International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue – NCITTATME'21

Development of Electronically Controlled 4x3 DCV

Devansh Bajwala, Author, Student, MIT-ADT University, Pune, India, devanshbajwala@gmail.com

Aneesh Bedekar. Author, Student, MIT-ADT University, Pune, India, aneesh.bedekar@gmail.com

Harshit Sharma. Author, Student, MIT-ADT University, Pune, India, harshitsharma@gmail.com

Abhin Paithane. Author, Student, MIT-ADT University, Pune, India, abhinpaithane@gmail.com

Nishigandha Patel. Author, Assistant Professor, MIT-ADT University, Pune, India, nishigandha.patel@mituniversity.edu.in

Abstract. Hydraulic power generated is to be put to use. The uses can be varied and may require different components in the hydraulic circuit in question. Most important component is the directional control valve (DCV) which directs the hydraulic fluid in the desired direction to achieve the function. The DCV basically consists of a spool, casing or body which has inlet and outlet ports. Operation of the spool may be assisted by hydraulic pressure or a spring. The DCV is used to actuate an actuator in the circuit which in turn operates the desired device. The operation of the spool is done electronically. Thus, DVC can be called the brain of the hydraulic circuit and hence the present deliberations.

***Keywords* —DCV, Directional Control, Hydraulic Pressure, Hydraulic Power, Hydraulic Circuit.**

I. INTRODUCTION

Directional Control Valve as the name implies is used to direct to flow of the working fluid in the hydraulic circuit for the operation of the actuator. The DCV is used for the extension, retraction and holding of the actuator piston and used to achieve linear motion. The key aspect of the DCV is to transfer fluid energy. They establish a certain path for the fluid. This is achieved by the help of a spool inside a steel or cast-iron casing. The spool slides to different positions inside the housing, transecting grooves and channels route the fluid depending on the spool's position. The spool has a central (neutral) position maintained with springs, in this position the supply fluid is blocked, or directed to the tank. Sliding the spool to one side routes the hydraulic fluid to an actuator and provides a return path from the actuator to tank. When the spool is moved to the opposite direction the supply and return paths are switched. When the spool is allowed to return to neutral (center) position the actuator fluid paths are blocked, holding it in position. The direction control valves that are generally used to perform certain operations are basically very small and are complex to understand in the first attempt. **[13]** Also, the DCVs are of multiple types but have the same basic mode of operation which is not visible due to its outer casing. The spool then moves in translational motion, it suddenly opens and closes the sleeves of the valve resulting in jerky entrances and exits of the fluid within the line which results in lack of precision of actuation. This jerky motion has an effect on the spool known as Bang Effect. This project involves the design and development of a directional control valve using electronic systems for the movement of the spool. The spool is functioned by the help of 2 motors which are controlled by a microcontroller. The selection of the motors is done so as to eliminate the bang effect and obtain accurate and precise operation of the spool for the faultless functioning of the DCV. This method cam be used where the actuation of the cylinder is needed to be precise.

II. BACKGROUND

For a spool type directional control valve, direction of the oil flow is determined by the relative position of spool with respect to sleeve holes. A spool type 4-way 3 position directional control valve was developed and tested after putting it in tractor hydraulic system and field trial was taken successfully. This paper reports for the design of the stated valve using different design tools like 3D CAD, CAM and subsequently it was also analyzed using CFD for performance evaluation before testing it in an actual system to verify different aspects of a product, such as manufacturability, weight and cost and functional aspects. The components for this valve thus designed can be easily manufactured in a simple machine shop without need of any special arrangement or machines which ultimately gives a low-cost product for application in tractor hydraulic system. **[1]**

In this paper they studied, flow forces acting on the spool rise mainly with increasing volumetric flow rate. The driving system should be able to overcome these forces if a fast valve opening is wanted. The peak value of the flow force increases with increasing pump flow rate, but its position remains fixed. Choosing a valve to a specific application is not only dependent on the valve function ports. The proposed solution

 DOI : 10.35291/2454-9150.2021.0466

has been verified by experimental test on prepared test stand, similar to the Wheatstone bridge circuit concept. The performance of proportional directional control valve used should be checked experimentally and compare its results with documents. The proposed controller provides performance of the PD controller for high-speed control.**[2]**

