THE INFLUENCE OF A BENT AXIS ANGLE ON THE DIMENSIONSOF AN AXIAL PISTON HYDROMACHINE

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In the machine-building hydrodrives, axial piston hydromachines (APH), which have small dimensions and weight at a high level of an operating pressure, efficiency and reliability, are widely applied. Application adjustable APH have allowed essentially to expand spheres of their use to increase complex technical and economic parameters of hydraulic drive gears. The best pumping characteristics are shown by APH with an inclined disk, and the best motor – by bent axis design hydromachines [1]. Traditional directions to the perfection of design in APH are: to increase the nominal and a maximum pressure, increase working rotary speeds, reduce the radial and axial dimensions of the pumping units.

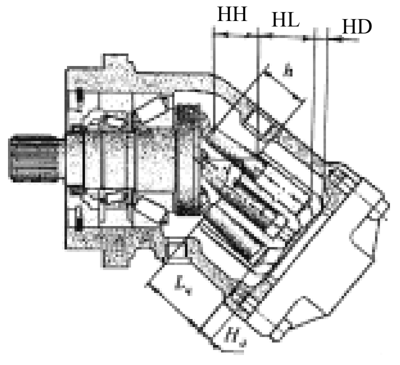

Fig. 1. Bent axis APH of the design "Mannesmann Rexroth" (series A2FM)

In the last decades the technical parameters of the bent axis APH were also increased due to the changes in designs: application of one piece pistons with piston rings, a hinge conducting the block of the cylinders (BC), increase of its discharge angle up to 40°, special piston rings used as a sealing, and also the bearing of mount assemblies with roller taper bearings. Modernization of designs and the current technologies of manufacturing have allowed to reach in the most perfect samples of hydromachines the specific weight of the type – 0.1-0.2 kg/kW. Fig. 1 presents the design of APH, series A2FM, of the concern "Mannesmann Rexroth" (Germany) at the discharge angle BC up to 40°. The increase of the discharge angle BC with the increase of an operating pressure have significantly lowered the specific weight of the given APH design, accompanied by the reduction of the pumping unit sizes.

Fig. 2 presents the dependence of an outer diameter fixed displacement of a bent axis APH, and Fig. 3 of the APH length, on their working volume for hydromachines series A2FM of the concern "Mannesmann Rexroth" (Germany) at the discharge angle BC $\gamma = 40°$and the maximal operating pressure $p_{\max} = 40$ MPa, the series BMF of the firm "Linde" (Sweden) at the discharge angle BC $\gamma = 28°$ and $p_{\max} = 42$ MPa and for the hydromachines of the series 200 and 300 (Ukraine, Russia) with the discharge angle BC $\gamma = 25°$ and $p_{\max} = 25$, 32 MPa, which were issued under the license of the firm "Hydromatik" (Germany) for hydraulic systems in road-building engineering. From the submitted dependencies it appears, that at rather small distinctions in diameters various APH designs show greater differences as to axial dimensions.

