УДК 519.876.5:621.225:62-192 DOI 10.36910/775.24153966.2025.84.33

Е.Л. Селезньов, Д.Е. Селезньов, В.С. Матвійчук

Луцький національний технічний університет

РЕЗУЛЬТАТИ ДОСЛІДЖЕННЯ МАТЕМАТИЧНОЇ МОДЕЛІ АКСІАЛЬНО-ПОРШНЕВОЇ ГІДРОМАШИНИ З ДЕФЕКТОМ В ПОРШНЕВІЙ ЧАСТИНІ

В роботі проведено дослідження математичної моделі аксіально-поршневої гідромашини з дефектом в поршневій частині з зазначеними розмірами дефектів.

Ключові слова: *математичка модель, аксіально-поршнева гідромашина, поршнева частина, шарнір, дефект, спектр, вібраційне прискорення, зазор, частота, пік, амплітуда..*

E.L. Seleznov, D.E. Seleznov, V.S. Matviichuk

RESULTS OF RESEARCH ON THE MATHEMATICAL MODEL OF AN AXIAL-PISTON HYDRAULIC MACHINE WITH A DEFECT IN THE PISTON PART

The paper presents research on a mathematical model of an axial piston hydraulic machine with a defect in the piston part with specified defect dimensions.

Keywords: *mathematical model, axial-piston hydraulic machine, piston part, hinge, defect, spectrum, vibration acceleration, gap, frequency, peak, amplitude.*

Introduction. The relevance of the topic is associated with the need for early diagnosis of defects in hydraulic drive elements. Today, there are many methods for diagnosing hydraulic drive elements, the most common in the modern world is static parametric analysis, based on measuring the parameters of a steady throttled flow of the working fluid [1, 2]. The value of the volumetric efficiency is used as a diagnostic parameter. However, this method is not able to detect a defect in the piston group of a hydraulic machine at an early stage, which entails the destruction of the piston group and the ingress of destroyed parts into the system, which contributes to the failure of all hydraulic drive elements. In this case, the vibration diagnostics method [3] surpasses existing methods and allows you to detect a defect in the piston part of a hydraulic machine at an early stage of its occurrence, preventing possible downtime of the hydraulic drive.

Presentation of the main material. The object of the study is a mathematical model of an axial-piston hydraulic machine with a defect in the piston part, developed in the Simulink software environment.

The mathematical model of the defect has the form of a gap, which is implemented as a conditional length determined by the length of the signal movement zone within which the detected defect is recorded.

The mathematical model of an axial-piston hydraulic machine with a gap in the piston part in the Simulink [4] software environment will look like this (Fig. 1).

The work investigated the change in vibration signals of a model of an axial-piston hydraulic machine without and with a defect in the form of a gap in the piston.

The study consists of conducting an experiment in the Simulink software environment (Table 1), which is implemented by simulating a gap of different sizes in the piston part of an axial-piston hydraulic machine, to identify emergency and permissible gap sizes in the device.

Table 1.

Experimental design

No.	Experimental site	Defects, mm	Bloc
1	Piston part	Gap 2×10^{-3}	"Dead Zone"
2		Gap 2×10^{-2}	
3		Gap 2×10^{-1}	

The results of the research of the mathematical model of an axial-piston hydraulic machine in the form of vibration acceleration spectra of an axial-piston hydraulic machine in the absence of a defect and with them are shown in Figure 2.

Figure 2a clearly shows three peaks: the drive frequency (45 Hz), the natural frequency of the shaft (25 Hz), and the inclined block (75 Hz). The absence of other spectra shows that the system is operating smoothly.

In Figure 2b, the spectra show that in addition to the existing natural frequencies of the shaft (25 Hz) and the inclined block (75 Hz), as well as the drive frequency (45 Hz), noise appears around the inclined block frequency (75 Hz), which leads to an increase in its amplitude from 0.1 m to 0.22 m. Harmonics are also noticeable at frequencies of 115 Hz, 135 Hz, 155 Hz, and 175 Hz.

