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Simulation features of the impeller in a centrifugal pump

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Abstract:

To ensure the operability of machinery and equipment for the oil and gas industry, it is important to study their operation with subsequent improvement. This scientific work is devoted to highlighting the operation simulation of the impeller in a submersible centrifugal pump, because the pump itself is the main equipment in oil production. The main parts of a submersible centrifugal pump are its stages, consisting of an impeller and a guide vane. When the impeller rotates, a force interaction of the flow with the impeller blades occurs, while a pressure difference in the fluid flow on both sides of each blade arises. The pressure forces of the blades on the flow create a forced rotational and translational motion of the fluid, increasing its mechanical energy. It should be noted that the movement of fluid in pump sections is a rather complex process that is difficult to accurately describe analytically. However, today there are various computer programs (SOLIDWORKS FlowSimulation, ANSYS CFD, etc.) based on the finite volume method (FVM). To study the operation of a submersible centrifugal pump impeller, there has been built its three-dimensional model. As a result of calculations, the distribution of pressure and velocity in the cross section of the impeller was obtained.

Keywords: impeller, pressure, simulation, speed, submersible centrifugal pump

1. Introduction

In the oil and gas industry, pumps with different principles of operation and structure are usually used. However, in the production and transportation of oil, in most cases, dynamic pumps (mainly centrifugal pumps) are used [1,2].

In all dynamic pumps, the liquid is accelerated (its speed increases) in the inter-blade channels of the rotor, thanks to the blades, and it is decelerated (the speed decreases) in the channels of the stator (guide vane), that is, the kinetic energy of the liquid is converted into potential energy in the stator. The acceleration and deceleration process can occur once in one pump stage or repeatedly or sequentially in several stages of a multistage pump [3,4].

Fig. 1 shows a diagram of a sectional (one section) centrifugal pump [5].

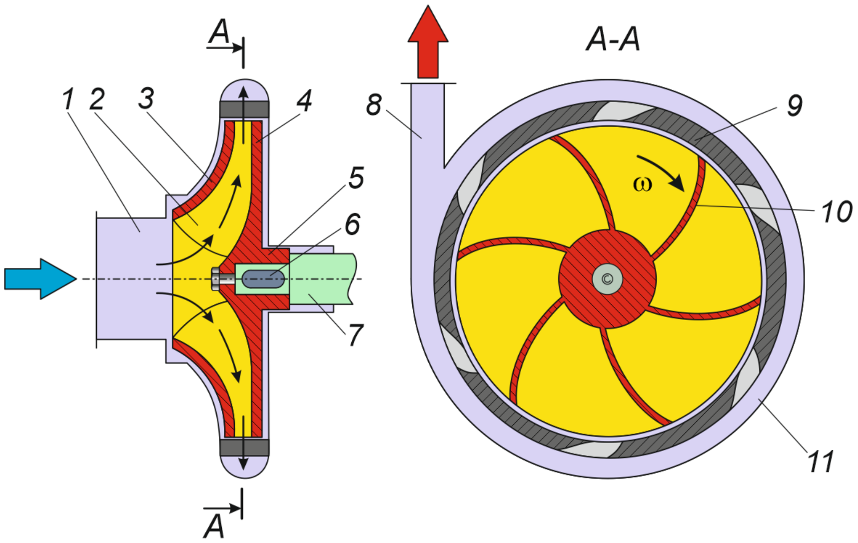

Fig. 1. Scheme of a sectional pump (one section)
1 - inlet pipe; 2 - impeller; 3,4 - impeller disks; 5 - hub;
6 - key; 7 - shaft; 8 - outlet pipe; 9 - guide vane;
10 - blades; 11 - annular branch

In sectional pumps, a guide vane element (stator) is used, in which the set of channels in the direction of fluid movement expands, leading to the transformation of the kinetic energy of the fluid into the potential one. In scroll pumps, this process takes place in a volute chamber [6].

When the wheels are connected in series, each of them creates a part of the total head, and the value of the pump head increases from impeller to impeller to the total value at the outlet (Fig. 2, Fig. 3) [7].

