An experimental study of flow in model of hydraulic turbine

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Abstract: The aerodynamic model of the hydraulic power plant flow path on a scale of 1/67.6 is constructed. Flow structure and pulsation characteristics of flow in draft tube downstream the runner of hydraulic turbine were measured using the laser-Doppler anemometer and sound-level meter. Modes with various modifications of models (with and without runner) in wide range of flow rates and runner speed were studied. Turbine operation modes with forming of precession vortex core were investigated. The effect of stabilizing constructions on the pulsating characteristics of flow was studied.

Key-Words: precession, vortex, pressure pulsation, hydraulic turbine

1 Introduction

As practice shows, operation of hydraulic plants sometimes unsafe without a description and understanding of the processes occurring in the unit. Unsteady effects associated with the formation of large-scale vortex structures have a great interest for the researchers. One of the mechanisms generating the flow pulsation is a precession of vortex core (PVC) [1, 2] formed behind the runner of hydraulic turbine where flow has a large residual swirling.

Numerical modeling is one of the reliable methods of research of such kind of processes. However, numerical modeling requires verification data. To obtain it, the flow path of the hydro turbine PO-230/833-B-677 on a scale of 1/67.6 was constructed (fig. 1). Most of the turbine elements were made on a 3D printer.

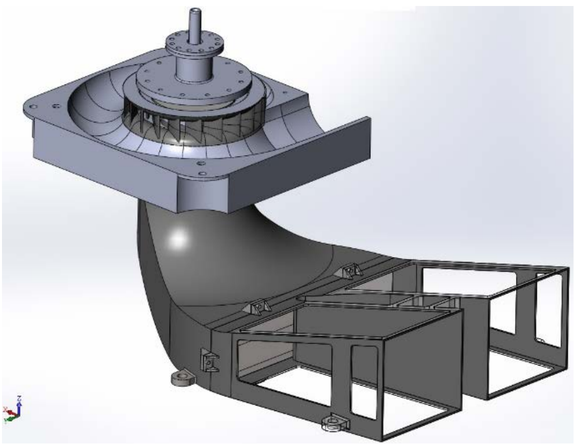

Fig. 1 – Hydraulic turbine model

2 Problem Formulation

Due to fluid dynamics similarity law hydraulic processes in turbine were experimental studied on an aerodynamic experimental set-up constructed in Institute of Thermophysics of Siberian Branch of Russian Academy of Science [3]. The scheme of stand is shown on figure 2. Air flow in the turbine was created by the blower regulated by frequency inverter. Flow rate was measured by ultrasonic flowmeter. Servomotor rotates the runner in wide speed range (0 - 3000 rpm)).

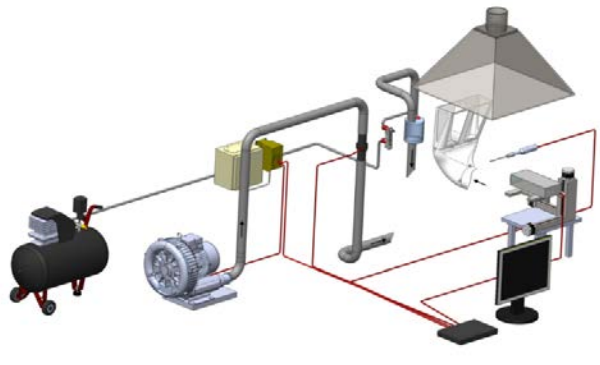

Fig. 2 – Scheme of experimental set-up IT SB RAS

The structure of flow downstream the runner was visualized and analyzed using the laser knife and flow tracers. The forming of the precessing vortex core in the draft tube diffuser was observed. Further instrumental and numerical study of the flow confirmed the presence of the PVC.

Measuring of the flow velocity downstream the runner was carried out using a LDA (Laser-Doppler anemometer) LAD-06I.

Figure 3 shows velocity profiles for different flow rates (Q = 100, 150, 200 m^3/h). Also velocity profiles were measured for modes with different rotation speed of runner including «freeze runner» mode.

