Functional Description of a Hydraulic Throttle Valve Operating inside a Hydraulic Circuit

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Abstract: *Nowadays the global manufacturers for industrial and mobile equipments offer products containing advanced hydraulic systems by means of which are accomplished the multiple tasks imposed by the designers in a convenient and easy manner. The hydraulic systems are comprised of components of last generation that are able to circulate the working fluid (mineral oil) at high values of pressure and considerable speed through their proper circuit. Besides the hydraulic pump and engine as the primary components of the hydraulic circuit there are also the pressure and flow control components necessary to change the pressure and flow rate parameters of circulated fluid at a specific moment of time. A variable throttle valve operation that can modify the fluid flow rate within the circuit is analyzed in this paper. A 3D model for a variable throttle valve unit was built and introduced into numerical analysis using ANSYS CFX. Based on the defined incoming data the model operation was analyzed and the results are presented in order to highlight how the parameters changes when using the throttle valve within the hydraulic circuit.*

Keywords*: fluid, hydraulic unit, fluidic actuation, hydraulic throttle valve*

1. Introduction

We are witnessing today an unprecedented development of multifunctional machines designed to achieve different heavy works in the fields of construction or agriculture. These works may consist of land digging using the provided bucket, ground leveling using a proper blade, loading various construction materials using the wheel loader with bucket, or different work tasks for agricultural land preparation. The simultaneous fulfilling of these tasks using a single machine is possible by means of multiple working devices that may be coupled to the basic machine. All of these special auxiliary equipments have mounted advanced hydraulic systems which enable them to carry out the tasks for which they are designed. A hydraulic system that works within a construction or agricultural machinery is a complex combination consisting of multiple components fitted together in a working circuit having a fluid as working agent. The primary components of the hydraulic circuit are represented by the pump and motor, but also components for limiting the pressure or flow control, filtering elements for hydraulic agent filtration, coupled by means of flexible or fixed ducts to allow a continuous circulation of the working fluid to accomplish the working process of respective equipments. The working fluid, represented by the mineral oil is the element by means of which the hydrostatic energy is transmitted from the hydraulic pump to the hydraulic motor which finally provides rotational or translational motion to the machine working body. The operation of a hydraulic circuit involves the use of hydraulic throttle valves that are capable of modifying the pressure or flow rate values for the circulated fluid at a specific moment of time, depending on momentary needs at the machine working body on which the hydraulic system is mounted.

2. Hydraulic valve models commonly used within hydraulic circuits

There are many models of pressure or fluid flow rate control devices used in hydraulic circuits. For each model are available a range of nominal sizes function of mounting parameters. The nominal size determines the maximum value of fluid flow rate circulated through the valve and the maximum pressure values inside the hydraulic circuit. The valves can be attached to the circuit using various mounting solutions. The most frequently encountered mounting solutions are the direct installation on pipeline, using the threaded connection, as cartridge, or in-plate mounting.
As hydraulic components the devices used for pressure and flow rate control inside a hydraulic circuit can be classified as in table 1. [5]

TABLE 1

Directional Control	Pressure Control	Flow Rate Control	Electro Hydraulic
Check valves Directional valves	Fixed throttle valve Variable throttle valve	Throttle valve (flow dependent) Control valve (flow independent)	Servo hydraulic valve Proportional hydraulic valve

A check valve mounted inside a hydraulic circuit is making possible fluid circulation in a certain direction and fluid flow blocking in the other direction.
The directional control valves are used as switching valves which can control the start, stop and change in direction of fluid flow.
The pressure control valves are generally used to realize the adjustment or pressure control at a certain value.
The flow rate control of the hydraulic agent (working fluid) during system operation can be achieved when using special valves capable to modify the momentary fluid flow by adjusting the orifices area.
Modern solutions in the field of pressure and flow rate control are represented by electro-hydraulic valves also known as proportional hydraulic valves and servo control valves, which may be used to perform the directional control, pressure control or flow control function.
Directional valves may be direct operated or pilot operated and depends on the actuating force needed to move the control element. It can be said that a directional valve is flow dependent. A direct-operated directional valve can be mechanically, electrically, hydraulically or pneumatically controlled.
When the pressure values of the hydraulic system is high, should be taken into account some losses at the valve level and this is happening when the pressure is over 250 bars. Besides the high values of pressure within the hydraulic system, the losses are determined by the gap size between the control element and the valve body, but also by the viscosity of the working fluid. [5]

3. Modeling aspects for hydraulic throttle valve

A three-dimensional model for hydraulic throttle valve was built using Solid Edge software as presented in Fig. 1. On the model will be declared fluid inlet and outlet and the fluid volume placed inside as fluid region. Inside it is placed the control element having the possibility of translational motion inside on the vertical direction, providing in this manner a variation of fluid flow area at a given time.

