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RESEARCH OF INFLUENCE OF A HYDRO-MACHINE BEARING ARRANGEMENT PARAMETERS ON A LOAD DISTRIBUTION WITHIN IT AS A FACTOR OF A PROJECT MANAGEMENT TO MAKE ITS DESIGN OPTIMUM

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Influence of some parameters of axial-piston hydro-machine bearing arrangement on a load distribution within it is researched. It's demonstrated that providing reasonable housing lengthwise stiffness can make bearing loads even to considerably increase the arrangement life. It is also shown that axial dimension of a bearing arrangement is to be chosen with taking a spacer ring extent into account. Limits of using a scheme holding duplex bearings are grounded.

Key words: rolling element bearing, hydro-machine, load distribution, distribution unevenness, bearing life, housing stiffness, bearing stiffness, bearing pliability, spacer ring, block of cylinders, tilt angle, project management.

Preface. Variety of construction schemes of rolling element bearing arrangements and bearings they consist of as well as non-linear nature of load distribution prevent from working out common recommendations as for choosing their optimum parameters. However, having methods of exact calculation of bearing arrangements as a research tool one can find how the arrangement basic parameters influence upon a load distribution and the arrangement calculated durability. Such a multi-factor analysis make it possible to choose optimum values of mentioned parameters and actually is a factor of a project management to create an optimum design of a machine as the whole from the standpoint of combination of both its overall dimensions and life expected.

A problem. Bearing arrangements (BA) of axial-piston hydro-machines (APH) often consist of three and more rolling element bearings with a load distribution between them to be too far from evenness, and this is unpractical from the standpoint of a size and durability of a BA and APH as the whole.

Analysis of recent researches and publications. In up-to-date reference books, manuals and teaching-scientific literature simplified expressions for bearing calculations are given to often produce too inaccurate results. This approach gives no way to make a multi-factor analysis of a BA with the aim to determine its parameters providing optimum combination of overall dimensions and durability, especially in case if the arrangement consists of many bearings.

Research purpose. Find out how basic parameters influence a load distribution within a BA and its durability for most widely used construction schemes of BA of APH with inclined block of cylinders.

Research results. Determination of a load distribution in an APH bearing arrangement and analysis of influence of some factors upon it were made on the basis of known system of equations [1] used for calculation of multi-support bearing arrangement at a general case of its loading.

1. Influence of a bearing arrangement stiffness parameters. As experience of exploitation as well as analysis of faults and calculations results show, lives of bearings in an arrangement can considerably differ and that signifies uneven loadings acting upon them. When designing a BA one should seek to draw a rationality factor k_{p} (the ratio of bearing maximum life L_h^{max} to that minimum L_h^{min}) nearer to 1. High values of k_{p} signify irrational use of bearings in an arrangement but at the same time mean that durability of a BA can be increased through the loads redistribution within it. One of the ways of making loads even is securing a correlation of bearings radial stiffnesses that provides their equivalent forces as well as expected lives to be equal, wherein an overall maximum life is reached through discharging more loaded bearings and additional loading of those less charged, with not a big difference in lives of single ones. Bearing radial stiffness depends on radial stiffness of rolling elements and the bearing ring, housing thickness, its material and nature of bearing fit into a housing. Below it is illustrated with the exemplary computation of a BA consisting of duplex tapered roller bearings, how the seat radial stiffness affects load distribution between the bearings. A scheme of such an arrangement is shown in Fig. 1, external forces values correspond to those acting with the BA of APH 210.32. Calculations made with use of technique described in [1] reveal (see Fig. 2) high unevenness of radial loading in case of equality of seats 1 and 2 suppleness (k_1=k_2). When securing for seat 1 k_1=3,6 μm/mm, radial forces F_{r1}=F_{r2} i.e. the seats become charged equally, with expected life of seat 1 limiting an overall durability of BA to increase by 34%. Raise of suppleness mentioned can be provided, for example, by means of change of a housing radial stiffness (applying interjacent sleeves), bearings with hollow rollers, etc. Loads equalization by means of securing variable lengthwise stiffness of ball bearings involves significant increase of seats deformations and is less efficient than for roller ones.

