Aspects Regarding the Special Hydraulic Distributors Operation

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Abstract: *At the beginnings of fluid use as an energy carrier medium inside mechanical systems called hydrostatic drives were not many differences between static or mobile drives because the majority of circuit specific components (pumps, motors) were the same. Lately they were developed highly efficient systems adapted for each application type. This has led to the development of a comprehensive array of different devices, specific to each application. Such devices used within the hydrostatic systems are hydraulic distributors necessary to adjust and direct the working fluid through the working circuit different branches. In this paper are described the hydraulic distributors of special construction which have the adjustment and control element of the working fluid a spherical piece centrally positioned within the body. They were designed and analyzed in terms of the operation principle two distributor models having two and three way. The obtained results are presented in terms of velocity and pressure of the working fluid in the fluid region declared and analyzed for each model.*

Keywords*: hydraulic distributor, fluid flow, 3D modelling, computational fluid dynamics (CFD)*

1. Introduction

The hydrostatic drive uses for energy transmission a working fluid of low compressibility. This constitutes the support through which the energy is transmitted between the power source and the working body of a certain machine or equipment. The energy transmission is carried out continuously by circulating the working fluid between the hydraulic circuit components represented by pumps, piping, distributors, motors, or filters.
The phenomenon of the working fluid flow within the circuit on a permanent or impermanent regime, according to the fluid mechanics laws, is always accompanied by energy losses, greatly influenced by the geometric shape of the flow section and flow regime.
The hydraulic distributors represent special devices that are designed to restrict, direct or obstruct the working fluid flow within the hydraulic circuit. The effect of these distributor sequences are having as effect motion or repose of a hydraulic motor acting a technological equipment working body.

2. Special constructive solutions for hydraulic distributor

The role of a distribution and direction device acting on the fluid in the hydraulic circuit is to ensure the achievement of the working program through the bond achieved with the technological process imposed to the installation by the project.
By means of a directional device in the hydraulic circuit are ensured various functions related to connection and disconnection of one or several motors simultaneously or successively connecting or disconnecting of a circuit or several circuits of or from a hydraulic pressure source.
Directing the working fluid to a receiver of the hydraulic circuit is intended to perform various rotational or translational movements at the equipment working body thereof and the overcoming of technological resistances from the driven equipment.
The most used hydraulic distributors are the drawer models used in both stationary and mobile applications. The working principle of this distributor consists of axial displacement of the drawer inside the device body, through which are realized the connection between the ramifications made inside the drawer and device body. The drawer axial movement is performed by axial forces applied to their ends by means of special command systems which can be hydraulic, pneumatic, and electric or combined (electro-hydraulic, electro-mechanical).
The characteristic parameters of a hydraulic distributor are the drawer nominal size, the connections number, the possible working positions, the positioning system on the drawer neutral position and the switching command systems.

An important feature of the hydraulic distributor is the ratio number of connections/number of positions. The representative states of operation represented symbolically are: open, closed, the choice state - number of positions (figure 1).

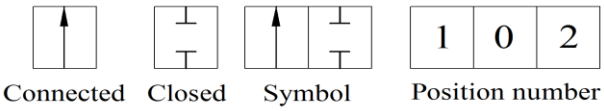


Fig. 1. Symbolization method

In addition to drawer distributors there are special hydraulic distributor models where the distribution of hydraulic fluid is performed by means of a rotational working body, which can be a sphere or a cam.
The distributor models with rotating sphere that may have two or three paths represent a constructive solution used currently in industrial hydraulics. The distribution working body is represented by a sphere provided with internal channels through which the fluid is directed depending on body relative position. At these constructive models the sealing between the sphere and the body is made directly metal on metal, or through the use of special gaskets.
The constructive principle for this particular distributor is shown schematically in figure 2.

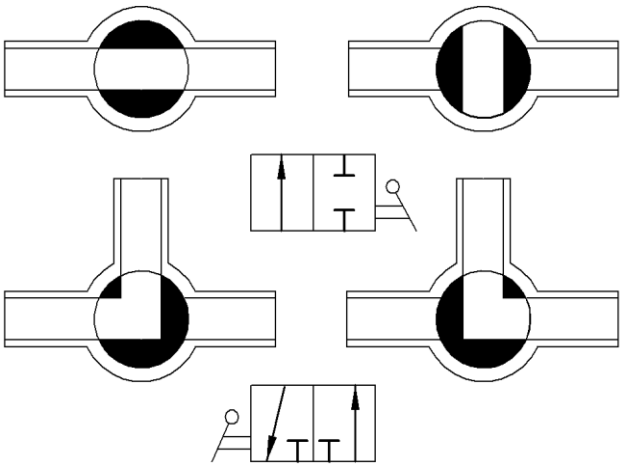


Fig. 2. The principle and symbol of two and three way distributor with spherical rotary piece

