

Ushapivsky I.L.

Experimental studies of vibrations centrifugal fire pump with defective bearings

*Ushapivsky Igor Lubomyrovych, Head of the department of emergency response
General Directorate of State Service for Emergency Situations of Ukraine in Lviv region, Lviv, Ukraine*

Abstract. The work deals with an experimental study of vibrations of centrifugal fire pump PN-40UV with defect. A worn-out bearing assembly was selected as internal defect. The vibration accelerations signals have been analyzed by their spectral structure. It was determined that the presence of the worn bearing in the pump leads to an appearance of additional harmonics with specific frequencies. This harmonics arises in the most dynamically loaded regime of operation - the usage of a pump filled with a water but without its filing. These vibrational symptoms of the analyzed type of hidden defects could be used in the procedures of fire pumps technical diagnostics.

Keywords: centrifugal fire pumps, diagnostic, technical state, vibrations

Introduction. One of the most important elements of the facility of emergency response divisions is the fire engine equipped with centrifugal pumps. Extreme conditions of operation together with long term of using lead to a high level of probability of hidden defects presence in the centrifugal fire-pumps. These defects could significantly decrease the efficiency of the operational activities of the emergency response divisions due to sudden failure or due to negative affect on the fire-pump performance characteristics such as discharge head, which is also reducing efficiency.

An experience of fire pump operation indicates that common defects usually lead to higher vibration levels during the pump operation. Thus, vibration diagnostics can be used as a good tool for identification of technical state of centrifugal fire pumps.

Testing technique. The methodology of experimental studies is based on series of measurements, which allows to define a regularity of vibration parameters changing caused by the presence of the hidden defects. Thus, a comparative analysis of changes in the dynamics of the systems with and without defect gives a possibility of definition of hidden defects symptoms. So, give us tools for diagnosis of its technical state.

Experiment conditions and facilities. In the work, the experimental tests have been done with the centrifugal pump, which has been installed on an active fire engine. Experiments were carried out on the base of a measurement system "Ultra-V-I" [1,2], which has been developed at the Department of the Dynamics and Strength of Machines of the National Technical University "Kharkiv Polytechnic Institute" (Kharkiv, Ukraine). The measuring system consists of (fig. 1): a detector of vibration accelerations, an analogue-to-digital converter (ADC) and a portable computer. "Ultra-V-I" has a valid certificate of state metrological certification and allows to make a measurement of vibration acceleration at the point of investigated object. Some details of experiments study facilities are presented in the paper [3]. The measurements have been carried out on the body of a suction pipe of the fire pump (fig. 1).

Vibration analysis of the defected centrifugal fire pump. The current analysis deals with an experimental study of vibration occurring during the operation of the fire pump PN- 40UV that has a defect of worn-out bearing. The study of pump vibrations has been carried out on

the most loaded regime, that provides to a pump an opportunity to realize different dynamic peculiarities.

The measurements have been carried out on the body of the suction pipe of the fire pump. During these tests, an angular velocity of rotor was set near the maximum operational value that was slightly more than 2000 rpm. It should be noted that the angular velocity of the pump rotor could not be precisely fixed due to the presence of irregularity of engine motion. Therefore, it is necessary to control the angular velocity of the pump rotor rotation - during measurements. It was decided to use frequency counter during the current investigation. The counter was installed at the connection of the pump rotor with a fire engine shaft. The data have been transmitted to the ADC and recorded on a computer in real time.

Fig. 2a presents an obtained vibrational acceleration in the vertical direction in the measurement point. A presence of the random fluctuations and polyharmonic nature in the signal could be observed.

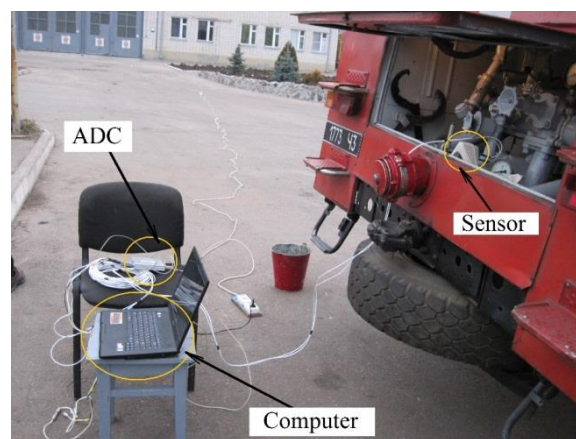


Fig. 1. Measurement system "Ultra-V-I" during the fire-pump vibration tests

Analogous tests with the over values of pump rotor angular velocities have been carried out to obtain more detailed information about the vibrational processes (Fig. 2b). Generalization of these results can be obtained by special tests, when vibrational signal is analyzed during continuous gradual increasing of the frequency of excitation. So, the test was made with the pump, that operates with the angular velocity, which is gradually increased from 800 rpm to 2100 rpm.

