ULTRASOUND DIAGNOSTICS OF THE PRESSURE VALVE PVV-25

УЛЬТРАЗВУКОВАЯ ДИАГНОСТИКА НАГНЕТАТЕЛЬНОГО КЛАПАНА PVV-25

Eng. Z. HEJMAL, CSc.
University of Defence-Brno, Czech Republic

Abstract: *The paper discusses the diagnostic possibilities of the pressure valve PVV-25, which is frequently used in mobile hydraulic systems. Standard diagnostic procedures are based on time-consuming flow rate and pressure measurement. Suggested approach is based on sensing and processing of ultrasonic signal emitted by the valve. Contrary to vibrational signal in the range of 20 Hz - 20 kHz, emitted ultrasonic signal is not influenced by mechanical vibration of drive and has its origin in cavitation processes. The information stored in ultrasonic signal can be used for diagnostic prediction of the valve operating condition.*
***KEYWORDS**: CONDITION MONITORING, ULTRASONIC EMISSION, FREQUENCY SPECTRUM, FLOW RATE*

1. Introduction

There are many available diagnostic procedures for fluid power systems nowadays. Different systems and different operating conditions require distinct approaches for condition monitoring. The most reliable and frequently used procedures for fluid power systems are usually based on direct flow rate and pressure measurements, which require installed flow meters and pressure gauges. Usually it is impossible to mount necessary measuring devices to all potential places and that is why we are looking for indirect measuring methods, which did not involve hydraulic circuit disassembly and are less time-consuming and more convenient for operational diagnostics. For example temperature or vibration measurement and its subsequent analysis can be mentioned. Vibrational signal measured on hydraulic elements in the range of 20 Hz ÷ 20 kHz (so-called audible range) always contains vibrational components generated by gearboxes and drives of hydraulic pumps. Another problem inheres in sensor mounting. Basically three types of accelerometer mountings can be chosen (stud mounting, adhesive mounting and magnetic mounting). Each of these mountings has its advantages and disadvantages. Because of easy operation the magnetic mounting is the most suitable for diagnostic purposes. Magnetic mounting adapters are used to attach accelerometers to ferromagnetic surfaces where the instrument is to be moved quickly from place to place. The accelerometer is attached to the magnetic adapter (usually by stud mount) and the assembly is applied to the surface. While this method is certainly convenient, the user may be misled by this convenience. In general, magnetic adapters should be used with caution and rarely trusted at frequencies above 1 kHz. The response degradation is in direct proportion to the weight of the accelerometer. All these obstacles make the condition monitoring of hydraulic elements based on vibration measurement in the range of 20 Hz ÷ 20 kHz quite difficult [1]. Pressure valve PVV-25 and accelerometer with magnetic mounting are shown in Fig. 1.

An alternative to this approach presents ultrasonic emission measurement and suitable processing of acquired data. This approach utilizes the fact that ultrasonic signal generated by cavitation processes is not significantly influenced by mechanical vibration of moving parts. Ultrasonic emission of pressure valve contains information about its operating mode and can be used for diagnostic purposes. It is necessary to point out that properties of emitted signal are specific for each type of hydraulic element and sensor position.

In the case of pressure valve condition monitoring our attention is primarily focused on the following basic questions:

1. Is the pressure valve closed or opened?
2. What is the flow rate through the pressure valve if it is opened?
3. What is the level of the pressure if it is opened?

The ability to give answers, based on ultrasonic emission measurement, to these questions can be established experimentally only.

Fig. 1 Pressure valve PVV-25 and accelerometer with magnetic adapter

2. Experiment set-up

The main goal was to find out whether detectable correlation between operating mode (valve is opened or closed, level of flow rate and pressure) and emitted ultrasonic signal of the pressure valve PVV-25 exists.

To perform proposed experiment the following equipment were used:

- Hydrotechnik Multi-Handy 2050 with RE-300 (pressure and flow rate measurement),
- Diagnost D400 FEL with ultrasonic sensor - frequency range 35 kHz ÷ 400 kHz (sensing and demodulation of ultrasonic signal),

- National Instruments shielded connector block BNC 2110 and NI DAQCard-6062E for PCMCIA (data acquisition and data transfer to control computer),
- NI LabVIEW Professional Development System Version 8.2 (control program for data acquisition),
- The Language of Technical Computing MATLAB The MATHWORKS Inc. (post processing and visualization).

Ultrasonic signal emitted by the pressure valve PVV-25 was led to the envelope detector D400 FEL and the output signal from the detector (modulating signal with frequency range 20 Hz ÷ 20 kHz) was sampled using NI DAQCard-6062E with frequency 50 kHz and stored on the notebook hard drive. All additional post processing and visualization was done using MATLAB.

Modulating signal of ultrasonic emission describes the time fluctuation of cavitation processes. To find out more about the nature of these fluctuations we have chosen to perform the frequency analysis using discrete Fourier transform.

3. *Measurement results and discussion*

Operational mode for pressure valve was considered and the decision was made to test primarily the ability to distinguish between opened and closed pressure valve. For this reason the first measurement was performed without fluid delivery (hydraulic fluid was led by directional valve to other part of hydraulic circuit) but with running hydraulic pump (driving mechanism vibrations) and then for low pressure setting 4 MPa and flow rate $8.3{\cdot}10^{-4}$ $m^3{\cdot}s^{-1}$. Results of both measurements are presented in Fig. 2 and Fig. 3.