For the constructive solution of the two-way distributor shown in Figure 2, the spherical piece has a longitudinal channel through which the fluid can be circulated and according to the relative position to the body can open or close the connection with the working circuit.
The second model presents a constructive solution for the three-way hydraulic distributor which features a spherical piece having an angular channel inside through which is ensured the momentary connection with two of the three distribution lines.
For these constructive distributor types the command is mechanical and can be manually enabled.
Figure 2 presents also the symbolization manner for these devices capable of fluid distribution in a hydraulic circuit.
The required characteristics for the selection of a hydraulic distributor in a particular installation are related to the nominal diameter and the required connection diagram to the hydraulic circuit.
The required diameter can be calculated after being established the limit velocity value regarding the fluid flow through the device in order to have lowest possible load losses: [1]

$$d_n = 10\sqrt{\frac{2Q_c}{3\pi w}} \tag{1}$$

where:
d_n - nominal diameter;

Q_C - fluid flow rate;

w - fluid velocity.

The limit velocity value of the fluid circulated through the distribution devices mounted on the hydraulic circuits is in the range 8-10 m / s.

The real velocity value of the fluid circulated through the distributor can be calculated using the equation: [1]

$$w_r = \frac{200}{3\pi} \quad \frac{Q_C}{d_n^2} \tag{2}$$

In the hydraulic circuit working operation there is a pressure drop across the distributor, which depends on factors such as the flow section shape, the hydraulic fluid nature or temperature. The pressure drop amount can be calculated with the equation: [1]

$$\Delta_p = \xi \frac{\rho}{2} w_r^2 10^{-6} \tag{3}$$

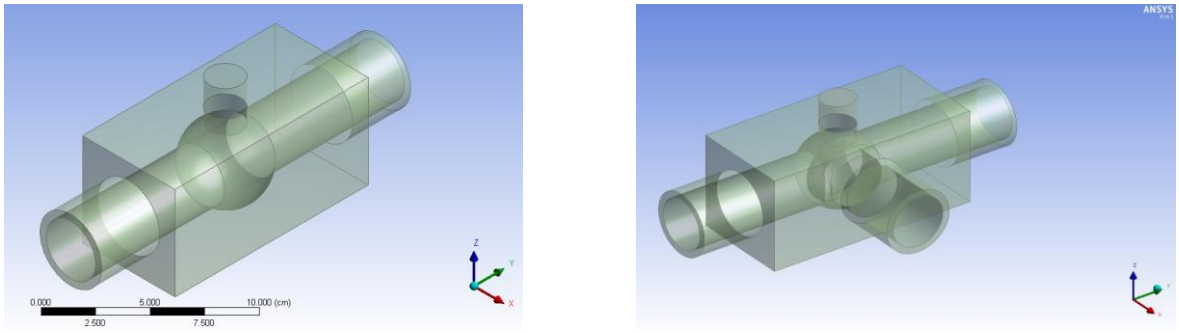
where:

ξ - local losses coefficient;

ρ - circulated fluid density.

3. Hydraulic distributor model analysis

Two distributor models having two and three way, presented in figure 3, have been considered for analysis. Two three-dimensional model assemblies have been constructed for the hydraulic distributors and analyzed using ANSYS CFX in order to emphasize the fluid flow parameters represented by velocity and pressure at the level of fluid region function of spherical piece relative position to the body.



a) Two way distributor model b) Three way distributor model

Fig. 3. Three dimensional hydraulic assembly models

The analysis was performed for each distributor model separately. For two-way distributor model the fluid region was declared within the body having inlet and outlet boundaries and a spherical piece inside capable of rotational motion on OZ axis. The obtained results are shown in Figure 4.

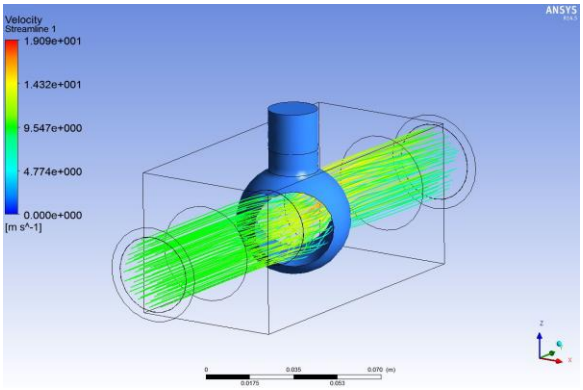
The fluid flow analysis for the three way hydraulic distributor model was carried out from the established initial data for an inlet and two outlets which are sequentially selected by the rotation of spherical distribution piece, positioned within the distributor body.