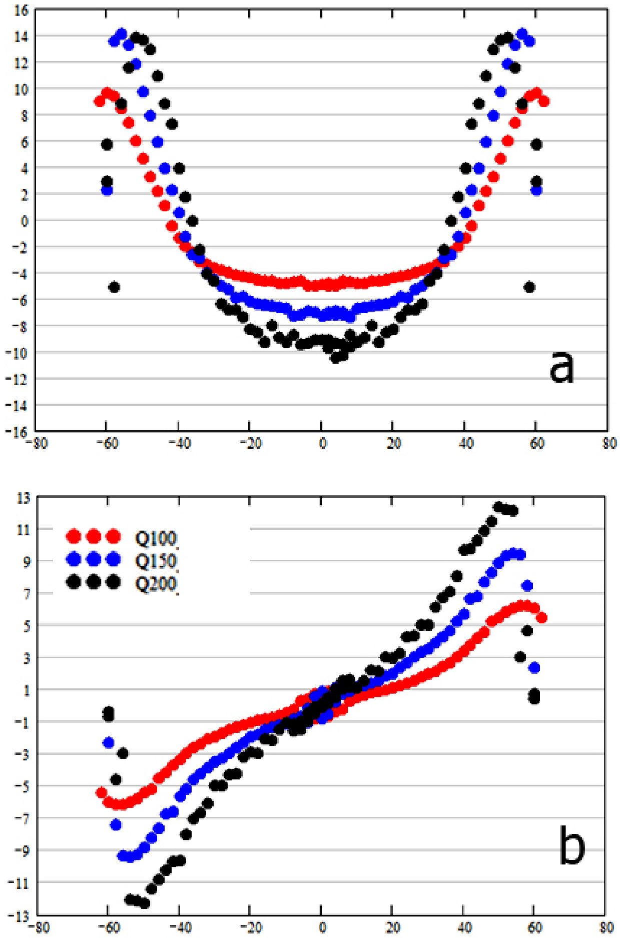

Fig. 3 – Profiles of axial (a) and tangential (b) velocity in draft tube diffuser

As can be seen from figure the stream in the draft tube is pressed against the walls. A powerful recirculation zone is formed in the center that causes the PVC forming.

Using the sound-level meter (Bruel & Kjaer Type 2250) and piezo-electric sensors an amplitude and frequency of the pressure pulsations were measured. Signals of sound-level meter and piezo-electric sensors were processed by the analog-to-digital converter.

For example, pulsation of pressure (a) and spectra of pulsations (b) for mode with flow rate Q = 200 m3/h and rotation speed ω = 2000 rpm shown at figure 4.

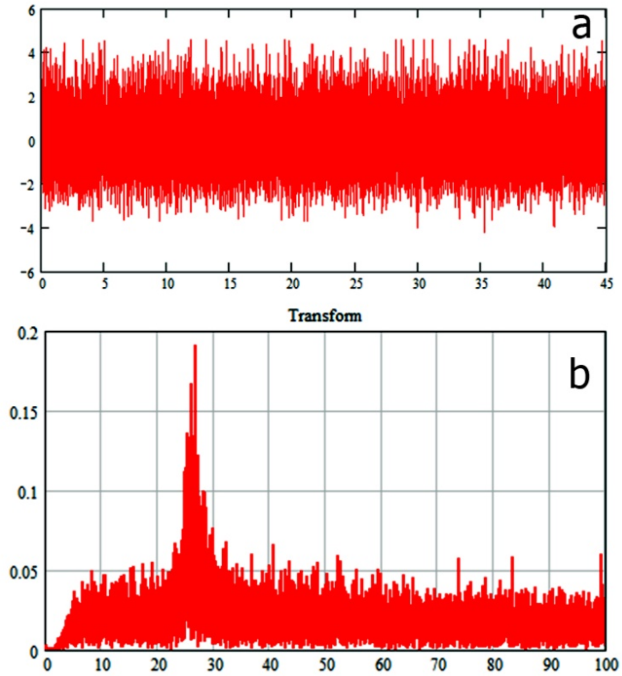

Fig. 4 – Pressure pulsations (a) and spectra of pulsations (b)

Frequency of pressure pulsation to flow rate dependence for different rotation speed shown at figure 5.

