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Design and Development of Hydraulic Control Valve Testing Machine

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***Abstract:** In this paper, hydraulic control valve, pressure relief-valve and main spool valve used in hydraulic plant has been studied.Hydraulic control valve is essential in agriculture field. Hydraulic control valve is used for lifting and lowering the load. In this work, testing machine is developed for testing of control valve. In existing control valve testing machine, there are 8 parameters which has been tested before sending control valve to pre-dispatched inspection zone. These parameters are tested in control valve test rig section and then again in Varry Touch Unit section at 30LPM oil flow. Due to testing of these parameters again, it increases the production cost, labour cost and production time. In this work, present 8 parameters are reduced and single parameter testing is suggested on new control valve testing machine. Only one parameter have a need to check in control valve test rig section i.e. relief valve pressure and other parameters directly check in varry touch unit section. New machice is design which will operate on 5 LPM flow to reduce flashing of oil and check relief valve pressure. It mainly includes design a new relief valve pressure checking machine.*
***Keyword:** Control valve,relief valve pressure, varry touch unit*

I. INTRODUCTION

Tractor hydraulic system unit is responsible for lifting, lowering or holding of mounted or semi-mounted equipments by hydraulic means. Hydraulic system have a two controls i.e. Position control and Draft Control. In Position Control, constant depth of ploughing is maintained by adjustment of position control lever and the lever position is directly related to the height of the three-point hitch. Draft control senses extra strain on the hitch and allow the plow to raise enough to get through the hard spot and immediately returning to the desired depth. Present work is the based on work carried out at tractor plant in Mahindra & Mahindra limited. The control valve consists of the two main parts, relief valve and main spool (direction control valve). When control valve is operating, it is desirable that, the average or peak oil pressure remain relatively constant and variable compression method is used for better economy of the fuel or oil. Pressure relief valve is used to release of pressure whenever the pressure exceeds preset value to protect a system from brusting.In the pressure relief valve, non-linear forces such as back pressure force, friction force, spring force, fluid force, and damping force plays an important role by acting on the moving part of the valve.

There are seven control valve testing machines on the shop floor in Mahindra company. This machines consumes more space as well as manpower needed is more.There are three types of model which is manufactured by Mahindra Tractors namely M-STAR regular, M-STAR adjustable and DHRUVE. On control valve test rig, presently industry have to check 8 parameters with 30 LPM oil flow and that 8 parameters are again tested on varry touch unit section. The main parameter on control valve test rig for Adjustable part is Relief Valve Pressure (RVP). Hence it is necessary to design a new machine which will operate on 5 LPM flow to reduce flashing of oil and also find the relief valve pressure range at 5 LPM flow of oil. This new machine set-up will be more versatile because it reduces the man-power, power consumption, production cost and increases productivity. In this project, emphasied is given on Relief Valve Pressure (RVP) related to 5 LPM. After testing done on 1000 control valves on 5 LPM flow, the best relief valve pressure range determined and that range is 2500 PSI-2600 PSI. When the control valve is between this range, the control valve is OK and dispatch it directly to the varry touch unit for futher testing.

II. PROBLEM IDENTIFICATION:

The existing testing machine usually comes along with a lot of wasteful aspects.There are seven control valve testing machines which set the relief valve pressure at 30 LPM oil flow on the shop floor in Mahindra Company. This machines consumes more space as well as needs more manpower. Time required for testing one control valve is likewise more since operator needs to test all the eight parameters in Control Valve Test Rig (CVTR) and again similar parameters in Varry Touch Unit (VTU) which increases the production and labour cost twice.

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At 30 LPM flow, flashing of the oil is more. Hence it is necessary to provide alternative to existing problem. This can be done by designing modified control valve testing machine which will reduce the production cost and increase the productivity which will operate at 5 litre per minute oil flow. Testing was carried out to find the best pressure range for effective utilization of this new machine.

III. COPONENTS OF MACHINE

A. *Hydraulic Hoses*

Hydraulic hoses as shown in fig.1 have characteristics like reliability, durability, flexibility good performance which make them more capable. The entire range covers different varieties viz. SAE100R1, R2, R3, R6, R5R, R5C. Hydraulic hoses are classified on the basis of pressure ranges, material which can be go through it and its fluid. Some hoses are specially designed for restricting oil and also are wire braided. They can easily connected between steel pipes. Industries are using this as in hydraulic bracket and automatic hydraulic systems. Working range of these hoses can be calculated in temperatures which are in between -40^{0}C to 100^{0}C. They can withstand maximum temperature around 120^{0}C. Other specification are as follows.

