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Optimization of a radial guide device with a no-vane transfer channel

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Abstract

Various studies show that the centrifugal multistage pump guide vane greatly determines the hydraulic efficiency of the pump and, as a result, the optimal mode of its operation. In order to increase the pump efficiency, the radial guide vane with a no-blade transfer channel was optimized. Three geometrical parameters and the number of channels of the guide vane were chosen as optimization parameters; the hydraulic efficiency was the optimization criterion. 128 computational models were made, and the efficiency values at the operating point were obtained by the method of hydrodynamic modeling. As a result, significant increase in the pump efficiency was achieved.

Introduction

Nowadays research of centrifugal pumps in our time are rising in number [1] - [10]. In these studies, various methods of mathematical modeling are becoming increasingly important. Publications [11] - [16] are of the greatest interest. It should be noted that for a long time the impeller was considered to be the main part of the pump, as it almost completely determines all its energy qualities. In the VNIIGidromash, Professor S. S. Rudnev together with the staff conducted a research, the results of which radically changed the status of the diverting device as a secondary pump unit. They have shown that the output device is no less important than the impeller. While the impeller determines the energy transfer to the fluid from the drive, the output device largely determines the hydraulic losses and, therefore, the hydraulic efficiency of the pump and the optimal mode of its operation.

One of the varieties of output devices is the guiding apparatus. Thus, the primary direction of a multistage centrifugal pump efficiency increase is the optimization of the guide vane.

The considered pump CNS 300-500 has 5 stages with nominal parameters: $Q = 300 \text{ m}^3/\text{h}$ -volumetric flow, $H=500 \text{ m}$ -head, $n = 2900 \text{ rpm}$ - rotor rotation speed, $n_s=97$ -specific speed coefficient.

Methods and results

The guide vane consisting of direct, transfer and reverse channels can be of several main types: radial with a no-vane transfer channel, radial channel and radial with a no-vane diffuser. Also guide vanes can be divided into blade and channel (tubular). For the study, the most common type of guide vane was chosen: a radial with a no-vane transfer channel (Fig. 1).





Fig. 1.Radial channel guide vane with a no-vanetransfer channel.

As a result of preliminary calculations of a guide vane, 3 geometrical parameters which have the greatest influence on the selected optimization criterion (hydraulic efficiency) were obtained. These are the entrance diameter of the guide vane (D_3), the ratio of the input and output diameters (D_4 / D_3) and the radial direction diffuser angle of the channel (Θ). In addition, z , the number of channels of the guide vane, was taken as an optimization parameter since it has a significant impact on the efficiency. The values of the optimization parameters are presented in Table 1.

Table 1.Vane guide optimization parameters.

Parameter	Min	Max
D_3 , mm	292	300
D_4/D_3	1,3	1,5
Θ , °	5	15
z	6	9

It was decided to use LP-tau search method as a quasi-random sequence generator to create an initial population. 128 models with different values of geometrical parameters for different z numbers were generated.

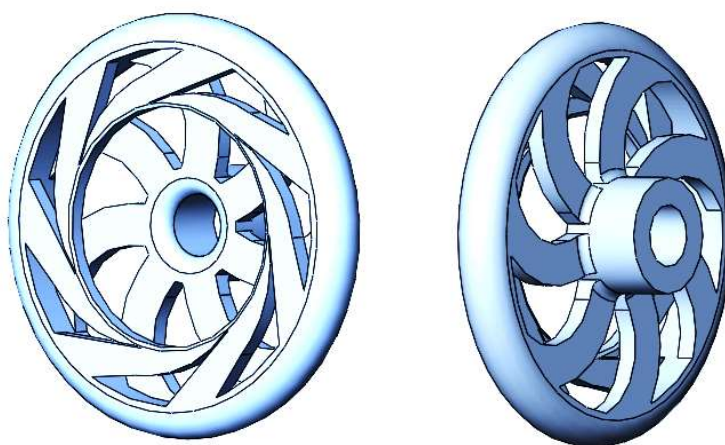
Table 2. Vane guide optimization parameter values.

