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Diagnostyka działania siłowników pneumatycznych z wykorzystaniem Emisji Akustycznej

Diagnostics of the function of pneumatic actuators using acoustic emission

ABSTRACT

This paper focuses on finding the diagnostic criteria that evaluate the pneumatic cylinder and detect the defects. Several undamaged cylinders were tested by acoustic emission before artificial defects were created in each one. The signals from the progress and retreat strokes were recorded and analysed into many parameters. The differences were identified by comparing the max root mean square from sensor A and the max root mean square from sensor B for one cycle in the retreat stroke. The damaged and undamaged cylinders were distinguished using the difference in energy values present in the signals of the two sensors in the retreat stroke. This paper is a continuation of a prior article and the extension of my work.

Keywords: *Pneumatic cylinders, Defects, Leakage, Acoustic Emission, Root Mean Square*

STRESZCZENIE

Przedstawiona w opracowaniu analiza miała na celu określenie dokładności w systemie oceny stosowanym przy badaniu złączy spawanych metodą ultradźwiękową z zastosowaniem techniki DGS. Podjęto próbę wyznaczenia reflektora odniesienia DDSR jako funkcji grubości badanego materiału. Wyznaczony reflektor pozwolił na ocenę czułości reflektorów odniesienia przyjętych wg normy PN-EN ISO 17640.

Słowa kluczowe: *badania ultradźwiękowe; technika DGS; czułość badania; dokładność oceny; złącza spawane*

1. Introduction

Pneumatic actuators convert fluid energy into straight-line motion (linear actuators). During normal operation of a pneumatic actuator, a variety of defects can occur, which could lead to a catastrophic failure if left undetected [1]. Therefore, it is crucial to detect even the minor problems and their sources as quickly and accurately as possible to ensure an uninterrupted safe operation [2]. The possible types of defects are sorted according to the construction of the cylinder and the value of the detection coefficient "D" and severity coefficient "S", with "S1" for a single defect with no consequences, and "S2" reflecting the worst possible consequences; both are derived from the FMEA method according to these coefficients defect of cylinder were chosen [3].

Acoustic emission is the transient elastic stress waves generated by the energy released when the escaping gas or liquid through a small breach creates a high frequency sound wave that travels through the cylinder [4]. The frequency spectrum changes over time depending on the type of damage and the number of completed cycles. The figure 1 shows the signal frequency of undamaged cylinder and the artificial mechanical damaged cylinder "Loosening 4 screws under the piston". After undamaged pneumatic cylinders were tested by AE, artificial defects were made on the same cylinders. The results were compared to find distinctive differences between the damaged and undamaged cylinders A set of defects was identified through this comparison, but the frequency spectrum, counts and events were not sufficient to identify all defects. The frequency spectrum was replaced later by the AErms during the monitoring of changes in the test results [5].

For the AE signal, the most frequently used AE parameters are the AErms and the average signal level (ASL) [6]. AErms can be defined as:

$$AE_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2(t)dt} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} v^2(n)} \tag{1}$$

Where v is the voltage of the signal from an AE sensor, t is the initial time, T is the integration time of the signal, and N is the number of discrete AE data within the interval T.

$$E = \int_{t_0}^{t_0+T} v^2(t)dt = \sum_{n=1}^{N} v^2(n) \tag{2}$$

Where v is the voltage of the signal from an AE sensor, t is the initial time, T is the integration time of the signal, and N is the number of discrete AE data within the interval T.

V. Augutis, M. Saunoris studied pneumatic cylinders by AE. During the lifetime service of the pneumatic cylinder, the housing wears down due to the piston repeated movement. This causes the leak between the piston and the pneumatic cylinder housing. The leak causes higher intensity of the HFV (High Frequency Voltage) in the cylinder. The basic parameters, that used in this work are root mean square value, the envelope of the root mean square values and the power spectrum density. The influence of the friction is approximately 10 times bigger than the influence of the leak between the piston and the pneumatic cylinder [7].