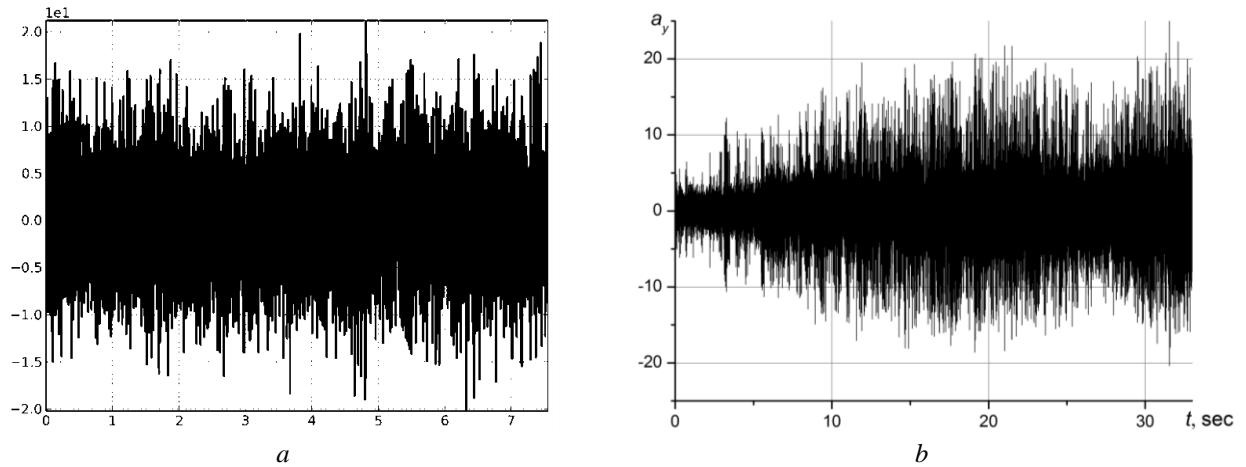


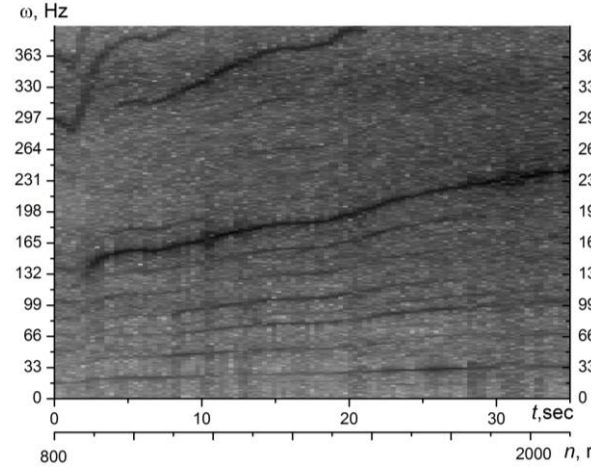
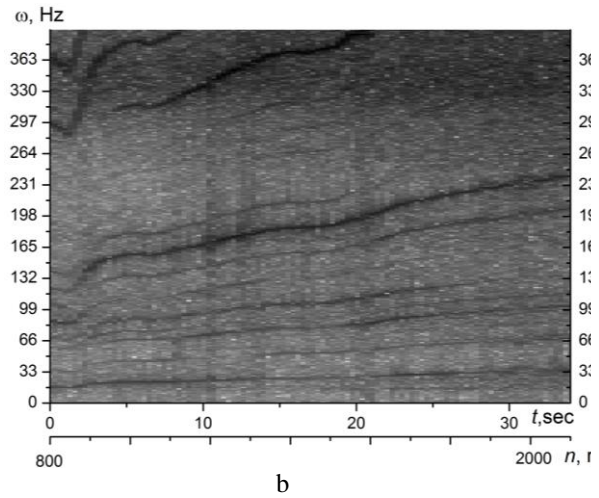
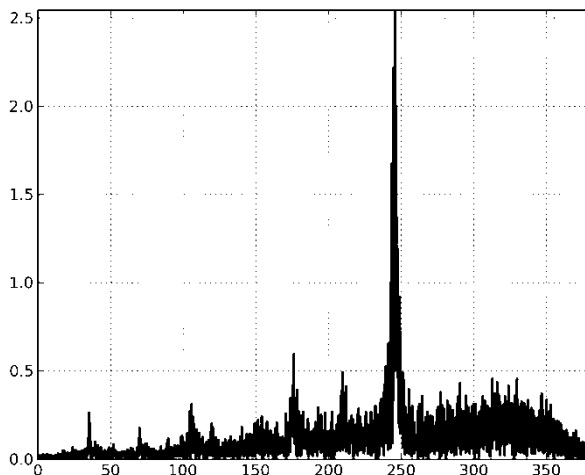
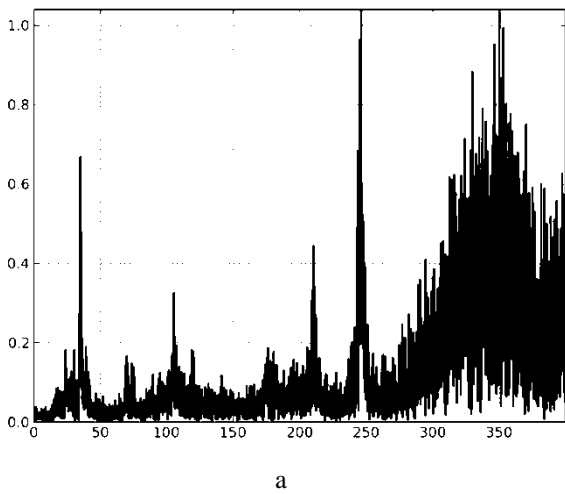
Fig. 2. A typical obtained signals during the tests of fire pump vibration a – recorded vibration acceleration signal; b - the test of the pump vibration with the continuous gradual increasing of the frequency of excitation

