Obtaining the head characteristic of a Low Flow Centrifugal Pump by numerical methods

IOP Conf. Series: Materials Science and Engineering **492** (2019) 012035 doi:10.1088/1757-899X/492/1/012035

Obtaining the head characteristic of a Low Flow Centrifugal Pump by numerical methods

A Shablovskiy[1,2] and E Kutovoy[1]

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

[2]E-mail: shabl@bmstu.ru

Abstract. During the study of various problems related with centrifugal pumps, it would be extremely convenient to have a head characteristic (head-capacity curve) approximated by any mathematical function. In so doing, in the field of small pump output flow experiments show that its characteristic is linear. In order to verify that this characteristic is truly linear, a mathematical experiment was carried out using the methods of hydrodynamic modeling and its approximation was carried out using the least square method and the maximum deviation from it was calculated.

1. Introduction

To solve a number of scientific and technical problems [1-5], it is interesting to obtain a head-capacity curve of a low flow centrifugal pump as an analytical function. It is supposed [6-12] that in the field of small pump output flow the head-capacity curve is linear as friction losses are proportional to the square of the head and in the field of small pump output flow the square of the head can be neglected.

It should be emphasized that the problems related to the study of head-capacity curve of centrifugal pumps are highlighted in the literature [13-18], but the problem of the approximation of the head-capacity curves by the analytical function has not been adequately debated.

2. Mathematical model

For a solving this problem was developed a 3D model of a low flow centrifugal pump and a number of points of the head-capacity curve of this pump were calculated by numerical methods using the STAR-CCM + software package. The results of this calculation are presented in table 1:

Table 1. Estimated points of head-capacity curve of experimental low flow centrifugal pump.

No	*H*, m	*Q*, l/min
1	5.1	0
2	5.02	0.25
3	4.94	0.5
4	4.8	1.0
5	4.75	1.5
6	4.66	1.75
7	4.59	2.0

Therefore, we have the following estimated head-capacity curve characteristic of a low flow centrifugal pump. Figure 1 illustrates that the characteristics of a low flow centrifugal pump are approximately linear, which accords well enough with practice.

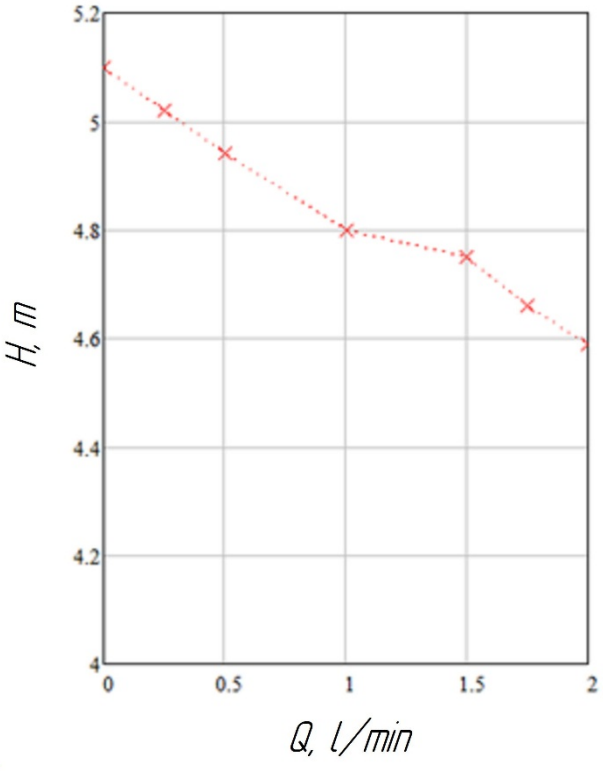

Figure 1. Estimated head-capacity curve characteristic of a low flow centrifugal pump.

However, it is interesting to check how linear the characteristic of a low flow centrifugal pump is. For this purpose, the method of least squares is used. We will carry out the approximation of the estimated head-capacity curve of the following function:

$$y = a + b \cdot x \tag{1}$$

As is known [18], in the case of a function form (1), the method of least squares for finding the coefficients a and b gives the following formulas:

$$\begin{cases} b = \dfrac{\sum_{t=1}^{n} x_t \cdot y_t - \sum_{t=1}^{n} \frac{x_t}{n} \cdot \sum_{t=1}^{n} \frac{y_t}{n}}{\sum_{t=1}^{n} \frac{x_t^2}{n} - \left(\sum_{t=1}^{n} \frac{x_t}{n} \right)^2} & (2) \\ a = \sum_{t=1}^{n} \dfrac{y_t}{n} - b \cdot \sum_{t=1}^{n} \dfrac{x_t}{n} & (3) \end{cases}$$

where
x_t – is the t-th (current) value of pump output flow in table 1;
y_t – is the t-th (current) value of head in table 1;
n – is the number of points, in our case $n = 7$.

Substituting the values from table 1 into the system of equations (2)-(3), for our particular case we have

$$\begin{cases} b = -0,241(m \cdot min)/l \\ a = 5,079\,m \end{cases}$$

Substitute the coefficients a and b into formula (1) and obtain the following approximation function:

$$H(Q) = 5,079 - 0,241 \cdot Q \tag{4}$$

Therefore, obtain following head-capacity curves (estimated curve is shown by dots, approximation curve is shown by line). Figure 2 illustrates that the maximum discrepancy between the approximation curve and the target points is observed at the point (4.8 m; 1 l / min) and is 0.037 m.