Model no	D_3 , mm	D_4/D_3	Θ , °
0	296	1,4	10
1	294	1,45	7,5
2	298	1,35	12,5
3	293	1,425	13,75
4	297	1,325	8,75
5	295	1,375	11,25
6	299	1,475	6,25
7	292,5	1,488	11,875
8	296,5	1,387	6,875
9	294,5	1,338	14,375
10	298,5	1,438	9,375

Окончание табл. 2

Modelno	D_3 , мм	D_4/D_3	Θ , °
11	293,5	1,363	8,125
12	297,5	1,462	13,125
13	295,5	1,413	5,625
14	299,5	1,313	10,625
15	292,25	1,406	9,063
16	296,25	1,306	14,063
17	294,25	1,356	6,563
18	298,25	1,456	11,563
19	293,25	1,331	10,313
20	297,25	1,431	5,313
21	295,25	1,481	12,813
22	299,25	1,381	7,813
23	292,75	1,394	13,438
24	296,75	1,494	8,438
25	294,75	1,444	10,938
26	298,75	1,344	5,938
27	293,75	1,469	7,188
28	297,75	1,369	12,188
29	295,75	1,319	9,688
30	299,75	1,419	14,688
31	292,125	1,459	14,531

The calculation of the characteristics of the guide vane was carried out via the hydrodynamic modeling methods. To carry out the calculations, it is necessary to have a solid model of the liquid in the guide vane (wet part) [17, 18]. These models were built for all 128 combinations of parameters. An example of a 3d model is presented on Fig. 2

**Fig. 2.** 3d model of the wet part of a guide.

According to the results of the calculation, the pump efficiency values at the nominal flow rate for 128 models were obtained and are summarized in Table 3.

Table 3. Efficiency values for the models.

№	z=6	z=7	z=8	z=9
0	71,84615	74,63696	76,16436	77,1819
1	72,13242	76,23065	76,64311	77,45546
2	71,62466	72,60727	74,96188	76,17113
3	72,87196	78,00551	77,58177	78,30279
4	70,52284	72,61815	74,64398	75,71789
5	71,34676	75,12726	76,28521	77,16787
6	71,84011	72,46152	75,10506	76,2552
7	73,24223	78,91635	77,83937	78,81076
8	71,18466	73,72123	75,46981	76,33718
9	71,31495	74,97471	75,99549	76,92168
10	71,84262	73,04025	75,51601	76,71559
11	72,04613	75,78705	75,8797	76,66931
12	72,26775	74,44898	76,72787	77,88402
13	71,34509	74,24394	75,44609	76,60036
14	72,29774	70,85749	73,75359	74,99172
15	72,90423	77,96368	76,84712	77,7681
16	69,43522	72,98789	75,01044	75,90298
17	71,04041	74,76312	75,45487	76,1858
18	71,41798	73,67538	76,19555	77,38556
19	71,32955	76,05073	75,82998	76,78656
20	70,75869	73,10948	75,03615	76,04021
21	72,88367	76,25514	77,46307	78,55237
22	69,79679	71,75854	74,40408	75,585
23	72,67881	77,68059	77,02212	77,94046
24	71,88522	74,79831	76,82994	77,92008
25	72,46815	76,24634	77,14632	77,99227
26	69,34801	71,35854	73,70893	74,95876
27	72,66588	76,41285	76,60459	77,66013
28	70,46876	73,04595	75,29463	76,46306
29	70,02588	73,53144	75,06103	76,10218
30	70,35392	72,18364	75,38302	76,25135
31	73,93425	79,14716	78,13022	78,68652

For greater clarity figure 3 shows a histogram of the pump efficiency distribution on the number of the computational model with $z = 9$.

