

# An experimental study of the influence of a pressure pulsation in the water turbine flow path on a vibration parameters of the hydraulic unit

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**Abstract.** The paper presents an experimental study of the relationship between the vibration of the water turbine unit and the pressure pulsations in the flow path. It is shown that the air injection into the flow path leads to a decrease in the hydraulic turbine vibration associated with the formation of the precessing vortex core.

## 1 Introduction

Hydropower is a significant part of the overall energy system. The reliability of the hydropower equipment operation is largely determined by its vibrational parameters. Vibrational signal is the sum of signals from all elements of the mechanism and hydromechanical processes that occur during the operation of a water turbine. It is generally believed that the most significant contribution of hydrodynamic processes is in the so-called transient modes of operation of the hydraulic unit (partial or high load). In such regimes a stable vortex structure with a pronounced precession frequency formed downstream the water turbine runner. The precessing vortex core (PVC) leads to generation of high amplitude low-frequency pressure pulsations [1, 2], which are the most dangerous in the case of resonance with the elements of the hydraulic turbine. In this case arising vibrations leads to a faster wear of the equipment and destruction of some unit elements. This work was carried out to determine the effect of pressure pulsations in the water turbine flow path on the vibration of its construction.

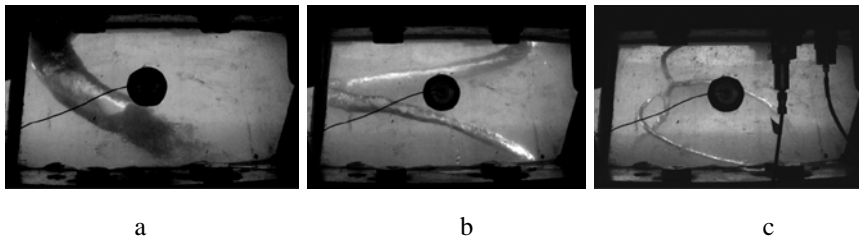
## 2 Experimental techniques

An experimental study was carried out at the research set-up with a model of a water turbine unit at a scale of 1/14.7. The opening of the guide vanes regulates by manual and electrical drives and is divided into 15 steps. The optimum operating mode by integral characteristics of the hydraulic unit and the pressure pulsation parameters in the flow path

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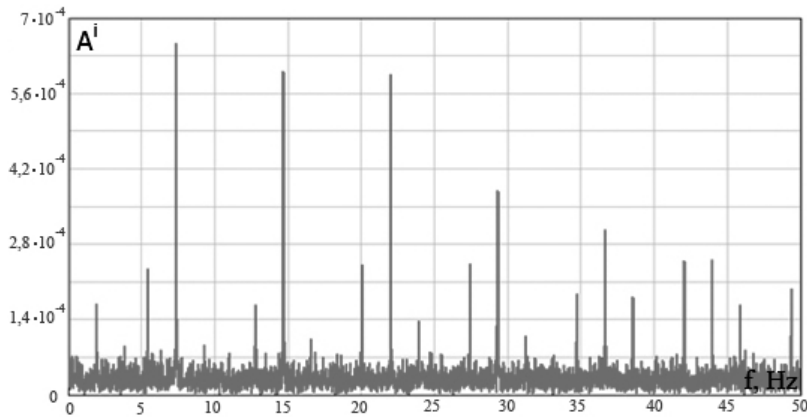
is the 9/15 opening. In this paper the modes with constant water head 3.5m for the guide vanes opening 1/15 - 8/15 was studied. The water turbine works at “free runner” mode. The frequency of the runner was determined using the optical tachometer and the frequency of the PVC was determined with the help of piezoelectric pressure sensors. A stable vortex core was visually observed at operating conditions corresponding to the openings 3/15, 4/15, 5/15 (Fig. 1a), at the opening of 6/15 a large spiral vortex with unstable structure was observed (Fig. 1b), in the mode of 7/15 a thin unstable vortex with the reconnection effect was observed (Fig. 1c), at the 8/15 mode no vortex structures observed.



**Fig. 1.** Varieties of vortices downstream the runner.

### 3 Experimental results

Investigation of the vibration parameters of the hydraulic turbine unit was carried out using a piezoelectric vibration acceleration sensor VD06A. The signal was transmitted to a PC via ADC and writing in mV. Spectra with evident frequency of the precession of the vortex core and the rotation frequency of the runner are obtained using a fast Fourier transform. Figure 2 shows the vibration spectrum for the mode with the opening of the guide vanes 4/15.



**Fig. 2.** Vibration spectrum.

The first peak at a frequency of 1.9 Hz corresponds to the PVC frequency, the peak at a frequency of 7.3 Hz corresponds to the rotation frequency of the runner. Harmonics of the runner rotation frequency are also visible, in addition, noticeable peaks equidistant from the rotation frequency and its harmonics by a positive and negative value equal to the PVC frequency are observed. This means that pressure pulsations make a serious contribution to the appearance of low-frequency vibrations. A similar dependence is observed for the 1/15 - 5/15 openings. When the opening is 6/15 and above only the double rotational frequency of the runner is observed.

The plot of the dependence of the vibration signal amplitude (peak to peak) on the opening of the guide vanes shows that the maximum of vibrations is observed in the case of openings 2/15 - 3/15, however, when it approaching the optimal operating modes of the turbine the signal intensity is significantly reduced.

Recently, various works have been conducted aimed at studying methods of decreasing of pressure pulsations in a flow with a precessing vortex core, including injection of air into the turbine flow path. In this work, air is also injected to the set-up, and its effect on the vibration level of the hydraulic unit is evaluated. Figure 3 shows the comparison of vibration with and without air injection.

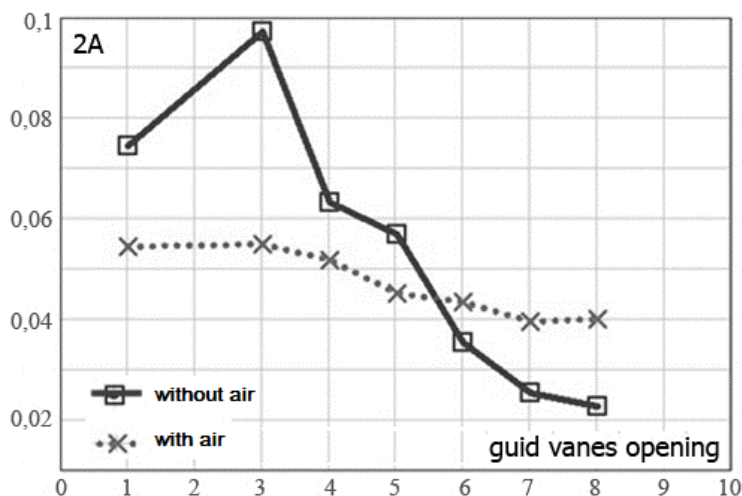


Fig. 4. Effect of air injection to vibration level

In this study, the airflow rate was constant and amounted to  $6.3 \text{ m}^3/\text{h}$ , it corresponds to 3.6% of the water flow rate when opening of guide vanes is 1/15 and 1.4% when opening is 8/15. It can be noted that the air injection significantly reduces the level of vibration signal at the non-optimal operating modes of the hydraulic unit, while at the same time it leads to some increase of signal in the cases close to the optimal mode. Hence, one can draw conclusions about the advisability of using air to reduce vibrations in non-optimal operating modes of hydraulic units.

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