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Optimization of axial volumetric drive aviation pump

A Protopopov[1,2], A Mukhlaeva[1] and E Melnichuk[1]

[1]Bauman Moscow State Technical University, 5 Second Baumanskaya Street, Moscow, 105005, Russian Federation

[2]E-mail: proforg6@yandex.ru

Annotation
This article discusses a volumetric drive aircraft axial pump and solves the problem of its optimization by the Sobol method. The optimization criteria were the radial dimension and the power expended. In this case, the non-uniformity of the pump operation over time and the variable value of the pressure consumed by the network were taken into account. The last two parameters act as constructive variable parameters. As a result of the work, we obtained a compromise curve. The radial dimension is the power expended.

Introduction

Methods for calculating dynamic pumps [1] - [4] are widely reported in the literature. Of greatest interest are publications [5] - [12].

When developing axial pumps for aviation technology, the essential characteristics are mass and power consumption and both parameters should be as small as possible. As the size of the pump impeller increases, its efficiency increases, thereby reducing power consumption. But at the same time growing mass. As both parameters increase, it is necessary to find the optimal diameter of the pump with high efficiency, provided a relatively small mass - a priority parameter for aviation. Additionally, the mass can be reduced by using high-speed machines with relatively low pressure. Therefore, this study considers a hydraulic unit consisting of an axial pump and an axial-piston motor with an inclined disk.

The indicated problem is widely reported in the literature [13] - [16], where the main emphasis is on the use of labor-intensive methods, such as hydrodynamic modeling. In this work, a less labor-consuming LP-Tau search method is used in its application to the considered area of mechanical engineering.

According to the efficiency of a small axial-piston hydraulic motor, which rotates the pump, it can be assumed constant; the same applies to the mechanical efficiency of an axial pump. Its volumetric efficiency is approximately equal to 1, which simplifies the task, and the hydraulic efficiency can be estimated using the Lomakin formula. The required flow rate of the axial pump determines the power consumption, which is thus the focus of the paper. The mass and power consumption of the pump, among other parameters, are influenced by the pressure and the relative operating time of the hydraulic unit, the reduction of which entails an increase in the pump flow rate and, therefore, pressure losses along the length of the pipeline.

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Methods

For the analysis, we use LP-Tau search, since this method does not imply a precise definition of the objective function. It generates points in a quasi-random manner in the selected interval for the two parameters we are considering — head and relative pump operation time: the relationship between pump durations and aircraft flight time. The head H can vary from 5 to 15 m; the relative operating time of the tp / in is from 0.05 to 1. Then the field of generated work points will be a rectangle (Fig. 1).

The calculated points obtained using LP-Tau search are in the table.

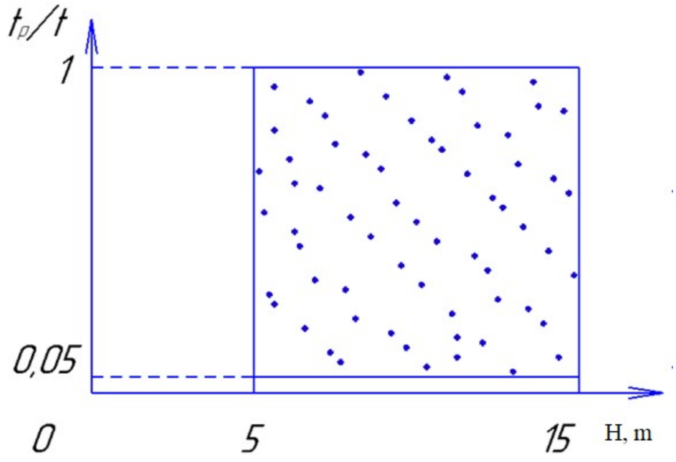

Figure 1. Point generation area.

Table 1. The calculated points of the LP-Tau search

Point #	*H*, m	t_p/t	Point #	*H*, м	t_p/t	Point #	*H*, m	t_p/t	Point #	*H*, m	t_p/t
1	10	0,5250	17	10,3125	0,0796	33	10,156	0,3320	49	10,46	0,7773
2	7,5	0,7625	18	7,8125	0,3171	34	7,6562	0,0945	50	7,9687	0,5398
3	12,5	0,2875	19	12,8125	0,7921	35	12,656	0,5695	51	12,96	0,0648
4	6,25	0,6437	20	6,5625	0,1984	36	6,4062	0,4507	52	6,7187	0,8960
5	11,25	0,1687	21	11,5625	0,6734	37	11,406	0,9257	53	11,718	0,4210
6	8,75	0,4062	22	9,0625	0,9109	38	8,9062	0,6882	54	9,2187	0,1835
7	13,75	0,8812	23	14,0625	0,4359	39	13,906	0,2132	55	14,218	0,6585
8	5,625	0,9406	24	5,9375	0,4953	40	5,7812	0,2722	56	6,0937	0,7179
9	10,625	0,4656	25	10,9375	0,9703	41	10,781	0,7476	57	11,093	0,2429
10	8,125	0,2285	26	8,4375	0,7328	42	8,2812	0,9851	58	8,593	0,4804
11	13,125	0,7031	27	13,4375	0,2578	43	13,281	0,5101	59	13,593	0,9554
12	6,875	0,3468	28	7,1875	0,8515	44	7,0312	0,6289	60	7,3437	0,1242
13	11,875	0,8218	29	12,1875	0,3765	45	12,031	0,1539	61	12,34	0,5975
14	9,375	0,5843	30	9,6875	0,1390	46	9,5312	0,3914	62	9,8437	0,8368
15	14,375	0,1093	31	14,6875	0,6140	47	14,531	0,8664	63	14,843	0,3617
16	5,3125	0,5546	32	5,15625	0,8070	48	5,4687	0,3023	64	5,0781	0,6808