In applications for which large forces are required, often with a fast response time, it is inevitable that oil-hydraulic control systems i.e. fluid power will be called on. Fluid power systems also have the capability of being able to control several parameters with valves, such as pressure, speed, and position, to a high degree of accuracy and at high power levels. **[14]** Hydraulic spool valves are found in most hydraulic circuits in which flow is to be modulated. Therefore, their dynamic performance is critical to the overall performance of the circuit. Fundamental to this performance is the presence of flow reaction forces which act on the spool. **[17]** From their research, they found that when the fluid flows through the valve there will be induced forces acting on the valve. The response of the spool displacement has a significant effect on the fluid flow and pressure. **[16]** The liquid stream flowing through the directional valve causes hydro dynamic response according to the principle of conservation of momentum. Liquid pressure acting on the spool surface affects the forces balance of valves pool as well. **[3]**

The present work is conducted to study the performance of hydraulic control system and the designer of electro-hydraulic control circuit contained hydraulic directional control valve size type. The analysis of the system is used to find the mathematical model to the electro-hydraulic system and a nonlinear analysis for the system for three position spools to proportional directional control valve. The theoretical results of the control system were developed using the MATLAB/SIMULINK to simulate the system and drawing the results as a step response. This paper, the researchers developed a unified model for proportional control valves and analyzed the effect of spool lapping on open – loop hydraulic system properties. The flow rates are expressed as a continuous but nonlinear function of lapping parameters, as well as other conventional parameters. **[4]**

III. CURRENT TECHNOLOGY

Directional Control Valves

Directional control valves have been commonly referred to as switching valves because they simply direct or "switch" fluid passing through the valve from the source of flow to one of a selection of available cylinder ports. The flow control variety of valve generally selects an orifice which only allows a specified volume of flow to pass. The specified volume controls the speed of a cylinder or hydraulic motor. Likewise, the pressure control type is used to select a particular pressure setting.

Changing direction, flow or pressure during machine operation with these valves would require a separate individual valve for each direction, flow or pressure desired. The hydraulic circuit would become quite complex very quickly. **[15]**

Proportional Valves

The technological solution to these more complex circuits has been the development of proportional valves. These revolutionary valves allow infinite positioning of spools, thus providing infinitely adjustable flow volumes. Either stroke-controlled or force-controlled solenoids are used to achieve the infinite positioning of spools. **[15]**

This variable positioning allows spools to be designed with metering notches to provide flow/speed control as well as directional control functions all in one valve, instead of requiring separate valves for direction and speed. The other major benefit is when the circuit requires more than one speed. The various speeds are achieved by changing the electrical signal level to deliver the flow/speed required. No additional hydraulic components are required! These proportional directional valves are controlled by DC power. **[15]**

The proportional controls, used with their associated electronic controls, also add the desirable features of acceleration and deceleration. This offers a variety of machine cycles, safely operated at greater speeds, yet with controlled start and stop characteristics. Regulated acceleration and deceleration result in improved machine overall cycle times and production rates. **[15]**

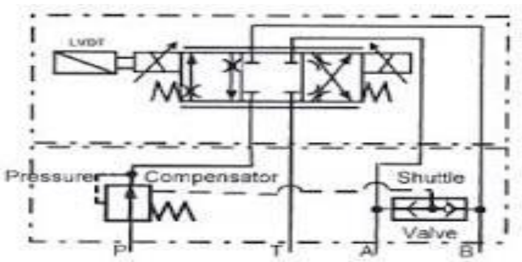

Fig. 1 Direction Control Valve

Many proportional valves are modified versions of four-way, on/off solenoid valves in which proportional solenoids replace conventional solenoids. In operation, solenoid force is balanced by spring force to position the spool in proportion to the input signal. Positioning accuracy can be improved by removing the centering springs and adding a positioning sensor to the end of the spool. The sensor signal then cancels the solenoid signal when the spool reaches the specified position. **[13]**

