Development of methods for high-speed centrifugal pump analysis

A Protopopov¹,² and V Vigovskij¹

¹Bauman Moscow State Technical University, 5 Second Baumanskaya Street, Moscow, 105005, Russian Federation
²E-mail: proforg6@yandex.ru

Abstract: The article deals with the problems associated with the analysis of high-speed low-flow centrifugal pumps. The existing methods for analysis of such pumps and their disadvantages were reviewed. A method of multi-criteria optimization of high-speed centrifugal pumps has been proposed. The method is based on the search for a compromise between the cavitation characteristics and the hydraulic head of the centrifugal pump by plotting a compromise curve. The LP-tau searching method was used for finding the points of this curve in the article. The LP-tau search in the article was carried out by two design parameters - the rotor speed of the centrifugal pump and the diameter of the impeller blades.

1. Introduction

Nowadays low-flow centrifugal pumps are used in various industries. They have found their use as power sources in various closed systems, for example, in experimental stands of various purposes for supplying the working fluid. The following hydraulic characteristics are specific for low-flow centrifugal pumps: pump flow from 0 to 20 l/min, head - from 0 to 25 m. Most of the existing methods for calculating the main parameters of centrifugal pumps, which are described in the literature, for example ([1] - [7]), are aimed at relatively large values of the working fluid input. The use of such techniques for low-flow centrifugal pumps will lead to distorted pump parameters after calculation.

In the literature [8] - [17], one can also find a wide use of hydrodynamic modeling methods. However, the high costs of human and machine time for calculations can be attributed to the disadvantages of such methods.

Thus, all of the above listed necessitates the search of new methods for calculating low-flow centrifugal pumps free from the above-mentioned disadvantages.

One of the main parameters affecting the operation of the pump are the pressure and cavitation margin. As a rule, these are conflicting parameters: the second has to be sacrificed when the first is increasing. There is a problem in finding a compromise solution, when the second parameter is maximum at the selected value of the first parameter. This question is not ordinary, taking into account that many other parameters and nuances affect these characteristics.

The pressure and cavitation safety margin in low-flow centrifugal pumps, among other parameters, are influenced by the pump shaft speed and the impeller diameter at the inlet. The attempt to determine the final dependence creates new difficulties, since both criteria are significant and it is not possible to determine the weights for them, since a large error appears. Therefore, it was decided to use LP-tau search.
2. Generating LP-tau sequence points

The LP-tau search generates points in a quasi-random manner within the specified interval for two parameters. In our case, the diameter of the impeller at the inlet of the working cavity "D" can vary from 3.5 to 6.5 mm, the rotational speed of the shaft "n" - from 13000 to 17000 rpm. Then the field of generated work points will be a rectangle.

The resulting LP-tau sequence in the study region is shown at figure 1.

![Figure 1. The point generation region.](image)

3. The construction of a compromise curve

The values of the cavitation margin and pump head are found according to the values of the design parameters obtained above.

![Figure 2. Distribution of calculated points.](image)
The compromise curve is constructed for this distribution by the following reasons: for the same value of one parameter, the point with the highest value of the second is considered to be the “winning”. It is clear that the compromise curve have to pass through these “winning” points.

![Figure 3. The compromise curve.](chart.png)

**Conclusion**
The use of LP-tau sequence for finding a compromise between the pressure and the cavitation margin when varying the rotor speed and the diameter of the impeller inlet is a very effective method. This is clearly seen from the obtained compromise curve - when considering the 32 points of the LP-tau sequence, 5 of them entered the Pareto set and formed a compromise curve. Thus, the above-mentioned method can be recommended for high-speed centrifugal pump analysis.

