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REDUCTION OF PRESSURE RIPPLE IN THE HYDRAULIC MICROPOWER UNIT

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Abstract: *The growing requirements as to the permissible normative values of noise generated by machines stimulate the development of methods of reducing noise emission. One of the sources of noise in hydraulic systems are sound vibrations caused by pressure ripple. The article presents a method of reducing pressure ripple for a selected frequency by means of a passive chamber damper in a hydraulic micro power unit. The paper presents research on the location of the noise source with the frequency of pressure ripple, based on the Spatial Transformation of Sound Fields (STSF) algorithm.*

Keywords: Pressure ripple, Microhydraulic, Chamber damper.

1. Introduction

The dynamic development of microelectronics and micromechanics in the last decade creates new opportunities for the development of fluid microcircuits, in particular microhydraulics (Kollek, 2009). Microhydraulic systems can be divided into two groups due to their function. The first group consists of systems in which the liquid substance acts as a carrier of hydraulic energy accumulated in the pumped working medium between the generator and the receiver, also called miniaturized hydraulics. They are used in the drives and control of small machines and devices. Working pressures in these systems often reach over 40 MPa. The second group consists of systems, the aim of which is to obtain specific parameters of the liquid. An example of an application of this type of system is the precise dosing of fluids. The biggest advantage of conventional and microhydrostatic drive is the possibility of obtaining a high density of the stream of transmitted power. A particularly important advantage of the hydrostatic drive is the simple and effective limitation of the maximum loads that may occur during the operation of the machine or device. Apart from numerous advantages, hydrostatic systems have their drawbacks, which are particularly noticeable when trying to miniaturize them. Hydrostatic drive always requires a primary energy source, which is usually an internal combustion engine or an electric engine. Primary energy sources additionally increase the weight and dimensions of the entire machine or device. Moreover, the hydrostatic drive is characterized by lower efficiency (Karpenko, 2017), especially in throttle-controlled systems. Another important aspect is the influence of pressure ripple and vibrations of individual drive components on the noise emission to the environment (Kollek, 2010, Kudźma, 2002, Stosiak, 2021). Successive lowering of the permissible normative values of noise emitted by machines and devices may often disqualify a hydraulic drive. The paper presents the results of measuring pressure ripple for a hydraulic micropower unit and the impact on the distribution of sound intensity on the source surface of the object was determined. The presented method may be useful in the design of micropower units, which, for operational and ergonomic reasons, should be characterized by low noise emission to the environment.

A significant problem is not to exceed the permissible sound levels in microhydraulic systems used, inter alia, in engineering and medical technology, e.g., in drives of operating and x-ray tables, dental chairs. The designed such a system must be characterized by the lowest possible noise level meeting the conditions of

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work in a medical laboratory L_{Aeq} = 40 dB [A] (PN-B-02151-2:2018-01). In order to verify the possibility of using passive silencers in the process of reducing pressure ripple and noise generated by microhydraulic systems, tests were conducted on a microhydraulic power unit intended to power the acceleration simulator in medical research (Kudźma, 2002). A view of this micropower unit is shown in Figure 1 (left). The basic element of the micropower unit was a gear micropump with the displacement of 0.25 cm^3 / rev and the number of teeth of the active and idle wheels z = 14. At the rotational speed of the pump shaft, n = 1390 rpm, the basic harmonic of the pump pulsation is f_1 = 324 Hz.

