ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING 15 (2015) 392–400

Available online at www.sciencedirect.com

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journal homepage: http://www.elsevier.com/locate/acme

Original Research Article

Ways of reducing the impact of mechanical vibrations on hydraulic valves

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ARTICLE INFO

Article history:
Received 6 December 2013
Accepted 14 June 2014
Available online 11 August 2014

Keywords:
Hydraulic valve
Vibrations
Tests

ABSTRACT

This paper deals with the impact of mechanical vibrations on the environment, particularly on hydraulic valves. The main sources of such vibrations and their effects on hydraulic systems are indicated. Some documents setting down standard requirements for resistance to vibrations and to the noise generated by vibrations are cited. Two ways of reducing the impact of mechanical vibrations on the valve are proposed and a theoretical analysis, constituting the basis for selecting a material for an effective vibration isolator for the valve, is carried out.

1. Introduction

A running engineering machine is a source of mechanical vibrations with a wide spectrum of frequencies, including low frequencies [1–3]. The vibrations act on the operator inside the machine [4], on all the machine subassemblies and subsystems and indirectly, on the surrounding environment. For the sake of the health of the machine's valves, it is essential to identify the mechanical vibrations to which they are subjected. Such vibrations often may disturb the operation of the entire hydraulic system of a mobile machine. A disturbance in the operation of such a system is reflected in a change in the pressure fluctuation spectrum. The disturbance may lead to a deterioration in the accuracy of positioning the actuators, to uneven operation, shortening of the machine's life and sometimes to a higher level of low-frequency noise emitted [5]. Low-frequency vibrations and noise have a particularly adverse effect on hydraulic valves and the human being. In hydraulic valves they may excite the vibration of their control elements (such as the slide and the head) [6,7]. This occurs when the frequency of the external mechanical vibrations is close to that of the free vibrations of the valve control element. In the case of a human being, the vibrations via the skin mechanoreceptors transmit specific information to the central nervous system, causing reflex reactions of the human body [3,8,9]. The vibrations are accompanied by noise [10], also with low-frequency components. The noise is the subject of EU standard regulations. Hydraulic equipment producers, however, rather seldom specify the operating requirements concerning the resistance of their products (e.g. valves) to mechanical vibrations. One of such rare examples is the proportional distribution valve Parker–Hannifin D1FP, whose product data sheet [11] specifies the vibration value (about

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http://dx.doi.org/10.1016/j.acme.2014.06.003

250 m/s^2) permissible with regard to its resistance to mechanical vibrations. The resistance of hydraulic valves to mechanical vibrations is usually tested in accordance with the relevant standards, such as, e.g. DIN-IEC68, part 2–6 [12] in the case of the D1FP distribution valve. Valve mechanical vibration resistance tests can also be conducted in accordance with other procedures described in Polish and international standards. Standard PN-IEC 68-2-59 1996 [13] specifies a method of testing electrotechnical subassemblies, equipment and other products (including hydraulic valves used in electrical applications) which during operation may be exposed to short-duration pulsating or oscillating forces generated by, e.g. seismic phenomena, an explosion or the vibrations of the machine in which they are installed. The tested product is excited by a certain number of constant-frequency sinusoidal beats. Standard PN-EN 60068-2-6:2008 [14] specifies a method of testing subassemblies, equipment and other products, which during transport or operation may be exposed to harmonic vibrations generated mainly by rotating, pulsating or oscillating masses. Such excitations occur in ships, planes, terrestrial vehicles and space vehicles. Resistance to mechanical vibrations in a frequency range of 5–3000 Hz is tested. A critical frequency identified by the test is a frequency at which faulty operation of the product or a deterioration in its properties due to vibration manifests itself or mechanical resonances (e.g. a valve control element) occur. Polish standard PN-EN ISO 4413:2011 [15] includes, among other things, requirements for the assembly of hydraulic valves (also pumps, servomotors, filters, etc.), but limited to a general statement that one should consider the effect of gravitation and vibrations on the valve.