Fig. 1. Hydraulic Hose

1) *Temperature Range:* -40^{0}C to 100^{0}C temperature range depend on the nature of work and requirement.
2) *Tube:* Material used for tube is synthetic rubber which not create resistantance to hydraulic fluid.
3) *Reinforcement:* Reinforcement contains only one braid wire. The wire must high tensile strength and made up of steel.

B. *Quick Release Coupling*

Quick release coupling as shown in fig.2 is the connector used for maintaining the alignment between fluid lines which required continuous and discontinuous flow. Sleeve provided in the quick release coupling is used for disconnection between tool and clamp. It is connected with shutoff valve to provide entire control of fluid flow through it. When both the halves are connected to the coupling then only the fluid will flow through it. If both the halves are not connected, it causes disconnection between the mechanical linkages which makes coupling valve closed. Compression of grooves makes inside teeth attach with the inside of tubing which forms strong grip.

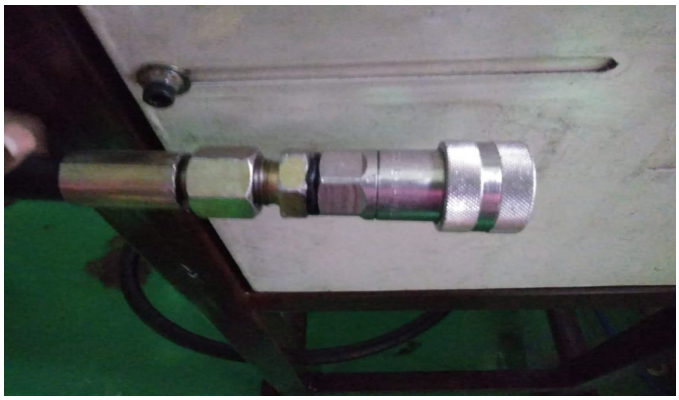

Fig. 2. Quick Release Coupling

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C. Flow Meter

Flow meter allows to measure the flow of fluid in a system.The STAUFF flowtell inline flow meter as shown in fig.3 is used for cheking the drain flow through the closed chamber tank. It also provide the information about the performance of the pump. It monitor the flow of media through hydraulic circuits and sub-circuits. It permits to positioned in any direction (horizontal, vertical or inverted) and is weather-proof for the utilization on outside as well as on framework where wash downs are required. It is reliable instrument which does not required periodic maintenance. Flow meter used for the project can measured the flow up to 65 LPM or 16 GPM.

Fig. 3 Flow Meter

This flow-meter provides the results with high accuracy. It also monitor the flow of oil with high pressure so precisely. The flow ranges of the flow meters are between 0.002 to 250 litre/minute (0.0005 to 66.00 US GPM) and it sustain the pressures of oil up to 450 bar (6500 PSI). Flow meters are directly integrated into the hydraulic circuit. Flow meters are used for the applications: hydraulic test stands, ink, lubrication systems, and brake fluid.

D. Transducer

The main use of the transducer is the conversion of the one form of energy into another form. In general, it deals with various sort of energies, for example, pressure energy, thermal energy, light energy, electromagnetic energy, mechanical energy, electrical energy, chemical energy, acoustic energy, etc. In this project, Transducer used for showing the value of relief valve pressure on digital display. Transducer is connected to the inlet hose pipe, prior to the flow meter, and attached with the digital pressure indicator.

E. Oil Restrictor

An oil restrictor as shown in fig.4 installs in the oil passages of the relief valve in control valve assembly. It limits the flashing of oil to some extend from the control valve. When oil restrictor is attached to relief valve, it reduces the excess oil draining through relief valve and hence, the amount of oil required by the control valve is greatly reduced.

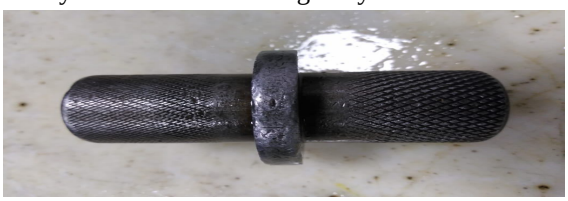

Fig. 4. Oil Restrictor

F. Digital Pressure Sensor & Indicator

Digital pressure indicators as shown in fig. 5 has a robust housings and it does not have any moving parts, for example, pistons or springs. The sensors used in pressure indicator mainly resist the shock and vibration. Due to no wear, it shows the accurate value of oil pressure in PSI on display.