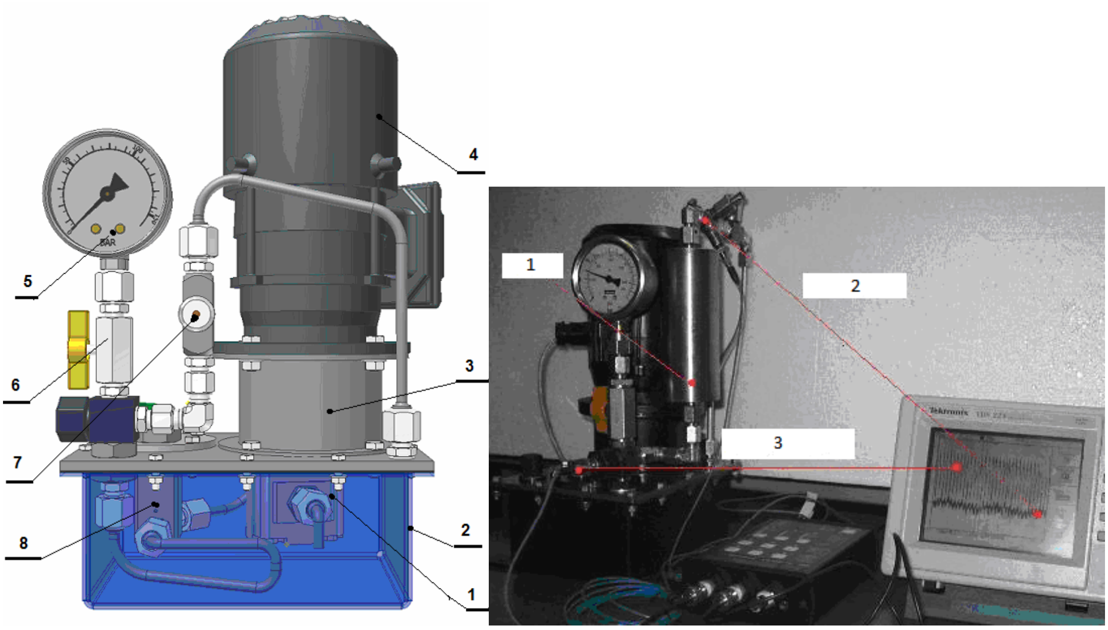

Fig. 1: Micropower unit (left) (Kudźma, 2012): 1 - gear micropump, 2 - tank, 3 - clutch, 4 - electric motor, 5 - pressure gauge, 6 - cut-off valve, 7 - adjustable throttle valve, 8 - microvalves: overflow, adjustable. Micropower unit with a ripple dampener (right) (Kudźma, 2012).

Taking into account the geometrical dimensions of the supply pipe and the parameters of the liquid, the volume of the chamber silencer was determined at the level of V = 85 · 10^{-6} m^3 (85 cm^3). The micropower unit with a mounted chamber silencer is shown in Figure 1 (on the right, marked as no. 1) with the course of pressure ripple before the damper (3) and after the damper (2) as a function of time. Figure 2 compares the pressure ripple amplitudes measured before and after the damper, obtaining a reduction of pressure ripple by 15 dB, which should be considered a very favorable result.

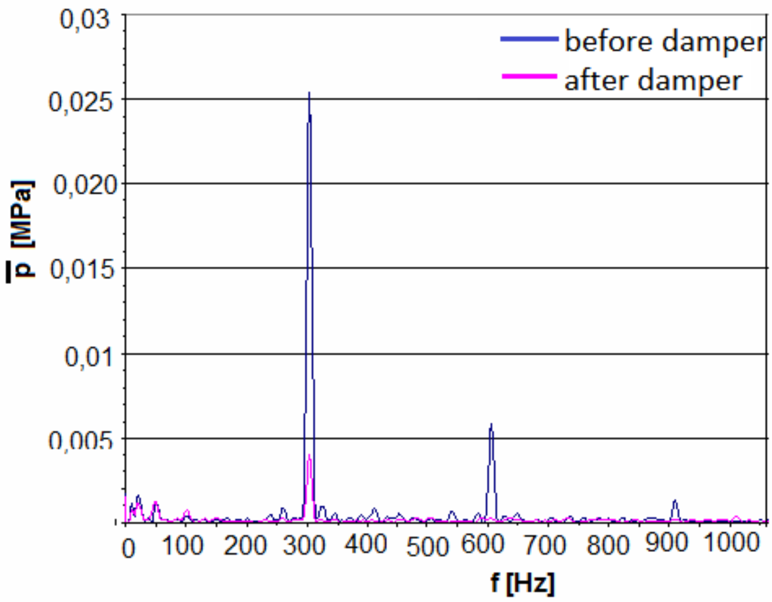

Fig. 2: Comparison of pressure ripple amplitudes in a microhydraulic power unit with a chamber pressure ripple damper. Discharge pressure p = 16 MPa (Kudźma, 2012).

2. Localization of the sound source by the method of Spatial Transformation of Sound Fields (STSF)

The diagram of the measuring equipment used for the acoustic holography method is shown in Fig. 3. The acoustic signal was received by a two-dimensional microphone array consisting of thirty six B&K 4196 (MM) pressure scanning microphones. The microphones were arranged in 2 columns and 18 rows. The distance between the microphones was 10 cm. Each of the microphones has a built-in preamplifier. In the next stage, the amplified voltage signal went through digital filters in the B&K 3561 (PW) multi-channel analyzer. The received data was recorded on the hard drive of the workstation (KO). The calibration of individual measurement paths was performed with a pistonphone type 4228 by Brüel & Kjaer (KA).

