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Influence of construction and operating pump parameters on pressure pulsations amplitude

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Introduction

Experience of centrifugal pumps operation, and also researches in this field of many authors allow to trace direct dependence of pressure pulsations intensity with vibration-noise characteristics of the pump. Thus, in addition to measuring vibration on the pump bearing shell, pressure pulsations are the only real way to obtain indirect information about the frequency and intensity of hydrodynamic vibration of the pump at the stage of it's initial design. The research of the nature and intensity of pressure pulsation in the entire supply range *Q-H* characteristic of the pump is the first step towards reducing the hydrodynamic vibration and improving the vibration state of pumping equipment.

Research methodology

The objectives of the research were solved by the literature reviewing, using numerical simulation of non-stationary fluid flowing in the flowing part of spiral centrifugal pump using software ANSYS CFX and using statistical analysis in a combination with a least squares method.

Using the ANSYS CFX software and basing on the numerical solution of the Navier-Stokes and Reynolds equations, was performed a numerical simulation of the non-stationary fluid flowing in flowing part of the pump. The object of the research was the workflow of spiral centrifugal pump type D2000-100-2 at supply range: 600 m^3/h…2000 m^3/h ($0.3Q_{opt}…Q_{opt}$). The subject of the research was influence of construction and operating pump parameters on RMS deviation of pressure values at the impeller outlet and pump *Q-H* characteristic.

Results

Basing on the results of numerical simulation of pump working process D2000-100-2 on the operation modes with supply: $0.3Q_{opt}$, $0.6Q_{opt}$, $0.8Q_{opt}$, and Q_{opt}, were obtained the frequency of pressure pulsations per one impeller revolution with 6 distinct maxima at the time when the impeller's blade passes cutwater tongue. Thus, the most intense hydrodynamic oscillations in the flowing part of spiral centrifugal pump type D are vane frequency pressure pulsations. The frequency of pressure pulsations at pump supply range $0.3Q_{opt}…Q_{opt}$ does not change, but their amplitude increasing when the operate mode of the pump deviates from Q_{opt}.

According to Fig. 1 (a) for the Q_{opt} supply pattern, the flow of liquid in the flowing part of the pump D2000-100-2 has a vortex-free homogeneous nature, but when reducing the flow to $0.6Q_{opt}$ - Fig. 1 (b), due to the separation of the flow there is a slight vortex along the front sides of the blade, due to the positive angle of attack, the curvature of the blade surface and the inconsistency of the circulating speed across its width of blade. The allocation of the relative flow velocity in Fig. 1 (b) shows that intense vortex formation and the occurrence of counter currents in the flowing part of the centrifugal pump D2000-100-2 is observed in its interblade channels, when passing between the part of the spiral volute with the highest spiral height and near the cutwater tongue, for the supply $Q \le 0.6Q_{opt}$.

Results

The research of the effectiveness of methods to decrease the intensity of pressure pulsations during pump operation below the lower limit of pump operating range given the RMS deviation of pressure values at the impeller outlet in supply range: $0.3Q_{opt}…0.6QQ_{opt}$ allows us to make the following conclusions:

- increase in the number of impeller blades (*z*) by 16%…33%, causes a decrease in RMS deviation of pressure values by 17%… 30%.
- reduction the blade width at the impeller outlet (b_2) by 10%...20%, causes a decrease in RMS deviation of pressure values by 11%...18%.
- increase in the ratio of volute initial diameter to the impeller outer diameter (D_3/D_2) by 5%...10%, causes a decrease in the RMS deviation of pressure values by 60% ... 73%.;
- inclined undercut of impeller output edge (φ) by 5%...15%, causes a decrease in the RMS deviation of pressure values by 17%...25%.
- decrease of the rotor's speed (*n*) by 10%...20%, causes a decrease in the RMS deviation of pressure values by 32%...56%.
- blades displacement of impeller halves by 1/3 and 1/2 shift step (33%…50%), causes a decrease in the RMS deviation of pressure values by 42%...56%.

Change curves of pressure pulsations amplitude are described by least squares method using PECM and based on the results of average relative values approximation of pressure values RMS deviation at the impeller outlet during pump operation mode: $0.3Q_{opt}…0.6Q_{opt}$ (Fig. 2).