Fig.5. Digital Pressure Indicator

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On digital display of the digital pressure indicator shows the operating pressure of the flowing oil into the machine. Most of the digital pressure gauges rely converted the pressure of the flowing media into an electrical signal. In pressure indicator, there is an wheatstone bridge circuit, which formed due to the connection of strain gauges. Hence this Wheatstone bridge circuit, maximize the output accuracy of the sensor and also reduce sensitivity to errors.

G. Control Valve Assembly

Control valve assembly as shown in fig. 6 is used to control the volume of flow of the pressurised oil. It consists of cylinder, piston and cylinder head assembly. The control valve consist of the two main parts, relief valve and main spool (direction control valve). When control valve is operating, it is desirable that, the average or peak oil pressure remain relatively constant and variable compression method is used for better economy of the fuel or oil.

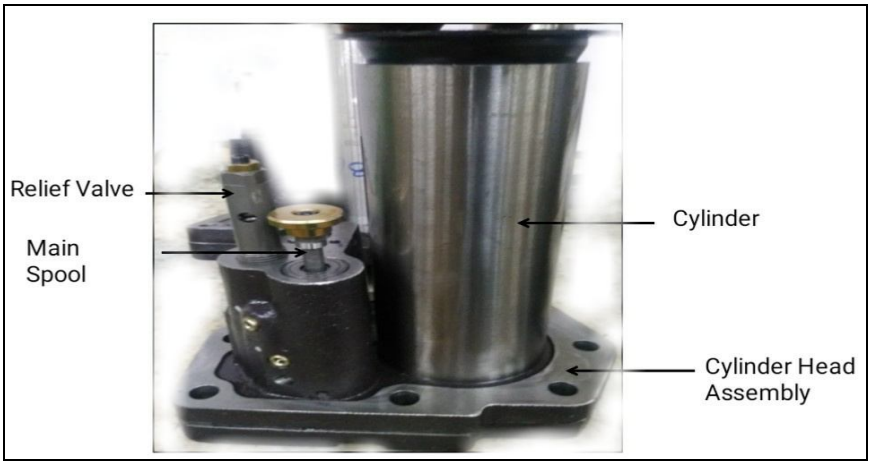

Fig.6. Control Valve Assembly

H. Direction Control Valve

Directional control valve as shown in fig. 7 is the most essential parts in hydraulic and pneumatic systems of the hydraulic plant. Direction of the hydraulic oil is control by the this valve. In this project, pressurized oil from the pump passed through the hose pipe, then through flow meter and at last, enter into the 4/2 directional control valve. It provide the path to the pressurized oil to enter into the compensator housing of the control valve assembly. The inside mechanism of the Direction control valve is that, it has a spool which is actuated mechanically or electrically inside a cylinder. Direction control valve control the fluid flow by changing the position of the spool.

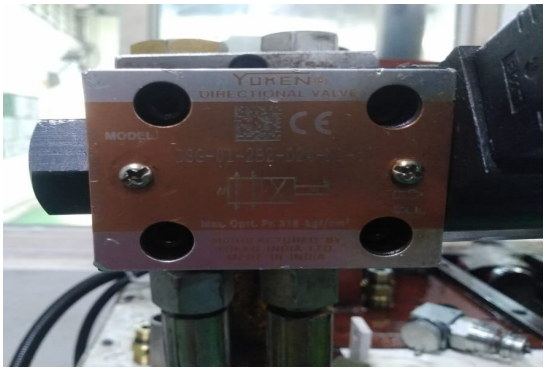

Fig. 7. Direction Control Valve

In direction control valve, grooves are present on the spool which permits or restricts oil or gas to flow around the spool and through the valve body. Directional control valve works on two fundamental positions i.e., normal position in which valve returns it's initial position when the actuating force is removed and another one is working position in which actuating force is applied by mechanical or electrical means. Classification of direction control valve (DCV) based on number of ports, number of positions, actuating methods and type of spool.

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I. Relief Valve

Relief valve as shown in Fig.8, is a sub-part of the control valve. It indicates the permissible pressure limit of hydraulic oil and control the pressure to avoid the damage to the hydraulic system.Pressure relief valve is designed to run system at maximum efficiency. When oil at an operating pressure also have significant effect on control valve.