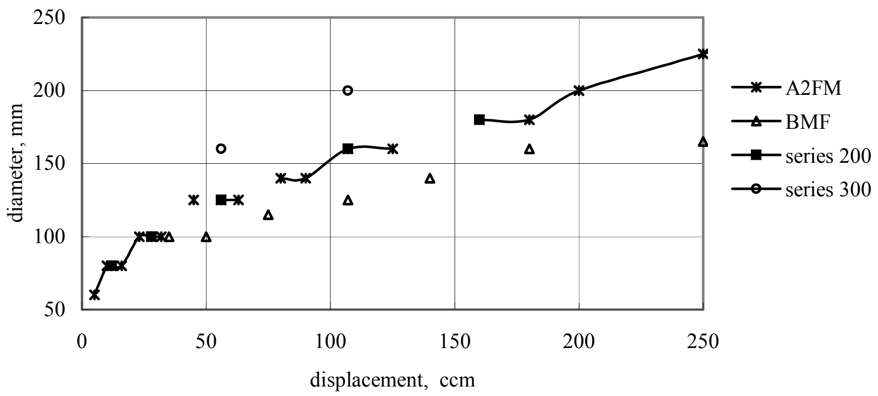

Fig. 2. Dependence of a diameter of APH with inclined BC on a working volume

From the submitted dependencies it appears, that the minimal radial dimensions are shown by the APH with inclined BC of the firm "Linde" of the series BMF. It is primarily due to the powerful bearing mount assemblies of these hydromachines, which ensure their high durability. The diameter of the hydromachines of the series BMF, at 1.15, is 1.28 times smaller than in the hydromachines of the series 200, and 1.6 times smaller than in the hydromachines of the series 300. The radial dimensions of the APH of the series A2FM coincide with the radial dimensions of the hydromachines of the series 200, but at a greater nominal pressure.

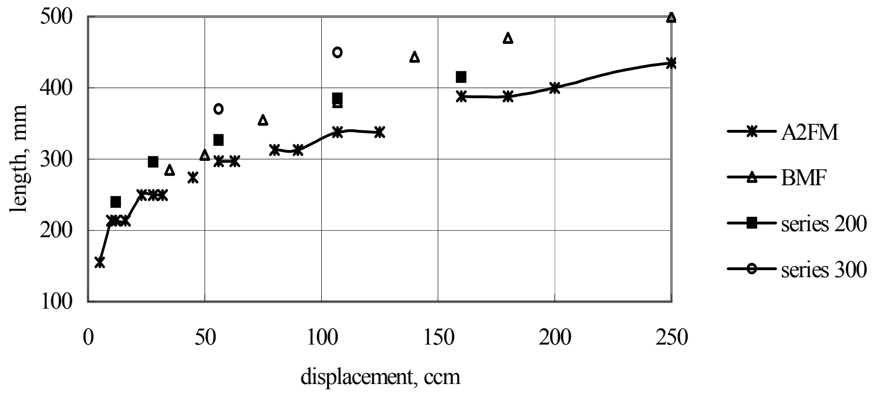

Fig. 3. Dependence of the length of APH with inclined BC on a working volume

From the submitted dependencies it appears, that the minimal axial dimensions are shown by the hydromachines of the series A2FM, independently on what is their maximum discharge angle BC, and consequently the maximum course of the bucket. Axial dimensions APH of the series A2FM are 1.1-1.2 times smaller than axial dimensions of the hydromachines of the series 200, and 1.25-1.4 times smaller in comparison with the series 300. From the given characteristics it is clear, that the modernization of designs of the 200 series hydromachines with the purpose of the increasing of a resource and an operating pressure in the 300 series was provided due to the increase of the sizes of pumping unit, which practically has not changed the relative characteristics of these hydromachines.

The values of the radial and axial sizes of the pumping unit are necessary for the development of a typical APH configuration. These sizes at a given working volume of the hydromachine should provide conditions of toughness, wear-resistance, durability at a given power loss of a hydromachine.

In work [2] the method calculation of the radial sizes of a pumping unit APH with inclined BC is submitted, and in work [3] – the axial sizes in relative parameters from the characteristic size:

$$\bar{q} = \sqrt[3]{q} \tag{1}$$

where:

q – a working volume of the hydromachine. Relative parameters represent the sizes of a pumping unit for APH which have a working volume q = 1.

The minimal sizes of a pumping unit are defined under the condition of maintenance of equal toughness of dangerous sections BC. The initial data for the calculation of the hydromachine are its working volume – q, a maximum pressure of a pressure head hydroline – $p_{\max}$, durability characteristics of material BC – $[\sigma]$, and also its tribological characteristics, durability and efficiency of the hydromachine. For simplification of calculations the factor of concentration of pressure in crosspieces BC which is equal is entered $k = [\sigma]/p_{max}$.

As a result of a design calculation, critical parameters of a pumping unit are determined: number and radius of cylinders – z and r, discharge angle BC – γ and its basic dimensions – radiuses of the seating of the centers of cylinders and external surface BC – R and R_0. The axial sizes of a pumping unit in view of a move of the piston is – h, lengths of cylinders – L_u and thickness of ground part BC – H_∂.

