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Finding the minimum number of optimization points for an axial aircraft pump

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Annotation
This article discusses issues related to the calculation of aircraft axial pumps. These pumps are subject to ever-increasing demands due to high competition in the aviation industry. The highest requirements for parameters are the dimensions of the impeller and power consumption. This article discusses the method of constructing the diameter of the impeller - the expended power of an axial pump.

Introduction

Methods for calculating centrifugal pumps [1] - [4] are widely reported in the literature. Of greatest interest are publications [5] - [11]. However, the calculation of axial pumps is much harder than described in the literature. The main characteristics of hydraulic machines for aeronautical engineering include their mass and power consumption, and the mass should be minimal, and the efficiency should be maximal. As the size of hydraulic machines increases, both parameters increase, so it is necessary to find the optimal diameter of the pump, at which rather high efficiency is achieved while maintaining a low mass, a priority parameter for aviation. Additionally, using high-speed machines with relatively low pressure can reduce the pump mass, so in this study, we consider a hydraulic unit consisting of an axial pump and an axial-piston motor with an inclined disk. Since the mass is directly related to the dimensions of the hydraulic machine, and the assessment of dimensions is a simpler task, we will indirectly estimate the mass by the radial dimension of the impeller of the axial pump. At the same time, since the efficiency is directly dependent on the power expended, the change in efficiency will be estimated by the change in power consumed.

In the literature [12] - [15], hydrodynamic modeling methods are commonly used to solve the problem of calculating dynamic pumps. The disadvantages of these methods can be attributed to the high costs of human and machine time, which necessitates the creation of a calculation methodology in which it is not necessary to resort to hydrodynamic modeling. Note that the literature [1] - [4] demonstrates the excellent ability to optimize dynamic hydraulic machines using the LP-Tau-search methods. Thus, it is possible to combine known methods for calculating dynamic hydraulic machines, such as the LP-Tau-search method, with unconditional optimization by any parameter and eliminate direct hydrodynamic modeling to save the machine and human time.

Unconditional optimization is carried out according to two criteria - dimensions and power consumption. Both parameters are made dimensionless by reference to the highest value of each of the requirements, and their weights are assumed to be equal. To eliminate the influence of the sign of these parameters, both of the non-measured criteria count in the square.

Methods

To optimize the method, you need to set the number of points for the application of LP-Tau-search required for accurate calculation, which does not require the excessive expenditure of time and PC resources. Note that the accuracy of the LP-Tau sequence calculation has its limitations since it carries out the calculation with a margin, taking into account the non-rigid characteristic of the axial pump and allowing for an error.

The number of calculated points is as follows. A dimensionless generalized quality factor Φ is introduced, which is determined according to the dependence:

$$\Phi = \left(\frac{D_{\text{тр}}}{D_{\text{тр max}}}\right)^2 + \left(\frac{N_{\text{з}}}{N_{\text{з max}}}\right)^2,$$

$$F = \left(\frac{D_t}{D_{t\,max}}\right)^2 + \left(\frac{N}{N_{max}}\right)^2,$$

Here, $D_{t\ max}$ and N_{max} are the values of the maximum diameter and maximum power consumption. The smaller this ratio, the better the quality of the axial pump.

After calculating the generalized quality factor for 64 points, select its minimum values for a certain number of points: 4, 8, 16, 32, and 64. Then build the dependence where is the minimum value of the generalized quality factor for a given number of points; n — number of points.

Table 1. Calculated points of power consumption and diameter of the pipeline equal to the diameter of the pump

Point	N_{max}, Vt	D_t, m	F
1	861	0,047	0,220
2	454	0,043	0,177
3	1892	0,057	0,362
4	438	0,048	0,220
5	2795	0,072	0,610
6	948	0,053	0,279
7	756	0,036	0,131
8	278	0,042	0,167
9	1024	0,049	0,243
10	1505	0,068	0,471
11	879	0,040	0,163
12	855	0,060	0,351
13	688	0,038	0,143
14	730	0,046	0,208
15	5419	0,082	1,089
16	424	0,052	0,258
17	5217	0,099	1,346
18	1062	0,060	0,357
19	771	0,038	0,145
20	1378	0,075	0,539
21	800	0,041	0,168
22	472	0,038	0,140
23	1457	0,047	0,241

