Fănel ȘCHEAUA

CFD ANALYSIS FOR HYDRAULIC FLOW RATE CONTROL DEVICE

Abstract: *The hydraulic drive systems are currently used on most construction and agricultural machines, but also for stationary industrial hydraulic applications. This actuation uses the method of energy transmission through the working fluid which is a mineral oil in order to achieve the equipment working tool actuation. In the composition of a hydraulic circuit in addition to primary elements represented by pump, motor or distributor enters other components that ensure the modification of fluid flow rate or pressure values at a certain time. The fluid flow rate control within the hydraulic circuit can be achieved through the adjustable throttle devices. In this paper it is described the construction and working process of an adjustable throttle device. To highlight the fluid dynamics inside the adjustable throttle model a computational fluid dynamics (CFD) analysis was performed using ANSYS CFX software. A fluid region was defined inside the device body while the spherical type closure element is modifying the circulated fluid flow rate.*

Key words: *variable throttle device, flow rate control, fluid flow analysis, hydraulic drive, 3D modeling.*

1. INTRODUCTION

The use of a working fluid through which the energy is transmitted in a circuit is generically referred as hydrostatic drive.

This actuation type is used in the composition of the different equipments to ensure the movement of working bodies.

During the last period they were developed powerful applications in stationary and mobile hydraulics based on hydraulic circuits made up of specific elements such as motors, pumps and special devices meant to achieve the modification of fluid flow rate and pressure values which are customized for each application.

Thus, in time were achieved diverse ranges of devices that may be applicable to various fields of use.

For example, on a basic structure of positive displacement pump a component may be added in order to modify the volumetric capacity and can be used in a fixed industrial hydraulic machine actuation or mobile equipment used in the construction industry or in agriculture.

In addition to the primary components of the circuit represented by hydrostatic pump, motor or distributor various devices are being used in order to perform the adjustment of pressure or flow rate values for the circulated working fluid during operation.

Flow rate control devices are represented by throttles, valves or hydraulic resistances commonly used to change the amount value of working fluid circulated through the ducts of hydraulic circuit.

In a more complex form, when they are part of a specialized device that contains multiple components that interact in achieving flow rate adjustment these devices are called resistive flow controllers [8], [9].

An adjustable throttle model is described in this paper in order to highlight the working principle of this device when connected to the hydraulic working circuit of a specific actuation.

2. THE ROLE OF FLOW RATE CONTROL DEVICES INSIDE HYDRAULIC CIRCUIT

In general, the devices for flow control are being used in a circuit in order to achieve fluid amount adjustment to a consumer at a predetermined value required by the functioning kinematic conditions of the hydraulic system or to maintain the flow rate to a consumer that can be a linear or rotary motor, regardless of the applied load.

The flow rate control can be achieved by changing the sectional flow area crossed by the liquid through the device, adjustment that can be influenced by the working fluid viscosity but also by the fluid working pressure [8].

A schematic representation symbolizing the way in which the momentary flow rate value can be changed by the variable throttle within a hydraulic circuit is shown in Figure 1.

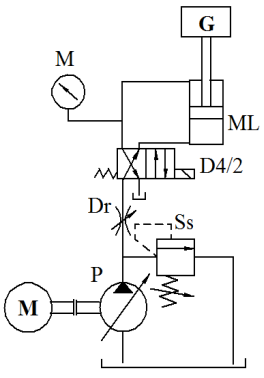


Fig. 1 Variable throttle valve symbolization within a hydraulic circuit

Into the presented circuit the fluid entrained by the pump (P) is restrictively flowing to the distributor. The throttle is used for changing the flow rate value for the working fluid with effect in reducing the piston velocity inside the cylinder resulting the slowing down of attached load to the piston rod.

The throttle (Dr) adjusts the flow value to the relief valve pressure adjustment (Ss). The pressure drop across the throttle can be appreciated by the relationship:

$$\Delta_p = p_1 - p_0 \quad (1)$$

The fluid flow circulated inside the throttle can be appreciated as [1], [2]:

$$Q_1 = \sqrt{\frac{2}{\xi\rho}} A_v \sqrt{\Delta_p} \quad (2)$$

The fluid flow rate circulated through the throttle is dependent on the sectional area of flow, A_v, pressure drop value, Δp, the fluid density, ρ, and the coefficient of load loss, ξ.

For the presented circuit the flow rate modification is achieved by discharging a portion of the total flow circulated by the pump to the reservoir through the valve (Ss) to a settled pressure value.

3. MODEL OF HYDRAULIC THROTTLE UNIT

There are various throttle models that can be used for flow rate change of the working fluid in a hydraulic circuit.

