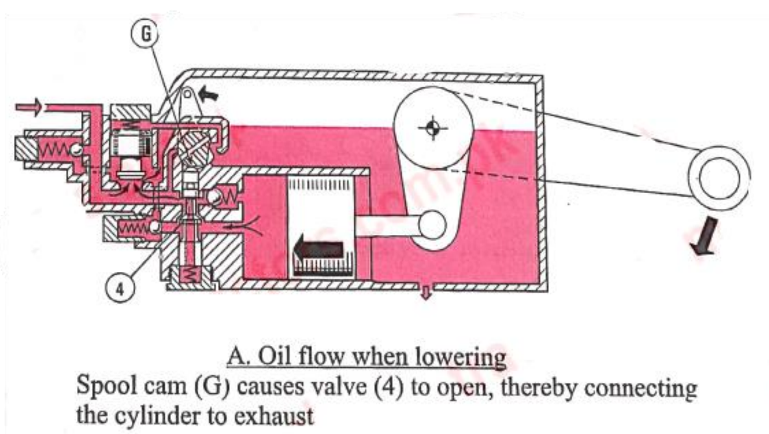


Figure 3: Oil Flow in Lowering Position [6]

2.3 AC Motors:

Alternate current(AC) motors has major two types ***Synchronous*** and ***Induction*** motors. Since we are using Induction motor it has further two types **Single phase** and **three phase induction motor.** To induce rotor current in the rotor AC winding, the induction motor (or asynchronous motor) always relies on a slight variation in speed between the stator and the rotating magnetic field and the rotor shaft speed called slip. [7,8]

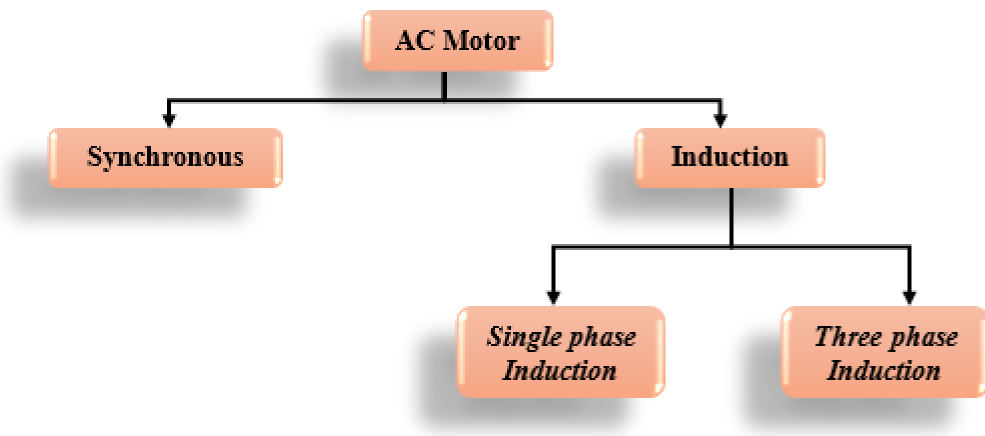


Figure 4: AC Motors Tree Diagram

The motor that converts the alternating current into mechanical power by using an electromagnetic induction phenomenon is called an AC motor. An alternating current is used to power this motor. The stator and the rotor are the two most important parts of the AC motors. The stator is the stationary part of the motor, and the rotor is the rotating part of the motor. The AC motor may be single phase or three phase.

The three phase AC motors are mostly applied in the industry for bulk power conversion from electrical to mechanical. For small power conversion, the single phase AC motors are mostly used.

2.4 Pump:

Pump is the component of hydraulic system which converts the mechanical energy into the fluid energy as oil flow. There are three major types of pumps Gear, Piston and Vane pumps.

2.4.1 Gear Pumps:

Gear pumps are also called as positive displacement pumps as they pump the same amount of fluid in each rotation of pump shaft and in each rotation of shaft it produces flow. The two identical meshed gears take the oil between their teeth and move it along the circumference of the inner case of the pump and pushes it out through the outlet of the pump. One gear has drive shaft connected to it and other is driven. If you want to change the inlet and outlet, then just change the positions of the gears. They are easy to maintain as they have fewer moving parts.

Figure 5: Gear Pump [9]

2.4.2 Piston Pumps:

Piston pumps are operated at higher pressures as they can withstand high pressure environment and they have a complex design as compare to the gear pumps. Their initial cost is also higher than gear pumps and they have less resistance against contamination. They have a cylinder piston assembly, piston which translate within the cylinder and pump housing, which causes the oil to draw from the tank/supply to the outlet.

Figure 6: Piston Pump [9]

2.4.3 Vane Pumps:

Vane pumps are also called positive displacement pumps, they have vanes mounted on the rotor, which rotates with in the cavity of the pump. They have longer length vanes on the intake side and shorter vanes at the outlet port which pushes the oil through outlet port with high velocity. Vane pumps were widely used in automobile (truck mounted), now gear pumps are widely used and available. In some cases, they have multiple vanes fixed on the rotor and they have variable lengths.

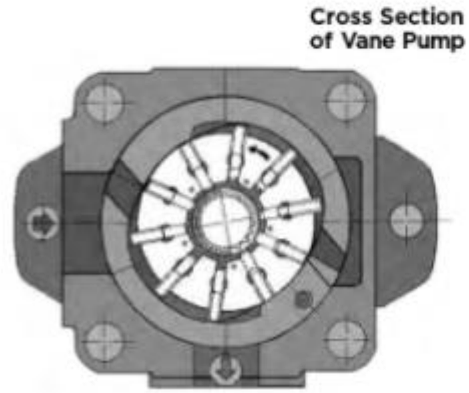


Figure 7: Vane Pump [9]

2.5 Hydraulic Valves:

Basically two types of Hydraulic valves are used here in the project, one is Relief valve and other is Directional valve, which will be discussed below and their working will be explained.