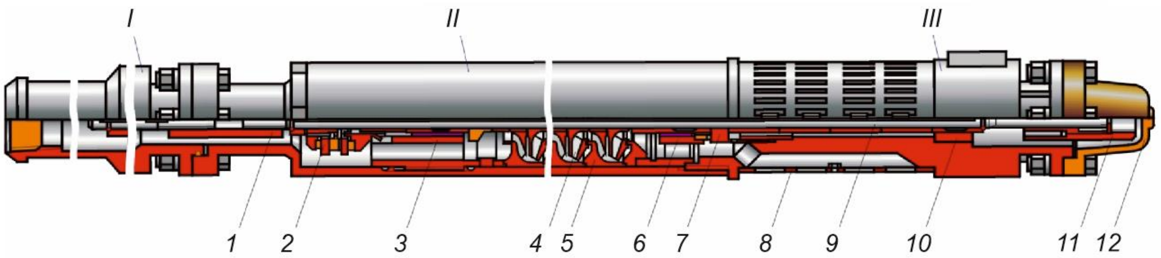

Fig. 2. Submersible centrifugal pump
I - head module; II - module-section; III - input module;
1 - splined coupling; 2 - knot of a support claque; 3, 6 - radial bearings;
4 - impeller; 5 - guiding element; 7 - support for the lower claque; 8 - mesh;
9 - shaft; 10 - radial bearing; 11 - splined coupling; 12 - protective cover

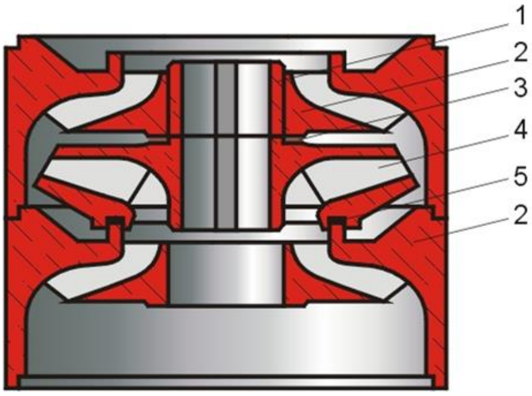

Fig. 3. Stage of a submersible pump
1 - protective sleeve; 2 - guiding device; 3 - top washer;
4 - impeller; 5 - lower washer

In centrifugal pumps, used in oil production, closed impellers are usually used. They most often contain 6 ... 8, and sometimes up to 12 vanes.

The geometric shape of the rotor blades has a significant effect on the head, flow and power of the pump. Centrifugal pumps mainly use backward curved vanes.

The movement of a real fluid in the interblade impeller channels is a rather complex hydromechanical process. Therefore, it is not possible to obtain the equation of motion in a purely theoretical way for a real centrifugal pump. For ideal conditions, the theoretical equations of fluid movement in the interblade channels of dynamic hydraulic machines (vane pumps and hydraulic turbines) were obtained by L. Euler. In such an impeller, the fluid moves in elementary streams (there is no phenomenon of a relative vortex), and the flow velocities, relative to the stationary walls of the housing channels, are the velocities of absolute motion. The scheme with an unlimited number of vanes in the impeller of a centrifugal pump leads to an elementary theory of the kinematics of the flow in the impeller.

When the fluid moves through the channels of the impeller with a limited number of blades, the nature of the flow changes significantly (Fig. 4). The relative movement in the interblade channels can be schematically considered as the sum of the movements: I - the movement of the fluid in the moving channels; II - vortex motion inside the interblade channels.