A three-dimensional model of a flow control device was built using Solid Edge V20 software. This model describes a device that can be mounted directly on the hydraulic circuit duct and flow momentarily value adjustment can be achieved with mechanically manual control.

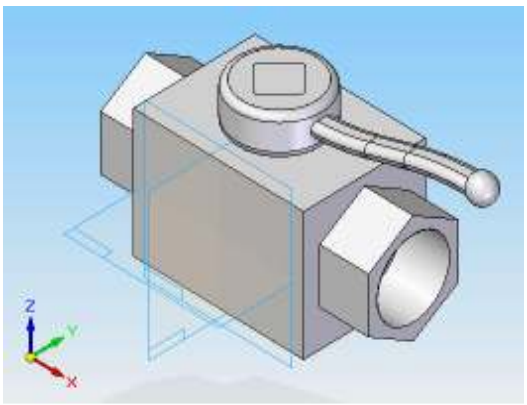


Fig. 2 Variable throttle valve symbolization

The assembly of the variable throttle device three-dimensional model is presented in figure 2.

It can be seen that such a model can be mounted directly on hydraulic circuit duct where it can change the flow section of the working fluid by the rotation of the spherical closing element.

In Figure 3 is represented an exploded version for the adjustable throttle model in order to highlight the assembly components.

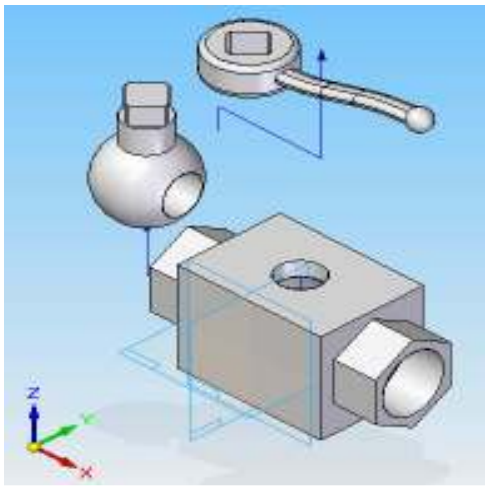


Fig. 3 Exploded view for variable hydraulic throttle device model

4. CFD ANALYSIS OF HYDRAULIC THROTTLE VALVE MODEL

The three-dimensional model of the throttle valve was introduced in a computational fluid dynamics (CFD) analysis using ANSYS CFX software in order to emphasize the operation principle of the throttle device regarding fluid flow rate variation while the spherical element is achieving a rotation motion.

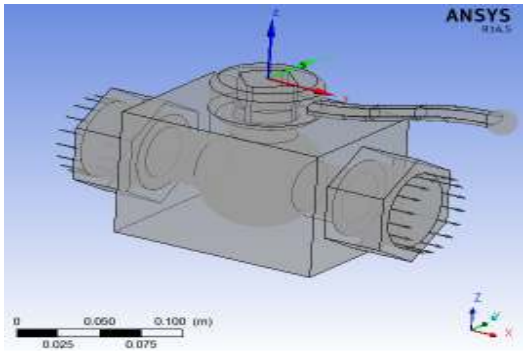


Fig. 4 The imported three-dimensional model for throttle valve in ANSYS CFX

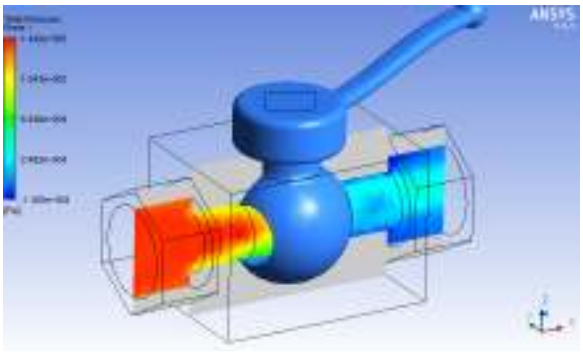
In the initial analysis conditions were established the fluid type as mineral oil, throttle device material as steel and have been declared the fluid region with input and output areas.

The spherical type closure element centrally positioned is declared as immersed solid into the fluid region.

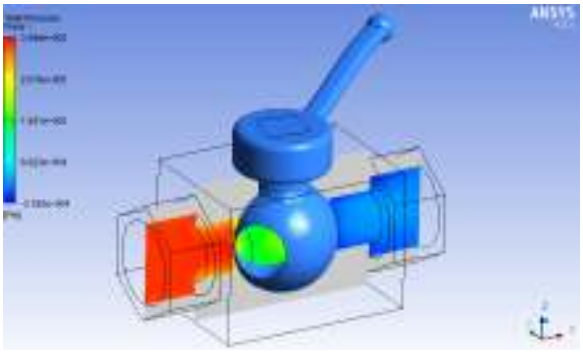
The analysis was declared as transient type with the total time of 0.5 s and calculation steps being settled at 0.1 s.

