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The determination of the optimal profile line of stator arc in the double-acting wing pumps

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Abstract. In the article there are results of the study of correction mechanism of the stator guide of the double-acting wing pumps. Software application has been developed and tested, it allows determining optimal profile line of stator arc of worn-out pump on the basis of spline interpolation, on condition of preservation and improvement of functional characteristics of the double-acting wing pump. As a result of theoretical and practical experiments the number of double-acting wing pumps has been repaired, their characteristics have been improved. The enterprise has managed not only to save money resources on the repair of wing pumps but also to get a significant profit after the realization of goods.

1. Introduction

The simplicity in use and compact size of double-acting wing pumps are the key for their wide application in the machine building. The double-acting wing pump in one rotor revolution performs two total cycles of work, two processes of uncharging and two processes of charging [1-4]. The significant effect for the pump work has the profile line of stator arc, which defines kinematics and dynamics of the wing. In most cases the breakdown cause of pumps is the deformation of stator guide, at the same time there is a possibility of quick change of the suite of the rotary group (stator, rotor, side discs) in case of its worn-out, as well as the possibility to get pumps with different displacement volume by changing only the radius and connecting stator profile line [1-6].

JSC «Rosuniversalsnab» (<http://www.russnab.ru>) offered to solve the problem of defining of the profile line of stator arc of the worn-out pump with the aim of improvement of its working efficiency and further use in practical activity [7]. To solve the task it is necessary to develop software application, which defines the profile line of stator arc, prints it on the screen, as well as calculates the main characteristics of the pump and directs them to CNC machine.

2. Theoretical basis of study

Efficiency of double-acting pumps is proportional to the difference between long and short radii of the stator, which is constant for this pump construction and in the process of work, cannot change. While choosing the arc of the stator profile line, it is necessary to take into consideration that wing movement



in rotor slots must be smooth with steady acceleration. On the basis of the analysis of technical literature on this problem three variants of theoretical profile line of stator arc were revealed [1-6].

Let R be a long radius of the profile line, and r_0 – a short radius of the profile line. As the first variant the equation of stator arc in the form of two functions is proposed:

$$\rho = \begin{cases} r_0 + \frac{2(R-r_0)}{\alpha^2} \varphi^2, & 0 \leq \varphi \leq \frac{\alpha}{2}; \\ 2r_0 - R + \frac{4(R-r_0)}{\alpha} (\varphi - \frac{\varphi^2}{2\alpha}), & \frac{\alpha}{2} \leq \varphi \leq \alpha. \end{cases} \quad (1)$$

While having this profile line of stator arc smooth speed rate increase is provided from zero to maximum value with the subsequent speed rate decrease and the absence of the detonation of the first kind.

The second variant of stator arc, developed in literature [1-4], due to sinusoidal character of speed and acceleration change, is written as

$$\rho = r_0 + \frac{R-r_0}{\alpha} \varphi (1 - \frac{1}{2\pi} \sin \frac{2\pi}{\alpha} \varphi). \quad (2)$$

The third variant of stator arc is based on the change of speed on sinusoidal wave and the change of acceleration on cosine wave, the equation is given by

$$\rho = \frac{R+r_0}{2} - \frac{R-r_0}{2} \cos \frac{\pi}{\alpha} \varphi. \quad (3)$$

In the view of most authors, [1-5] stator profile line, providing sinusoidal change of wing acceleration as in equation (3), is considered the most theoretically excellent, as the one, excluding the detonation of the second kind, though allowed ration $\frac{R}{r_0}$ at this profile line is less than at the

other two. The greatest allowed ratio $\frac{R}{r_0}$ is provided at the stator profile according to equation is in

the first variant of the arc (1), when the acceleration of the wing is constant. Dependences between R and r_0 , defined by arc equations, are based on the value exceedance of centripetal acceleration over the value of relative acceleration. In theory and in practice there are stators, produced with all the tree profile lines, moreover the results of tests show [3], that from the point of view of smoothness and noiselessness of pump work, stators with profile lines, defined by the last equations, do not have advantages in comparison with the stator, the profile line of which is made according to the first type of equation. That's why it is reasonable to use stators not with a complex but with a more simple profile line, creating constant wing acceleration and providing a greater ratio of radii [5-6].

3. Methodics of study and the main parameters of developed software application

Under the optimal profile line we consider the one, which keeps the pump worked and at the same time its displacement volume does not decrease. The algorithm of defining the optimal stator arc of wing pump will be described without giving pure mathematical manipulations. After the series of practical measurements of real stator radii at different angles of rotation, the prescribed function is got tabularly. To calculate new coordinates of stator arc of the pump, arc approximation by the method of spline interpolation is used [8], after the comparison of the received function with the above mentioned theoretical arcs; the choice of the optimal stator arc is made, considering theoretical pump displacement.

Software application was developed in the programming environment Builder C++ [9]. The program calculates the coordinates of stator profile line and shows the profile line of stator arc pictorially; then it directs the data to CNC machine, as well as it calculates theoretical volume of hydraulic fluid consumption at this profile line of working chambers and defines the optimal arc,

necessary for the repair of the corresponding worn-out stator, on conditions of preservation and increase of the pump displacement.

