ANALYSIS OF ACOUSTIC EFFICIENCY OF APPLYING POLYMERIC MATERIALS IN A PUMP

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The previous research has shown that it is possible to replace several parts of the gear pumps with plastic ones. This substitution leads to noise reduction of the pump. Experimental results indicate that the proposed measures for replacing a metal rotor with a plastic one reduce micropump noise within the studied modes. The maximum achieved acoustic efficiency on equivalent level is up to 37%. We have identified and evaluated the most effective polymer materials by a criterion of mechanical losses for their application in the design of displacement pumps.

Keywords: micropump, plastic material, energy dissipation

1. Introduction

As is known, the nature of noise in gear pumps is mechanical and hydrodynamic [1]. The hydrodynamic noise component has been studied in sufficient detail, the causes of its occurrence have been revealed [1-5]. On the other hand, the mechanical component is given secondary attention [6-8] due to a number of features. Recently, due to the appearance of a group of new polymeric materials (PM) [9-10], the positive effect of their introduction into volume-type pumps has been studied [11-14].

One of the main reasons for the increased vibroacoustic loading of the gear pump is the process of mechanical engagement of the rotors teeth [1].

Reduction of acoustic loading in the noise source can be achieved by using pump rotors made from materials with large internal energy losses [11,15-17]. Traditional materials of gear pump rotors have a low damping capacity [16]. Modern structural PMs are deprived of these disadvantages as they possess a greater (than steel) loss factor of mechanical energy [11, 16].

While operating in order to reduce the acoustic loading of a gear pump, the method of reducing acoustic loading in the source is used due to the use of PM in its construction instead of traditional materials. Therefore, we carried out an experimental study of the acoustic radiation of the gear pump with PM parts.

Our objective is to assess the acoustic efficiency of using modern PMs in the gear pump design.

The purposes of the study are: analysis of methods to reduce the mechanical noise of the gear pump, evaluating the damping characteristics of modern structural PMs and an experimental study of the effect of the pump parts material on the acoustic characteristics of the pump.
2. Analysis of measures to reduce the pump vibroactivity

Analysis of the main ways of reducing mechanical noise in a gear pump showed that low noise of a gear pump at high accuracy and class of manufacturing its rotors [1] is achieved by using a misalignment in the gear train, by improving the tooth shape [6,7] or by using a PM in the casing parts [1].

By analyzing a number of generally available and experimental pumps of rotor type with PM parts [11, 18-20], we can represent the distribution of the number of parts made of PMs in accordance with the main parts of the pumps (Figure 1).

![Figure 1 - Distribution of the number of parts made of polymeric materials by the pumps parts](image)

Therefore, the largest number of PM parts among the analyzed displacement pumps was implemented in their casings and rotors, while for paddle-type pumps, the distribution between the elements is uniform.

The frequency of PM use in pump parts is of interest. The most common PM according to the review of all studies: PEEK, PPS, PPA, PTFE, PPO, PE, PP, PVDF.

3. Dissipative abilities of polymeric materials

Dissipative abilities of the material play a huge role in the dynamic behavior of the unit. They characterize the weakening of natural oscillations, the decrease in amplitudes under forced oscillations, and the smoothing of stresses in the concentration zone under oscillations [16].

Traditional steels used in the pump industry have a small dissipating capacity. Modern PMs which in addition to steels of comparable physical, mechanical and chemical properties are more inclined to dissipation of mechanical energy; these include PM of these groups (PEEK) and polyphenylene sulfides (PPS) [21].

In order to evaluate damping characteristics of materials, the tangent of the mechanical loss angle \( \tan \delta \) [16] is used. Analysis of literature on damping characteristics and of modern PM manufacturer's certificates [10,17] is shown in Figure 2.
By analyzing $\tan \delta$ of the above shown materials (Figure 2), we can state that:
- $\tan \delta$ of materials based on PEEK is 10 times larger than that of steel, 2 times greater than that of aluminum, 1.7 times greater than that of grey cast iron, 1.5 times greater than that of copper;
- for modern PMs (Zedex 324, Zedex 324 V2T) $\tan \delta$ is approximately 2 times greater than for the main PM in mechanical engineering industry in the 1970s - 1990s (PA-66, POM).

4. Experimental Investigations

Investigations of the influence of the PM parts of the pump on its acoustic characteristics were carried out in a laboratory on a test bench. Features of the study are presented in this study [22].

Acoustic loading of the pump was estimated by the equivalent level and calculated as the ratio of the difference in sound pressure radiated by the pump with different rotor arrangements ("steel-steel" and "steel-PEEK") to the "steel-steel" arrangement:

$$L_{equiv} = \frac{L_{equiv\ steel} - L_{equiv\ PEEK}}{L_{equiv\ steel}} \cdot 100\%$$  \hspace{1cm} (1)

For the experiment we used a pump with the "steel-polymer" and "steel-steel" arrangements of the rotors .

The results of the experiment are shown for the rotor and tooth frequencies of the gear pump (Figure 3).
We have obtained the following results in the course of investigation and have drawn these conclusions:

1) we have estimated damping characteristics of modern construction materials PEEK and PPS: the tangent of the mechanical loss angle of PM on the basis of PEEK and PPS is 10 times greater than that of steel;

3) Based on the experiment, the acoustic efficiency of using a plastic rotor in a pump was found to be:
   - up to 37% at the main operating frequencies of the micropump at different drive speeds depending on the load;
   - up to 15% by an equivalent sound pressure level depending on the drive speed and outlet pressure;

4) steel rotors are the parts which are more commonly replaced with PM ones in the pump design. As a rule, both rotors are being replaced.

5. Conclusion

Fluid power machines are commonly used in the design of hydraulic drives and systems of machines. There are prospects of further development for such units and together with the improvement of their efficiency and outlet pressure limits, it is possible to achieve a significant noise emission reduction.

The carried-out experiment provides the results which clearly establish the relationship between acoustic efficiency and rotor materials in gear pumps. This is specifically refers to plastic materials. The achieved acoustic efficiency of 2...8 dB depends on outlet pressure on the main working process frequencies of the gear micropump at n=2000 rpm, and 2...17 dB on an equivalent level depends on outlet pressure and shaft speeds. The most effective materials for reducing noise among the examined ones were polymers of the PEEK and PPS groups. These materials have a \( \tan \delta \) 10 times greater than that of steels with comparable strength characteristics.

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