Proportional valve parts are built to be interchangeable; thus, the spool in low-performance valves can have considerable overlap in the null position. This overlap causes flow dead band, which is not critical for flow-control systems but can cause errors and instability in positioning systems. **[13]**

However, a definite trend in the valve industry is the increasing difficulty in differentiating between servo and

 DOI : 10.35291/2454-9150.2021.0466

ISSN : 2454-9150 Special Issue – NCITTATME'21

proportional valves. Historically, proportional valves could not match servo valve performance and were primarily used in open-loop applications. They were mass produced, while servo valves required meticulous manufacturing and fit-up, making them up to ten times more expensive. Proportional valves also had wider clearances, making them more forgiving and more tolerant of contamination. However, such definitions no longer hold in many cases. **[13]**

For example, closed-loop proportional valves are available that function much like servo valves. By using high-force, continuous-action solenoids, minimum-friction mechanical moving parts, and rapid-response electronics, the valves offer servo like performance without drawbacks like contamination sensitivity and high pressure drop. A key feature in the valve is a spool and sleeve assembly with no overlap in mid position. While this requires precise manufacturing, it is less costly than other servo designs. **[13]**

The valves control flow or pressure, or actuator position, velocity, force, or torque, and can synchronize the action of a number of cylinders. They are suited for applications such as press systems and moulding machines, for traditional servo markets like flight simulators and airframe testing, and for those areas currently using proportional systems that need to further upgrade performance with a closed-loop system. **[13]**

Some manufacturers are producing proportional valves that are essentially servo valves made to mass-production specifications, with much greater tolerance allowances and looser fits than in their standard servo line. However, adding electronic feedback results in performance almost as good as that of a servo valve. In many cases, this gives performance perfectly suited to an application at a lower cost.**[13]**

Servo Valves

The third type of hydraulic directional control technology is the servo valve**.** Servo valves are not a new technology as servo valves were first used in the 1940s. Servo valves operate with very high accuracy, very high repeatability, very low hysteresis, and very high frequency response. Servo valves are used in conjunction with more sophisticated electronics and closed loop systems. As a result, servo valves are always much more expensive. A proportional control valve system can be used to improve control of most machines without the high price tag of servo control systems. **[15]**

Quality Hydraulics & Pneumatics, Inc. offers design, products and systems for all three types: directional, proportional and servo valve control systems. The Certified Fluid Power Specialists at Quality Hydraulics will assist you in selecting the best component, with the most efficient and cost-effective solution. **[15]**

Many proportional valves are modified versions of four-way, on/off solenoid valves in which proportional solenoids replace conventional solenoids. In operation, solenoid force is balanced by spring force to position the spool in proportion to the input signal. Positioning accuracy can be improved by removing the centering springs and adding a positioning sensor to the end of the spool. The sensor signal then cancels the solenoid signal when the spool reaches the specified position. **[13]**

Proportional valve parts are built to be interchangeable; thus, the spool in low-performance valves can have considerable overlap in the null position. This overlap causes flow dead band, which is not critical for flow-control systems but can cause errors and instability in positioning systems. **[13]**

However, a definite trend in the valve industry is the increasing difficulty in differentiating between servo and proportional valves. Historically, proportional valves could not match servo valve performance and were primarily used in open-loop applications. They were mass produced, while servo valves required meticulous manufacturing and fit-up, making them up to ten times more expensive. Proportional valves also had wider clearances, making them more forgiving and more tolerant of contamination. However, such definitions no longer hold in many cases. **[13]**

For example, closed-loop proportional valves are available that function much like servo valves. By using high-force, continuous-action solenoids, minimum-friction mechanical moving parts, and rapid-response electronics, the valves offer servo like performance without drawbacks like contamination sensitivity and high pressure drop. A key feature in the valve is a spool and sleeve assembly with no overlap in mid position. While this requires precise manufacturing, it is less costly than other servo designs. **[13]**