The results for the three-way distributor model of are shown in Figure 5.

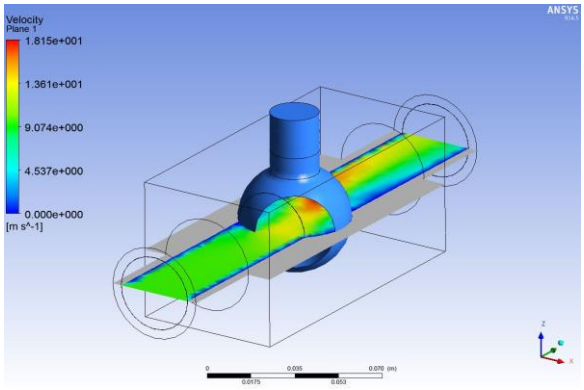
For both models was declared a fluid circulation velocity at the inlet of 10 m/s and the reference fluid pressure across the region being 1 atm.

The working fluid is a hydraulic oil (H60A), having a density of 0.905 g/cm3 and kinematic viscosity at 40 degrees Celsius of 60 cSt. [6]

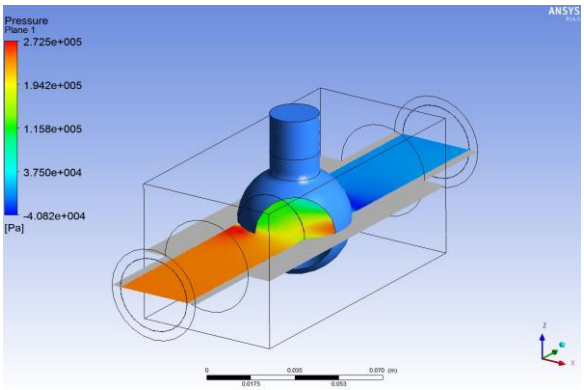
The rotation of the spherical piece has been declared at 0.5 rad/s, and the total flow analysis was of 3 seconds with a time step of 0.3 s.