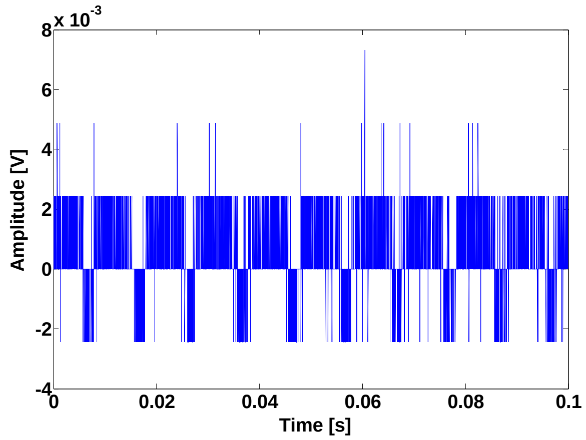

Fig. 2 Ultrasonic emission - pressure valve closed

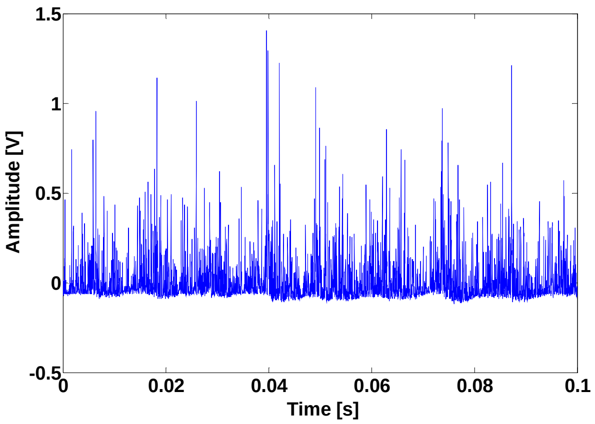

Fig. 3 Ultrasonic emission - pressure valve opened, p = 4 MPa, $Q = 8.3{\cdot}10^{-4}$ $m^3{\cdot}s^{-1}$

As long as the pressure valve is closed, the ultrasonic emission reaches approximately ± 1 LSB of A/D signal conversion (± 2.44 mV). As soon as the pressure valve opens (Fig. 3), the ultrasonic emission signal increases by more than two orders of magnitude. Distinction between opened and closed state of the pressure valve is quite easy and reliable.

In order to find out the correlation between flow rate and ultrasonic signal emitted by the pressure valve PVV-25 the measurements on the flow rate levels $Q = 8.3{\cdot}10^{-4}$ $m^3{\cdot}s^{-1}$, $9.2{\cdot}10^{-4}$ $m^3{\cdot}s^{-1}$ and $1.0{\cdot}10^{-3}$ $m^3{\cdot}s^{-1}$ at pressure levels 6 MPa and 12 MPa were performed. Results obtained in the time domain did not prove clear relationship between ultrasonic signal and the flow rate or pressure. For this reason the decision was made to compare the frequency spectra of individual measurements. Obtained results are displayed in Fig. 4 and Fig. 5.

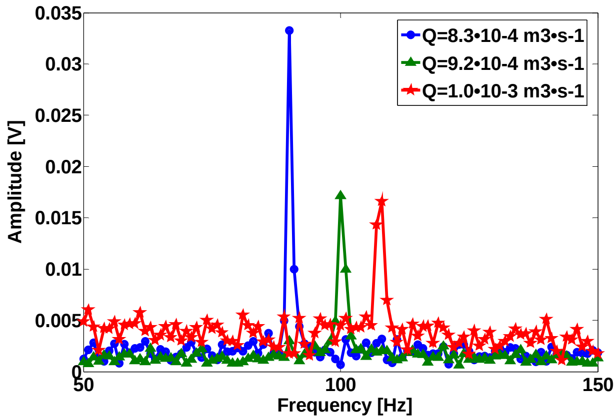

Fig. 4 Frequency spectrum at pressure level 6 MPa

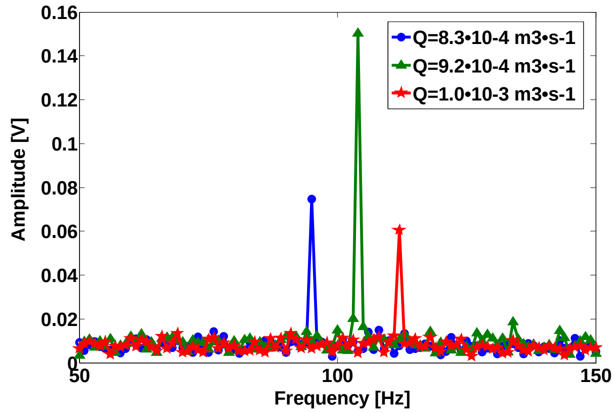

Fig. 5 Frequency spectrum at pressure level 12 MPa

Only significant parts of the frequency spectra are presented in Fig. 4 and Fig. 5. There is no single-valued relationship between the value of amplitude and the flow rate but we can observe correlation between the flow rate and the frequency of respective component with maximum amplitude. The frequencies of individual components slightly increase with increasing pressure.

4. *Conclusion*

The ultrasound diagnostics is an alternative to standard methods for condition monitoring of the pressure valves. In comparison with vibration measurement it is less demanding with regard to sensor mounting and in this way more suitable for operational diagnostics. This method enables to distinguish between opened and closed state of the pressure valve with high probability. Frequency analysis of the ultrasonic emission fluctuations revealed certain relationship between flow rate and frequency of the component with maximum amplitude. It is highly probable that this effect has its origin in flow rate fluctuations. To completely describe this functionality and take advantage of this knowledge for diagnostic purposes will require additional experimentation and subsequent analysis.

5. References

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Reviewer: Faculty of Military Technologii, University of Defence, Brno, Czech Republic, phone: +40973442278, e-mail: jiri.stodola@unob.cz