All the obtained signals was spectrally analysed. A Fast Fourier Transform (FFT) is used for these procedures [4,5]. A vibration acceleration signal, which was obtained at the test with continuous excitation frequency increasing, was analysed using spectrograms [6]. Fig. 4 presents vibration spectra at the fixed value of the pump rotor angular velocity (2000 rpm) and spectrograms for the vibration accelerations in three different directions.

Vibration analysis shows a wide spectrum of harmonics. It is 1, 2, 3, 5, 6 and 7 harmonics and resonance mode is also observed in the range 300-400 Hz. The largest amplitudes are 1, 7. Existence and domination of 7 harmonic

are associated with turbulent flows in the chamber of the pump that forms near the edges driven wheel blades. The pump driven wheel has 7 blades.

The presence of harmonics with a frequency of about 120 Hz is an important observation. The spectrum also has a harmonic with a frequency close to 0.5 from the main rotor angular velocity. Identified the frequencies of vibrations are confirmed by the pattern of the spectrogram, where frequencies of 0.5 and (3.5 - 3.6) of the main harmonic are observed at the almost of the full range.



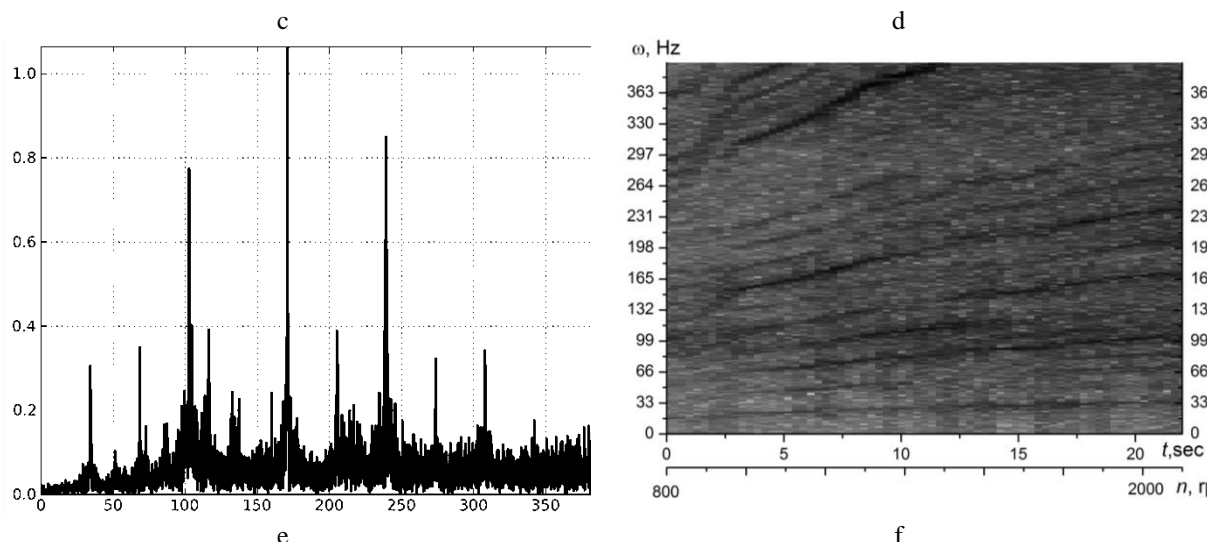


Fig. 6. Spectrums (a, c, e) and spectrograms (b, d, f) of vibration accelerations of the fire pump, which has defect (worn-out bearing) in the vertical (a, b), the axial (c, d) and horizontal (e, f) directions