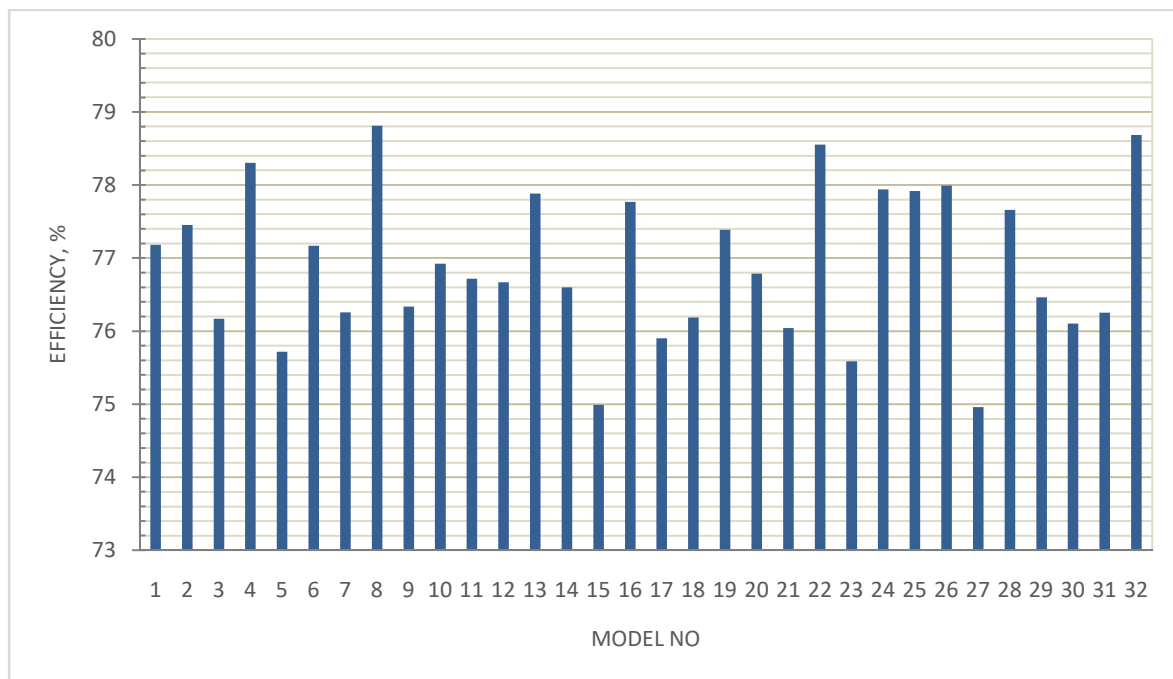


Fig. 3. histogram of efficiency distribution at $z=9$.

Fig. 4 shows the dependence of the efficiency on a value equal to the ratio of the diameters of the entrance to the guide vane and the output of the impeller, D_3 / D_2 , where D_2 is the impeller diameter with $z = 6$.