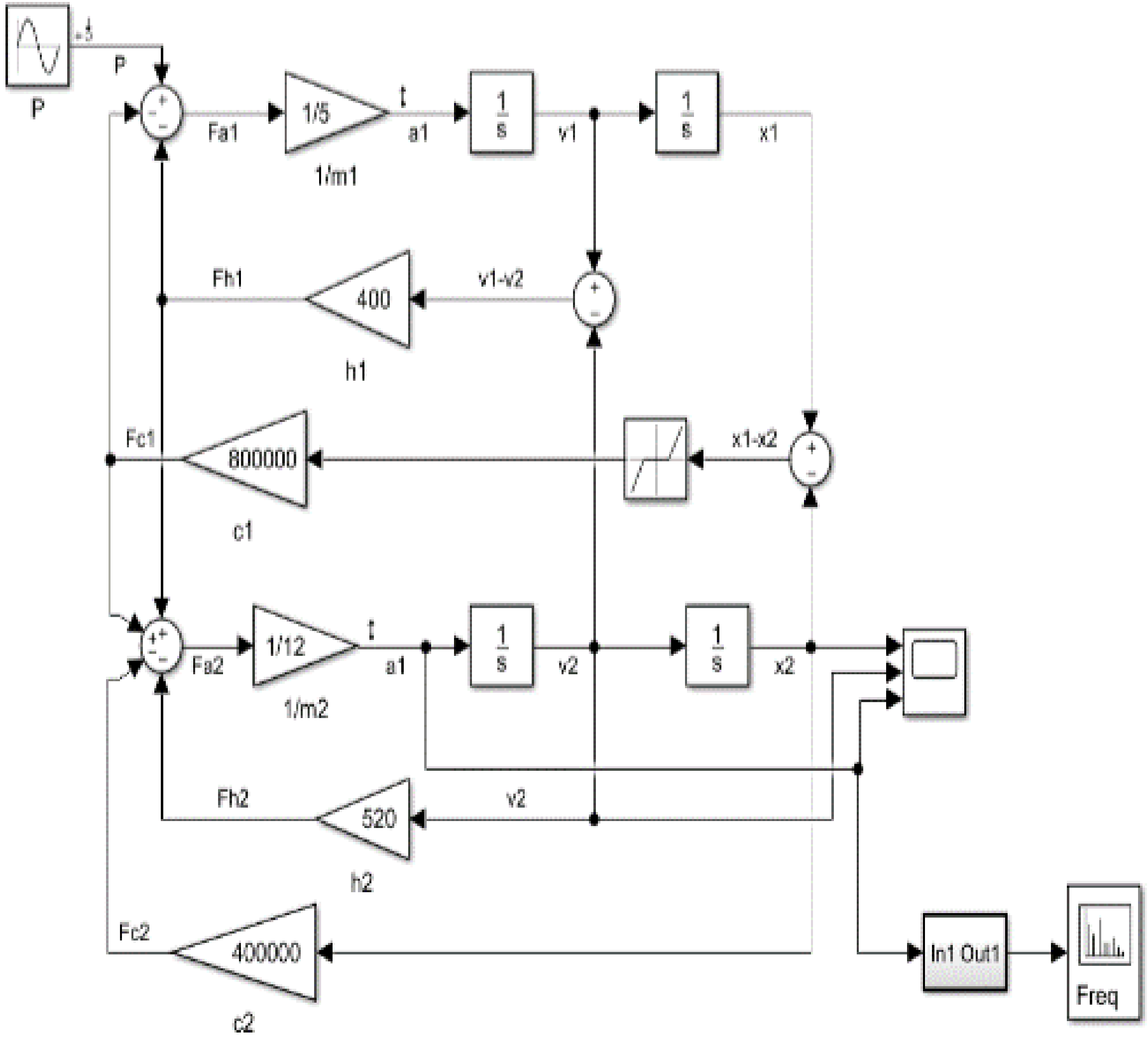

Fig. 1. **Model of an axial-piston hydraulic machine with a gap in the piston part in the Simulink software environment**

In Figure 2, the spectra show that the harmonics that appeared at a gap of $2\cdot10^{-3}$ mm increase to 0.07 m, and additional noise is generated around them.

In Figure 2d, the spectra show that the noise increases as the excitation frequency decreases to 0.55 μm. If the gap size increases further, the system stops working.

Conclusion. The results of the study showed (Fig. 2) that the vibration acceleration parameter, which changes at the initial stages of defect occurrence, demonstrates high sensitivity, which confirms the theory of hypersensitivity of the vibration acceleration parameter to defects in the form of a gap.

It was determined that in the case of a defect in the form of a gap in the hinge of an axial-piston hydraulic machine, the vibration acceleration spectrum contains several harmonics with a fairly large amplitude. For this device, these are harmonics with frequencies of 115 Hz, 135 Hz, 155 Hz, and 175 Hz.

Figure 3 shows the limits of permissible frequency values for a defect in the hinge section of an axial-piston hydraulic machine, according to which, at a harmonic with an amplitude of up to 0.07 m, the device is in satisfactory condition, at a harmonic with an amplitude of 0.07 m to 0.1 m, the device is in danger, and at a harmonic with an amplitude of 0.1 m, the piston section is destroyed and the hydraulic machine is inoperable.