2.5.1 Relief Valves:

These are safety valves, which has a screw on top of it which controls the pressure setting of the valve, as we tighten the screw it is set at relatively high pressure settings. When we set relief valve at a specific pressure setting, relief valve will not drain until it reaches that pressure. When that pressure is reached and excess pressure in the line is going to generate it will immediately drain the oil. See figure. [10]

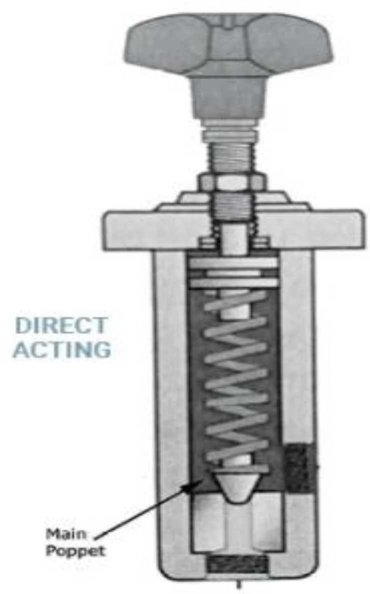


Figure 8: Relief Valve [10]

2.5.2 Directional Valve:

Directional control valves(DCV) are multiport hydraulic valves, which has four ports namely P, T and A, B. Port P is for pressure and port T means tank and port A, B are either output in which only one will be active at a time. They switch their output between port A and B by operating the valve(DCV) by providing the appropriate voltage supply. A and B are both outputs and T is usually set to drain. Solenoid operated are widely used and spool position changes the direction of fluid flow.

Four way three-position directional control valve is used, which has one inlet flow and three direction ports two to the actuator and on to the tank/drain. See figure. [11]

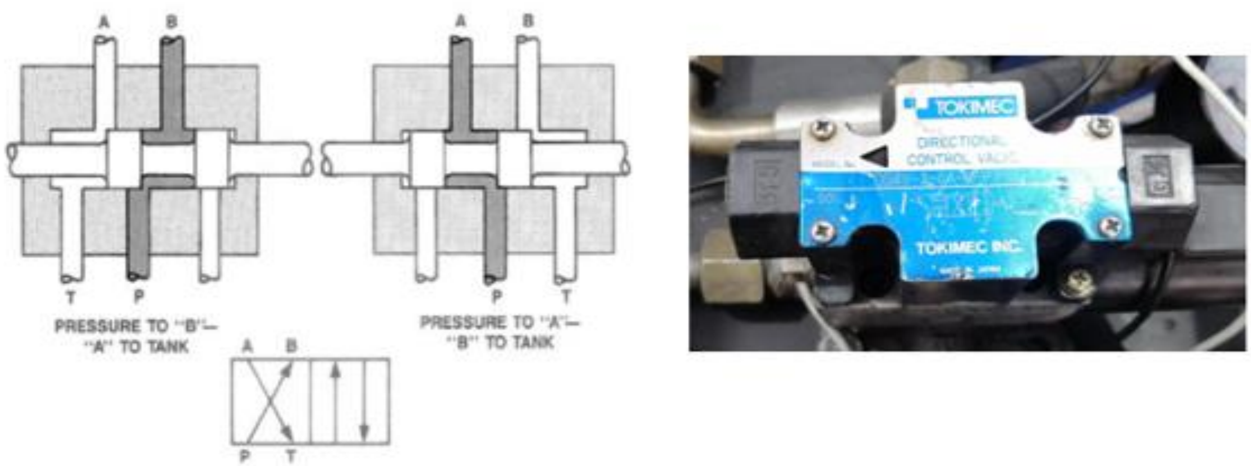


Figure 9: Directional Valve [11]

Chapter 03: Methodology

3.1 Components chosen and Specifications:

Here we will discuss one by one all the components used in the development of the test rig/machine. Each of them will be named here their specifications, working and purpose of selection will be discussed.

01. Frame
02. Tank
03. Actuator
04. Hydraulic Hoses/Pipes & Fittings
05. Circuit Diagram
06. Couplings
07. Pumps
08. AC Motors
09. Stepper Motor & Gear Screw
10. Rotary Encoders/Pressure Sensors/Pressure Gauges
11. Relief Valves/Directional Control Valves(DCV)
12. Oil Filter/Heat Exchanger
13. Thermocouple
14. Float Switch /Level Gauge

3.2 Frame:

The frame is made of square pipes(45*45mm) of Mild steel(MS). Its length is 1730mm and width is 850mm and height is 920mm. It has different plates attached, 2 for the pump mountings and 01 for the Hydraulic distributor and 02 pieces for the actuator mounting. 16 SWG sheet is used.

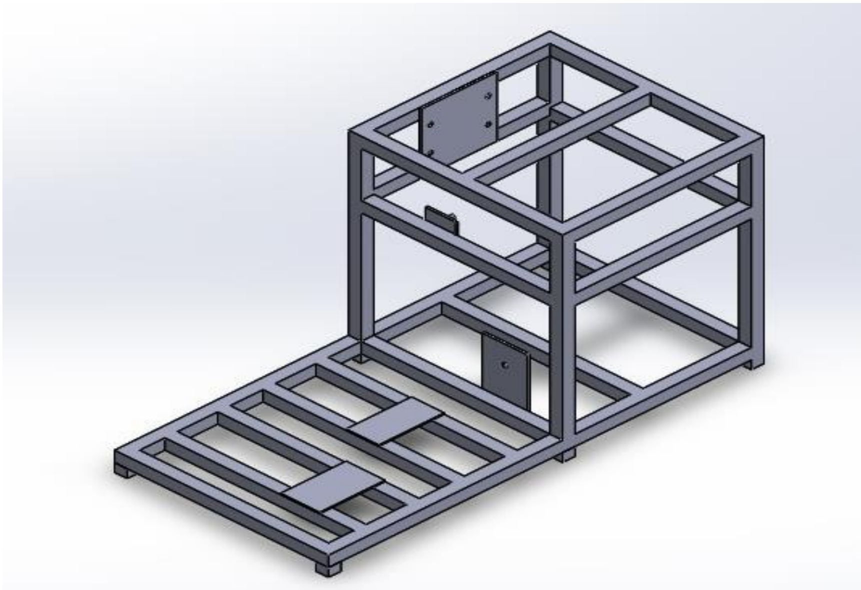


Figure 10: MS Frame

3.3 Tank:

Tank is also made up of Mild steel(MS) and 14 SWG sheet is used for its construction its length is 640mm and height is 395 mm and width is 410mm. It has multiple holes of two sizes i.e. 20mm and 35mm for pipes and different sensors. For top cover 20mm collar is made on all sides of the tank and M6 drill is made on corners for fixing top cover using nut and bolt. It has full capacity of 99 liters.