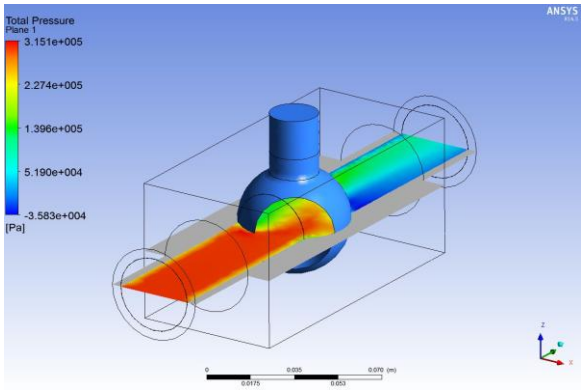
a) Fluid velocity values on streamlines



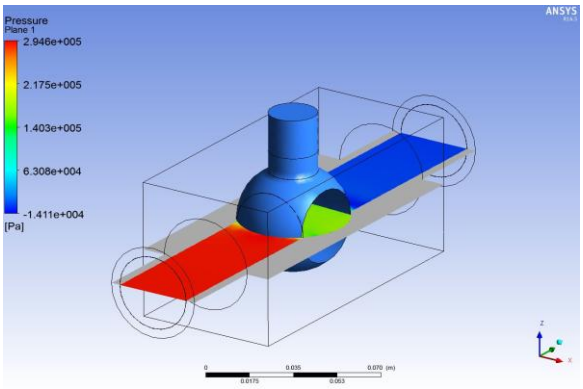
b) Fluid velocity values on XY plane



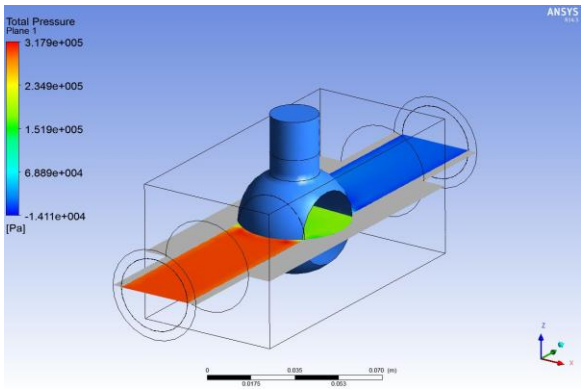
c) Pressure values at half of stroke



d) Total pressure values at half of stroke



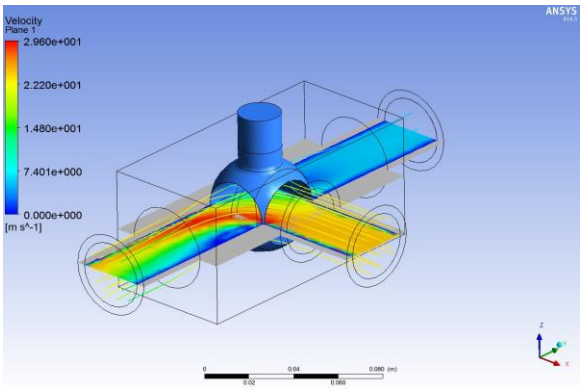
e) Pressure values at maximum stroke

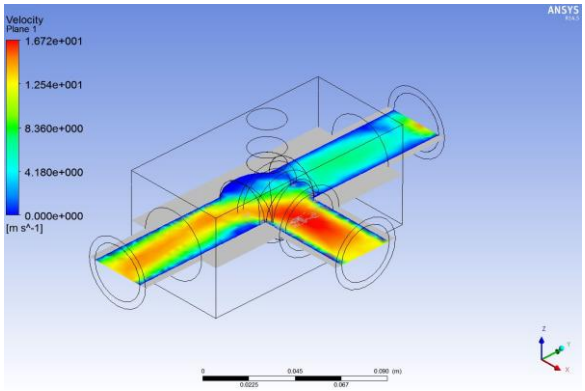


f) Total pressure values at maximum stroke

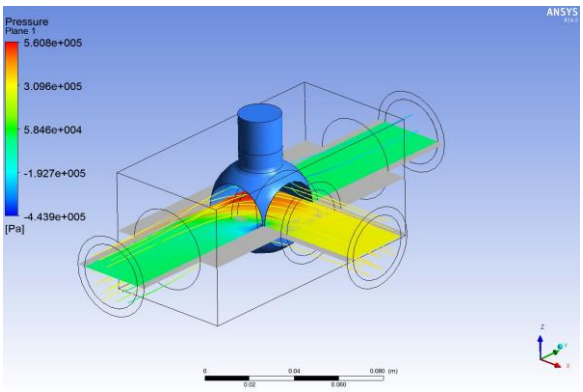
Fig. 4. The obtained results for the two way hydraulic distributor model

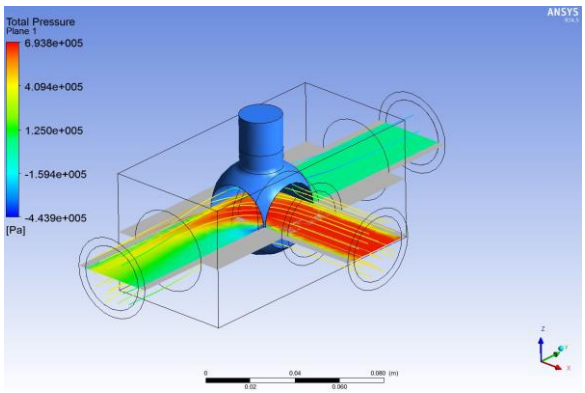
The result values obtained for the working fluid velocity and pressure achieved in the considered fluid region are presented, depending on the spherical piece adjustment position. For the two-way distributor model are shown in Figure 4 the intermediate position set for the spherical piece at half of stroke and at the stroke end, when it is performed the full closure of the flow channel of the working fluid.





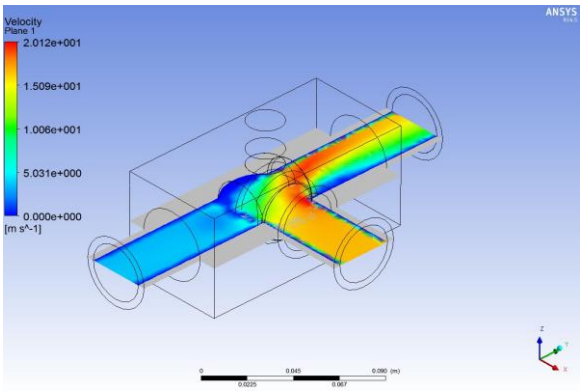
a) Fluid velocity values for circulation on outlet 1