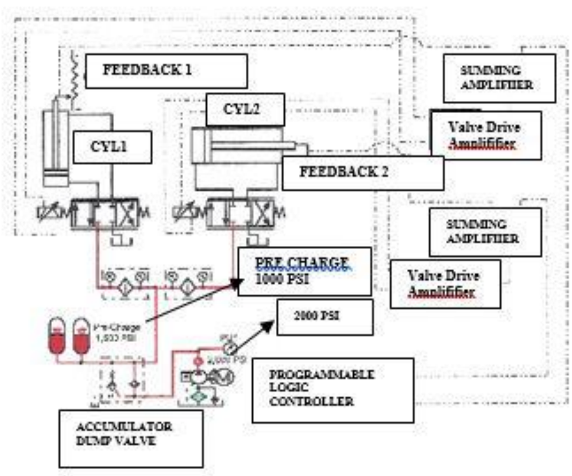

Fig. 2 Servo Valve Circuit.

The valves control flow or pressure, or actuator position, velocity, force, or torque, and can synchronize the action of a number of cylinders. They are suited for applications such as press systems and moulding machines, for traditional servo markets like flight simulators and airframe testing, and for those areas currently using proportional systems that need to further upgrade performance with a closed-loop system. **[13]**

DOI : 10.35291/2454-9150.2021.0466

Some manufacturers are producing proportional valves that are essentially servo valves made to mass-production specifications, with much greater tolerance allowances and looser fits than in their standard servo line. However, adding electronic feedback results in performance almost as good as that of a servo valve. In many cases, this gives performance perfectly suited to an application at a lower cost.**[13]**

IV. METHODOLOGY

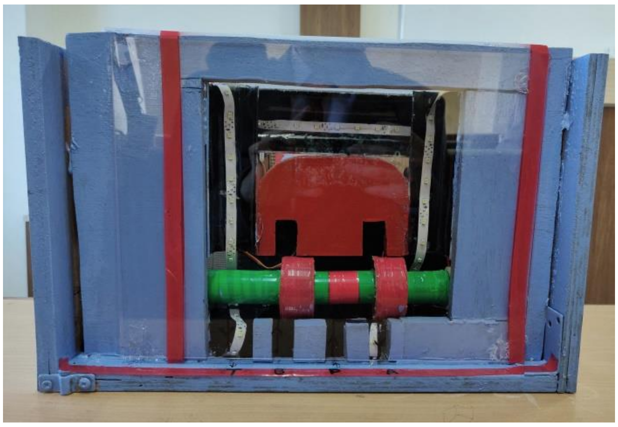

Fig. 3 Cut section of 4*3 DCV.

The idea was to run the DCV without the inlet pressure of the fluid and so motion of spool was controlled by motors.

Case:

The material of the outside case was chosen to be wood as it was sturdy and manufacturing processes became simpler. Aluminium and mild steel were discarded because of weight factor and fabrication difficulties. Small parts were cut as per requirement as per the actual cut section of a 4*3 DCV.

Spool:

Spool is the part which directs the fluid into the system. The spool was made of pipes of varied cross-sections and joined together. These were then connected to the motors attached to them.

Firstly, the spool was made and then according to the length of the spool the case was designed so that the spool will move effectively inside it. The motors were then mounted inside the casing which would direct the spool to the left or right. Micro-controller was attached to the motor and programmed accordingly. The left and right motion of the spool is controlled by switches.

V. WORKING

The normal 4*3 DCV works because of the inlet pressure of the fluid or another way is by using solenoids which would open ports as per the electrical instructions. These can cause jerky movements in between because of the inlet fluid pressure and the motion of spool won't be smooth. To overcome these problems the spool in the DCV can be electronically moved with the help of servo motor. Our project will showcase this electronically working of a 4*3 DCV. The entire project is supplied with external power source of which is then stepped down for the microcontroller. Here microcontroller is controlling the speed and the motion of the spool. The spool and the motor are connected via a wire attached to the arm of motor. Initially this arm of the motor is at 90º angle with the spool in its initial position. This DCV can perform 3 positions of the actuator, Extension Retraction and pause position. The spool moving to right will allow the extension of actuator connected to the DCV and spool when moving left will indicate the retraction of the actuator connected to the DCV. These left and right movements are controlled by spring actuated switches (works only when pressed and kept pressed). Two switches are used for this, one for the extension stroke of the actuator and another for the retraction stroke.

