Overview of methods for optimizing the flow of the centrifugal pump

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Abstract. This article is devoted to a review of the flow part of the centrifugal pumps (CFP), as well as methods for its optimization. The components of the flow part (inlet, impeller and outlet) were considered, and methods for their optimization were given. The analysis of the literature was carried out. Conclusions are drawn on the development and improvement of vane pumps.

Introduction

Pumps of the centrifugal type are widely used in various fields of industry: mining, chemical, municipal engineering, etc. [1]. So the centrifugal pumping system is designed to pump neutral cold water with a temperature of 1 to 45 °C with a small amount of mechanical impurities, the first type of centrifugal pump is used to pump hotter water up to 105 °C, the second type of centrifugal pump is used to pump acidic water, the third type of centrifugal pump is used to pump oil and the fourth type of centrifugal pump - for work in the oil system.

Since before the beginning of the previous century, pumps of the CFP type were produced on the basis of centralized orders of enterprises, by the development of serial production (1968–1970), there were more than 30 types, and the number of standard sizes produced exceeded 250 units. By the beginning of the 90s, the nomenclature was reduced by manufacturers to 22 types. On the one hand, the multiplicity was justified by the variety of operating parameters and conditions of water pumping, on the other — the lack of a sound scientific approach. Further actions in the field of CFP development were aimed at building a rational parametric device with a minimum number of pumps in this series and optimizing the flow part [2].

The main characteristics of vane pumps are resource and efficiency. These two parameters are often mutually exclusive: when you increase the first, you have to sacrifice the second. Thus, the optimization task is to find a compromise solution that will satisfy both parameters [3].

Optimization of the flow part

The flow part of the vane pump (Fig. 1) consists of three main elements: supply, impeller and outlet. The inlet is designed to supply liquid from the inlet pipe to the impeller. The impeller transmits the energy of the liquid. And the outlet transfers the fluid from the impeller to the pump outlet pipe or to another stage [4].
Most often, the goal of optimization is to increase the efficiency of the pump, but it is equally important to improve their cavitation quality, reliability and vibro-acoustic characteristics. Optimization can be performed using two methods: an intuitive method or optimization algorithms [5].

With intuitive optimization, a number of experiments are performed under the same conditions with a change in a certain part of the pump and the effect of the change is investigated. When using optimization algorithms, calculations are performed in the program using hydrodynamic modeling methods [6–10]. The person sets the step and sequence of actions, and selects the best result. The use of optimization algorithms reduces the influence of the human factor on the research result, but it is more difficult to perform [10–15] describes other methods for modeling processes occurring in centrifugal pumps.

**Methods for optimizing the supply include:**

1. Shifting the maximum efficiency towards higher feed rates by increasing the area of the inlet to the taper cone. Increasing the area allows you to increase the design flow rate and reduce the head, but increases the size of the pump [16];

2. Method for optimizing the side semi-spiral branch (Fig. 2), in which the entire supply is divided into three sections: the confuser section before entering the wheel, the spiral section from the confuser to the transition section, and the section from the transition section to the inlet pipe. In the zone of the spiral section, a "tongue" is installed that optimizes the flow of the shaft and prevents the flow of liquid in the direction opposite to the rotation of the wheel. The method is described in more detail in [17]. It allows optimizing the geometric parameters of the side semi-spiral branch, but there is an uneven distribution of liquid velocities and their moments at the inlet to the impeller, especially with large pump feeds. This in turn leads to a decrease in efficiency and deterioration of cavitation qualities;

3. Optimization semi-spiral inlet, based on [17], which decreases the width of the calculated and the intermediate sections, increase the radius of the volute, and changing the shape of the section "language", thereby achieving higher uniformity of the velocity distribution of the fluid and moments and reduce the vortex formation at the entrance to the wheel, which leads to increased efficiency and better cavitation characteristics [18];

4. Semi-spiral inlet with an increased moment of fluid velocity at the inlet to the impeller, which leads to an increase in the pump efficiency [19];

5. The use of B-splines for constructing a side semi-spiral inlet when working in CAD helps to simplify the design process of the inlet [20];
6. Optimization of the cross-section area and edge structure geometry in the study of the supply geometry under non-structural conditions, in which it is shown that the performance parameters depend on both geometric conditions and operating conditions [21].

![Diagram of a semi-spiral inlet](image)

**Fig. 2.** Diagram of a semi-spiral inlet

**Ways to optimize the impeller:**
1. The impeller with slits allows for a more uniform distribution of pressure, reduce cavitation, with the correct location and configuration will not affect the efficiency of the pump, but such a wheel will be more difficult to manufacture [22];
2. Reducing the radius of the impeller leads to a reduction in the optimal flow rate, but maintaining efficiency, this allows you to trim the impellers [17];
3. Changing the shape of the impeller blades affects the efficiency of the pump, this is considered and given in the form of an algorithm in [23];
4. The angle of installation of the blades at the outlet affects the head, so when the installation angle increases, the theoretical head increases, when the installation angle is greater than 90°, the proportion of dynamic head increases intensively, and for static head falls [24];
5. The number of blades depends on the speed coefficient and the size of the wheel, with a smaller size, usually choose a smaller number of blades to reduce the flow constraint of the blades [24].

**Ways to optimize the outlet and guide device:**
1. Changing the diameter of the guide device, the angle and the number of guide channels affects the efficiency. Thus, increasing the number of guide channels increases the efficiency of the pump [25, 26];
2. Comparison of channel and blade-less guide devices is given in [27];
3. The graph from [28] shows that as the channel width of the guide device increases, the maximum position shifts towards larger feeds;
4. Reducing the throughput of the spiral output is achieved by inserting into the outlet section or adding the outlet tongue, this is required to improve performance [29];
5. Greater diffusivity reduces the radial force by orders of magnitude [30]

**Conclusions:**
Various ways of optimizing the flow part of a CFP-type pump were considered. These methods are mainly aimed at increasing the efficiency of the pump. In addition, its cavitation qualities, reliability and vibro-acoustic characteristics are improved. In the design of the inlet and outlet for optimization, it is often suggested to use diffusivity and "tongues". Optimization is recommended using algorithms, since this saves time, reduces the likelihood of human error, and avoids creating a large number of real models of poor quality, and therefore saves money.
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