The length of APH with inclined BC can be presented as the sum

$$L_{AHP} = L_B + L_{KY} \tag{2}$$

where:

L_B – length of the shaft with a bearing mount assembly,
L_{ky} – a projection of pumping unit to the shaft of the hydromachine.

The length of the shaft is determined basically by a design bearing unit of the hydromachine. The projection of the length of a pumping unit of APH with inclined BC on its shaft is represented as:

$$L_{\kappa y} = \cos\gamma \cdot \left(h + L_{ц} + H_\partial + H_p + H_{\partial\kappa}\right), \tag{3}$$

where:

H_p, $H_{\partial\kappa}$ – thickness of the allocator and the cover of the case accordingly.

The constructive sizes of a bearing mount assembly are determined on critical parameters of a pumping unit and can change in the wide enough limits. Thickness of the allocator of the hydromachine and a cover of the case can be accepted in relative parameters:

$$H_p = \delta_p \overline{q} \tag{4}$$

$$H_{\partial\kappa} = \delta_{\partial\kappa} \overline{q} \tag{5}$$

where:

δ_p, δ_{dk} – relative parameters of thickness of the allocator and the cover of the case accordingly.

Parameters δ_p, δ_{dk} do not depend on durability characteristics of the material BC but depend on durability characteristics of the material of connections plate and cover, pressure of a working liquid, as well as joints. Therefore we shall consider the influence on axial dimensions APH of a component from the sizes of a pumping unit the formula of which can be presented as:

$$L_{\kappa y}' = h\cos\gamma + L_{ц}\cos\gamma + H_\partial\cos\gamma \tag{6}$$

According to kinematic dependencies for bent axis APH, the move of the piston at the optimum axial forming the mechanism is determined on the dependence:

$$h = 4R \cdot \mathrm{tg}(\gamma/2) \tag{7}$$

Transform this expression to a kind

$$h = \chi \bar{q} \tag{8}$$

where:

χ – relative parameter of a course of the bucket which is defined on the dependence.

$$\chi = 4 \cdot \beta \cdot \mathrm{tg}(\gamma/2) \tag{9}$$

where dimensionless parameter $\beta = f(z, \gamma, k)$ is determined under the condition of maintenance of equal toughness of dangerous sections BC for preset values of factors of concentration of pressure.

We shall designate a composite which corresponds to a projection of a course of the bucket to a shaft of APH:

$$HH = \chi \cos\gamma \tag{10}$$

The method of the definition of the length of cylinders APH on relative parameters is given in work [2], according to which the length of the cylinder is in a range of rational values:

$$3 \cdot \lambda \cdot \bar{q} \le L_{ц} \le 6 \cdot \lambda \cdot \bar{q} \tag{11}$$

where:

$\lambda = f(z, \gamma, k)$ – a relative parameter of the length of the cylinder under the condition of the maintenance of equal toughness of the dangerous sections BC.

At smaller values of the cylinder length deformations in its entrance part are increased [4], which causes leaks of the working liquid and changes the kinematics of the forming mechanism in APH. At higher values of the cylinder length axial dimensions of a pumping unit are increased without change in BC toughness or stiffness. Calculation of a relative parameter of length of the cylinder shall be defined under the condition of (7). It is necessary to take into account that for constructing reasons it is also necessary to provide the condition $h < L_C$.

We shall designate a composite which corresponds to a projection of minimal length BC to a shaft of APH:

$$HL_{\min} = 3\lambda \cos\gamma \tag{12}$$

and a composite which corresponds to a projection of maximal length BC

$$HL_{\max} = 6\lambda \cos\gamma \tag{13}$$

In Fig. 4 dependencies of parameters HH, $HL_{\min}$, $HL_{\max}$ on discharge angle BC for APH with the number of cylinders $z = 7$ are shown at the factors of concentration of pressure of the material of the block $k = 3, 5, 8$.