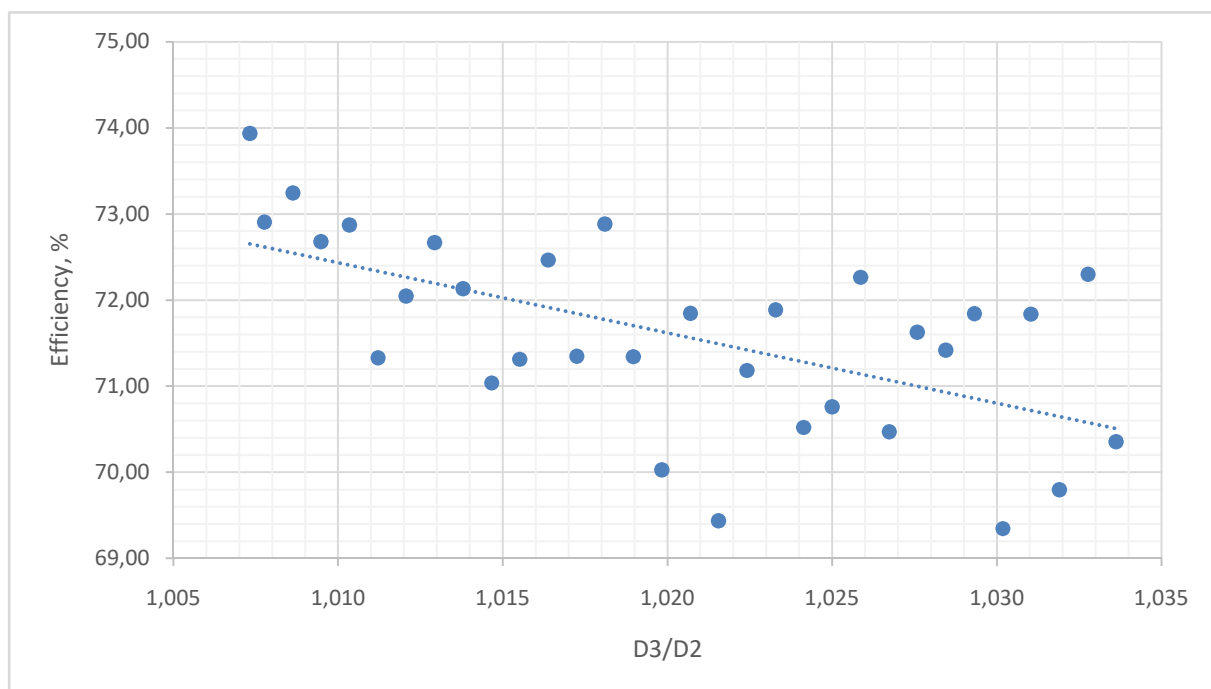


Fig. 4. Efficiency dependence on D_3/D_2 at $z=6$.

Figure 5 shows efficiency dependence on D_4/D_3 , for $z=6$.

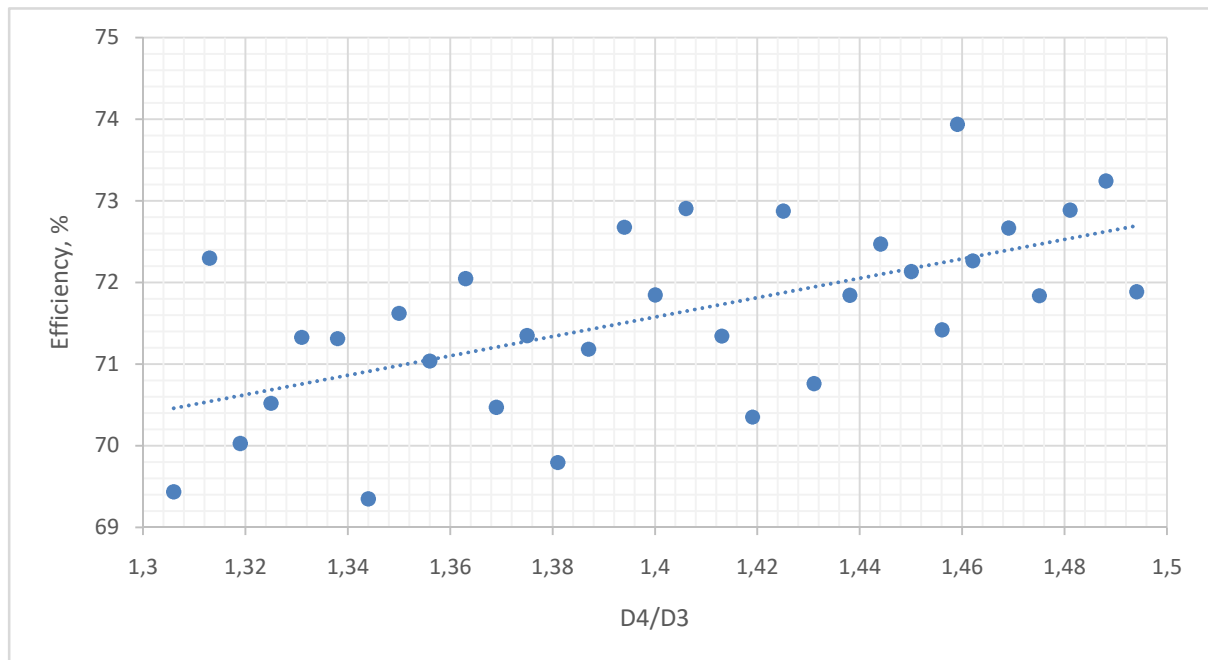


Fig. 5. Efficiency dependence on D_4/D_3 at $z=6$.

Figure 5 shows efficiency dependence on the channel diffuser angle Θ , for $z=6$.