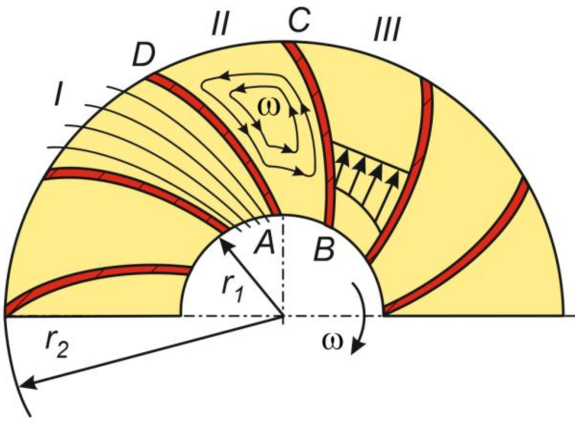

Fig. 4. The movement of fluid in the interblade channels of the impeller
I - fluid movement in the moving channel; II - vortex motion in the interblade channel;
III - velocity diagram in the interblade channel

The purpose of the work is to highlight the simulation features of the operation of a submersible centrifugal pump impeller.

2. Materials and Methods

Today, special computer programs based on the finite element method can be used to study the motion of a fluid flow in an impeller. These include, for example, SOLIDWORKS FlowSimulation, ANSYS CFD, etc. [8-11].

For the study, a three-dimensional model of a submersible centrifugal pump section (Fig. 5) was built. Fig. 6 shows a model of the impeller 2, located in the guiding device 1. It should be noted that the guiding device 2 (Fig. 3) is of an arbitrary shape, since the characteristics of the impeller are of interest for this study. In the future, it is planned to investigate the liquid movement through the whole section of the centrifugal pump.

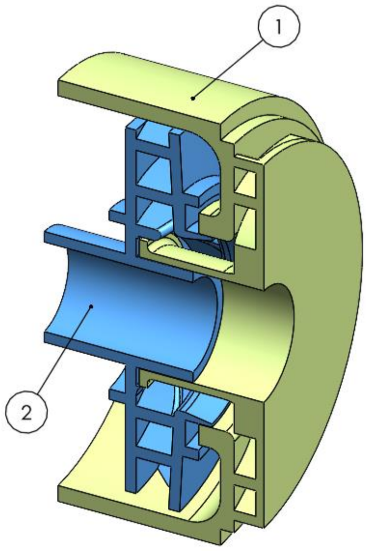

Fig. 5. A three-dimensional model of a submersible centrifugal pump section
1 - guiding device; 2 - impeller

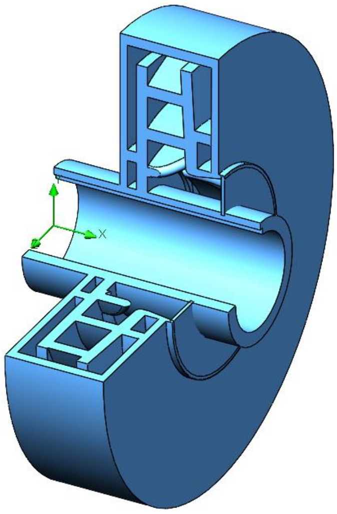

Fig. 6. Impeller model for the simulation

The input data for simulation are taken as follows: working medium - water; outlet pressure - atmospheric (1 atm); the flow rate of the working medium - 0.002 m^3/s; impeller rotational speed - 2820 rpm.

The design scheme is shown in Fig. 7. A feature of specifying the rotation of the pump impeller is that the program sees the entire model as a rotating one. Next, it is needed to choose the surfaces of the model that should not rotate and indicate them in the program window (Fig. 7). In our case, all internal surfaces of body 2 are chosen (Fig. 8).