In general, the vibrational resistance standards specify the permissible level of external mechanical vibrations which may adversely affect a machine, a piece of equipment or their components. In the precision industry, the experimentally determined maximum acceleration of about 0.981 m/s^2 has been adopted as the norm ensuring the vibrational resistance of measuring instruments and industrial equipment [16]. As regards rotor machines, they can be exposed to external mechanical vibrations below 9.81 m/s^2, without any adverse effect on their operation.

In this paper, the possibility of reducing the vibrations of the hydraulic distribution valve is studied. The experimental studies have been broadened with a general theoretical analysis of the problem of reducing the vibrations of a valve or a control element, which can be helpful in selecting the characteristics of antivibration materials and vibration damping systems for this purpose.

2. Experimental studies

Two ways of reducing the effect of external mechanical vibrations on hydraulic valve operation were investigated. One way consisted in flexibly fixing the distribution valve housing to a vibrating foundation while the other way consisted in introducing specially designed damping washers made of oil-resistant rubber into the distribution valve.

A linear hydrostatic drive simulator, capable of generating mechanical vibrations up to a frequency of 100 Hz, was used as the source of external vibrations. The simulator is described in more detail in [17]. As part of the experimental studies aimed at reducing distribution valve vibrations through flexible fixing, the acceleration of simulator table vibrations (excitation) and that of distribution valve housing vibrations (response) were measured (Fig. 1). In the case of the experiments aimed at reducing the vibrations of the distribution valve slide through the introduction of oil-resistant rubber washers into the distribution valve, the accelerations of both distribution valve vibrations (excitation) and slide vibrations (response) were measured (Fig. 2). The distribution valve was rigidly fixed in the simulator clamps.

PCB-ICP accelerometers, a signal conditioner VibAmp PA16000D, a Tektronix four-channel digital oscilloscope with

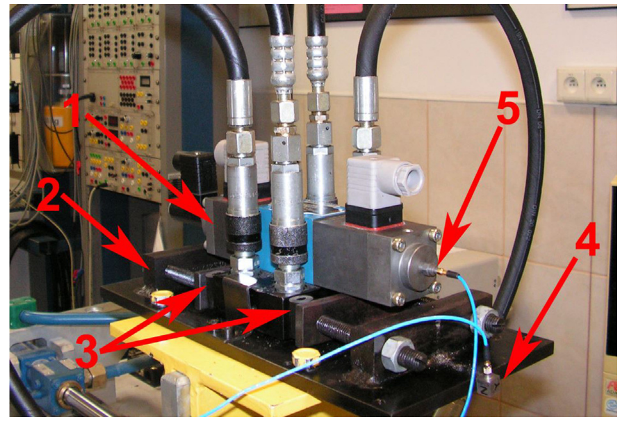

Fig. 1 – Way of fixing distribution valve and arrangement of accelerometers: 1 – hydraulic distribution valve, 2 – simulator table clamp, 3 – set of elastomer washers, 4 – accelerometer for measuring simulator table vibration acceleration (excitation), 5 – accelerometer for measuring distribution valve housing vibration acceleration.

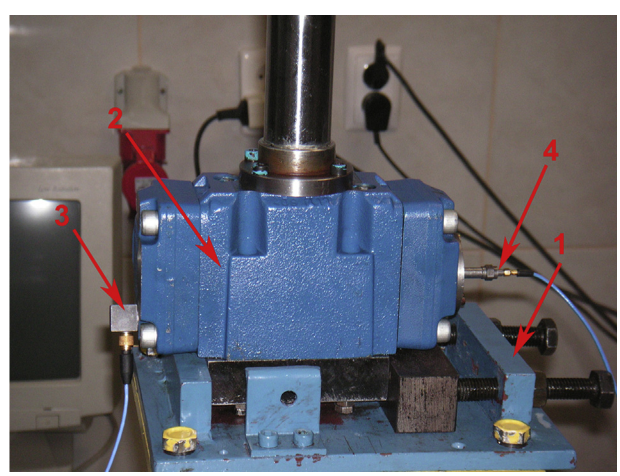

Fig. 2 – Way of fixing distribution valve and arrangement of accelerometers: 1 – simulator table clamp, 2 – hydraulic distribution valve, 3 – accelerometer for measuring distribution valve housing vibration acceleration (excitation), 4 – accelerometer for measuring distribution valve slide vibration acceleration (response).