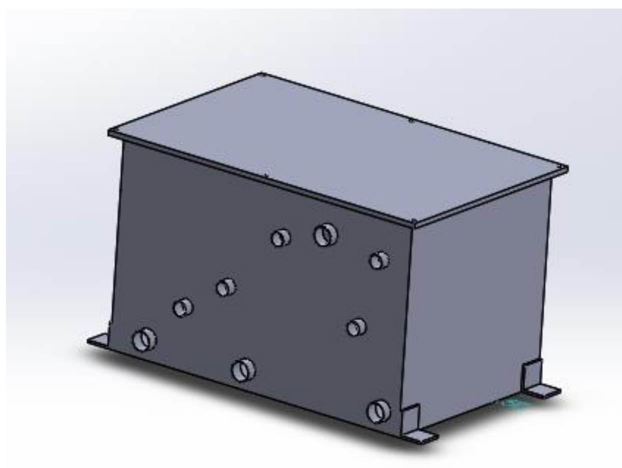


Figure 11: MS Tank

3.4 Actuator:

Double acting hydraulic actuator with double end rod is used for the load simulation. Model used is “YOLON HOB 80-200-LB” is used whose tube id is 80 and stroke length is 200mm and LB is mounting type as shown in figure. [12]

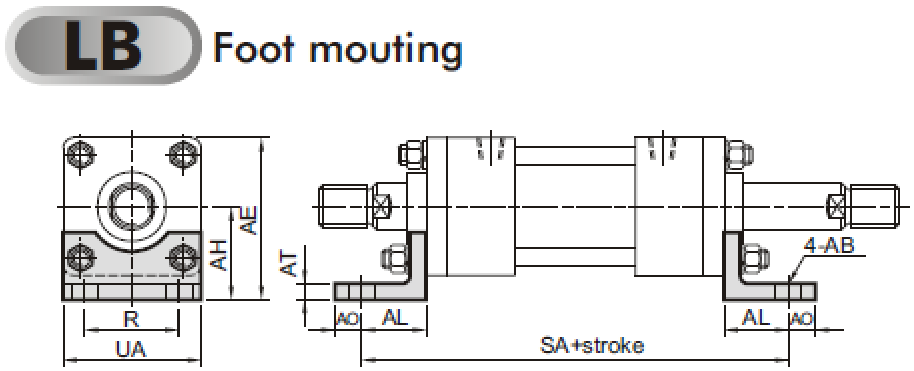


Figure 12: Hydraulic Actuator [12]

3.5 Hydraulic Hoses/Pipes and Fittings:

In the machine, we have used two standard size of hoses namely 01" and 1/2". 01" size hoses are only used for the suction lines of pumps as they need more oil at inlet due to suction, so we make the suction line bigger than the delivery line, and all other hoses are of 1/2" size.

We have used hydraulic fittings in the Rig, they are also called high pressure fittings. We have used multiple Tee, Nipples, Elbows, Sockets, Dead plugs. [13,14]

Figure 13: Hydraulic Fittings and Hoses [13,14]

3.6 Hydraulic circuit:

In hydraulic circuit, oil at 120bar from Main Motor is pumped to the Directional control valve(DCV) port P, where it will either go to hydraulic distributor via port A or to Heat Exchanger (H.E) via port B. Filter is connected to the outline of the H.E, which is then drain into tank. After oil reaches the Distributor it is then directed to the Actuator, where it applies the pressure on the piston.

From load motor side, relief valve is set at 25bar for now, as it can be adjusted according to test need. It enters the DCV port T and from there it will either go to actuator via port A or to H.E via port B and drain is set at 100bar to tank via port P. All the oil is passed through the H.E to cool it down and after that it is also passed through the Filter, where any contaminants present in oil will be filter out to save the components from damaging.

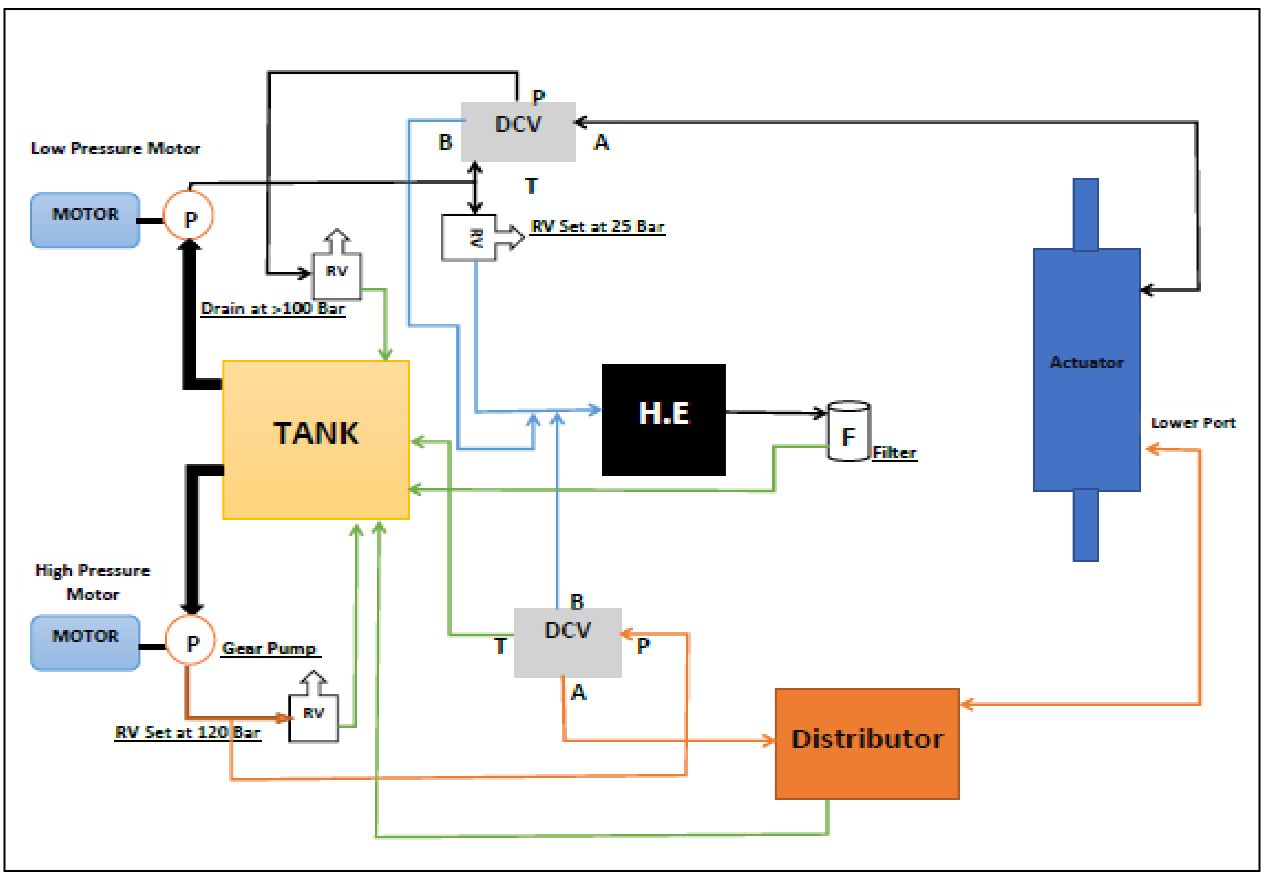


Figure 14: Circuit Diagram

3.7 Couplings:

Couplings are used to connects two shafts, the have two types, rigid and flexible couplings, we have used flexible coupling, by using flexible coupling we can adjust the misalignment of the two connecting shafts. It has a rubber material in between the coupling jaws, which helps in the alignment of the shafts. See figure. [15]