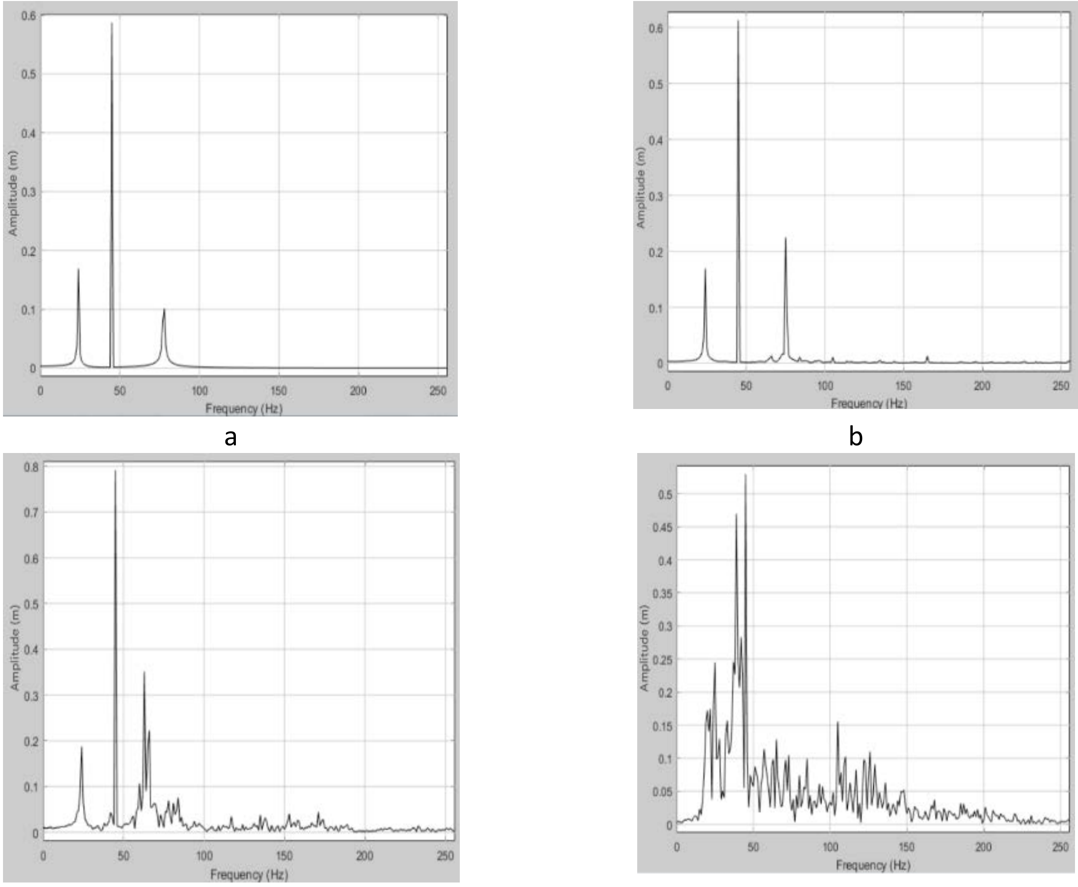

Fig. 2. **Vibration acceleration spectra of an axial piston hydraulic machine: a) in the absence of defects, b) with a gap of $2\cdot10^{-3}$ mm in the piston part of the hydraulic machine, c) with a gap of $2\cdot10^{-2}$ mm in the piston of the hydraulic machine, d) with a gap of $2\cdot10^{-1}$ mm in the piston of the hydraulic machine**

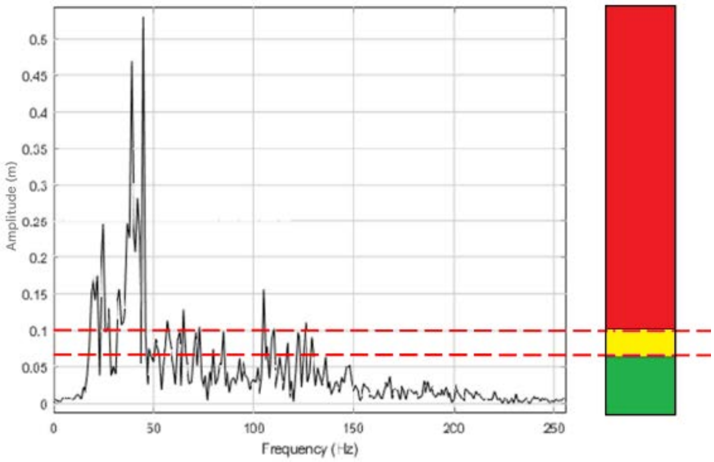

Fig. 3. **Limits of permissible frequency values for a defect in the hinge part of an axial-piston hydraulic machine**

References.

1. Baker R. C. Flow Measurement Handbook: Industrial Designs, Operating Principles, Performance, and Applications. 2nd ed. Cambridge: Cambridge University Press, 2016. 784 p.

2. Esposito A. Fluid Power with Applications. 7th ed. Upper Saddle River: Pearson Education, 2013. 656 p.

3. Lees A. W. Vibration Problems in Machines: Diagnosis and Resolution. 1st ed. Boca Raton: CRC Press, 2016. 348 p

4. Klee H., Allen R. Simulation of Dynamic Systems with MATLAB and Simulink. 3rd ed. Boca Raton: CRC Press, 2018. 830 p.