Fig. 8. Relief Valve Assembly

J. Main Spool Housing

Main Spool as shown in Fig. 9, is the sub-part of the control valve assembly. This main spool (reciprocating type) consists of lands and grooves. The lands of the main spool restrict the flow of oil through the valve body. The grooves on the spool permits the flow of pressurized oil or gas through the valve body.

Fig. 9. Main Spool

The shifting of the pressurized oil in main spool housing to the different path is due the reciprocation of the spool inside the main sleeve, core opening and closing the path of the oil flow. It has a three way position control.

1) Lift control for lifting.
2) Lower control for lowering.
3) Neutral control for holding.

IV. METHODLOGY

Previous control valve testing machine as shown in Fig.10, is used to check and set the value of relief valve pressure between the range of 2770PSI-2850PSI.

Fig. 10. Old CVTR setup

There are 8 parameters which has tested on this machine are as follows.

1) Relief valve pressure (2770 PSI-2850 OPSI)
2) Isolator valve leakage (0.0025 thousandth of an inch in 30 sec.)
3) Lifting pressure (1400 PSI)
4) Main Spool Deflection (0.060 thousandth of an inch - 0.110 thousandth of an inch)
5) Lifting Time (4 sec. max.)
6) Lowering Time (2 sec. max.)
7) Drop in 30sec. in full lift condition (0.012 thousandth of an inch max.)
8) Drop in 30sec. in centre lift condition(0.012 thousandth of an inch max.)

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Schematic of existising control valve testing of hydraulic plant is shown in fig 11 which consists of 7 Control Valve Testing (CVTR) machines and 7 Varry Touch Unit (VTU). Control Valve from the sub-assembly station has been transferred to the CVTR machine where operator inserted the control valve into the machine.Then start the clamping motor to clamped the control valve by hydraulic cylinder diagonally. After that,control valve tighten with the machine by the nut-bolt arrangement. Then, 30LPM flow pump motor is started, and operator checked all the 8 parameters on the machine. For testing all the parameters, operator required minimum 6 minutes. After testing done, control valve is shifted to VTU section for testing again that 8 parameters which increases the production time as well as labour cost.

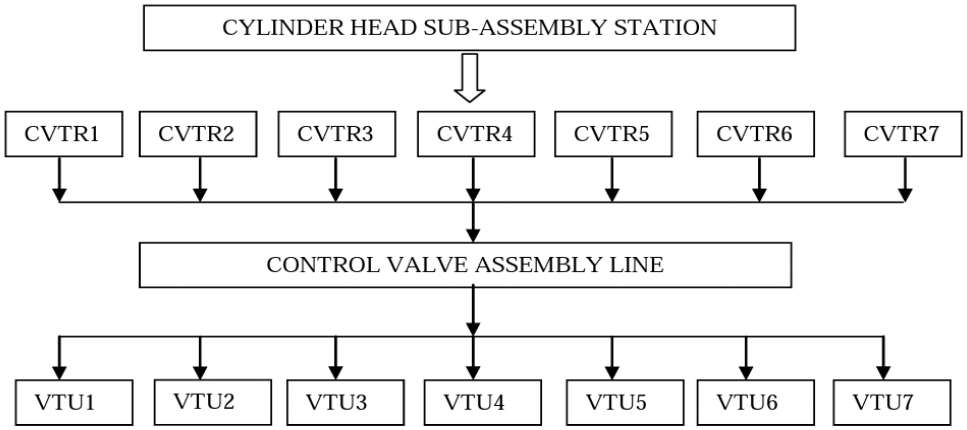

Fig. 11. Schematic of existising control valve of Hydraulic Plant

Fig.12(a) and Fig.12(b), shows modified set up of control valve testing machine. New control valve testing machine consists of a close chamber, holding clamp, pull-up lever, analog pressure gauge, digital pressure indicator and from top there will be the cylinder sub-assembly tightening mechanism. After sub-assembly of the cylinder head, it is directly place in closed chamber. The supply of 5 LPM is from the pump.