Each point corresponds to values of the diameter of the pipeline, equal to the diameter of the impeller of an axial pump, and the power expended, which can be obtained by the following:

$$D_t = \frac{0,0827 Q^2 L_p \lambda}{H},$$

$$N = \frac{\rho g Q H}{\eta}.$$

After calculations (Table 2), it is possible to construct the distribution of all calculated points in the coordinates D_t —N.

Table 2. Calculated points of power consumption and diameter of the pipeline equal to the diameter of the pump

Point #	*N*, Vt	D, m	Point #	*N*, Vt	D, m	Point #	*N*, Vt	D, m	Point #	*N*, Vt	D, m
1	861	0,047	17	5217	0,099	33	1335	0,056	49	634	0,04
2	454	0,043	18	1062	0,06	34	3268	0,098	50	663	0,049
3	1892	0,057	19	771	0,038	35	1024	0,043	51	8031	0,103
4	438	0,048	20	1378	0,075	36	624	0,055	52	350	0,041
5	2795	0,072	21	800	0,041	37	594	0,036	53	1244	0,05
6	949	0,053	22	473	0,038	38	597	0,043	54	2104	0,073
7	756	0,036	23	1457	0,047	39	2791	0,063	55	1015	0,04
8	278	0,042	24	528	0,053	40	897	0,068	56	386	0.046
9	1024	0,049	25	545	0,036	41	677	0,04	57	1957	0,063
10	1505	0,068	26	533	0,043	42	401	0,038	58	798	0,05
11	880	0,04	27	2257	0,059	43	1190	0,045	59	696	0,035
12	856	0,06	28	393	0,041	44	613	0,051	60	2413	0,089
13	689	0,038	29	1436	0,052	45	3267	0,074	61	952	0,043
14	731	0,046	30	2879	0,08	46	1073	0,053	62	556	0,039
15	5419	0,082	31	1118	0,041	47	814	0,036	63	1829	0,05
16	424	0,052	32	292	0,045	48	768	0,066	64	335	0,049

The obtained results allow us to construct a compromise curve.

Results

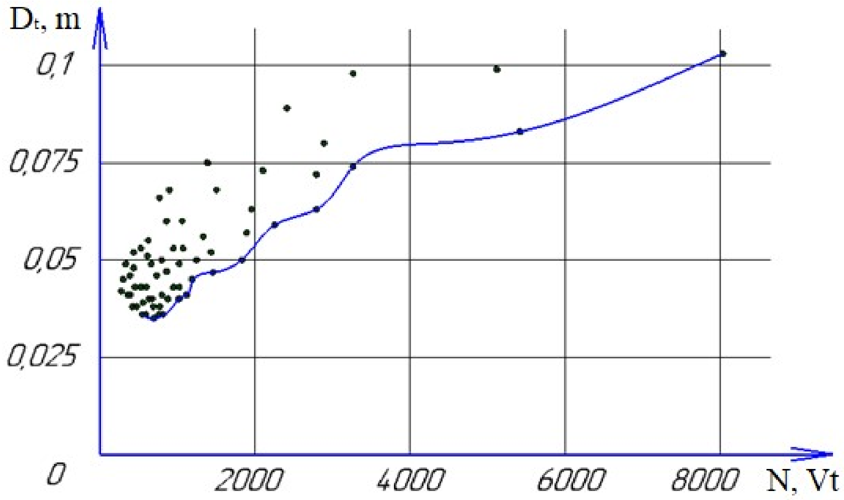

Figure 2. Distribution of calculated points and a compromise curve constructed from them.

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According to this distribution, we build a compromise curve according to the following rule: with the same value of one parameter, the point with the minimum value of the second is considered optimal.

Conclusion

According to this distribution, we build a compromise curve according to the following rule: with the same value of one parameter, the point with the minimum value of the second is considered optimal. This is seen from the compromise curve obtained - when considering 64 LP-tau sequence points, 13 of them entered the Pareto set and formed a compromise curve, but with a power consumption of more than 4000 W, only two points hit the curve. Thus, the described method is recommended when calculating high-speed low-power axial pumps.

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