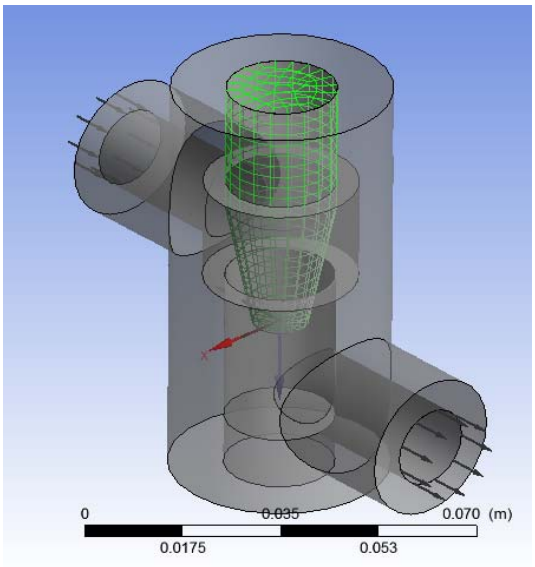


Fig. 1. Hydraulic throttle valve assembly model

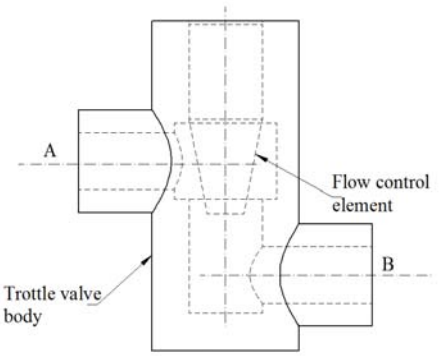
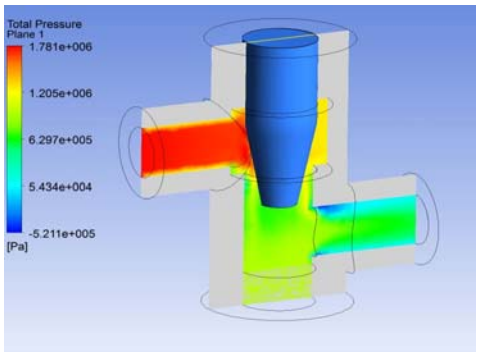


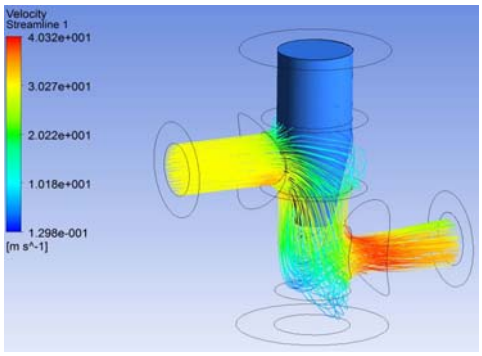
Fig. 2. Schematic representation for hydraulic throttle valve (A – fluid inlet; B – fluid outlet)

4. Computation fluid dynamics analysis for anchoring model

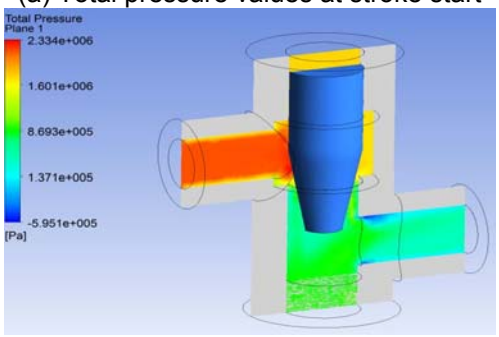
The 3D model was analyzed using ANSYS CFX software to highlight the hydraulic throttle valve operation while the control element is performing a translational motion on the vertical direction. It was declared a fluid velocity at the inlet of 30 m/s, the reference pressure value inside the fluid region was set at 100 bars, valve material body is represented by steel, the flow actuator is stated as immersed solid within the fluid region and it has a speed of 0.01 m/s on vertical (z) direction.



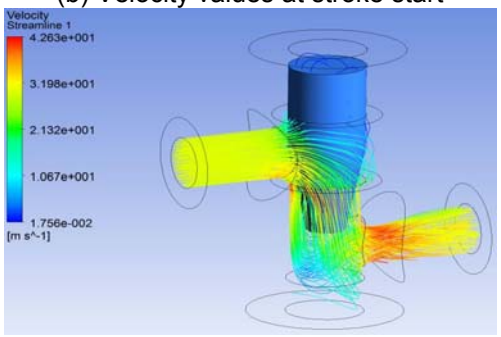
(a) Total pressure values at stroke start