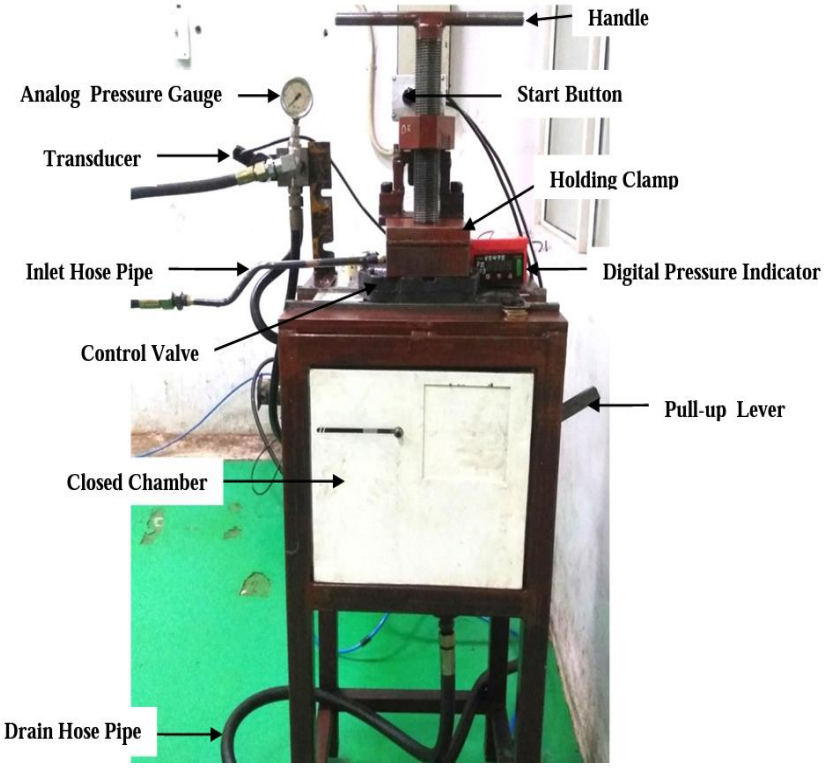

Fig. 12(a) Control Valve Testing Machine

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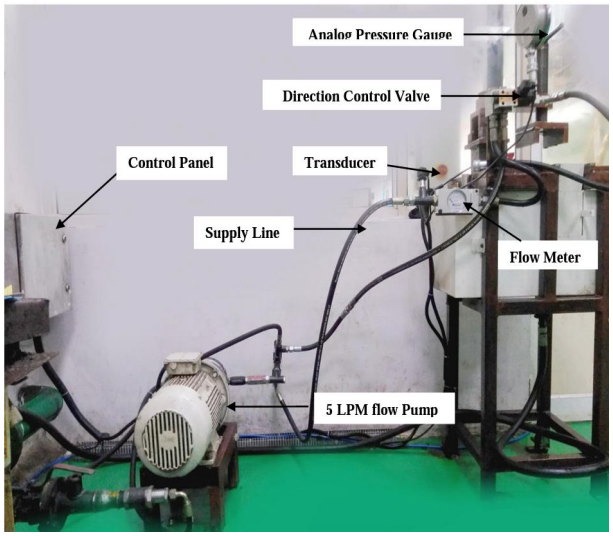

Fig. 12(b).Control Valve Testing Machine

Schematic of New control valve testing hydraulic plant is shown in fig.13. In this plant, 7 control valve testing machines of 30 LPM are replaced by the 2 machines of 5 LPM which results in less floor space.

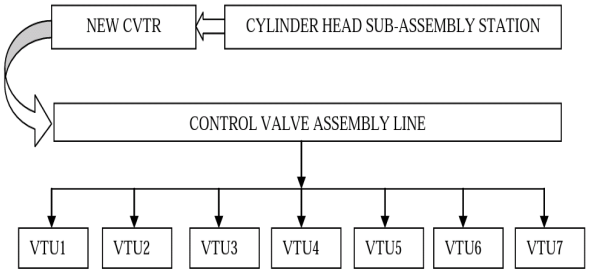

Fig.13. Schematic of New control valve testing hydraulic plant

This modified design is more effective as control valve is moved directely into the machine after sub-assembly of cylinder. In this testing, relief valve pressure is checked at 5 LPM by closing of isolator valve. If the relief valve pressure between 2500 PSI-2600 PSI, then contro; valve will be send in VTU section for futher parameter testing.

V. RESULTS AND DISCUSSION

Table 1. shows the testing result of control valve for 30 LPM flow in old CVTR. For the 10 control valve, 8 parameters have been checked and all that parameters are within the range and the control valve has been acceptable. Same control valve tested on 5 LPM flow.