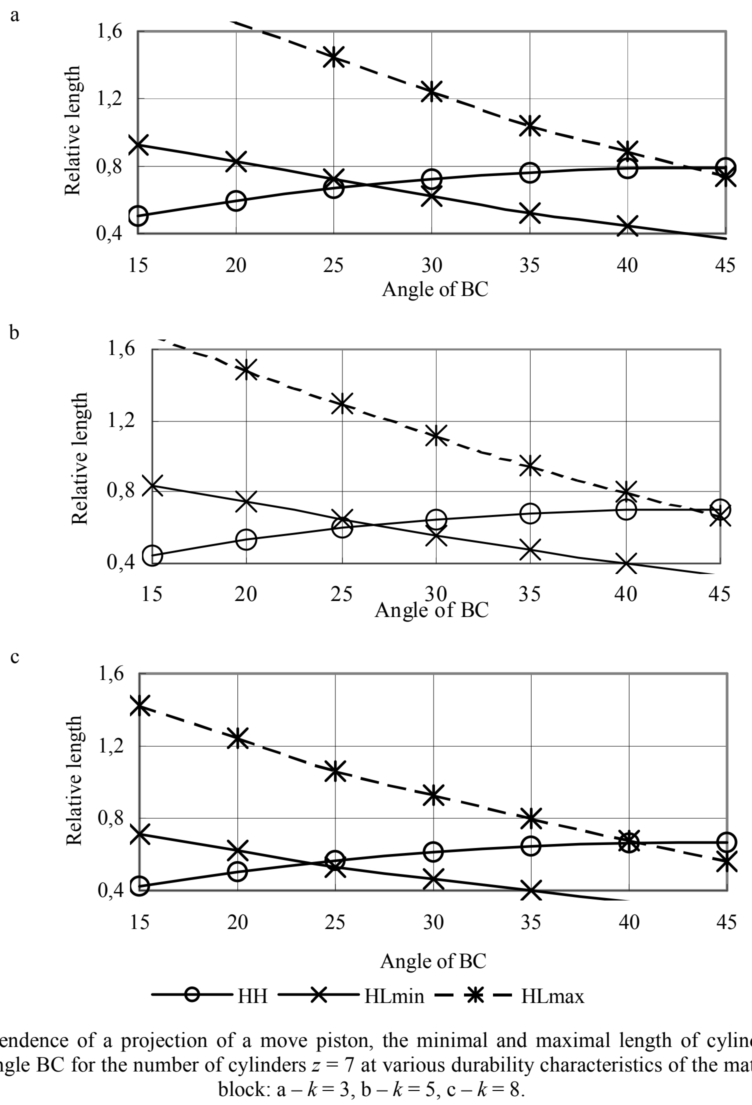

Fig. 4. Dependence of a projection of a move piston, the minimal and maximal length of cylinders on the discharge angle BC for the number of cylinders $z = 7$ at various durability characteristics of the material of the block: a – $k = 3$, b – $k = 5$, c – $k = 8$.

From the submitted dependencies it is visible, that at discharge angles BC $\gamma \leq 24\text{-}26°$ a projection of the minimal length of the block and a course of the piston size are constant. Hence, at such discharge angles BC, the axial dimension APH does not depend on it, and is defined only by the durability characteristics of a material block. At discharge angles BC 24-26 < $\gamma \leq 35°$ the size of a move piston becomes greater than the minimal length of the cylinder, and therefore the length of the cylinder is determined by a move of the piston. Hence, the axial dimension APH is increased proportionally to the discharge angle. At discharge angles BC 35 < $\gamma \leq$ 40-43° a projection of a move of the piston to a shaft had a constant size, but was smaller than a projection of the maximal length of the cylinder. Therefore, at such discharge angles the axial dimension APH does not depend on it, and is determined only by the durability characteristics of the material of the block. An increase of the discharge angle from the above $\gamma >$ 40-43°, as for such a move of the piston it is necessary to provide greater lengths of cylinders, which is allowable on conditions of stiffness BC.

The thickness of the ground part BC summed up with the length of cylinders is determined by the length BC, and also essentially influences the bend stiffness of the ground part. The influence of the thickness of the ground part on the distribution of pressure and deformations in BC were considered in work [5]. The thickness of the ground part results, according to [3], in a range of rational values:

$$0.38 \cdot \delta \cdot \overline{q} \leq H_{\partial} \leq 1.76 \cdot \delta \cdot \overline{q} \tag{14}$$

where:

δ – relative parameter of the thickness of the ground part.