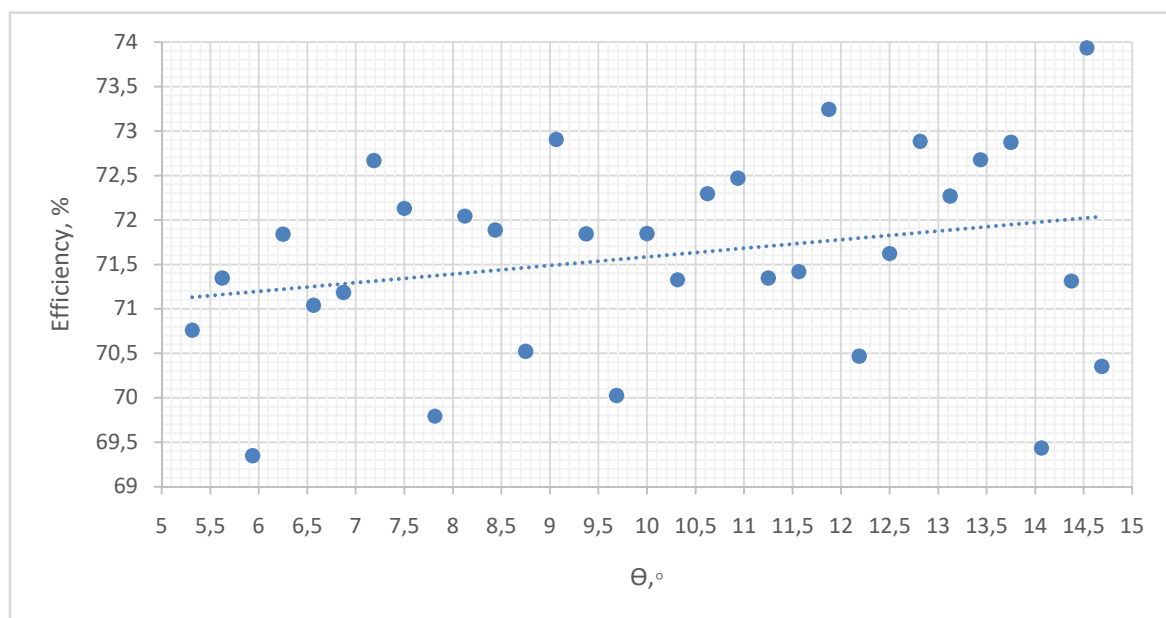


Fig. 6. Efficiency dependence on Θ at $z=6$.

Diagram on figure 7 illustrates z influence on efficiency. Maximum efficiency value is achieved at z equal to 9 in 90,2 % of all cases which proves advisability of 9 channels.

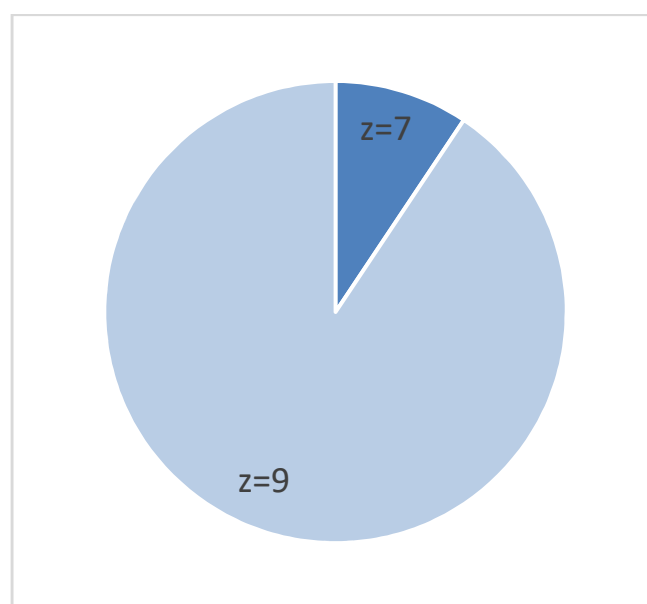


Fig. 7. Maximum efficiency value distribution diagram for different z numbers.

The best option for combining geometrical parameters for the pump is model No. 7 with $z = 9$, the efficiency value of this model is 78.8%, which is almost 10% more than that of the model with the minimum efficiency value. Parameter values of the best model are presented in Table 4.

Table 4. Optimal model.

№ модели	D_3 , мм	D_4/D_3	Θ , °	z	η , %
7	292,5	1,488	11,875	9	78,81076

Conclusion.

In this work, the influence of the main geometrical parameters of a multistage centrifugal pump guide vane on its efficiency was determined. After analyzing the results of hydrodynamic modeling, the laws of the parameter values influence on the optimization criterion were formulated. These patterns can serve as a recommendation when designing a pump guide vane.

In the future it is planned to expand the parameter space and conduct a similar study of the radial channel translational and radial transfer guide vanes with a no - vane diffuser, which will make further pump efficiency increase possible.

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