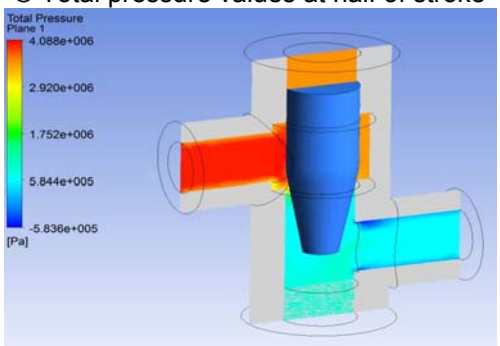
(b) Velocity values at stroke start



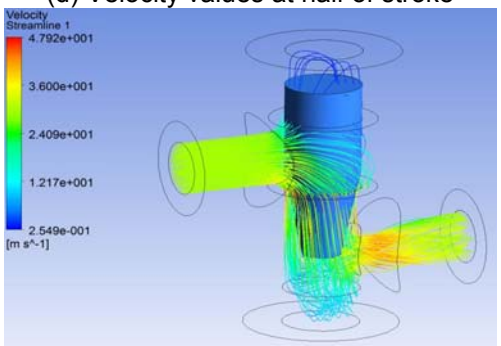
© Total pressure values at half of stroke



(d) Velocity values at half of stroke



(e) Total pressure values at stroke end



(f) Fluid velocity values at stroke end

Fig. 3. The obtained results for hydraulic throttle valve operation

A final report was generated by the program where all information is available regarding the numerical analysis performed on the hydraulic throttle valve model. They were defined three domains (fluid domain, throttle valve body and the flow control element). For each of the domains a mesh was made having the number of nodes and elements as shown in table 2.

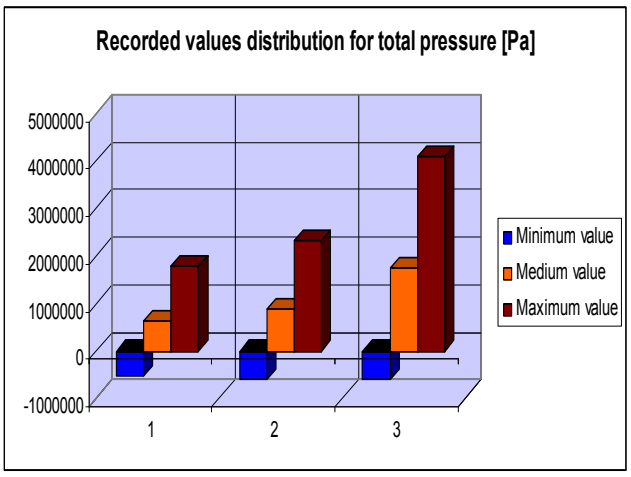
TABLE 2: Mesh information

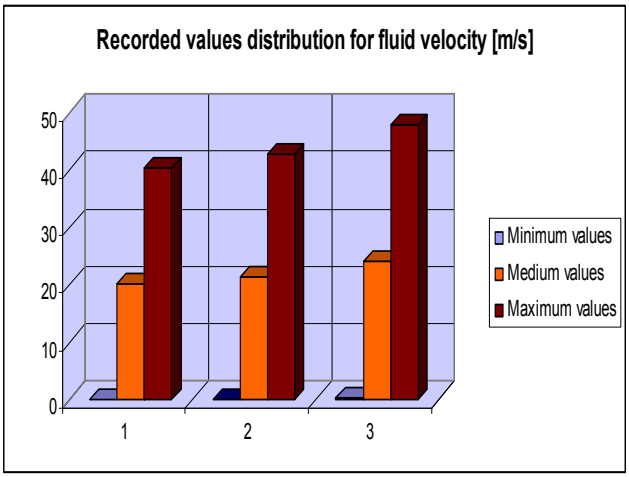
CFX Mesh	Fluid domain	Throttle valve body	Control element
Nodes	3238	4884	1265
Elements	14719	21879	968

The movement of the valve control element is achieved on the vertical direction and the results presents the values obtained for total pressure and velocity within working fluid region. The results are presented with recording values from the stroke start, middle stroke and at stroke end as shown in table 3.

TABLE 3: Values recorded for total pressure and velocity

Position number	Control element position	Total pressure Values [Pa]			Velocity values [m/s]		
		Minimum	Medium	Maximum	Minimum	Medium	Maximum
1	Stroke start	-521100	629700	1781000	0.1298	20.2200	40.3200
2	Half of stroke	-595100	869300	2334000	0.0175	21.3200	42.6300
3	Stroke end	-583600	1752000	4088000	0.2549	24.0900	47.9200





5. Conclusions

A hydraulic throttle valve model was realized and analysed using ANSYS CFX software in order to highlight the fluid flow inside the device body when the valve control element performs a translational motion on the vertical direction. They were presented the values for total pressure and fluid velocity registered inside the fluid region. The role of the control element is highlighted inside the hydraulic throttle valve as the component able to modify the working fluid flow rate inside and downstream from the hydraulic device.

References

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