Figure 15: Flexible Couplings [15]

3.8 Pumps:

Pumps used are gear pumps which are positive displacement pumps, we have used **HEMA** ***1PN-119*** pump and ***MARZOCCHI GHP2A-D-16-FG***. Whose specifications are given below. [16,17]

MODEL	İLETİM HACİM *DISPLACEMENT* cm^3/dev *(cm^3/rev)*	DEBİ *FLOW* (1500dev/dk - *rpm*) lt/dk - *lt/min*	MAKS. ÇIKIŞ BASINCI *MAX. OUTLET PRESSURE* bar	MİN. HIZ *MIN. SPEED* dev/dk -*rpm*	MAKS. HIZ *MAX. SPEED* dev/dk -*rpm*
1PN-040	4.0	5.7	250	600	3000
1PN-055	5.5	7.8	250	600	3000
1PN-061	6.1	8.7	250	600	3000
1PN-082	8.2	11.8	250	600	3000
1PN-095	9.5	13.6	250	600	3000
1PN-119	11.9	13.6	250	600	3000
1PN-135	13.5	17.1	250	600	3000
1PN-140	14.0	19.4	250	600	3000
1PN-146	14.6	20.1	250	600	3000
1PN-168	16.8	24.1	250	600	3000
1PN-192	19.2	27.6	250	600	3000
1PN-229	22.9	32.9	210	600	2500
1PN-250	25.0	36.0	210	600	2500
1PN-281	28.1	40.4	175	600	2500

ISO VG68 yağ 50°C kullanıldığında alınan değerdir. / *For ISO VG68 oil at 50°C*

Figure 16: Data sheet HEMA 1PN-119 [16]

Size	Displ cm3/ rev	Max Pressure (Bar)			Dimensions				Max Speed (rpm)
		Contin'	Interm'	Peak	L	M	d	D	
GHP2A D 6	4.5	280	295	310	45.5	92	7/8"-14UNF	1 1/16-12UNF	4000
GHP2A D 9	6.4	280	295	310	47	95	7/8"-14UNF	1 1/16-12UNF	4000
GHP2A D 10	7.0	280	295	310	47.7	96	7/8"-14UNF	1 1/16-12UNF	4000
GHP2A D 13	9.6	280	295	310	49.5	100	7/8"-14UNF	1 1/16-12UNF	3000
GHP2A D 16	11.5	280	295	310	51	103	7/8"-14UNF	1 1/16-12UNF	4000
GHP2A D 20	14.1	260	275	290	53	107	7/8"-14UNF	1 1/16-12UNF	3200
GHP2A D 22	16.0	260	275	290	54.5	110	7/8"-14UNF	1 1/16-12UNF	2800
GHP2A D 25	17.9	260	275	290	56	113	7/8"-14UNF	1 1/16-12UNF	2500
GHP2A D 30	21.1	230	245	260	58.5	118	7/8"-14UNF	1 1/16-12UNF	2200
GHP2A D 34	23.7	230	245	260	60.5	122	7/8"-14UNF	1 1/16-12UNF	2000
GHP2A D 40	28.2	200	215	230	64	129	7/8"-14UNF	1 1/16-12UNF	1800

Figure 18: MARZOCCHI GHP2A-D-16-FG, Data Sheet [17]

Specifications	
Basic Design:	External gear
Body:	Aluminium
Flange and cover:	Cast Iron
Recommended Filtration:	20/18/15 (ISO 4406)
Viscosity range:	From 6 to 500cSt
Temperature range:	-15°C to 80°C using standard seals
Fluids	Best performance with std mineral oils
Inlet Pressure:	Min 0.7 Bar abs - Max 3 Bar abs

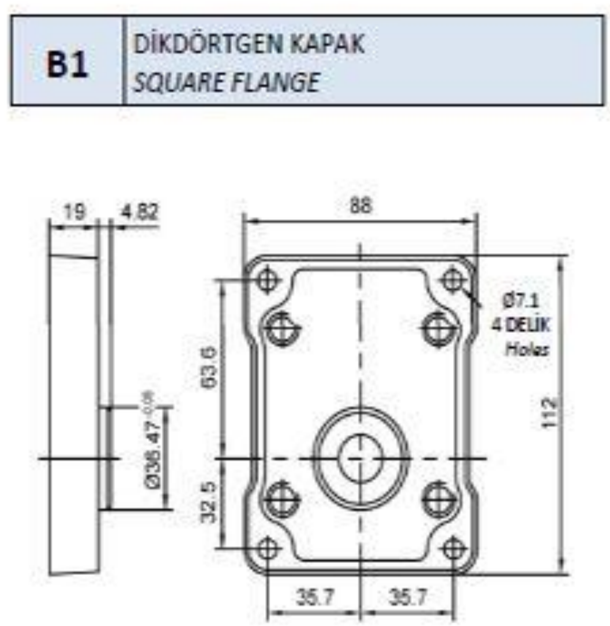


Figure 19: Pump Specs and Drawing [16,17]

3.9 AC Motors:

We have used two (02) AC 3-Phase induction motors, one is SIEMENS 10HP(7.5Kw) and other one is HYDAC 3.5HP(2.5Kw), 1400rpm each. 10HP is for the high pressure pump and 3.5HP is for the load pump to drive. The direction of the motors is synchronized with the pump direction. The direction can be changed by changing the position of two of the live wires.