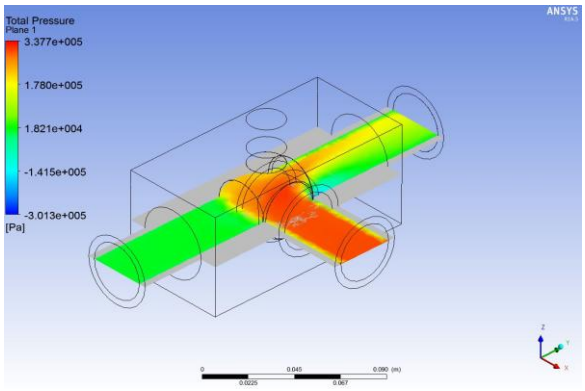




b) Pressure values on the flow outlet 1

c) Total pressure values on flow outlet 1





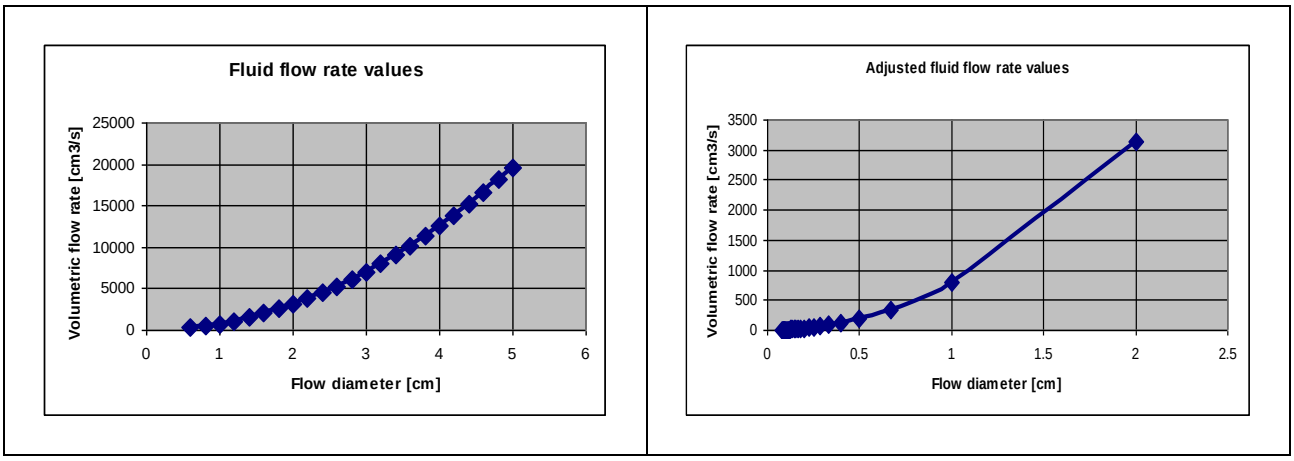
d) The fluid velocity values for outlet 2

e) The total pressure values for outlet 2

Fig. 5. The obtained results for the three way hydraulic distributor model

For the model of the three-way distributor the analysis was performed according to the changing position of the spherical piece within the body so that it can accomplish the sequential connection of the inlet of the working fluid and two outlet ports. The results obtained present the values for velocity and pressure of the working fluid inside the fluid region (Figure 5).

TABLE 1: The diagrams for fluid flow rate and adjusted flow rate values



In Table 1 are presented the results diagrams for the theoretical fluid flow rate values according with the orifices diameter of the distributor model. Also are presented the results for the adjusted fluid flow rate obtained at hydraulic distributor model operation. They have been considered the volumetric flow rate values of fluid circulating through the distributor according with the spherical piece control positions which achieves a full stroke.

4. Conclusions

In this paper were presented and analyzed two special constructive solutions for hydraulic distributor. These are in fact directional regulatory elements for the hydraulic fluid flow in a hydraulic circuit which may be used to serve in practice particular installations.
Two distributor assembly models were designed having two and three way, which were analyzed with ANSYS CFX program in order to highlight the operating characteristics.
The results obtained from the carried out analyzes show the values of the working fluid velocity and pressure created in the fluid region for each model, according with the spherical piece position which achieves control and direction of fluid flow inside the distributor body. The working fluid was declared a hydraulic oil (H60A) used in the practice of hydraulic actuations.
Such devices for which they were built and analyzed virtual models are currently used for various applications in industrial hydraulic involving high levels of working pressure up to 300 bar, with a range of nominal diameters from 6 to 50 mm and ability to work in a temperature range between -30 and +150 degrees Celsius. [7]

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