The projection of the minimal thickness of the ground part BC to a shaft of APG is designated

$$HD_{\min} = 0.38\delta\cos\gamma \tag{15}$$

and the composite which corresponds to a projection of the maximal thickness of the ground part BC:

$$HD_{\max} = 1.76\cos\gamma \tag{16}$$

In Fig. 5 dependencies of parameters of the thickness of the ground part for APH with the number of cylinders $z = 7$ are shown and the factors of strain concentration of the material block cylinders $k = 3, 5, 8$.

The high values of the thickness of the ground part correspond to its indefinitely high bend stiffness, and smaller values correspond to its conditionally zero bend stiffness. An indefinitely big stiffness of the ground part provides its minimal deformations, but thus axial pressure in the ground part of the cylinders is increased to the maximal values and the intensity of pressure in this part BC is maximal. At zero stiffness of the ground part BC – there are the maximal deformations of a ground part, but the minimal values of the pressure intensity in the ground part of the block. At small stiffness of the ground part BC – there are the maximal deformations in the ground part which increase leakages of the working liquid in an end clearance the block – port plate, but thus the values of the pressure intensity are minimal in this zone of the block where the basic concentrators of pressure are placed. The degree of intensity of pressure in the ground part defines the durability of all BC.

From the submitted dependencies it is visible, that the minimal thickness of the ground part practically does not depend on the discharge angle BC or on durability characteristics of a material from which it is made. The value of the ground parts maximal thickness is essentially influenced by the durability characteristics of the material BC and the corner of its inclination.

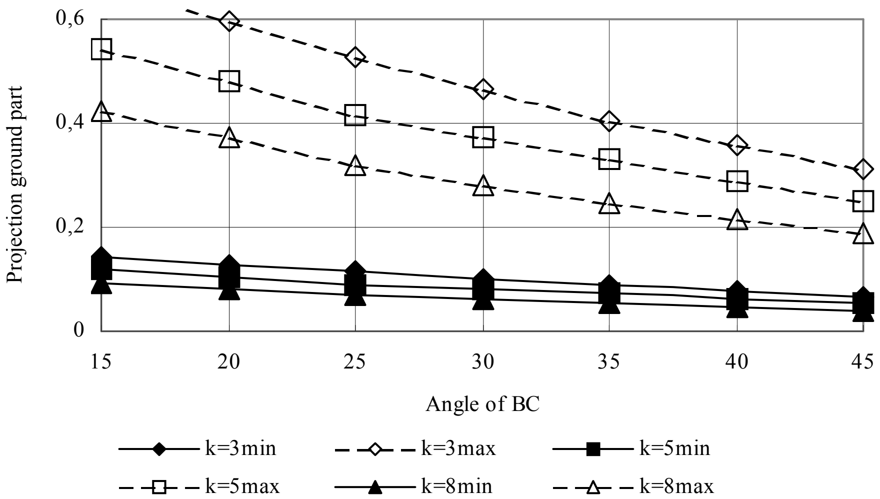

Fig. 5. Dependence of a projection of the minimal and maximal thickness of the ground part BC on its discharge angle for the number of cylinders $z = 7$ at various durability characteristics of the material block cylinders

The increase of discharge angle BC reduces the projection of thickness of the ground part, and consequently the dimensions of a pumping unit. At an increase of the discharge angle BC from $\gamma = 25°$ up to $\gamma = 40°$ the value of the projection of thickness of the ground part is 1.43-1.48 times smaller.

The materials provided in the present article are not a completely exhaustive result of the tests concerning the problem of technical forecasting of APH designs, as it is necessary to analyse an influence of a number of cylinders on the considered parameters. Such results will be given in the following articles.

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SUMMARY

The paper aims at the determination of an influence of the bent axis angle on the dimensions of an axial piston hydromachine. The best motor characteristics are shown by bent axis design hydromachines. As the research proves, axial dimension APH is increased proportionally to a discharge angle. Also, the increase of discharge angle BC reduces a projection of thickness of a ground part.