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OVERVIEW OF DIRECTION CONTROL VALVE WITH VARIOUS METERING NOTCHES

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ABSTRACT

Present era provides us with high end technology but these high end technology also associated with high cost which many a times not justifiable. One such area is hydraulics systems in the machines. Many high end technologies like proportional valve and servo valves are developed which can provide the accurate controls on the processes as per the requirements. Still many machines in the industry are with conventional technologies. So there is a need for some low cost systems for specific application in the areas like injection molding and die casting. In this review literature survey is done to check the modeling of direction control valve and other hydraulic valves. Also the experimental results of various literatures are studied. The review paper outlines the theoretical background of Metering notches in the Direction control valve. Hydraulic set up outline diagram is drawn and Equipments required are listed with future scope, to analysis the effect of various metering notches with different viscosity fluids.

KEYWORDS: Metering Notches, Direction control valve, Spool, Volume flow characteristics, Pressure, Viscosity.

INTRODUCTION:

Technology revolution in mechanical industries has resulted in development of new systems and replacement of the methods in order to enhance the productivity and performance. The hydraulic systems have developed to work with the dynamic requirements. CFD analysis has made it possible to design and develop the solution with flexibility of design parameters. The control of liquid flow is effectively done with the help of control valve. Simulation is one of the effective tools in design of mechanical systems.

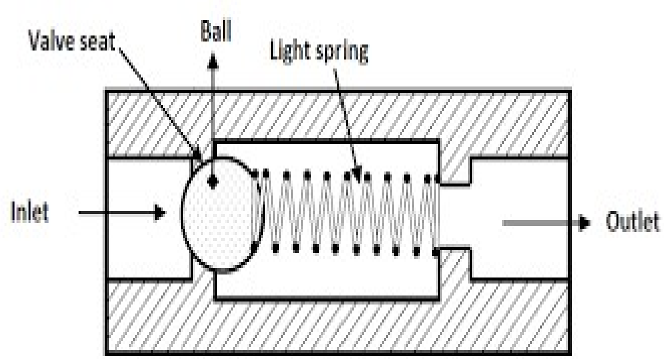


Fig.1: Representation of a Direction Control Valve

The basic valve representation is shown in above diagram. The spring controls the motion of fluid from inlet to outlet.

LITERATURE SURVEY

Authors have studied the research presented by various researchers as below

Table 1: Literature Review

Sr. No.	Paper Details	Key Points Discussed
1	Modelling of Hydraulic spool valves with specially designed Metering Edges by Marco Simic et.al.	• Modelling approach with Mathematical Expression • Modelling for Metering Notch • Advantages
2	Evaluation of the flow forces on an open centre direction control valve by means of a computational fluid dynamic analysis by R. Amirante et.al.	• Driving forces by Numerical Analysis • Validation with Experimental results • Evaluation of fluid dynamic performance
3	Thermal-Hydraulic Modelling and Simulation of the Hydraulic system based on Electro-Hydraulic actuators by KaiLi et.al.	• Lump parameter model • Thermal Hydraulic modelling • Electro hydraulic Actuators
4	CFD Analysis with fluid structure interaction of opening High pressure safety valves by A.Beune et.al.	• Opening Characteristics • 2 Analysis of Valve Movement • 3 Valve Opening phenomena
5	Design Strategy for improving energy efficiency in series Hydraulic/Electric synergy system by R.Ramkrishnan et.al.	• Storing Regenerated power • Mechatronic system • Basis for zero emission system
6	Theoretical and Practical aspects of the wear of vane pumps, Adaption of a Model for predictive wear calculation by A.Kunz, R. Gellrich et.al.	• Predicting the wear behaviour • Abrasive and Adhesive wear Phenomena • Comparison with experimental results
7	Thermodynamic effects of safety relief valves by A.A. Kendoush et,al	• Experimental Study of Performance • Changes in flow through SRV • Numerical solution based on results
8	A viscosity correction factor for shear-thinning liquid flows in safety valves by D.Moncalvo, L.Friedel et.al.	• Formulation of Reynolds Number • Validation • Recommendation of Generalized Reynolds Number

ANALYTICAL MODELING AND SIMULATION

Analytical modeling is the step towards the designing the complete system. Let us consider the design of 3D model for a hydraulic spool notch. The radial and axial flow of liquid is shown in the models below.