The digital signals are provided by the microcontroller. Microcontroller understands the language of 1 and 0 or high and low. The switches connected to the Spool gives these signals to the microcontroller in the form of digital signals. These signals are sent to the motor attached to it. Initially the arm of motor was at 90º angle as mentioned, when the extension switch is pressed, the arm moves towards its right hence pushing the spool towards the right and making way for the fluid to enter. As soon as the switch is released, the spool comes to its normal position. At the end of the spool on both the side there is switch attached to it which is connected to the LED lights. As the Spool moves towards the right, the space created for the fluid for entering is lighted with these LED's.

In the same way retraction stroke works, but this time the motor arm is pulled towards it's left and hence the spool is pulled towards the left, hence making vacant space in the right where again the LED's will start glowing so as to show the fluid has entered.

Hence, this can also reduce the jerky motion of the spool as the inlet pressure of the fluid doesn't create any impact on the spool.

VI. CONCLUSION

The current technology is great for low precision demanding applications like boat steering and earth moving. But for precise jobs like material handling and automated logistical management systems these valves fail to reach required levels of accuracy. Our solution provides for a cheap and optimum replacement for the servo and proportional valve.

Also this is programmatically controlled and hence gives the user a scope of alterations in the levels of rate of spool movement based upon the changes in type of load or application.

REFERENCES

[1]. Subrata Kumar Mandal, Bibhuti Bhusan Ghosh, Ashok Kumar Prasad, 'Design of a spool type 4-way 3 position directional control valve for use in tractor hydraulics system',

 DOI : 10.35291/2454-9150.2021.0466

CSIR-Central Mechanical Engineering Research Institute': - ISSN 2277 – 9442.

[2]. Paswan, Ramashankar, Jayanta Das, N. Kumar, Ajit Kumar, Santosh Kumar Mishra, and Kumar Sujit. "Performance Analysis of Directional Control Valve: An Overview", Applied Mechanics and Materials, 2014.

[3]. www.ejournals.eu

[4]. ijiet.com.

[5]. www.engineersedge.com

[6]. D. M. Kim, S. C. Kim, D. K. Noh, J. S. Jang. "Jerk phenomenon of the hydrostatic transmission through the experiment and analysis", International Journal of Automotive Technology, 2015.

[7]. Hirohisa Tanaka, Electro-hydraulic PCM Control, The Journal of Fluid Control, 1988(17) 2: 34~46

[8]. Wang Xuanyin, etc, Fluid modulation technology and its application in fluid servo control, MACHINE TOOL & HYDRAULICS, 2000(4):7~9 (in Chinese)

[9]. Wang Xuanyin, Yue Jiguang, The Theoretical Analysis and Experimental Research on The Pneumatic Servo System with Generalized Pulse Code Modulation, JOURNAL OF ASTRONAUTICS, 1999(2) (in Chinese)

[10]. Wang Xuanyin, et al, The Theoretical Study of Hydraulic Position System with Pulse Code Modulation Control, Journal of Zhejiang University (natural Science), Vol.31, Supplement, 1997: 381~385 (in Chinese) [5] Li Hongren,

[11]. Hydraulic Control System, Peking, National Defense Industry Publish, 1986 (in Chinese) [6] Chintae Chot and

Jong Shik Kim, Robust Control of Positioning System with a Multi-step Bang-Bang Actuator, Mechatronics Vol.6, No. 8: 867~880, 1996, Elsevier Science Ltd [7]

[12]. Lawrence Perko, Differential Equations and Dynamical System, Springer, 1998 [8] Wu Qi, Automatic Control Theory, Tsinghua University Publish House, Peking, 1992: 270~297 (in Chinese)

[13]. www.machinedesign.com

[14]. Submitted to Atlantic International University.

[15]. https://www.qualityhydraulics.com

[16]. William W. Ni, Steven Heitz, Daniel Bartholme, Michael Cass. "Compensation Force CFD Analysis of Pressure Regulating Valve Applied in FMU of Engine and System Controls", SAE International Journal of Aerospace, 2011

[17]. ecommons.usask.ca

 DOI : 10.35291/2454-9150.2021.0466