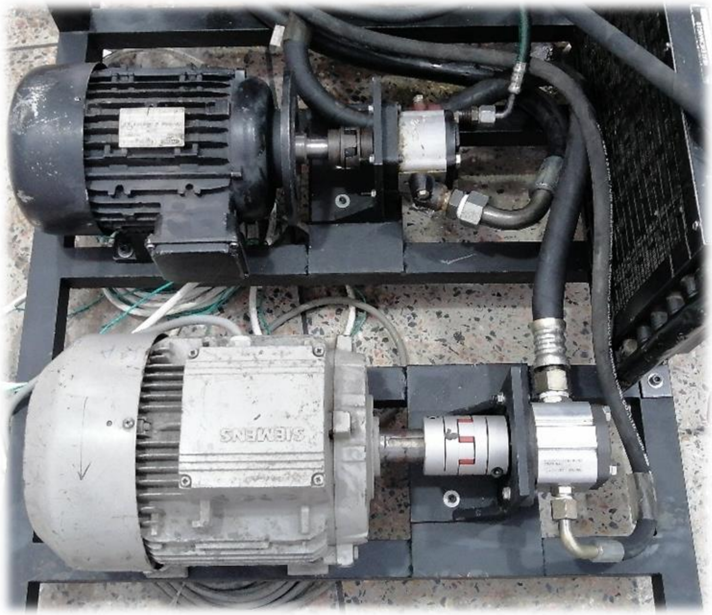


Figure 17: 3-Phase AC Motors

3.10 Stepper Motor and Gear Screw:

The ***NEMA 23 stepper motor*** has a 2.3*2.3 in (58.485 mm) flange size and a 1.8° step angle (200 steps per revolution). It has ***maximum torque*** value of ***3 Nm***. It has 4 leads and 2 poles, 2 wires are of each pole, it can be define by touching any two wires and turn the stepper if it stiffens/hard to rotate then these are the wires of same pole.

To obtain more torque from smaller stepper motor we have attached a gear screw mechanism which will translate more torque and will help in smooth and easy operation of control lever for the operation of the machine.

Figure 18: Stepper Motor and Gear Screw

3.11 Rotary Encoder, Pressure Sensor and Gauge:

Pressure sensors and pressure gauges are mounted at both the ends of the hydraulic actuator to monitor the pressure of oil going in or out of the actuator, pressure sensor output is taken from the NI DAQ and can also be seen from dial gauge. Its model is ***GEMS 3100S0400S05G000RS00.*** Whose working pressure is 400bar, input is 24VDC, output signal is 0-10V.

Rotary encoders are used for finding the position and direction of lever arm, one encoder is mounted on the cross shaft of the hydraulic distributor to define the position of the lever arm. The other encoder is mounted on the lever arm, from which we operate the hydraulic distributor manually. It is used for locating the position and direction of the lever arm. The model used is ***P3036-C-360-V2-LS24H6.*** Its output is also 0-10V and input is 24VDC.

Specifications

Performance	
Long Term Drift	0.2% FS/YR (non-cumulative)
Accuracy	
3100	0.25% FS
3200	0.25% FS for >1000 psi (60 bar) 0.50% FS for <1000 psi (60 bar)
Thermal Error	
3100	0.83% FS/100°F (1.5% FS/100°C)
3200	2% FS/100°C for <1000 psi (60 bar)
Compensated Temperatures	-40°F to +257°F (-40°C to +125°C)
Operating Temperatures	-40°F to +257°F (-40°C to +125°C) for elec. codes B, C, E, G, 6, 8, 9, Y -5°F to +180°F (-20°C to +80°C) for elec. codes F, 3, W
Zero Tolerance	
3100	0.5% of span
3200	0.50% of span for >1000 psi (60 bar) 1.00% of span for <1000 psi (60 bar)
Span Tolerance	
3100	0.5% of span
3200	0.50% of span for >1000 psi (60 bar) 1.00% of span for <1000 psi (60 bar)
Response Time	1 ms
Fatigue Life	Designed for more than 100 M cycles
Mechanical Configuration	
Pressure Port	See under "How to Order," last page
Wetted Parts	17-4 PH Stainless Steel
Housing	304 Stainless Steel
Electrical Connection	See under "How to Order," last page
Enclosure	IP67 (IP65 for electrical codes G & W)
Vibration	40G peak to peak sinusoidal, (Random Vibration: 20 to 1000 Hz @ approx. 40G peak per MIL-STD-810E)
Shock	Withstands free fall to IEC 68-2-32 procedure 1
EMC (Radiated Immunity)	100 V/m
Approvals	CE, conforms to European Pressure Directive, Fully RoHS compliant, CRN Registered to ANSI/ASME B31.3, UL recognized files # E219842 & E174228
Weight	1.8 - 5.3 ounces (50 - 150 grams). Configuration dependent.
Voltage	
Output (3-wire)	0 V min. to 10 V max. See under "How to Order," last page
Supply Voltage	2 Volts above full scale to 30 VDC max @ 4.5 mA (6.5 mA on dual output version)
Source and Sinks	2 mA
Current	
Output (2-wire)	4-20 mA
Supply Voltage	8-30 VDC
Maximum Loop Resistance	(Supply Voltage-8) x 50 ohms
Ratiometric	
Output	0.5 to 4.5 VDC @ 4 mA (6.5 mA on dual output version)
Supply Voltage	5 VDC ±10%

Figure 19: Pressure Sensor Specs [18]

Figure 20: Pressure Sensor[18]