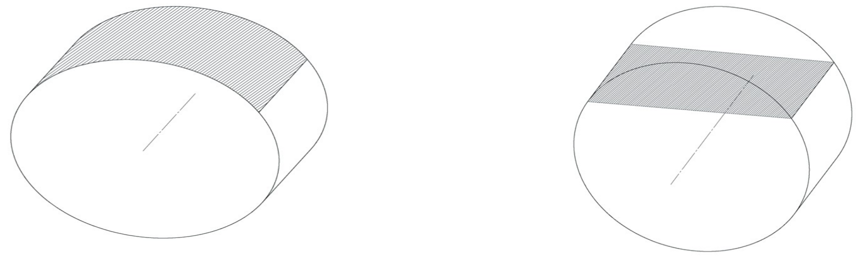
Let,

A = Area of Cross Section

Ar = Radial Area

Aa = Axial Area

Generally in the hydraulic chamber the flow of fluid is initially radial and then axial. The geometry of the system is well understood in following two views.



[a] [b]

Fig.2: Representation of Radial Cross-sectional Area in Curved and Simplified View

The geometry of the flow control metering notch of the spool is shown in figure below.

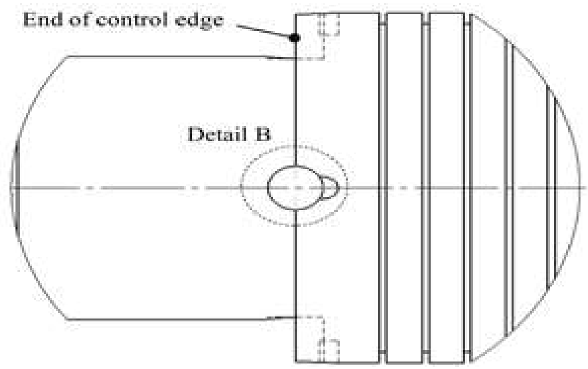


Fig.3: Geometry of the Flow Control Metering Notch

MATHEMATICAL MODELING

Mathematical Modeling for Direction Control Valve Spool:

Operation of directional control valve has been examined in the hydraulic system, the schematic diagram of which is shown in Figure. Hydraulic cylinder 4 is assumed to be working element. The system is supplied by a fixed displacement pump of capacity QP. The pump is connected with a hydraulic directional control valve by means of the conduit with volume V capacity Qp1 and pressure p [6].

This line is characterized by constant volumetric elastic modulus B1. At the output of the directional control valve and the inlet of the hydraulic line having a volume V2 and equivalent volumetric elastic modulus B2, flow is Q. Pressure in this line is p2. The liquid of flow rate Q flows into the hydraulic cylinder and flows out of flow rate Q3 to the hydraulic line V3 with an equivalent volumetric elastic module B. In this line, there is pressure p. The cylinder load is simulated by means of pressure relief valve 6. On energizing the solenoid 3, pilot valve 1 gives pressure into control chamber of the spool initiating the process of moving the spool and allowing the flow of fluid in the system.

It is assumed that the system is in thermal equilibrium, and the mass of the liquid is concentrated in specific points of the system, that is, the valve spool, the individual sections of the line and the rod (and the piston) of the cylinder. The pressure in the drain line is omitted. Under these assumptions, the mathematical model will constitute the differential equations for the valve spool movement and cylinder piston rod movement, equations of flow continuity and the principle of conservation of momentum as well as equations of flow through the slot and performance curves of pressure relief valves [1].