Control Valve No.	RVP	Lifting Pressure	MSD	Drop in (At Top)	Drop in (At Centre)	Isolator Valve Leakage	Lowering Time	Lifting Time
1	2819	1304	77	4	3	0.001	1.5	2.5
2	2835	1337	71	3	2	0.000	1.5	2
3	2829	1326	73	5	4	0.000	1	2
4	2845	1314	68	6	5	0.001	1.5	2.5
5	2840	1333	75	5	4	0.000	1.5	2
6	2836	1311	74	7	6	0.0015	1.5	2
7	2842	1311	75	5	4	0.000	1	2.5
8	2827	1341	74	5	4	0.000	1	2
9	2810	1312	74	4	3	0.002	1	2.5
10	2843	1332	74	3	2	0.000	1.5	2.5

Table 1. Testing result of control valve for 30 LPM flow in old CVTR

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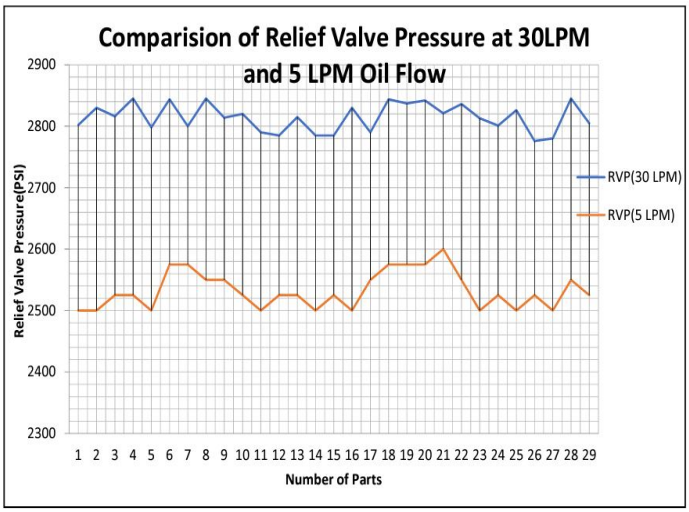
Control Valve No.	RVP	Lifting Pressure	MSD	Drop in (At Top)	Drop in (At Centre)	Isolator Valve Leakage	Lowering Time	Lifting Time
1	2550	1330	77	4	3	0.001	1.5	2.5
2	2525	1335	71	4	5	0.000	1.5	2
3	2575	1320	73	5	4	0.000	1	3.5
4	2550	1320	68	6	6	0.001	1.5	2
5	2600	1340	75	5	4	0.000	2	3
6	2525	1335	74	7	6	0.0015	1.5	2
7	2550	1340	75	7	7	0.000	1	2.5
8	2500	1325	74	6	4	0.000	1.5	2.5
9	2525	1330	74	4	5	0.002	1	2.5
10	2550	1335	74	3	4	0.000	1.5	2.5

Table 2. Testing result of control valve for 5 LPM flow in New CVTR in VTU

Table 2. shows the testing result of control valve for 5 LPM flow in New CVTR in VTU. In this, the relief valve pressure within the range and also the 8 parameters tested in VTU section are within the range. From table 1 and table 2, it is found that the, relief valve pressure are within the range and other 8 parameters have some variations in reading but that readings are also within acceptable range. Only one parameter i.e. relief valve pressure is checked on new machine rather than 8 parameters.



Graph 1.Pressure Range for 30LPM and 5LPM flow

Graph 1. shows the comparision of relief valve pressure at 30 LPM and 5 LPM flow. It is found that, relief valve pressure for a control valve at 30 LPM oil flow has a range of 2770PSI-2850 PSI. But when relief valve pressure is checked for the 5 LPM flow, the new range of pressure is 2500 PSI-2600 PSI. From the graph, it is found that, the relief valve pressure at 5 LPM is not linear with 30 LPM flow i.e. if pressure at 30 LPM have maximum value then it doesn't mean that pressure at 5 LPM have a maximum value, but the pressure will be within the range. At 5 LPM, there is small variations in other parameters but the parameters are within the acceptable range.

