Analysis of various design methods for unloading a centrifugal pump rotor from axial forces

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Abstract. This article is devoted to a review of the main methods of unloading the rotor of a horizontal multistage pump from axial forces. Two methods are considered: a hydrofoam and an opposite arrangement of blocks of driving wheels. The drawings are given and a method for compensating axial force for each of them is described. Their advantages and disadvantages are described. General design guidelines are provided.

Introduction

Centrifugal pumps are widely used in various industries, such as mining, chemical, food, as well as in the field of public utilities. Currently, a lot of numerical research is being conducted aimed at improving the performance of pumping equipment. The main area of such research is pump optimization. However, do not forget about other equally important parameters, such as reliability. [1,2].

Optimization is performed using hydrodynamic modeling methods [3]–[7]. However, the application of these methods is sometimes difficult due to the large number of necessary calculations. In [8]–[13] other methods for modeling processes occurring in centrifugal pumps are described.

A large axial force acts on the rotor of a high-pressure horizontal multistage pump, which, in the absence or failure of unloading devices, can lead to axial displacement of the shaft with impellers in it in the axial direction towards the suction side.

Axial force in a multistage centrifugal pump and methods of balancing it

In the impeller of a one-way inlet due to its lack of symmetry relative to a plane perpendicular to the axis of rotation of the pump, an unbalanced hydraulic force arises, directed along the axis towards the entrance to the wheel. [14] This is due to the difference in pressure on the walls of the impeller (Fig. 1).

To balance this force in multistage pumps, the following discharge methods are used:

1. Hydraulic heel (hydraulic balancing device) The most common device for compensating axial force in multi-stage sectional pumps is the hydroheel. The hydrofoil contains a unloading disk 5 rigidly fixed to the shaft, a fixed support ring (pillow) 2, sequentially arranged cylindrical 1 and end 3 inductors and a chamber 4 separating these inductors (Fig. 2)
The full differential pressure at the heel is the difference between the discharge pressure and the pressure in the chamber behind the hydro-point, which is usually connected by a bypass pipe to the pump inlet. Part of the total pressure drop is throttled at the end throttle, the conductivity of which depends on the axial displacement of the rotor. For example, if under the influence of excessive axial force the rotor moves to the left, then the clearance in the end throttle decreases, which in turn will cause the pressure in the chamber to increase to a level that ensures the restoration of the equilibrium of the rotor. In addition to the axial balancing of the rotor, the hydrofoil performs an additional function of unloading the end seal of the pump from the discharge side from high pressure.

2. Opposed arrangement of groups of impellers

In using this method, the impellers are installed in groups in the opposite direction to each other (Fig. 3). The application of this method allows almost completely compensating for the axial force, as well as getting rid of the unloading unit, which increases the manufacturability of the design and increases the volumetric efficiency of the pump, since there will be no leakage through the unloading device. At the same time, it is necessary to provide for the construction of complex transfer channels, which leads to an increase in the dimensions of the pump and an increase in hydraulic losses.

In designing, it is important to choose the most optimal method of unloading the axial force. The main design criteria in this case should be the efficiency and service life of the pump. The joint analysis of these criteria can be carried out by analogy with the methodology described in [15]. To improve the overall efficiency of the pump, you must also pay attention to the design of the guide device for each stage. In addition, to verify the results obtained, a simulation can be performed using the method described in [16]. At the same time, it is necessary to take into account the criteria for manufacturability of the guide device [17].
Conclusion
In the article were considered the basic structural methods of unloading the rotor of a horizontal multistage sectional high-pressure pump from axial forces. According to the criteria of constructive reliability and ease of maintenance, the opposed arrangement of the groups of impellers is a more optimal constructive solution. General recommendations were given on the choice of a solution and the design of appropriate pumps.

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