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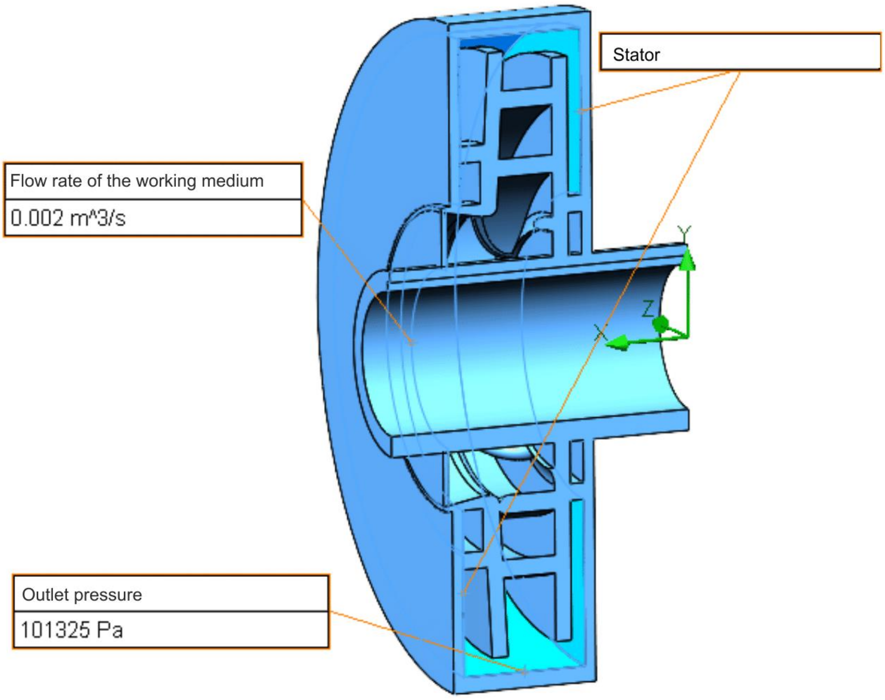

Fig. 7. Design scheme

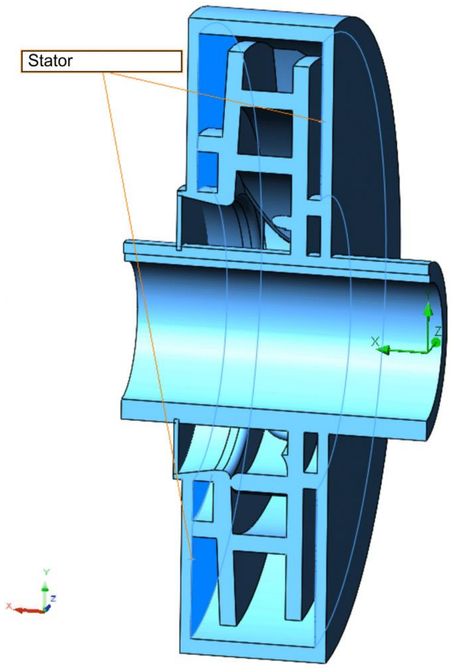

Fig. 8. Selecting model surfaces that should not rotate

After applying all the constraints and tasks of the initial data, the simulation process of the centrifugal pump impeller is started.

3. Results

Let us analyze the simulation modelling results presented in the form of the corresponding diagrams. Fig. 9 shows pressure distribution in the cross section of the studied centrifugal pump impeller, and in Fig. 10 - velocity distribution in the same section.