VI. CONCLUSION

It is concluded that, at 5 LPM flow, the new modified control valve setup gives the relief valve pressure in the range of 2500 -2600 PSI. This new setup reduced the friction losses and pipe losses which occurs in previous machine. When relief valve pressure is set for the for 5 LPM, then there is no need to set the range at 30 LPM. At 5 LPM , flashing of oil is eliminated and also reduced the consumption of oil. This new setup also tests the control valve within 2 minutes as previous time was 6 min. This helps to increases the production rate and reduces the production cost. The relief valve pressure at 5 LPM is not linear with 30 LPM flow i.e. if pressure at 30 LPM have maximum value then it doesn't mean that pressure at 5 LPM have a maximum value, but the pressure will be within the range. The old CVTR machine required 6 minutes for testing all parameters but new machine required only 2 minute that means in 6 minutes there are 3 control valve will be tested which increases the productivity.

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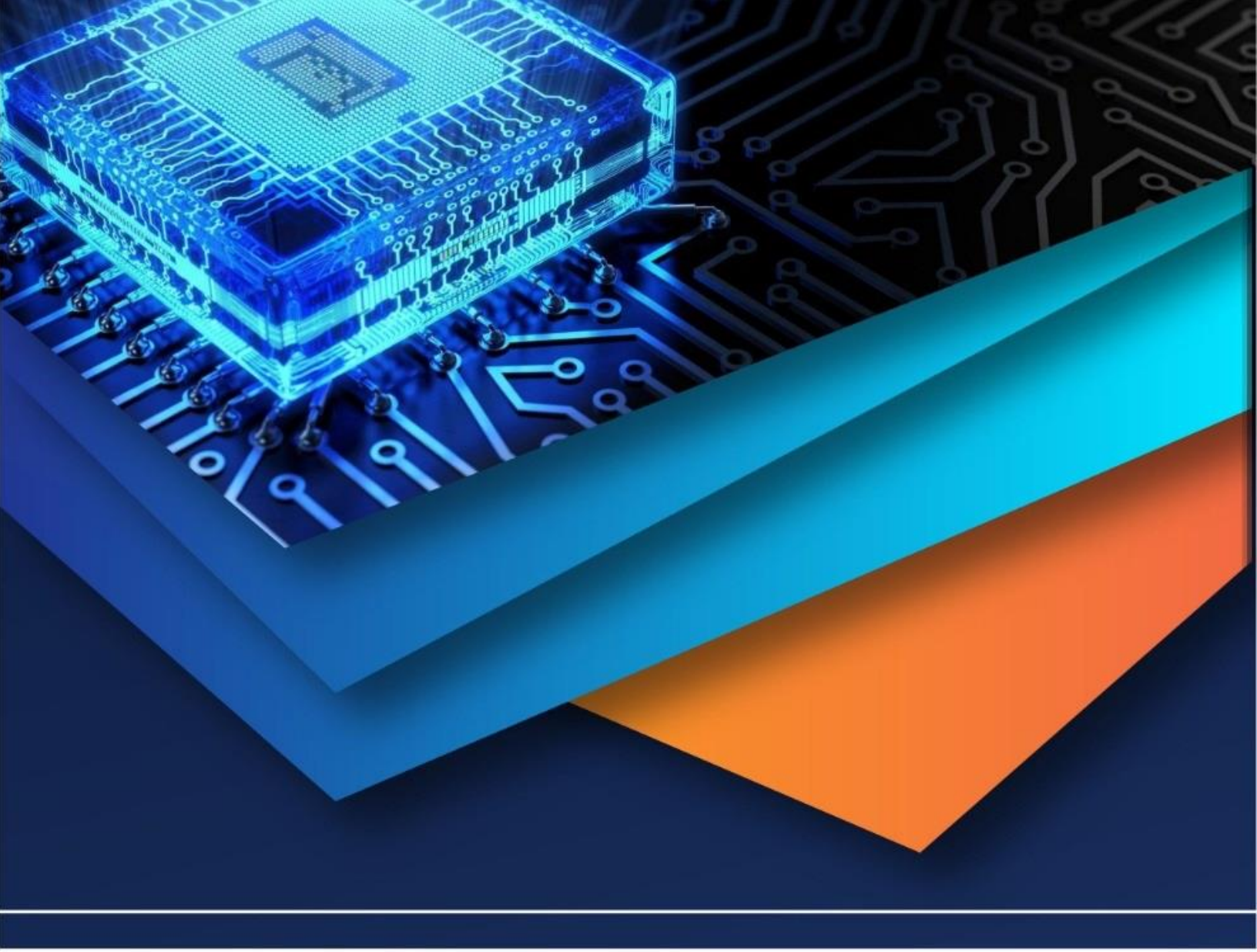

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