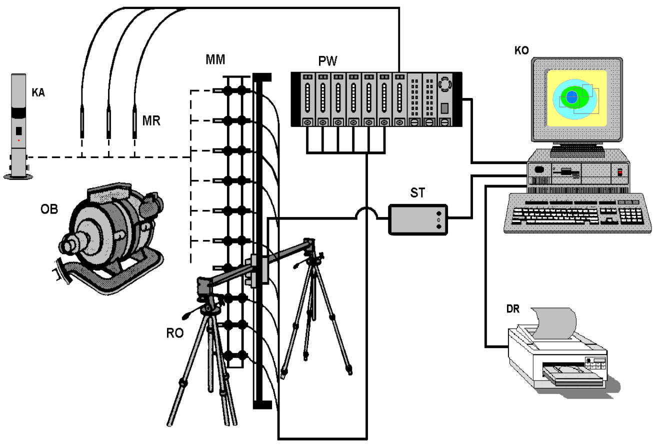

Fig. 3: Diagram of the STSF measurement set (Kollek, 2000) : KA - intensity calibrator B&K 3541, MR - reference microphones B&K 4196; MM - scanning matrix B&K WA0807 with B&K 4196 microphones; PW - Multichannel transducer B&K 3561; ST - controller B&K 9655; RO - measuring robot B&K 9655; OB. – object of research; KO - HP workstation with B&K 7688 software, DR - printer.

The sound intensity distribution on the source surface was analyzed for the center frequency of 350 Hz. The bandwidth was 50 Hz. The map below (Fig. 4) shows the length of the sound intensity vector. Such imaging allows to locate sound sources and assign the analyzed frequency to the place from which the acoustic wave is radiated to the environment. As a result of the performed localization, it was determined that the place of sound generation for the frequency of 350 Hz is a hydraulic collector with a part of the installation.

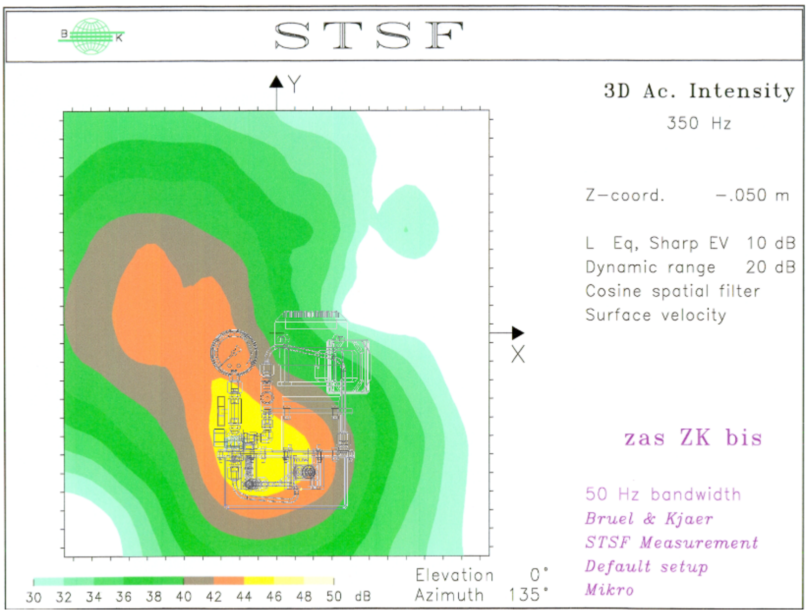

Fig. 4: Distribution of sound intensity on the source surface for the frequency f = 350Hz (Kollek, 2011).

3. Conclusions

The principle of the passive damper (effective for higher excitation frequencies) is based on the interference of the moving pressure wave with a reflected wave. This damper is an acoustic filter of hydrostatic systems. The amplitudes of pressure ripple can also be influenced by the geometry of the hydraulic lines supplying the system, resulting in the effect of increasing or decreasing the pressure ripple amplitudes at a given frequency, depending on the length of the lines. The pressure ripple generated in this way can be transmitted from the point of origin (vibrating hydraulic valve, pump) to other system and machine components via hydraulic lines. Moreover, they may contribute to the reduction of the precision of the movement of the working parts, the unevenness of their work and may shorten the service life. The concept of pressure ripple reduction in the microhydraulic power unit for a selected frequency of 350 Hz by means of a passive-chamber damper is presented. Its application led to a fivefold reduction in pressure ripple amplitude for the frequency of 350 Hz (Fig. 2). The second component of the pressure ripple spectrum was also reduced. Pressure ripple causes noise vibrations in the hydraulic system (lines and system components). Lowering the pressure ripple in selected frequencies will result in lowering the noisiness of the microhydraulic power supply for the corresponding frequencies. The presented energy method (STSF) for locating areas with the highest levels of noise is very practical and allows you to effectively eliminate the sources of noise at the highest levels, contributing to the reduction of global noise of a working facility.

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