2. Influence of a bearing arrangement axial dimensions. Axial dimensions of a bearing arrangement in an APH of considered type are determined by width of bearing rings, spacer ring thickness and a distance from the plane including centers of the piston-rod's spherical heads to the bearings (external loading cantilever). Increase of a spacer ring thickness leads to decrease of the bearings radial loadings and raise of their durability. Fig. 4 presents, for hydro-machine of 210.25 type (design see Fig. 3), relations of durability of weaker bearing (which contacts the shaft flange) L_{h1} and the tandem seat bearings relative life t = L_{h2}/L_{h1} to distance l between the bearings. Expected lives were computed with use of (which contacts the shaft flange) L_{h1} and the tandem seat bearings relative life t = L_{h2}/L_{h1} to distance l between the bearings. Expected lives were computed with use of distribution between the rolling elements found [1]. The graphs show that durability of most charged bearing steps up with extending the distance mentioned whereas relative life t (the bearings loading unevenness rate) goes down. One can emphasize a peculiar point N there (l_N ~ 83 *mm*) characterized by decrease of the limitative bearing life growth speed. Prior to this point 30% extension of distance l gives 15% life growth while after it 50% leads to 13% correspondingly. Point N meets optimum combination of the arrangement overall dimensions and durability [2]. The shaft misalignment angles for minimum,

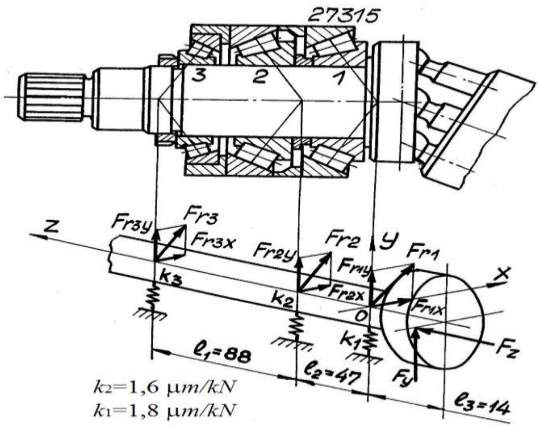

Fig. 1. Scheme of a bearing arrangement consisting of duplex tapered roller bearings.

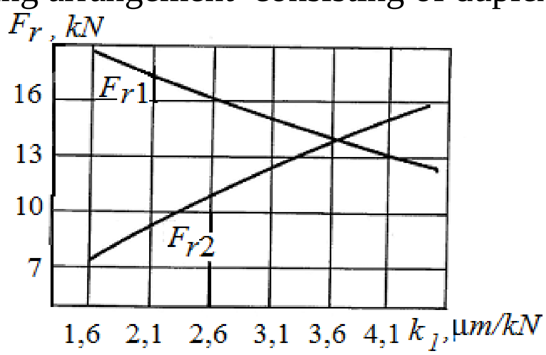

Fig. 2. Loadings upon bearings of a duplex seat.

optimum and maximum distance between the bearings are also pointed there out to be within allowable limits (less than 1 *mrad*) for all considered range of distance l between the bearings. Relationship between the weakest bearing life L_{h1} of hydro-machine 210.25 bearing arrangement and distance z_p, defining external loading cantilever is shown in Fig. 5. For the APH that is studied here, the loading cantilever bigness affects the BA durability less than change of distance between the bearings. So, the cantilever 20% growth leads to just 6,5% decrease of life of the bearing most charged. It should be noted that the z_P extent is firstly determined by design considerations when composing a pumping unit. Increase of a distance between bearings as well as that of external loading cantilever results in growth of an APH axial size and therefore its

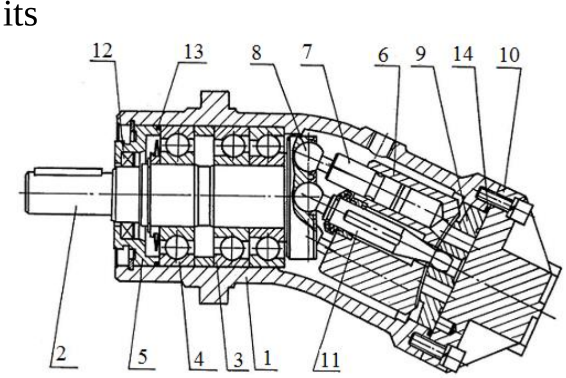

Fig. 3. Non-regulable axial-piston hydro-machine with inclined block of cylinders.1 – housing; 2 – shaft; 3 – angular contact bearing; 4 – radial bearing; 5 – cap; 6 – block of cylinders; 7 – piston; 8 – piston-rod; 9 – distributor; 10 – cap; 11 – central tenon; 12, 13, 14 – seals.

overall dimensions and weight. Hence, to define whether choice or change of these parameters is expedient one should take this into account jointly with changes associated with manufacturing of an APH housing and shaft.