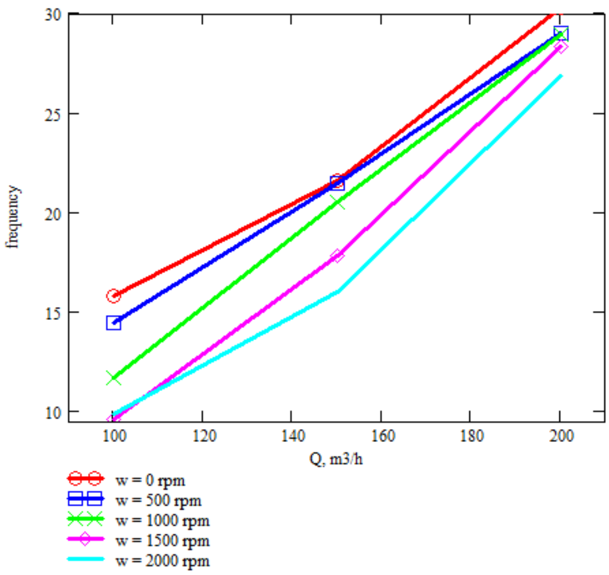

Fig. 5 Frequency of pressure pulsation to flow rate dependence

It is evident that increasing the flow rate leads to increasing the pulsations frequency. At the same time with increasing the runner speed the pulsations frequency reduced. It is quite logical because with increasing runner speed the flow swirling is reduced due to the fact that runner takes the whole flow swirling created by the stator and guide vanes.

3 Stabilizing construction

Also the effect of stabilizing construction (cross) on the pulsating characteristics of flow was studied. This study was carried out on an experimental model modification without runner and with three different opening angles of guide vanes.

Figure 6 shows typical spectra of pressure pulsation for the cases without cross (a) and with cross (b). It is clearly seen that the stabilizing contracture reduces the amplitude of the pressure pulsation and slightly changes the frequency of the pulsations.

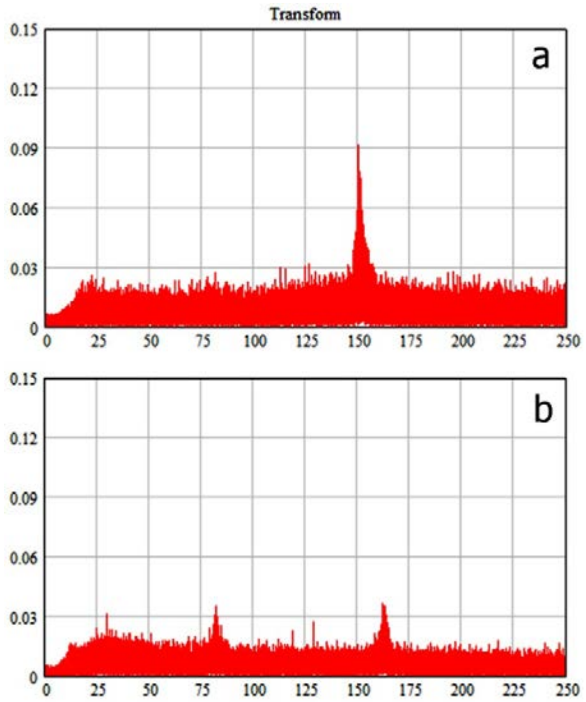

Fig. 5 - Spectra of pressure pulsation without cross (a) and with cross (b)

The model is designed in such a way that makes it easy to install and investigate any types of stabilizing structures (ribs, runner cowl, cross, and combinations thereof). These studies are also conducted.

4 Conclusion

As a result of work established that the cause of pressure pulsations in the flow path and as a consequence of large dynamic loads on all the units of hydraulic turbine is the forming of precessing vortex core downstream the runner.

The profiles of velocity components and pressure pulsation in draft tube diffuser for different operation modes of the turbine were measured. Frequency and intensity of pressure pulsations to the flow rate and speed of runner dependence experimental studied.

Analysis of the measured velocity profiles in the diffuser of the draft tube showed that on modes with the precessing vortex a vast recirculation zone with high-speed reverse flow is formed. Thus, it is shown that the components of the flow velocity behind the runner can serve as indicators characterizing the intensity of unsteady phenomena in the draft tube of hydraulic turbines.

The positive effect of stabilizing constructions on the pulsation intensity in the draft tube diffuser is shown.

References:

[1] Gupta, A.K., Lilley, D.G. & Syred, N., *Swirl Flows*, Abacus Press, 1984

[2] Alekseenko S., Kuibin P., Okulov V. , *Theory of Concentrated Vortices: An Introduction*,Springer, 2007

[3] Litvinov V., Shtork S., Kuibin P., Alekseenko S., Hanjalic K., *Experimental study and analytical reconstruction of precessing vortex in a tangential swirler*, International Journal of Heat and Fluid Flow, 42, 2013 pp. 251–264.