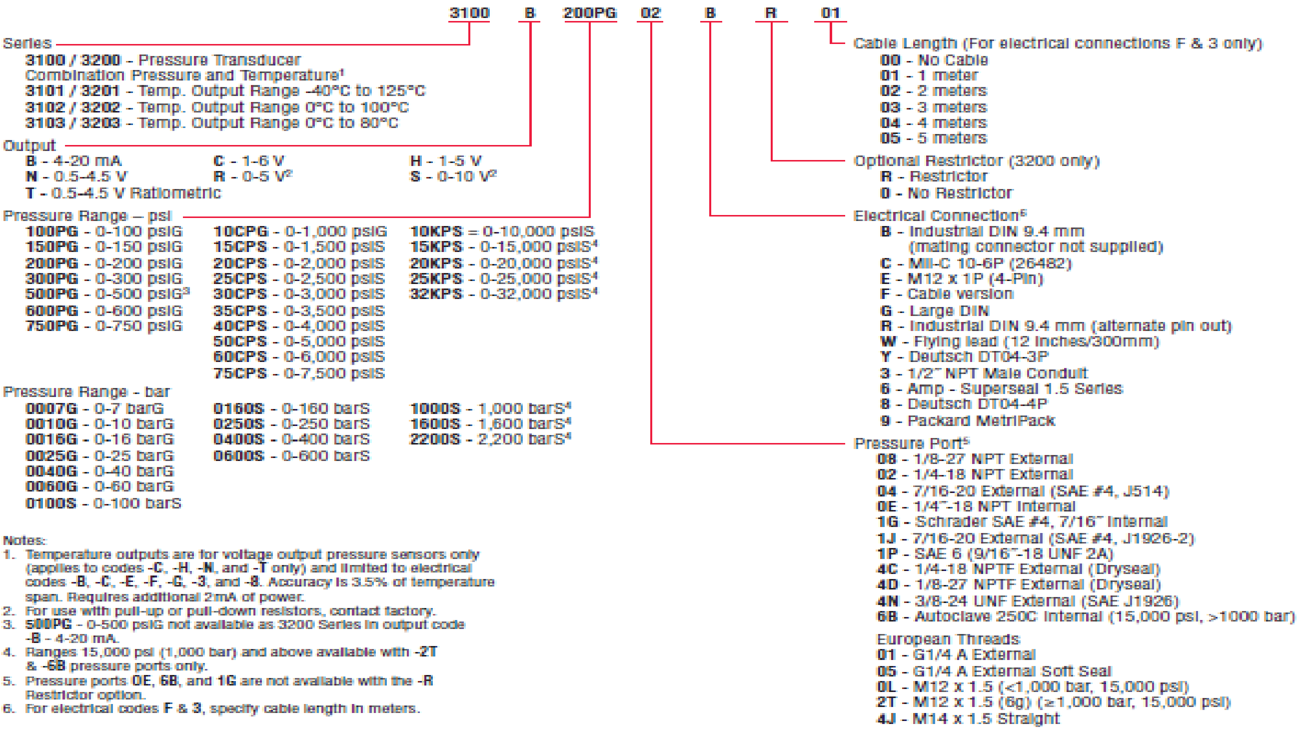


Figure 21: Pressure Sensor Code Tree[18]

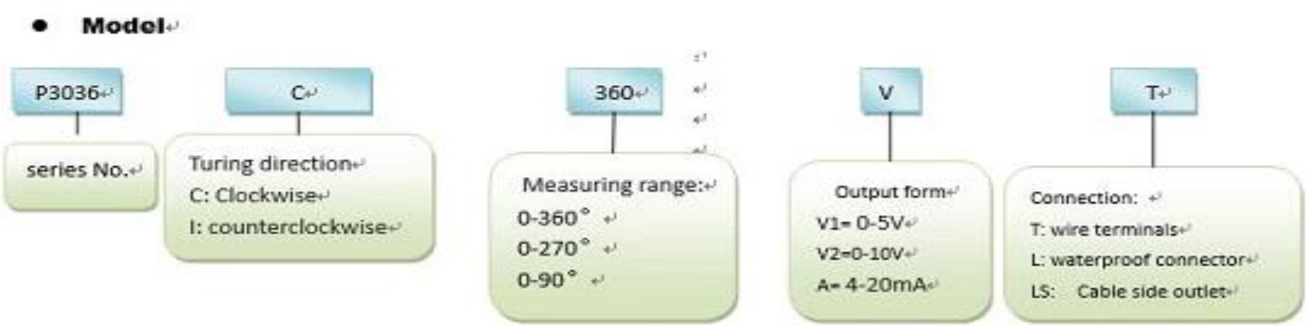


Figure 22: Rotary Encoder Model Detail [19]

Figure 23: Rotary Encoder[19]

3.12 Relief Valves/Directional Control Valves(DCV):

Number of relief valves and DCVs are used in rig. Relief valves are basically safety valves which are operated when certain value of pressure is reached at which it is set. Then relief valve releases the oil to drain maintaining the set pressure in line, Model no. ***LONGLI DBDH6G 10/150-M*** & ***LONGLI DBDS6G 10/50***, & ***DBDA60 10/200***, maximum working pressure is ***200bar***, 03x relief valves are used in circuit at different positions shown in circuit diagram.

DCVs are used to direct the oil to different directions, it switches the direction when it is operated. Its working is discussed in previous chapter. 02x DCVs are used in circuit. Model no***. DG4V-3-2A-M-P7-H-7-52.*** Maximum working pressure of ***350bar.***

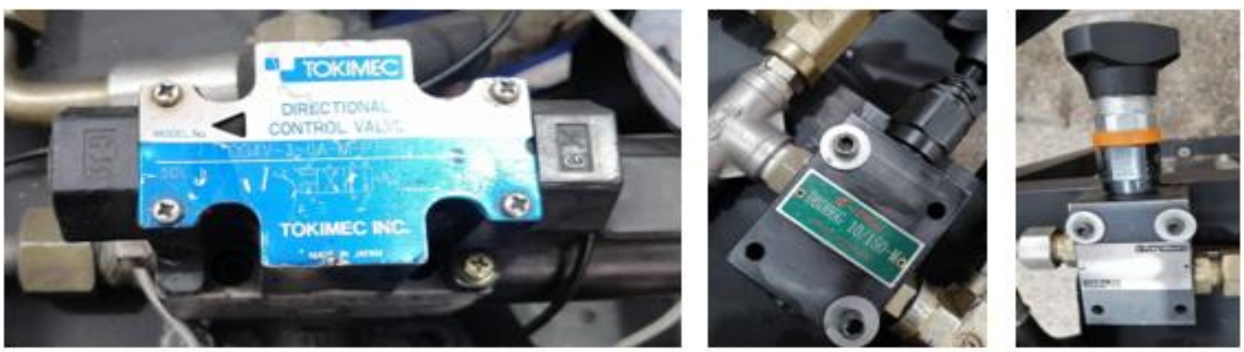


Figure 27: Directional Control Valves and Relief Valves

3.13 Oil Filter and Heat Exchanger:

Oil filter is used for the cleaning of hydraulic oil, to protect the critical components like gear pump from wear and tear due to presence of particle. Filter is attached to an aluminum casing and that is casing is attached to a machined plate, which is designed and fabricated. Filter used is Millat genuine filter whose ***model number is 2654408.*** Drain oil is passed through the Heat Exchanger and at the outlet of the H.E the filter is attached and oil from the H.E is passed through the oil filter and then dump into the tank.

FASCO single phase Heat Exchanger is used, whose ***max. working pressure and temperature is 300psi and 180°C respectively***. 1400 RPM. ***Model no. is AOC-220-1***, Serial no. C-75037(Thermal transfer products ltd.).

