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INVESTIGATION OF THE MOMENT ON THE CONTROL BODY OF A SYNCHRONISED ADJUSTABLE SWASH PLATES DOUBLE AXIAL PISTON HYDRAULIC MACHINE

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Abstract

In modern volumetric hydraulic drives, swash plate axial-piston hydraulic machines are widely used, which is due to their high-energy consumption and simplicity of design. A significant disadvantage of hydraulic machines of this type is a large insensitivity zone. To solve this problem, a design of a synchronised adjustable swash plates double axial piston hydraulic machine with the possibility of synchronous rotation of swash plates in opposite directions was proposed. The purpose of this work is to research the moment on the control body of a synchronised adjustable swash plates double axial piston hydraulic machine and compare it with the moment on the swash plate of a single-block swash plate axial piston hydraulic machine.

Keywords: Hydraulic machines; Axial piston machines; Synchronised adjustable double swash plates axial piston hydraulic machine; Flow pulsations; Control system; Volumetric hydraulic drive.

1. Object of investigation

The object of investigation in this work is a synchronised adjustable swash plates double axial piston hydraulic machine, which refers to a volumetric hydraulic drive, or rather to a type of swash plate axial piston hydraulic machine. Hydraulic machines of this type have high weight and size characteristics, which simplifies the layout in a limited space of machines [1].

The constructive difference between the synchronized adjustable swash plates double axial piston hydraulic machine and the single-block swash plate axial piston hydraulic machine consists in the presence of two groups of modified piston mechanisms [2], which rely on oppositely arranged swash plates[3].

The synchronised adjustable swash plates double axial piston hydraulic machine regulation is carried out by means of synchronous rotation of the swash plates around the axis passing through the center of the shaft of the hydraulic machine, at a given angle in opposite directions.

Figure 1a on the left shows the synchronised adjustable swash plates double axial piston hydraulic machine [4] with the arrangement of swash plates that provide either the maximum angular speed of rotation of the shaft 5 (in motor mode),

or the maximum flow of working fluid in pumping mode. Figure 1b on the right shows a hydraulic machine with an arrangement of swash plates that provides zero angular velocity (in motor mode) or zero flow of working fluid (in pumping mode).

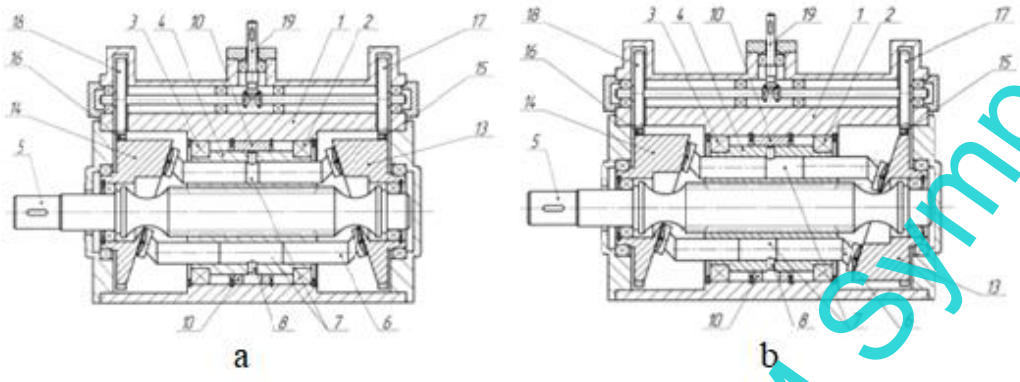

Fig. 1. Synchronised adjustable swash plates double axial piston hydraulic machine

2. The effect of flow pulsation at the moment on the control body of the hydraulic machine

The flow rate in the synchronised adjustable swash plates double axial piston hydraulic machine is regulated by synchronously changing the angle of rotation of the swash plates in opposite directions and is calculated by the formula:

$$Q_s = \omega * F * R * tg\beta * \sum_{i=1}^{n} \left[\sin\left(\alpha + \frac{2\pi}{n}(i-1) + \gamma\right) + \sin\left(\alpha + \frac{2\pi}{n}(i-1) - \gamma\right) \right] \quad (1)$$

$$\alpha \in [0; \pi]$$

where ω is the speed of rotation of the hydraulic machine shaft, rad/s,
F – the area of the piston, m^2,
R – the radius of the cylinder block, m,
β – the angle of inclination of the swash plates, radians,
α – the angle of rotation of the cylinder block, radians,
γ – the angle of rotation of the swash plates, radians,
n – the number of pistons,
i – the piston number.

