Experimental study of the effect of air injection on the pressure pulsations in the hydro turbine flow path under different operating conditions

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Abstract. The paper presents an experimental study of oscillatory response in the Francis turbine of hydraulic unit. The experiment was performed on large-scale hydrodynamic test-bench with impeller diameter of 0.3 m. The effect of air injection on the intensity of pressure pulsations was studied at the different regimes in the hydraulic unit. It was revealed that air delivery into the flow path system of the turbine results in almost two-fold reduction of pressure pulsations, but for optimal regimes, there is an increase in pressure pulsations.

1 Introduction

An important task for HHPP is regulation of power in the energy system. During load changing hydraulic units repeatedly undergo off-design modes of operation. Under these flow conditions a significant part of swirl, after passing through the water turbine impeller, is remained. With the instability of swirling flow is related the emergency of intense low-frequency hydrodynamic fluctuations that threaten the reliability of turbine design [1-3].

Vortex rope precession is a serious danger for the hydraulic turbine equipment in relation with the powerful flow pulsations that lead to strong vibrations of hydraulic turbine construction and in the case of resonance can lead to destruction of the equipment. Pressure pulsations generated by the vortex rope precession, may also affect cavitations processes, enhancing cavitations erosion.

Up to date, numerous methods are proposed to stabilize flow in the hydraulic units [4-7]. Each of them has its advantages and disadvantages, and requires further detailed study. In this study, the effect of air delivery on the oscillatory response of the flow was experimentally investigated on the model hydrodynamic stand with Francis turbine.

2 Experimental techniques

The model water turbine with radial-axial impeller is part of the hydropower test-bench at the Laboratory of Hydraulics and Hydraulic Machines of the Siberian Federal University

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(Fig. 1.). Maximum water head in the test-bench is 3.5 m, the diameter of the impeller is D=0.3 m.

Hydraulic unit includes a pressure tank, performing the functions of the upper pool, power conduit with the diameter of 400 mm, and penstock valve, equipped with electric drive.

Water from the penstock enters the spiral chamber, where from flows through the guide vanes to the impeller and then passing the draft tube gets into the lower pool, which is a glass groove 1.52 m in width. Diffusion grid is designed to reduce fluctuations in water level before weir gauge. Weir gauge is used for measuring water flow rate and is fixed by water gauge.

After weir gauge, the water is discharged into the collecting tank and then is diverted through pipe into the pool. From the pool, water is pumped into the pressure tank. The water intake in the collecting tank is performed through the suction cap with mesh. The water flow rate is controlled by gate valve with electric actuator.

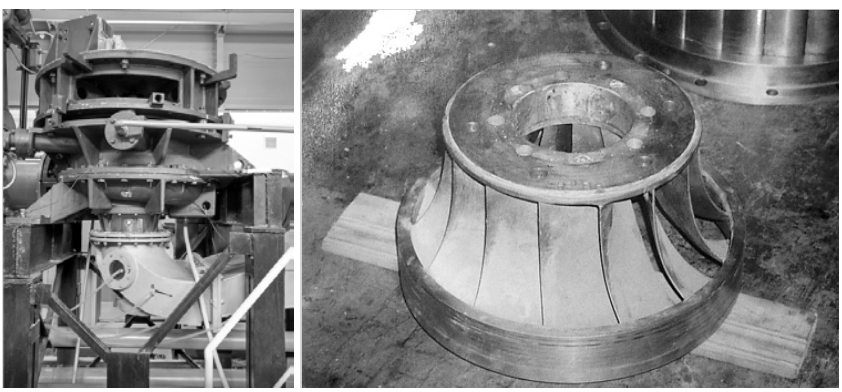

Fig. 1. Model of water turbine with radial-axial impeller.

3 Experimental results

In the course of experiments we carried out measurements within a wide range of the hydraulic unit operation as with air and without air.

The degree of opening of the guide vanes were varied in the experiment the pressure remained constant.. Then all the necessary parameters, namely, impeller rotation frequency, the flow rate through the hydraulic unit, and generating current and voltage were recorded.

The behavior of the frequency and the pressure pulsations intensity in the water-conveyance system of the turbine is of great interest for high-head power plants since the precession of a vortex core is a serious hazard to the water turbine equipment. Pressure pulsations were recorded at specified points during five minutes for each of the operation modes.

Figures 2 and 3 below present the results of the experiment time dependence of pressure pulsation in the draft tube diffuser carried out for two of the operating modes of the hydrodynamic stand: opening 5/15 – maximum pressure pulsation regime, opening 8/15 – the is near optimum regime. In the figures indicate the moment of air inject into the flow path (red line), it is evident that for a regime with maximum pulsations, a significant decrease is observed in amplitude of pressure pulsations, while for in the regime is near to the optimum conversely - increase.