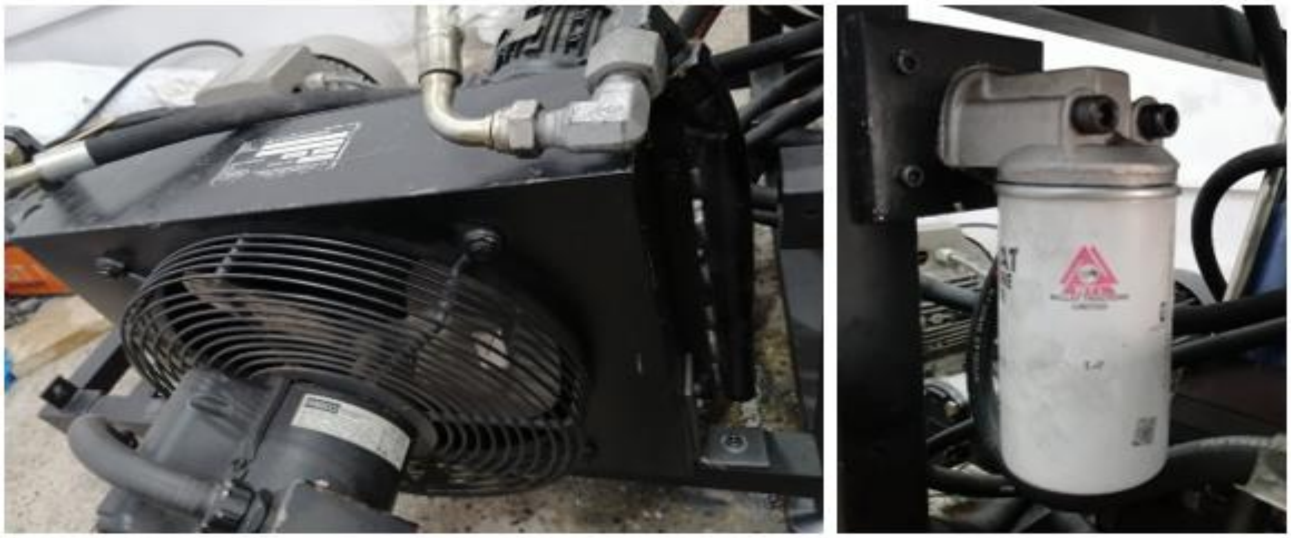


Figure 28: Heat Exchanger and Oil Filter

3.14 Thermocouple:

A thermocouple is used to monitor the temperature of the hydraulic oil. Because, at high pressure applications the oil gets hot and results in damaging the seals and critical components as they have a certain range of operating temperature. To avoid this problem, we used this thermocouple.

Thermocouple model is ***1AA800098-1m*** and it is ***K-Type thermocouple*** and its maximum measuring temperature range is ***-120°C to 1250°C.***

Figure 29: Thermocouple [20]

3.15 Float Switch and Level Gauge:

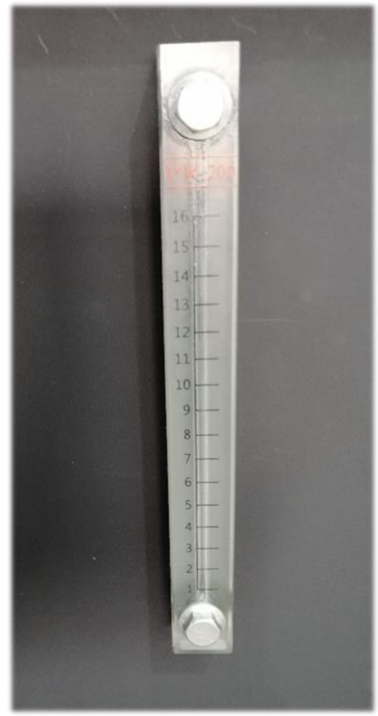


Figure 31: Level Gauge

Flat type lever switch (Float Switch) is used in tank at the level of 45% capacity of the tank from the bottom. [21] When it reaches the level below the 45% of the tank capacity it will give an output signal. The operator can also manually look into the level gauge, level gauge is also mounted on the tank to see the oil level in the tank and to maintain a specific level of oil.

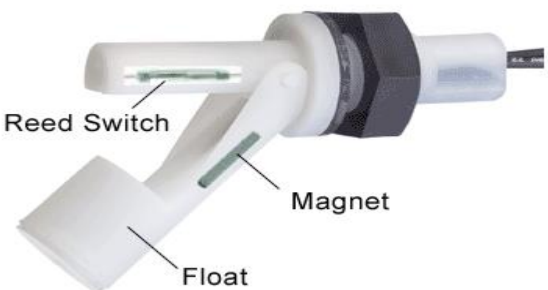


Figure 30: Float Switch [21]