Vibration in the axial direction has a less amplitudes of harmonics in the spectrum and 7th harmonic is completely dominates. The harmonic with frequency around (116-120) Hz is also present in the spectrum. Spectrogram confirms made observations. Vibrations in the horizontal direction is close to the pattern of vibrations in the vertical direction so all the harmonics from 1 to 8 are excited. The largest amplitude has 5 harmonic. The harmonic with a frequency of 116 Hz is also excited.

So, vibrations of the pump with worn-out bearings characterized by the presence of the harmonic with frequency about 120 - 116 Hz, which corresponding to frequencies that characterize the presence of damage in the inner bearing cage or separator.

Comparison of quantitative parameters of vibrations of the pump with worn-out bearings makes possible to detect

that an increase in vibration most strongly formed in the vertical plane XY.

Conclusions. Thus in the current experimental studies of vibrations of centrifugal fire pump PN- 40UV. A spectral analysis of vibration have been carried out. It is determined that the vibration spectra of pump with worn-out bearings has special harmonic which is characterize the damage of separator or cage of bearings. These vibrational symptoms of the analyzed type of hidden defects could be used in the procedures of fire pumps technical diagnostics. A usage of this technique will improve system technical check-up and preventive maintenance, that, on the one hand, leads to a reduction of the idle standing of fire equipment that are associated with untimely repair work, and on the other hand will prevent sudden failures of pumps in operation.

REFERENCES (REFERENCES TRANSLATED AND TRANSLITERATED)

1. Vodka A.A. Measurement system on the base of MEMS sensor / A.A. Vodka, A.I. Trubaiev, Yu.N. Uliyanov // Bulletin of the Volodymyr Dal Eastern Ukrainian National University. – Lugansk, 2012.– № 9 (180). Vol.1. – Pp.. 140-147 (in Russian).
2. Uliyanov Yu.N. A system for vibration acceleration measurements on the base of MEMS sensor / A.A. Vodka, A.I. Trubaiev, Yu.N. Uliyanov // Proceedings of the III International Scientific conference “The problems of the transport technical and logistics”, Evpatoria, Ukraine, – 2012. – Pp.. 191 (in Russian).
3. Larin O.M. A diagnosis of the technical state of the support of fire pump by the spectra of its vibrations / O.M. Larin, O.O. Larin, V.V. Chigrin // Science and Education a New Dimension: Natural and Technical Science, Vol. 8, Budapest, 2013, Pp. 112-116 (in Ukrainian)
4. Brigham, E. Oran The fast Fourier transform and its applications. Englewood Cliffs, N.J.: Prentice Hall, 1988
5. Oppenheim, Alan V.; Schafer, R. W.; and Buck, J. R. Discrete-time signal processing. Upper Saddle River, N.J.: Prentice Hall, 1999
6. J.B. Allen. Short Time Spectral Analysis, Synthesis, and Modification by Discrete Fourier Transform. - IEEE Transac. on Acoustics, Speech, and Signal Processing, 1977. - ASSP-25 (3): Pp. 235–238

Ущипивский И. Л. Экспериментальные исследования вибраций центробежного пожарного насоса с дефектными подшипниками

Аннотация. Работа посвящена экспериментальным исследованиям вибрационного состояния центробежных пожарных насосов ПН-40УВ с и без дефектов. В качестве скрытого дефекта был выбран характерный тип неисправности насоса - изношенный подшипниковый узел. Полученные вибрационные сигналы по виброускорениям были проанализированы по их спектральному составу. Определено, что наличие изношенного подшипника в насосе приводит к появлению дополнительных гармоник со специфическими частотами, которые проявляются на наиболее динамично нагруженном режиме работы - использование насоса с водой без ее подачи. Полученные вибрационные сигналы по виброускорениям были проанализированы по их спектральному составу. Полученные вибрационные признаки могут быть положены в методику диагностики технического состояния пожарных насосов.

Ключевые слова: центробежные пожарные насосы, диагностика, техническое состояние, вибрации