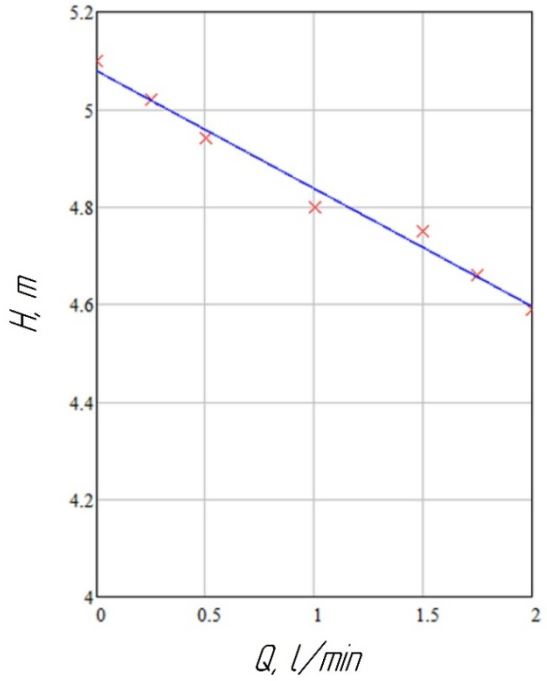

Figure 2. Estimated head-capacity curve of a low flow centrifugal pump.

Define the maximum admissible error of this discrepancy:

$$\sigma = \frac{4,837 - 4,8}{4,837} = 0,76\%$$

3. Conclusions

Therefore, it can be concluded that in the field of small pump output flow, the head-capacity curve of the low flow centrifugal pump is linear with an accuracy of less than 1%. This result can be used in scientific and practical activities for the mathematical modeling of low flow centrifugal pumps.

References

[1] Lomakin V O, Petrov A I and Kuleshova M S 2014 Investigation of a two-phase flow in an axial centrifugal wheel by methods of hydrodynamic modeling *Science and education: electronic scientific edition of Bauman MSTU* (9) pp 45–64 (in Russian)
[2] 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 Flow path *Biomedical Engineering* 4 pp 229–233
[3] Lomakin V O, Chaburko P S, 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
[4] 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
[5] Lomakin V O, Kuleshova M S and Bozh'eva S M 2016 Numerical Modeling of Liquid Flow in a Pump Station *Power Technology and Engineering***5** pp 324–327
[6] Lomakin V O 2015 *Proceedings of 2015 International Conference on Fluid Power and Mechatronics*
[7] Min'kov L L, Krokhina A V and Dueckc J 2011 Hydrodynamic mechanisms of the influence of injection on the classification characteristics of a hydrocyclone*Journal of Engineering Physics and Thermophysics***84** (4) pp 807–819
[8] Isaev S A, Kornev N V, Leontiev A I and Hassel E 2010 Influence of the Reynolds number and the spherical dimple depth on turbulent heat transfer and hydraulic loss in a narrow channel *International Journal of Heat and Mass Transfer***53** (1-3) pp 178–197
[9] Marchevskii I K and Puzikova V V 2016 Numerical simulation of the flow around two fixed circular airfoils positioned in tandem using the LS-STAG method *Journal of Machinery Manufacture and Reliability***45**
[10] Ionaitis R R and Chain P L 2009 Principles for engineering active-passive hydrodynamic control-and-safety systems for nuclear reactors *Atomic Energy***106** (3) pp 175–184
[11] Pelevin F V, Avraamov N I, Ir'yanov N Y, Orlin S A, Lozovetskii V V and Ponomarev A V 2018 Intensification of Heat Exchange in the Regenerative Cooling System of a Liquid-Propellant Rocket Engine *Journal of Engineering Physics and Thermophysics***91** (3) pp 601–610
[12] Aref'ev K Yu, Voronetskii A V, Il'Chenko M A 2013 Dynamic characteristics of a resonant gas-dynamic system for ignition of a fuel mixture *Combustion, Explosion and Shock Waves* **49** (6) pp 657–661
[13] Krapivtsev V G 2017 Model Studies of Coolant Flow Hydrodynamics in VVER-1000 In-Reactor Pressure Channel *Atomic Energy***122** (5) pp 304–310 (2), pp. 130-136.
[14] Lomakin V O, Artemov A V and Petrov A I 2012 Determination of the influence of the main geometrical parameters of the pump outlet NM 10000-210 on its characteristics *Science and education: electronic scientific edition of Bauman MSTU* no 8 p 5 (in Russian)
[15] Lomakin V O, Petrov A I and Shcherbachev P S 2012 Development of a casing with an increased velocity moment at the impeller inlet. *Proceedings of Higher Educational Institutions. Machine Building* (S) pp 3–5 (in Russian).
[16] Petrov A I, Martynov N D, Pokrovsky P A, Pashchenko V I, Ustyuzhanin P Yu, Korolev P V, Artyemov A V 2010 Experience in developing a testing workbench for large centrifugal pumps *Science and education: electronic scientific edition of Bauman MST*U, (11) 2 p (in Russian)
[17] 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 (in Russian)
[18] Linnik Yu V 1962 *The method of least squares and the basics of mathematical-statistical theory of processing observations* 2nd ed Moscow (in Russian)