3.16 Some Pictures of the System:

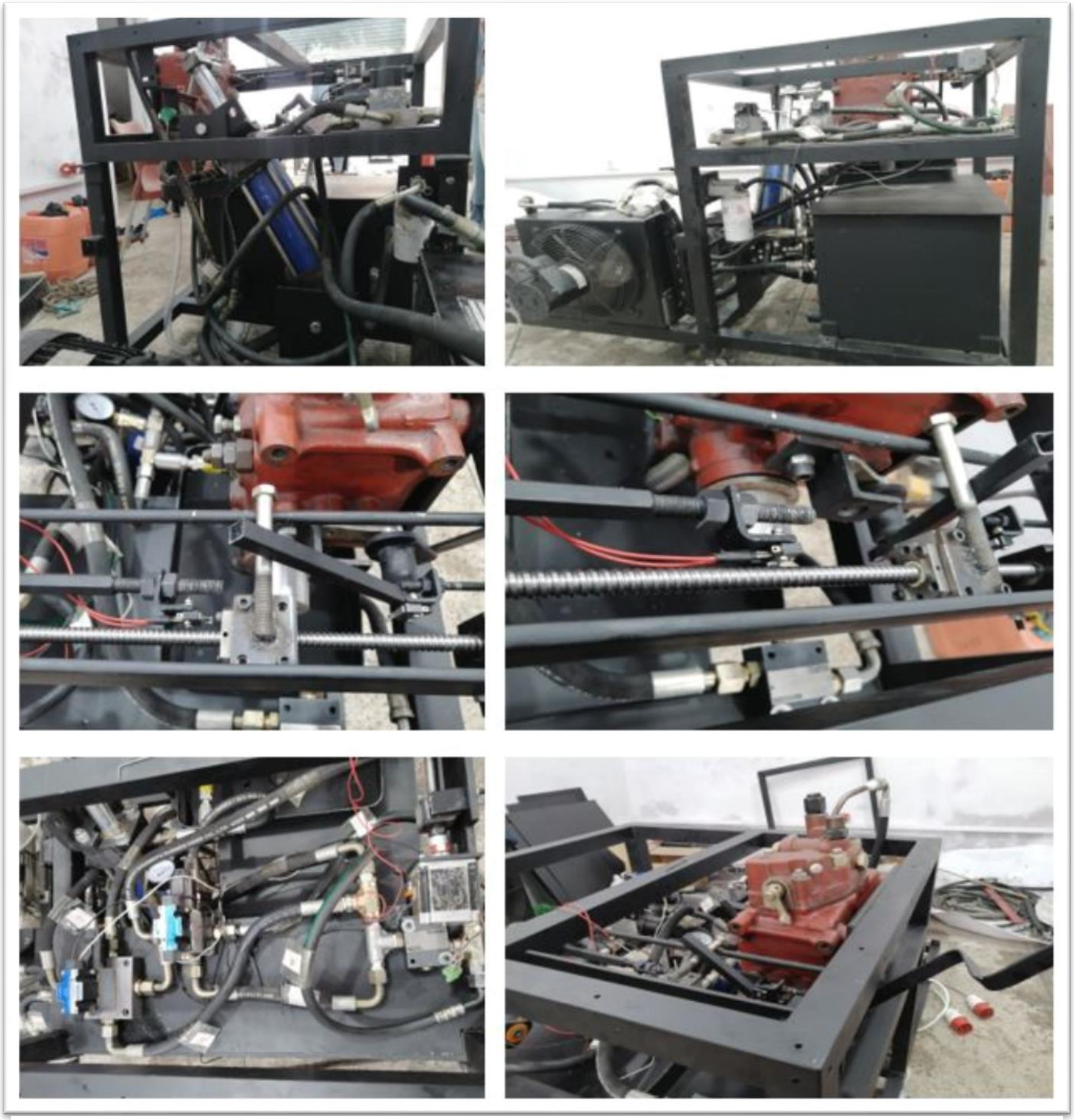


Figure 32: Random Pictures of the Rig

Chapter 04: Results and Conclusions

Our main objective was, to develop a test rig which is autonomous in performing all the test required by the industry to check the hydraulic control valve by applying variable loads, with automation and manually as well. A screen is installed to perform all the tests without doing any load work and a single operator can perform all the tests.

4.1 Tests performed:

- **Ramp/Play Test**
- **Jerk/Lag Test**
- **Overload Test**
- **Still/Leakage Test**
- **Lap Test**

Ramp/Play Test:

In Ramp/Play test we start from the home position *(home position is when the stone is placed at the ground level),* the control lever and Arm(crank) lever both move simultaneously toward the top position after a slight play at the start of the test and at the top(max.) position the stone is lifted and then from the top(max.) position it goes all the down towards the home position.

While performing these test all the data is recorded on the computer screen, raising and lowering rate graph of both the control lever and arm(crank) and raising and lowering rate is shown on the screen. Also the dead/play angle is obtained, which means that the crank doesn’t move until the hand lever covers that angle.

By getting values of the test, system compares it with the set valves and a light is turn on either RED/GREEN, Red light for the FAIL test and Green light for the PASS test.

Technical data:

Hand lever dead/play angle = 18.4 °

Operating lever up rate = 3.93546 °/sec

Operating lever down rate = 4.43262 °/sec

Weight lift rate = 6.03362 °/sec

Weight down rate = 8.36312 °/sec

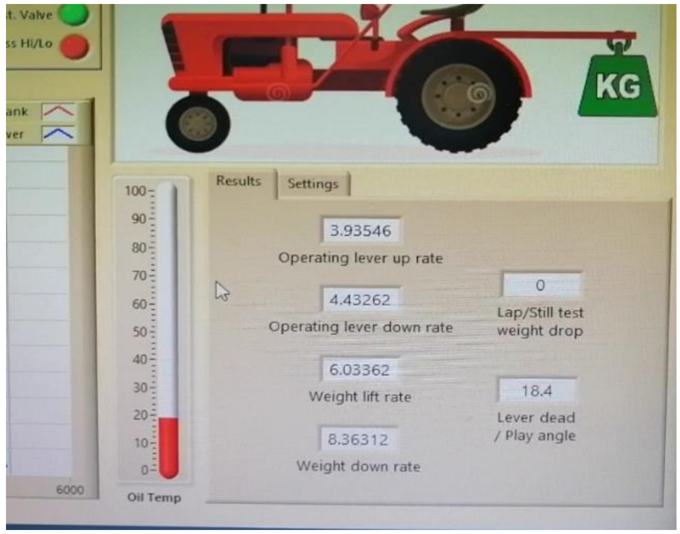


Figure 37: Ramp/Play test result

Jerk/Lag Test:

In Jerk test, the actuator is positioned in the center and both the pumps are on and at the end of the test the actuator pressure line is set to drain and the actuator is moved all the way down at the end of the test. Test duration can be set by the user choice, it can be changed. The jerk test is recorded as % smoothness of the test.

If the values are within the range the Green light will ON, if out of range Red light will ON.

Overload Test:

Overload test is the part of the Ramp/Play test, it starts from the home position and goes all the way up(max.) position and stays there for the specified time while noticing the pump inlet pressure is within the range, defined by the manufacturer. Pressure range can be changed according to the requirement.
If it is in the range the Green light will ON, if not in range the Red light will ON.

Still/Leakage Test:

In Still/Leakage test the actuator will stop in the mid position and high pressure pump is set to drain and load is applied on it, in this test we will the monitor the movement of the arm(crank) after positioning the Actuator in middle position.

If it is in the safe range Green light will glow otherwise Red light will ON.

Test result shows: Crank lever dropped during test = 4.8°

Lap Test:

In this test the load on the actuator is zero, and it monitors the crank angle, that how much does it move in this test. If it is in the safe range the Green light will ON, which means the test is passed, otherwise Red light will ON, which means the test is failed.

Test result shows: Crank lever raised during test = 0.8°

4.2 Conclusion:

The designed system can measure all the required test according to the standards provided by the industry. All tests have been demonstrated one by one and their results have been verified. Graphical and visual outputs are also provided for the better understanding and concluding the results of the tests.

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