We will be calculating volume flow rate for various metering notch design by using flow equation:

$$Q = \alpha_D \, . \, A \, . \sqrt{\frac{2.\Delta P}{\rho}}$$

In this Equation –

Q- Flow in LPM
α_D—Coefficient of Discharge or Contraction
Δ P—Pressure Drop across the valve
ρ—Density of fluid

α_D—Coefficient of Discharge or Contraction- Coefficient of discharge can be calculated from following equation

$$\frac{A_1 A_2 \sqrt{2gh}}{{A_1}^2 - {A_2}^2}$$

Where A1 and A2 are the Notch area and output Orifice Area
h — Pressure Head
In this project we will be considering this for Different Metering Notch areas.
ρ—This we can get for Different Fluids
Δ p – maintaining as measured for the standard spool

The Reynolds number is defined below for each case.

$$Re = \frac{\text{Inertial forces}}{\text{Viscous forces}} = \frac{\rho u_m D}{\mu} = \frac{u_m D}{\gamma}$$

Where:

1. u- is the velocity (m/s)
2. D is a characteristic linear dimension, (travelled length of the fluid; hydraulic diameter when dealing with river systems) (m)
3. μ is the dynamic viscosity of the fluid (N·s/m²)
4. v is the kinematic viscosity (m²/s)
5. ρ is the density of the fluid (kg/m³).

Dimensional Analysis Yields
π1= f (π2, π3')

$$\frac{\Delta P}{\rho U2} = f\left(\frac{L}{D}, \rho UD/\mu\right)$$

Experimental Setup:

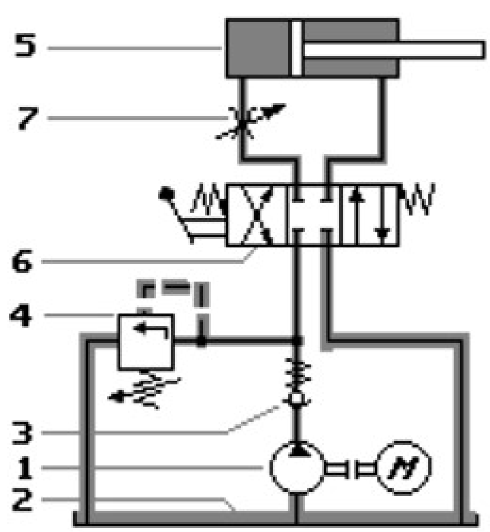


Fig.4: Experimental Setup

In this case checking the flow as per the variation in metering notch area.
The independent variables are as below:
1 Metering notch area
2 Viscosity of oil
3 Density
4 Spool displacements

Dependent variable:
1. Pressure difference –This we are going to maintained constant as per the standard valve pressure difference.

2. Temperature.
Comparing the output flow of the valve with respect to all the independent variable. This will give us flow characteristics in comparison with the standard valve.

Observations-
1. S-1- Standard spool
2. M-1- Modified Spool-1
3. M-2- Modified Spool-2
4. M-3- Modified Spool-3
5. Hydraulic Oil (Castrol 32, Castrol 46, Castrol 68)
6. Spool Displacement (0.5, 1, 1.5, 2.0, 2.5) mm

Proposed Data Analysis approach:
Comparing the flow characteristics of standard spool with different spool area and displacement at different flow conditions is necessary. With this we can arrive at particular area where we will get the desired characteristics.
Result validation: Validate the result with the mathematical model for particular flow condition.

CONCLUSION

Standard valves available in the market are designed with standard spool metering notch areas. In Industries there are application which needs very fine controls which today is done by using advance technologies like servo valves and Proportional valves.
The report imposes that the metering notches with various areas may give rise to a combination which may be suitable for particular application like in the field of Injection Molding and Die Casting. Also one can decide the spool geometry in advance depending on the application. This report focused on Literature survey and Mathematical Modeling for Direction control valve flow with various metering notch area.
This report also discuss about the Mathematical Modeling and Experimental setup required for performance testing on the spool of an open center ON–OFF hydraulic directional control valve. The Mathematical analysis has been realized in order to explain some fluid dynamic phenomena described in a previous work and evidenced by an experimental investigation. Gantt chart and Observation table to make along with parameters to be compared.

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