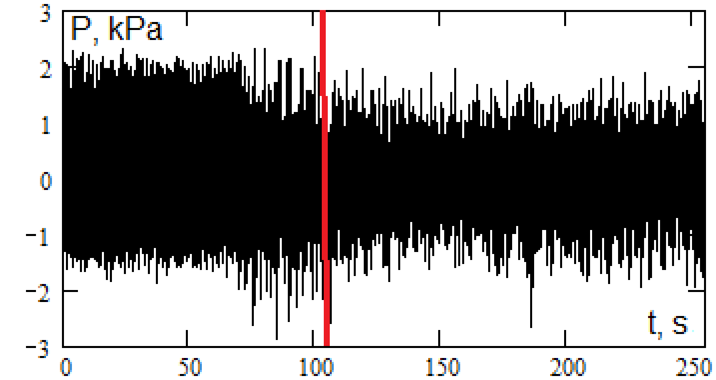

Fig. 2. Time dependence of the pressure pulsation in the draft tube diffuser *(opening 5/15)*.

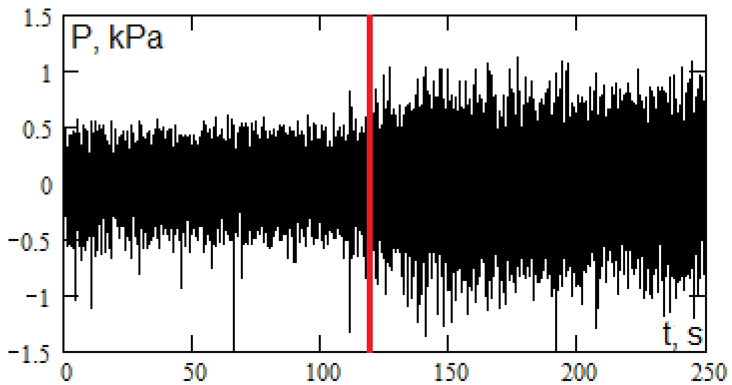

Fig. 3. Time dependence of the pressure pulsation in the draft tube diffuser *(opening 8/15)*.

Figures 4 present experimental dependence of the pressure pulsation amplitude in the draft tube cone on the opening of the guide vanes. From the dependence, the air inject allows one to reduce the pressure pulsations in the most dangerous zones by more than 2 times, however, in the region of optimal regimes, the pressure value increases. This fact indicates the advisability of air supply only on certain loads on the hydroelectric unit.

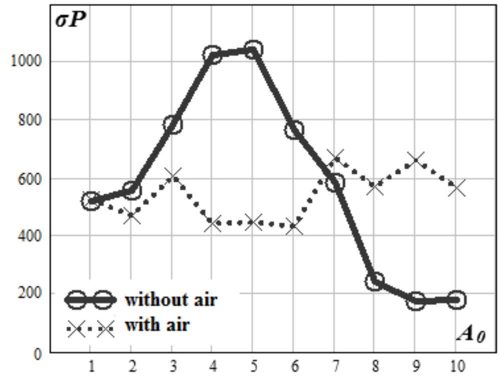

Fig. 4. Dependence of the pressure pulsation amplitude in the draft tube cone on the opening of the guide vanes.

4 Conclusion

The work deals with experimental investigation of pressure pulsations for different flow regimes in the hydraulic unit of the medium-scale hydrodynamic stand with air inject in flow path.

The authors obtained correlations between the pressure pulsations and the opening of the guide vanes for constant pressure heads, in the hydraulic turbine taking into account the air phase.

Air was supplied into a spiral chamber of the turbine. This method is one of the most promising to reduce loads on the hydraulic unit, caused by the precession of the vortex core in the space behind the impeller.

The results of the study have shown that it is possible to significantly reduce the pressure pulsations using air on the maximum pressure pulsations regime. However, this effect needs further investigation. In particular, it is necessary to investigate to study the effect of air injection point.

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References

1. A.V. Minakov, A.V. Sentyabov, D.V. Platonov, A.A. Dekterev, A.V. Zakharov The numerical simulation of low frequency pressure pulsations in the high-head Francis turbine, Computer and fluids, p. 197-205

2. A.V. Minakov, A.V. Sentyabov, D.V. Platonov, A.A. Dekterev, A.V. Zakharov The analysis of unsteady flow structure and low frequency pressure pulsations in the high-head Francis turbines International Journal of Heat and Fluid Flow, Volume 53, 2015, Pages 183–194

3. D. Platonov, A. Minakov, D. Dekterev, A. Sentyabov, A. Dekterev, Numerical and experimental study of low-frequency pressure pulsations in hydraulic units with Francis turbine, Journal of Physics: Conference Series, 2016, Volume 754

4. Falvey, H.T. Draft tube surges – a review of present knowledge and an annotation bibliography / H.T. Falvey // Report No. REC-ERC-71-42, U.S. Bureau of Reclamation, Dec. 1971. – 33 pp.

5. Wahl, T.L. Draft tube surging hydraulic model study: MS Thesis / T.L. Wahl – Colorado: Colorado State University, 1990. – 77 pp.

6. Grein, H. Vibration Phenomena in Francis Turbines: Their Causes and Prevention / H. Grein // Proceedings, 10th Symposium of the International Association for Hydraulic Research Section for Hydraulic Machinery Equipment and Cavitation, Tokyo, Japan, 1980.

7. Bhan, S Reduction of Francis Turbine Draft Tube Surges / S. Bhan, J.B. Codrington, H. Mielke // Proceedings, 5th International Symposium on Hydro Power Fluid Machinery, Chicago, Illinois, 1988. – pp. 95 – 102.