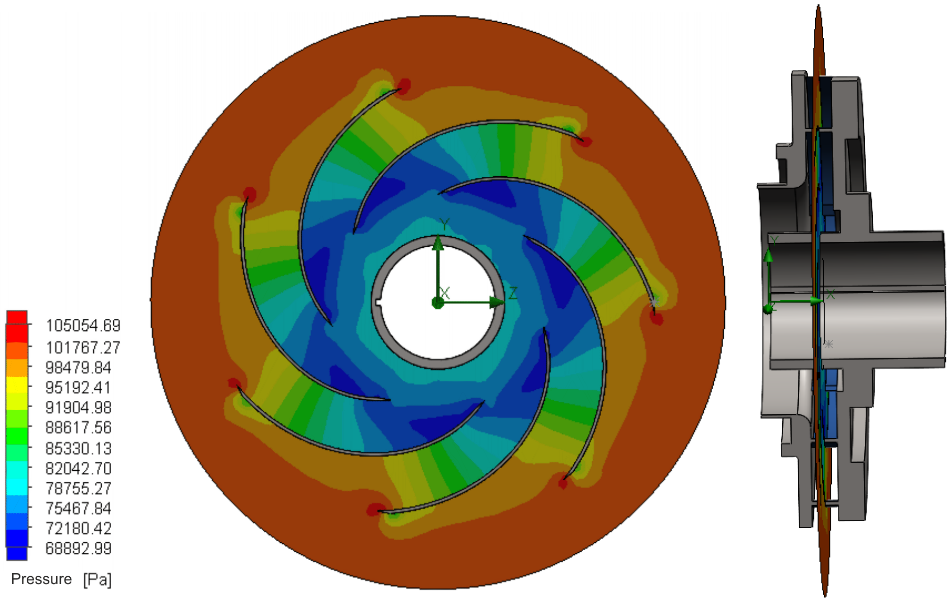

Fig. 9. Pressure distribution in the cross section of the impeller

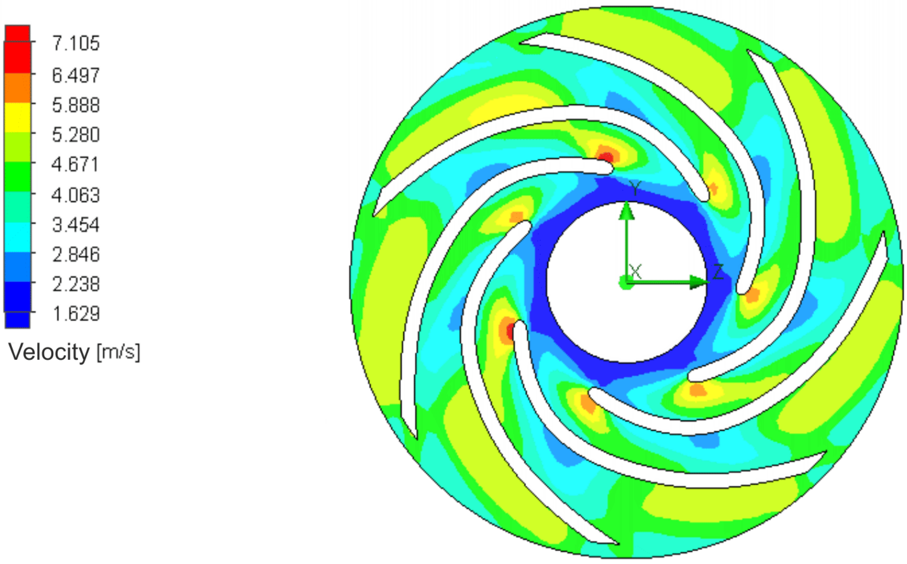

Fig. 10. Velocity distribution in the cross section of the impeller

4. Discussion

The given diagrams show the zones of change of the considered parameter with a wide range of colours. Considering the diagram of Fig. 9 changes in the pressure distribution, it can be seen that in the path of fluid flow through the interblade channel of the centrifugal wheel there are areas with minimal values of pressure at the beginning of the blade with a gradual increase in pressure towards the periphery. It is interesting that the pressure decreases from the inlet towards the beginning of the centrifugal wheel blade with its subsequent growth. Regarding the distribution of fluid flow velocity in

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the cross section of the impeller, there are areas where the velocity increases sharply. These zones are concentrated near the wheel blades at the inlet of the fluid. This phenomenon leads to an increase in the hydraulic resistance of the fluid flow, and as a consequence to a decrease in the hydraulic efficiency of the pump stage. Also in the zones of speed increase, depending on the pressure, the phenomenon of cavitation can occur, which negatively affects both the impellers and the characteristics of the pump as a whole. It should be noted that the results obtained correspond to the theory of fluid motion in the interblade channels of the impeller. The proposed method of simulation tests allows to design and optimize the design of the impeller depending on the required parameters at the pump outlet, taking into account the characteristics of the pumped liquids.

5. Conclusions

From the research work described in this paper, the following conclusions can be drawn:

- features of simulation enable to determine the amount of pressure generated by the wheel of the centrifugal pump depending on the required parameters of fluid flow at the pump outlet;
- the above simulation algorithm can be used when studying the movement of fluid through the section of the centrifugal pump, taking into account the real conditions of its operation (temperature, physical properties of the fluid, etc.); optimization of the geometric parameters of the impeller in order to increase its efficiency can be conducted.

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