It was achieved a mesh network for the analyzed throttle device model having 24776 nodes and 116850 triangular elements.

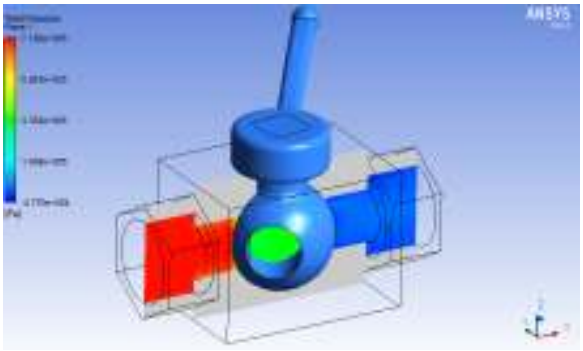
The CFD results are presented in figure 5, regarding total pressure and fluid velocity values within the fluid region on XOZ cutting plane.



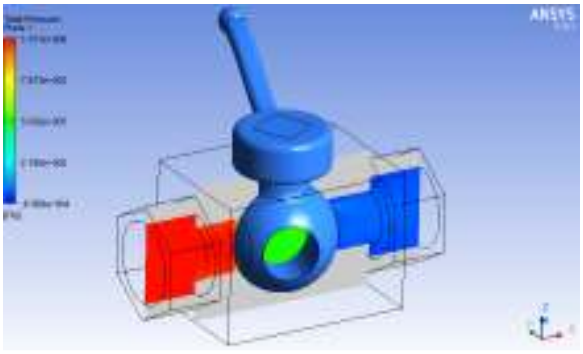
(a) Timestep 1



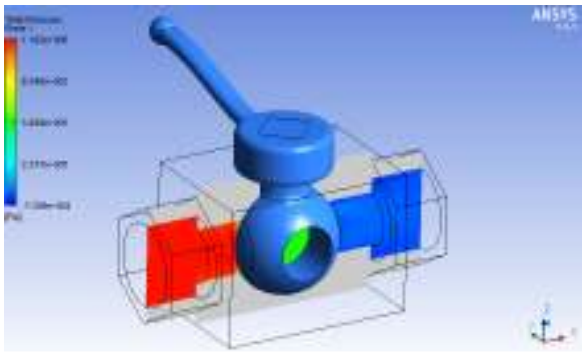
(b) Timestep 2



(c) Timestep 3



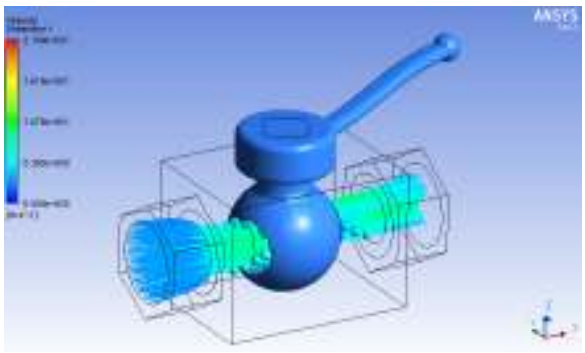
(d) Timestep 4



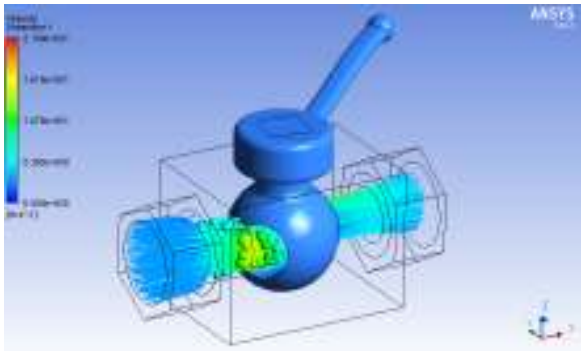
(e) Timestep 5

Fig. 5 The total pressure values obtained on CFX timesteps

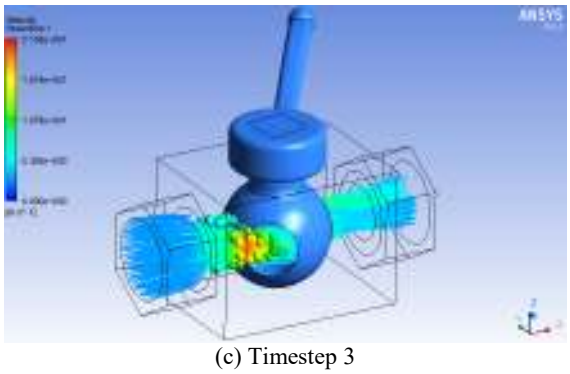
The results obtained for the working fluid velocity inside the throttle device model are shown in Figure 6.