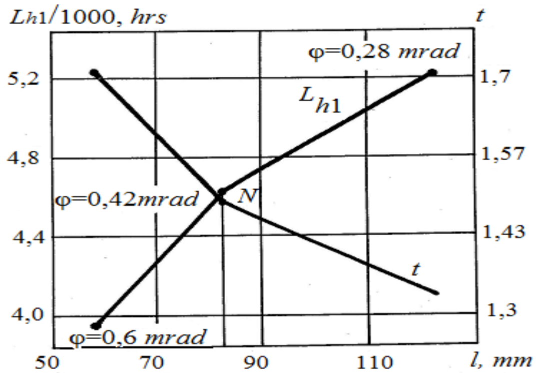

Fig.4. Expected life L_{h1} and unevenness t relations to distance l between the bearings.

3. Influence of a block of cylinders incline angle. For APH with inclined block of cylinders, the block incline angle γ affects distribution of radial forces between the bearings significantly. Fig. 6 shows how unevenness t depends on angle γ. At angles γ>30° unevenness of loading t>2 while expected life goes down. Moreover, as computations demonstrate, every single angle γ corresponds with certain length l_N and besides, the more angle γ is the more value of l_N corresponds [2], thence applying the above scheme of BA is limited by raise of a block of cylinders incline angle γ and at its high values is not advisable. Analysis of other bearing arrangements and definition of their optimum parameters are to be carried out similarly.

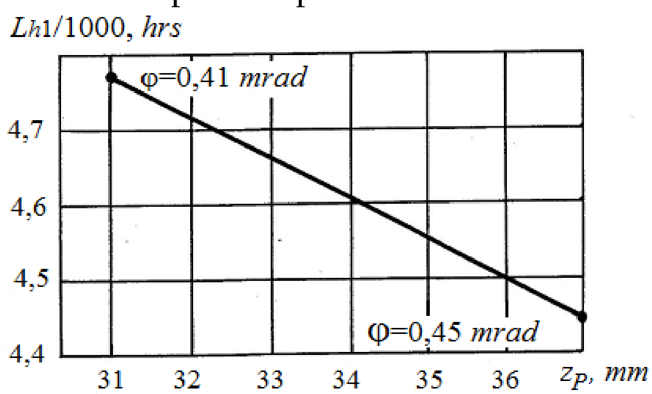

Fig. 5. Expected life L_{h1} relation to loading cantilever z_P.

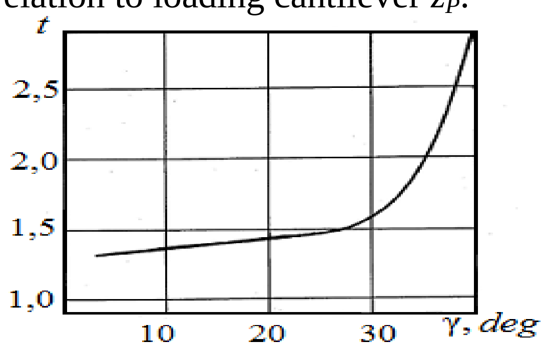

Fig. 6. Bearing loading unevenness t relation to a block of cylinders incline angle γ.

Conclusions. By means of rational choice of lengthwise stiffness of an APH housing one can equalize forces acting upon bearings and increase their durability considerably. Axial dimensions of a bearing arrangement are to be set with taking certain size of a spacer ring into account with a view to secure optimum combination of a BA overall dimensions and durability.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПАРАМЕТРОВ ОПОРНОГО УЗЛА ГИДРОМАШИНЫ НА РАСПРЕДЕЛЕНИЕ НАГРУЗОК МЕЖДУ ПОДШИПНИКАМИ КАК ФАКТОР УПРАВЛЕНИЯ ПРОЕКТОМ СОЗДАНИЯ ЕЁ ОПТИМАЛЬНОЙ КОНСТРУКЦИИ

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Ключевые слова: подшипник качения, гидромашина, распределение нагрузок между подшипниками, неравномерность нагружения, ресурс подшипника, жесткость корпуса, жесткость подшипника, податливость опоры, дистанционное кольцо, угол наклона блока цилиндров, управление проектом.

Резюме

Исследовано влияние основных параметров опорного узла аксиально-поршневой гидромашины на распределение нагрузок между подшипниками и их ресурс. Показано, что за счет рационального выбора продольной жесткости корпуса можно выровнять действующие на подшипники нагрузки и существенно повысить долговечность узла. Также показано, что осевые размеры подшипникового узла следует выбирать с учетом определенной длины дистанционного кольца, что обеспечивает оптимальное сочетание ресурса и габаритов узла. Обоснованы границы применения схемы со сдвоенными (дуплексированными) подшипниками.

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Summary

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