After program run the user may either open the formerly saved file or create a new profile. To create a new profile, it is necessary to go to the menu “Graph”, to choose the option pumps. On the screen there will be the menu of setting practical measurements of the worn-out stator profile line, the values of these parameters the user can see in the top left-hand corner of the window. There are only eight parameters: r —short stator radius, R —long stator radius, Π — angle, inside of which the stator arcs are located, B —stator thickness, b —wing thickness, n — the number of rotor rotations, z — the number of wings, angle — angle of angular inclination of wings on radius R . Radii and angles affect the arc profile line directly, and all the other in data affect the volume (theoretical efficiency). The user can change all the parameters on demand. Later, using all the input measurements, the program calculates all the theoretical profile lines of stator arc, defines the optimal profile and shows it on the screen. If necessary, any of the profile lines, calculated by the program, can be analyzed and forcedly selected to be shown on the screen and directed to CNC machine. In the bottom right-hand corner, while pressing button V_1 and V_2 volume of hydraulic fluid consumption is calculated, V_1 — the volume before the repair, V_2 — the volume after the repair.

4. The main results of the study

In figure 1 there is one of the possible graphic presentations of the cross section of the part of the worn-out stator (in mm), needing planarization, in accordance with equations (1), (2) or (3).

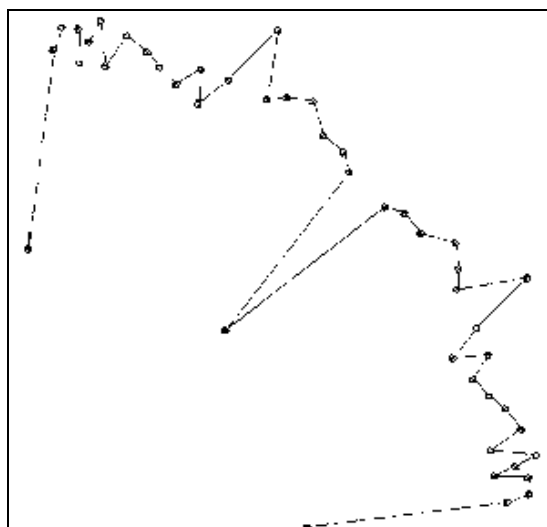


Figure 1. Graphic presentations of the cross section cut of the stator part.

Using the values of long and short stator radii, received as a result of the measurements, the program defines the possible profile lines of the stator arc theoretically, chooses the optimal one of them. In table 1 there is a percentage rating of the chosen profile lines.

Table 1. Percentage rating of the profile lines of worn-out pumps, chosen by the software application.

Arc profile line	Per cent
Equation (1)	7.62
Equation (2)	4.09
Equation (3)	5.17
Approximable	83.12

In figure 2 there is a screenshot of one of the calculated stator profile lines. In the top left-hand corner the master data are presented. In the bottom left - hand corner and the top right - hand corner there are control coordinates of a new profile line. In the bottom right-hand corner the values of the volume of hydraulic fluid before and after the repair are input. The option Help contains recommendations on the work with the program, gives measurement units of all the values. It is evident that in a depicted stator profile line the displacement volume has gone up more than two times, which proves the efficiency of the conducted study.

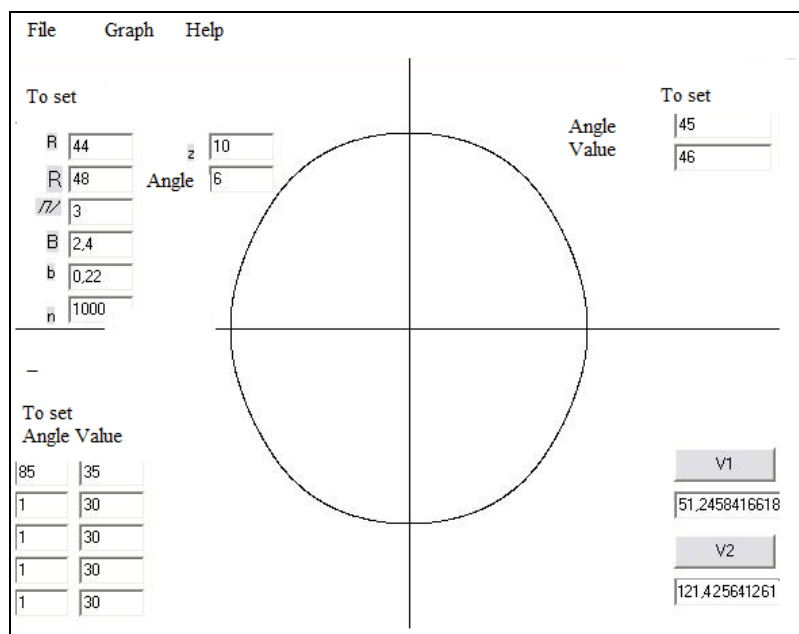


Figure 2. Application window for the calculation of the optimal stator arc.

The given software application was tested at the enterprise JSC «Rosuniversalsnab», where the stators were manufactured (repaired), they were made on various profile lines with the choice of the optimal kind of profile line arc, practical testing has shown that approximable arc is considered to be optimal most often, the arcs presented in theoretical literature are considered to be optimal much rarely.

5. Conclusions

The suggested methodics of the calculation of the optimal profile line of the stator arc in double - acting wing pumps is efficient and may be used while manufacturing and repairing pumps.

Software application:

- enhances the efficiency of the view of the stator arc;
- shows the arc on the screen;
- calculates theoretical volume of the hydraulic fluid consumption, at this profile line of working chambers.

Using this application some wing pump stators with different efficiency have been repaired, they have been tested on a special testing facility with different prescribed pressure. Deviations from normal work have not been noticed. The results of the experiment have shown that pump displacement has increased in all the cases. Thanks to this application displacement of the working pump can be increased.

The application has been introduced into the production successfully; enterprise trading volume has been increased.

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