(a) Timestep 1



(b) Timestep 2



(c) Timestep 3

Fig. 6 The results obtained for fluid velocity on CFX timesteps

For the numerical results obtained graphic representations were made, shown in Figure 7, in order to highlight value changes of total pressure in time inside the flow control device.

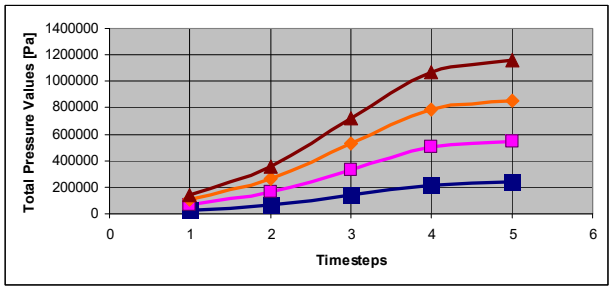


Fig. 7 Graphical representation of the experimental values obtained for total pressure range

5. CONCLUSIONS

An adjustable throttle device model was designed and analyzed in this paper. This model has a spherical closing element which by rotation around its own axis changes the flow area inside the device.

A CFD analysis was performed using ANSYS CFX software to highlight the flow of the working fluid inside.

The results are presented in terms of total pressure and velocity for the working fluid, represented by mineral oil.

Such a device can be used in the hydraulic circuit in order to achieve a modification for circulated fluid flow rate value. A change of fluid flow rate is required when aiming to obtain a reduced velocity for a certain working body which is driven by the linear or rotary hydraulic motor.

In order to protect the hydraulic circuit by high pressure values, safety valves are used which can discharge the fluid surplus to the installation tank (reservoir) when pressure increases above the settled value and opens the valve.

An adjustable throttle device model can be easily operated during circuit operation when the hydraulic installation is working under high pressure values up to 400 [bar].

The majority equipments currently existing from mobile and stationary hydraulic are using hydrostatic actuation type systems that use the potential energy of the working fluid in the form of hydrostatic pressure.

These in contrast to the hydrodynamic systems comply better to stability rate requirements imposed to machine tools, control or reversal conditions and are much simpler from the structural point of view.

REFERENCES

[1] Axinti, G., Axinti A.S., (2008). *Acţionări hidraulice şi pneumatice – Dinamica echipamentelor şi sistemelor*, Editura "Tehnica-Info", Vol III, Chişinău.

[2] Axinti, G., (2008). *Acţionări hidraulice şi pneumatice – Componente şi sisteme, funcţii şi caracteristici*, Editura "Tehnica-Info", Vol I, Chişinău.

[3] Axinti, G., (2009). *Acţionări hidraulice şi pneumatice – Baze de calcul, proiectare, exploatare, fiabilitate şi scheme de acţionare*, Editura "Tehnica-Info", Vol III, Chişinău.

[4] Axinti, G., Nastac, S., Axinti, A., Potirniche, A. (2002). *The analysis of the dynamic response of the hydrostatic driving systems in a closed circuit,* The Annals of "Dunarea de Jos" University of Galati, Fascicle XIV Mechanical Engineering, ISSN, 1224-5618.

[5] Şcheaua, F., (2012). *Assembly design optimization for gear pump hydraulic units*, JIDEG Magazine, Volume 7, Issue no. 1, ISSN 1843-3766.

[6] Şcheaua, F., (2013). *Considerations on fluid dynamics inside a hydraulic seismic energy absorber,* JIDEG Magazine, Volume 8, Issue no. 1, ISSN 1843-3766.

[7] Scheaua, F. D., (2016). *"Functional Description of a Hydraulic Throttle Valve Operating inside a Hydraulic Circuit"*, Hidraulica Magazine, no. 1 (2016): 47.

[8] *http://hydraulicspneumatics.com/200/TechZone/HydraulicValves/Article, accessed at 2016 March 20*

[9] *https://www.boschrexroth.com/productgroups/industrial-hydraulics/valves/flow-control, accessed at 2016 March 21*

[10] *http://dta.eu/hydraulics/hydraulic-valves/, accessed at 2016 March 22*

Author:

Assistant professor PhD Eng. Fănel ŞCHEAUA, "Dunărea de Jos" University of Galaţi, Engineering and Agronomy Faculty of Brăila, Department of Engineering Sciences and Management, Research Center for Mechanics and Technological Equipments - MECMET, e-mail: fanel.scheaua@ugal.ro, tel. 0040749843765.