Figure 2 shows a diagram of the flow rate change Q_s at the speed of rotation of the shaft 104.72 rad/s for synchronised adjustable swash plates double axial piston hydraulic machine depending on the synchronous angle of rotation γ of the swash plates in opposite directions, where the maximum angle is 1.5708 radians, the minimum is 0, and the rotation of the cylinder block α, where the minimum is 0, the maximum is 0.698 radians, so as with n=9, the angle between the pistons is 0.698 radians.

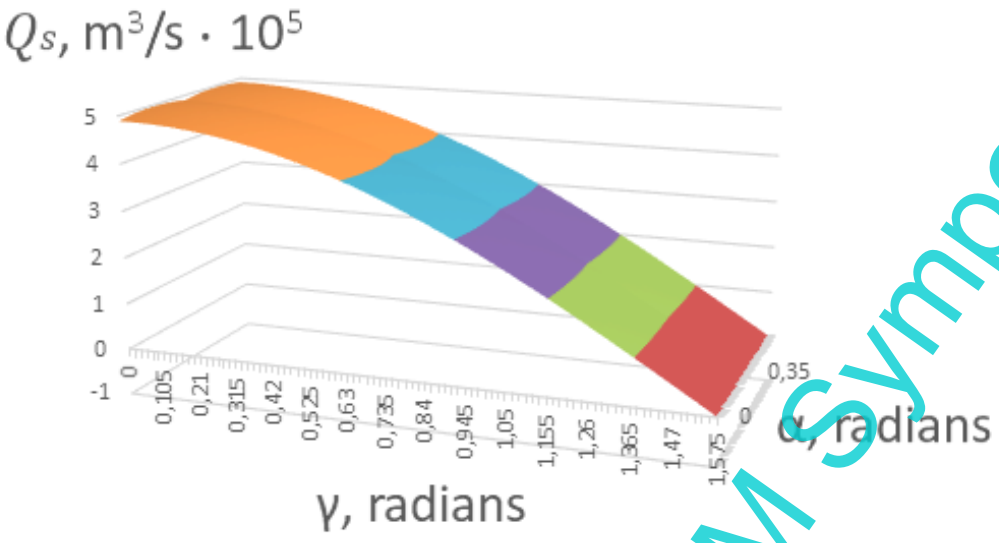

Fig. 2. Flow pulsation in a synchronised adjustable swash plates double axial piston hydraulic machine

Based on the schedule and the calculations made, the flow pulsation for synchronised adjustable swash plates double axial piston hydraulic machine is 1.5192%. This means that for further force analysis of the synchronised adjustable swash plates double axial piston hydraulic machine control body, when calculating the moment on the control roller, this pulsation can be neglected [5] and the pressure can be taken as a constant value [6].

3. Calculation of the moment on the control body of the synchronised adjustable swash plates double axial piston hydraulic machine

With the arrangement of swash plates providing zero angular velocity (in motor mode) or zero flow rate of the working fluid (in pumping mode), for calculation we assume that the oppositely arranged swash plates rotate in one direction, since the moments created by the piston mechanisms acting on the washers will try to tip them in the direction, shown in figure 3:

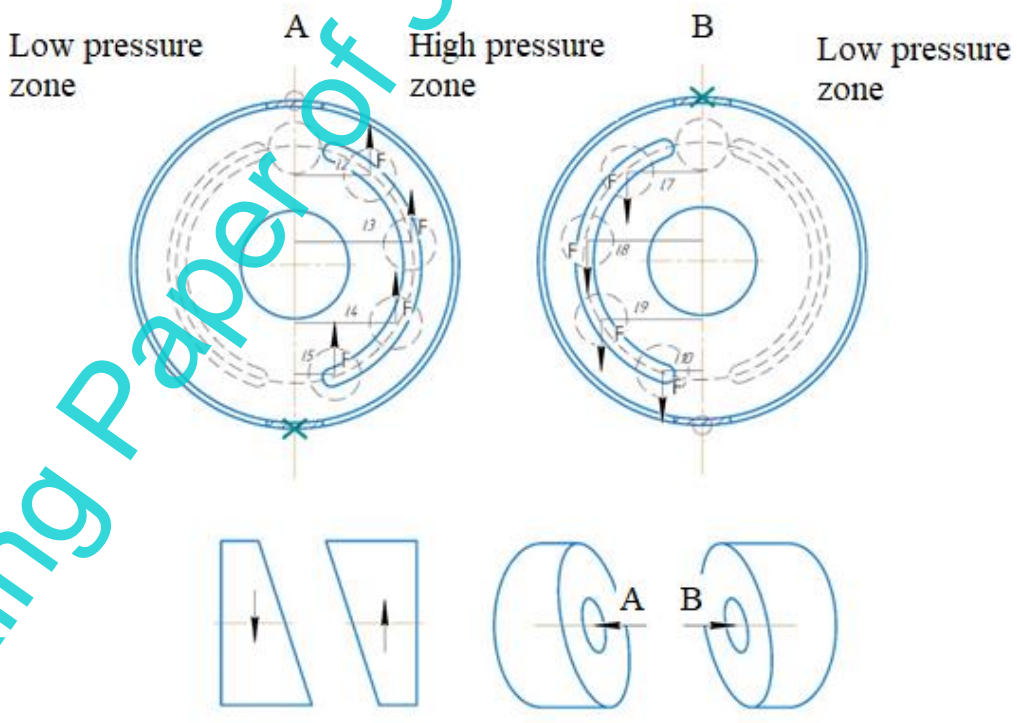

Fig. 3. Swash plates at zero angle position

The moments transmitted by the swash plates to the cylindrical gears, and then to the conical gears, will cause them to rotate in one direction. Then two moments will act on the synchronised adjustable swash plates axial piston hydraulic machine control body at once, which will turn the conical gear of the control body in opposite directions. This means that one moment counteracts the other. Then the total moment acting on the control body will be determined by the difference between the moments of the swash plates. At the same time, depending on the sign of the common moment, the direction of rotation of the control body will change. Then, to find the full moment of the control body of the control system of a synchronised adjustable swash plates double axial piston hydraulic machine, we use the formula:

$$\sum M = p * F * R * tg\beta * \sum_{i=1}^{n} \left[sin\left(\alpha + \frac{2\pi}{n}(i-1) + \gamma\right) - sin\left(\alpha + \frac{2\pi}{n}(i-1) - \gamma\right) \right] \quad (2)$$

$$\alpha \in [0; \pi]$$

where p is the pressure, MPa,
F – the area of the piston, m^2,
R – the radius of the cylinder block, m,
β – the angle of inclination of the swash plates, radians,
α – the angle of rotation of the cylinder block, radians,
γ – the angle of rotation of the swash plates, radians,
n – the number of pistons,
i – the piston number.

Figure 4 shows a diagram of the change in the total torque M on the control body during the mutual rotation of the swash plates and the rotation of the cylinder block:

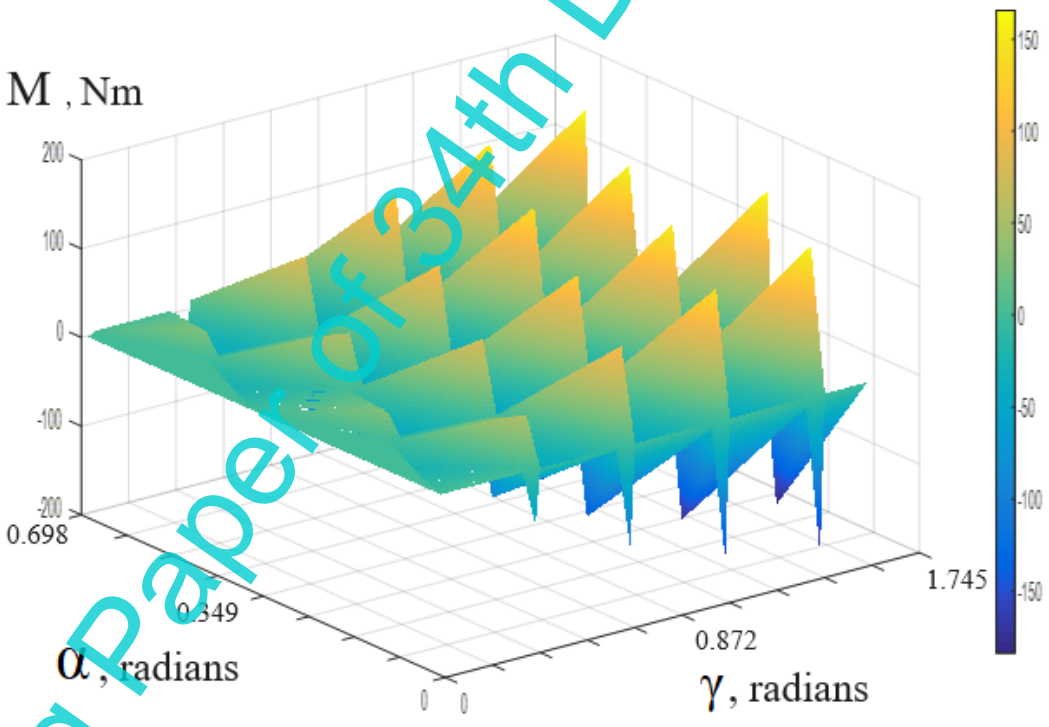

Fig. 4. Moment on the synchronised adjustable swash plates double axial piston hydraulic machine control body

It can be seen from the graph that with an increase in the angle of rotation of the swash plates, the moment on the synchronised adjustable swash plates double axial piston hydraulic machine control body increases.

4. Comparative analysis of the control moment of a single-block swash plate axial piston hydraulic machine and a synchronised adjustable swash plates double axial piston hydraulic machine

For a comparative analysis, it is necessary to calculate the total control moment of a single-block swash plate axial piston hydraulic machine [7]. Formula for calculating the total moment of force on a swash plate [8]:

$$M_s = p * F * \frac{R}{cos^2\gamma} * \sum_{i=1}^{n}\left[cos\left(\alpha + \frac{2\pi}{n}(i-1)\right)\right] \quad (3)$$

$$\alpha \in [0;\pi]$$

where p is the pressure, MPa,
F – the area of the piston, m^2,
R – the radius of the cylinder block, m,
α – the angle of rotation of the cylinder block, radians,
γ – the angle of inclination of the swash plate, radians,
n – the number of pistons,
i – the piston number.

Figure 5 shows a comparison of the control moments under the same conditions and the sizes of piston mechanisms for the single-block swash plate axial piston hydraulic machine and synchronised adjustable swash plates double axial piston hydraulic machine:

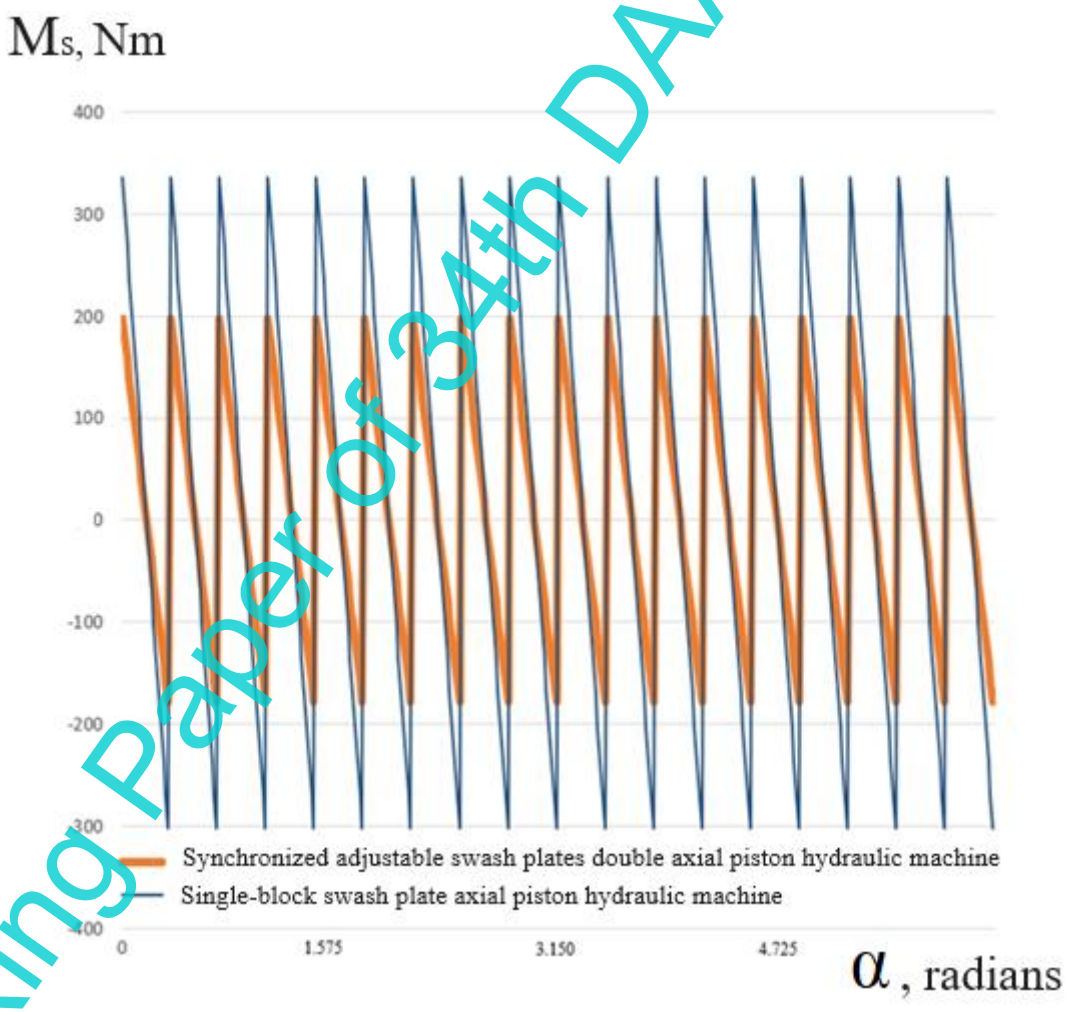

Fig. 5. The moment on the control body at the maximum angle of regulation

According to the results of calculations – for a single block swash plate axial piston hydraulic machine, the maximum moment is M_s = 336.4 Nm, for synchronised adjustable swash plates double axial piston hydraulic machine M_s = 197.751 Nm.

5. Conclusion

This investigation presents the dependence for calculating the flow rate and the moment on the control body of a synchronised adjustable swash plates double axial piston hydraulic machine.

After the calculations, it was found that the pulsation of the flow rate in the synchronised adjustable swash plates double axial piston hydraulic machine is 1.5192%, therefore, for further calculations, this pulsation can be neglected.

Calculations of the total moment of control body for single-block swash plate axial piston hydraulic machine and synchronised adjustable swash plates double axial piston hydraulic machine are carried out.

Force analysis showed that the total moment on the control body of the synchronised adjustable swash plates double axial piston hydraulic machine repeats the form of a single-block swash plate axial piston hydraulic machine, but has a smaller amplitude of oscillations.

The moment on the control body of the synchronised adjustable swash plates double axial piston hydraulic machine is 1.7 times less than the control moment of a single-block swash plate axial piston hydraulic machine.

Reducing the torque on the control body will reduce the dead zone of the hydraulic machine, and, consequently, increase the accuracy of the hydraulic drive control as a whole.

In the future, our team plans to make a model of the dynamics of the control mechanism synchronised adjustable swash plates double axial piston hydraulic machine.

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