Published under licence in *Materials Science and Engineering* by IOP Publishing Ltd. Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

**References**
[1] Lomakin V O, Petrov A I and Kuleshova M S 2014 Issledovanie dvuhfaznogo technenija v osecentrobezhnom kolese metodami gidrodinamicheskogo modelirovanija *Nauka i obrazovanie: jelektronno nauchno-tehnicheskoe izdanie* no 9 pp 45–64

[2] Lomakin A A1966 *Centrobezhnye i osevye nasosy* Moscow Mashinostroenie Publ. 354 p

[3] Lomakin V O, Artemov A V and Petrov A I 2012 Opredelenie vlijanija osnovnyh geometricheskikh parametrov otvoda nasosa NM 10000-210 na ego karakteristikи *Nauka i obrazovanie: jelektronno nauchno-tehnicheskoe izdanie* no 8 pp 5

[4] Lomakin V O and Petrov A I 2012 Verifikacija rezul’tatov rascheta v pakete gidrodinamicheskogo modelirovanija STAR-CCM+ protochnoj chaste centrobezhnogo nasosa AH 50-32-200 *Izvestija vysshih uchebnih zavedenij. Mashinostroenie* no C p 6

[5] Lomakin V O, Petrov A I and Shherbachev P S 2012 Razrabotka bokovogo poluspiral'nogo...
podvoda s uvelichennym momentum skorosti na vhode v rabochee koleso. Izvestija vysshih uchebnyh zavedenij. Mashinostroenie no S pp 3–5.

[6] Petrov A I, Martynov N D, Pokrovskij P A, Pashhenko V I, Ustjuzhanin P Ju, Korolev P V and Artemov A V 2010 Opyt razrabotki stenda dlja ispytaniij krupnyh centrobezhnyh nasosov Nauka I obrazovanie: jelektronno nauchno-tekhnicheskoe izdanie no 11 2 p

[7] Borovin G K and Lapshin V V 2018 Mathematica Montisnigri

[8] Guskov A M, Lomakin V O, Banin E P and Kuleshova M S 2017 Minimization of Hemolysis and Improvement of the Hydrodynamic Efficiency of a Circulatory Support Pump by Optimizing the Pump Flowpath Biomedical Engineering 4 pp 229–233

[9] Lomakin V O, Chaburko P S and Kuleshova M S 2017 Multi-criteria Optimization of the Flow of a Centrifugal Pump on Energy and Vibroacoustic Characteristics Procedia Engineering 176 pp 476–482

[10] Gouskov A M, Lomakin V O, Banin E P and Kuleshova M S 2016 Assessment of Hemolysis in a Ventricular Assist Axial Flow Blood Pump Biomedical Engineering 4 pp 12–15

[11] Lomakin V O, Kuleshova M S, Bozh’eva S M 2016 Numerical Modeling of Liquid Flow in a Pump Station Power Technology and Engineering 5 pp 324–327

[12] Lomakin V O 2015 Proceedings of 2015International Conference on Fluid Power and Mechatronics

[13] Lomakin V O, Kuleshova M S and Kraeva E A 2015 Fluid Flow in the Throttle Channel in the Presence of Cavitation Procedia Engineering 106 pp 27–35

[14] Pugachev P V, Svoboda D G and Zharkovsky A A 2016 Calculation and design of blade hydraulic machines. Calculation of viscous flow in blade hydraulic machines using the ANSYS CFX package. St. Petersburg Publishing house of Polytechnic University 120 p.

[15] Petrov A I 2016 Technique of continuous obtaining of characteristics of a vane pump for variable temperature and viscosity of a working fluid during tests in a thermal pressure chamber Engineering Bulletin Electronic Journal no 10 Available at: http://technomag.edu.ru/doc/850931.html

[16] Petrov A I and Isaev N Ju 2017 Gidrodinamicheskoe modelirovanie raboty centrobezhnogo nasosa v zone otricatel'nih podach Gidravlika no 3 pp 91–101

[17] Petrov A I and Isaev N Ju 2017 Issledovanie raboty lopastnogo nasosa v zone otricatel'nih podach metodami gidrodinamicheskogo modelirovanija Nauchnoe obozrenie no 13 pp 75–80