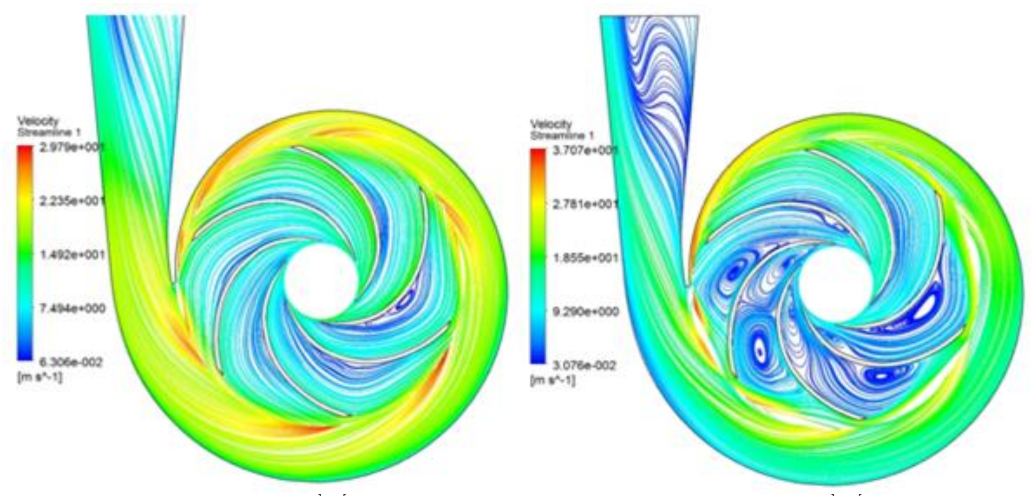

Figure 1. Graphical interpretation of fluid flowing in flowing part of the pump D2000-100-2 at supply mode: Q_{opt} (a) and $0.6Q_{opt}$ (b).

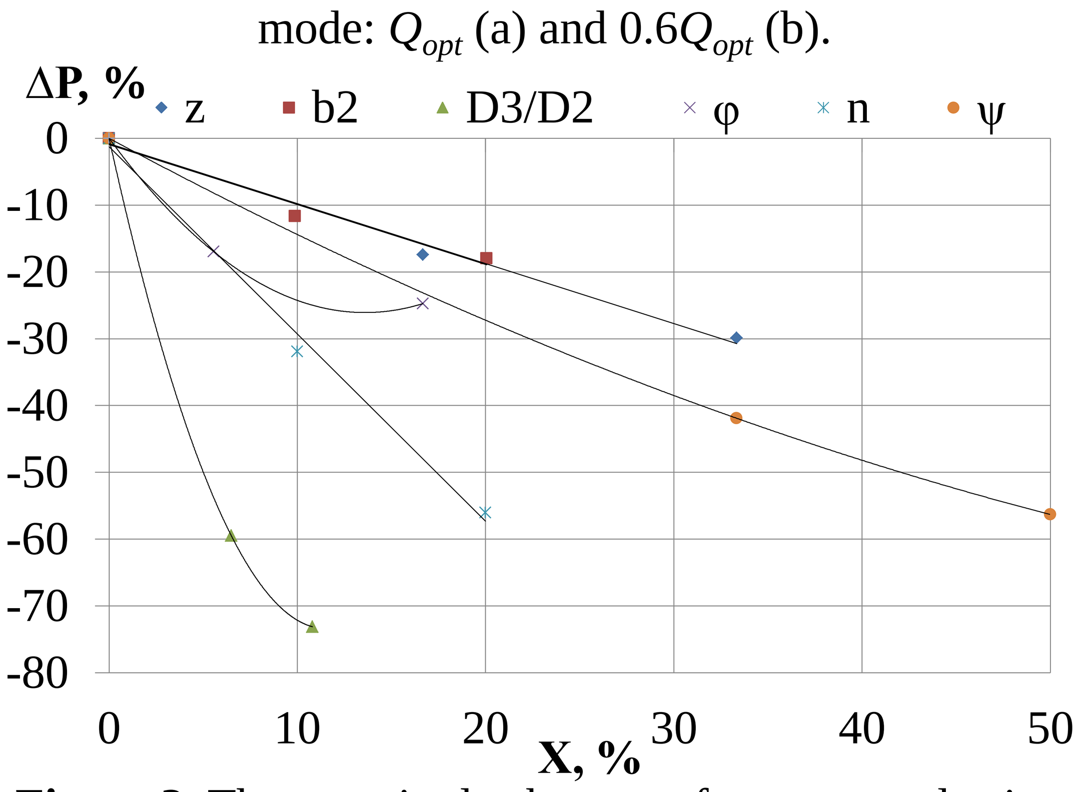

Figure 2. The magnitude changes of pressure pulsations amplitude depending on the magnitude changes in construction and/or operating parameters of pump at supply mode: $0.3Q_{opt}…0.6Q_{opt}$:
ΔP - changes in pressure pulsations amplitude concerning their initial value, %;
X - changes in the pump parameter concerning to its initial value, %.

Conclusions

1. At supply mode $0.3Q_{opt}…1.0Q_{opt}$ of spiral centrifugal pump the main source of pressure pulsations in pump flowing part is flow heterogeneity at impeller outlet, due to RSI interaction of the impeller blades with the cutwater tongue. Increasing of pressure pulsations amplitude at the impeller outlet at supply mode $0.3Q_{opt}$… $0.7Q_{opt}$, due to the process of coincidence of the vortex during the passage of impeller interblade channels between the cutwater tongue. The frequency of these pressure pulsations is superimposed on blade frequency.

2. According to the research results on pump operating modes at supply $0.3Q_{opt}…0.6Q_{opt}$ excessive pressure pulsations can be reduced by changing the construction and/or operating parameters of pump, however, it is necessary to take into account the impact of these changes on *Q-H* characteristics of pump.

3. Given the value of the change in pressure pulsations amplitude depending on the magnitude of the change in construction pump parameter, the most effective way to reduce pressure pulsations amplitude is to increase the ratio of volute initial diameter to impeller outer diameter (D_3/D_2), but the most optimal way is blades displacement of impeller halves by 1/2 shift step (ψ), as this measure does not change the *Q-H* characteristic of the pump.

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