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Point	N_{max}, Vt	D_t, m	F
24	528	0,053	0,269
25	545	0,036	0,127
26	532	0,043	0,179
27	2257	0,059	0,407
28	393	0,041	0,161
29	1436	0,052	0,287
30	2879	0,080	0,732
31	1118	0,041	0,178
32	291	0,045	0,192
33	1335	0,056	0,323
34	3268	0,098	1,071
35	1024	0,043	0,191
36	623	0,055	0,291
37	594	0,036	0,128
38	596	0,043	0,180
39	2791	0,063	0,495
40	896	0,068	0,448
41	677	0,040	0,158
42	400	0,038	0,139
43	1190	0,045	0,213
44	612	0,051	0,251
45	3267	0,074	0,682
46	1073	0,053	0,283
47	814	0,036	0,132
48	768	0,066	0,420
49	633	0,040	0,157
50	662	0,049	0,233
51	8031	0,103	2,000
52	350	0,041	0,160
53	1244	0,050	0,26
54	2104	0,073	0,571
55	1015	0,04	0,167
56	386	0,046	0,202
57	1957	0,063	0,433
58	797	0,050	0,246
59	696	0,035	0,123
60	2413	0,089	0,837
61	952	0,043	0,188
62	556	0,039	0,148
63	1829	0,050	0,288
64	335	0,049	0,228

This scatter of points allows us to obtain a graph of the dependence of the generalized quality factor on the number of points.

Results

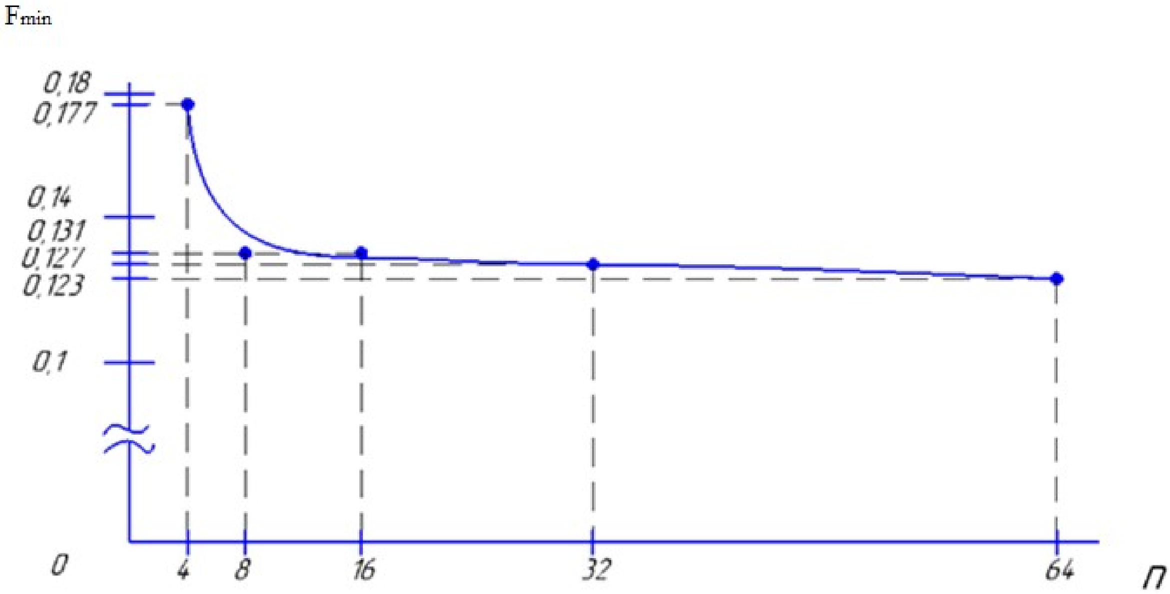

Figure 1. Scatter of the chosen points

For the successful application of LP-Tau-sequence when finding a compromise between mass and power consumption with varying head and relative time of work, at least 32 points must be used. The example of the obtained curve shows this - when considering 64 points of the LP-tau sequence, the graph slowly approaches the shape of the horizontal line for n> 16.

Conclusion

Thus, the above method can be recommended for use in calculating high-speed axial pumps of low power with a relatively large number of points and the availability of software packages that can facilitate data processing and graphical construction of a trade-off curve. It is evident that a further increase in the number of points obtained by the LP-Tau-search method will not lead to a significant improvement in the characteristics of the axial pump. At the same time, the rejection of hydrodynamic modeling in favor of simpler estimated calculations, even for the case of 64 design points, will save the machine and human time, provided that automatic methods for calculating the main design parameters of axial pumps are in use.

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