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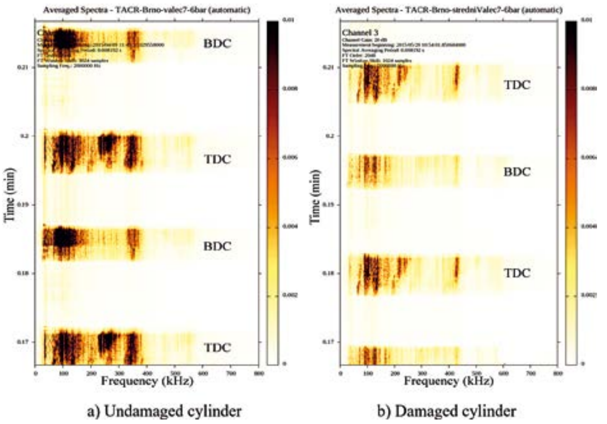

Fig. 1. Differences between damaged and undamaged cylinder by frequency spectrum.
Rys. 1. Różnice między uszkodzonym i nieuszkodzonym cylindrem według widma częstotliwości.

In our research, the measurements by ATEQ F620 leak tester on the undamaged cylinder showed that the value of the leak at a pressure below the piston (progress stroke), and the value of the leak at a pressure above the piston (retreat stroke) change slightly and sometime do not change after 101500 cycles [8].

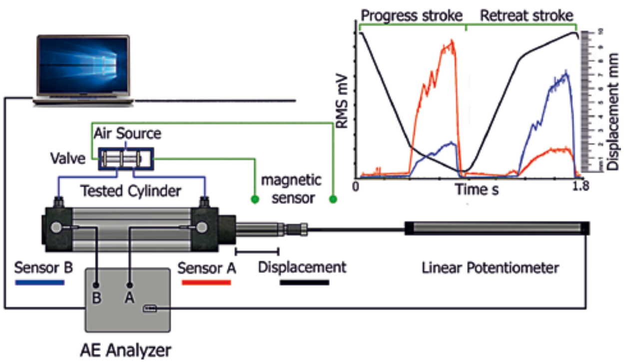

Fig. 2. Assembly of experimental equipment.
Rys. 2. Montaż układu doświadczalnego.

2. Experiment

The experiment took place in a specialized laboratory at Brno University of Technology:The experiment platform contains testing devices including tested cylinders PS ISO Piston diameter (40mm), piston stroke (100 mm), thread (M12x1.25), air pressure supply (6 bar), pneumatic control system, linear potentiometer, working range of potentiometer is (0-200 mm), global measurement period is (156.25 Hz). Two magnetic sensors were positioned at the piston track to define the start and the end of the stroke by controlling the beginning of progress and retreat strokes. The distance between them is (100 mm) and the AE monitoring system with the analyser DAKEL-ZEDO with two channels. Global measurement period of AE parameters (AErms, Energy) (sampling) is 250 Hz (0.004 s). To reducing the noise using sensor with integrated low-noise preamplifier IDK-14 built-in preamplifier (34 dB) frequency range [20-400 kHz]. Using a high dynamic range measuring apparatus [24 kHz – 2700 kHz] and resolution is (16 bits) time resolution is (1ns). Frequency bandwidth was limited by digital filters: High-pass filter (50 kHz) and Low-pass filter (400 kHz). Digital Filter: (HP: 15-2500 kHz + LP: 25-2500 kHz) software switchable. Two sensors were installed at the cylinder and were referred to as (A) on the head cap and (B) on the rear cap as shown in figure 2.

The sound waves travel from the surface of the cylinder to the sensors; sensors convert these waves to voltages after that to the preamplifier then the analyser. The analyser converts the signals from analogue to digital signals after that to the software to many parameters as RMS, ASL and Counts etc. the magnetic sensors is responsible for the changing of progress and retreat stroke by a digital signal to the valve when the piston arrives near the sensors.

3. Types of cylinders

Three types of cylinders were tested - PS, PB and RD (producer Polices strojirny a.s.) [9].

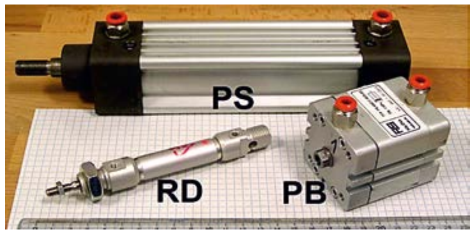

Fig. 3. Types of tested pneumatic cylinders.
Rys. 3. Rodzaje badanych cylindrów pneumatycznych.

4. Results

The signals were obtained by two AE sensors, one of them is fixed on head cap (A) and the other on the rear cap (B). In addition, a potentiometer was used to obtain a signal that represents the displacement of the piston. While digital signals were obtained from two magnetic sensors, which determine the start and end positions of the piston in retreat and progress strokes.

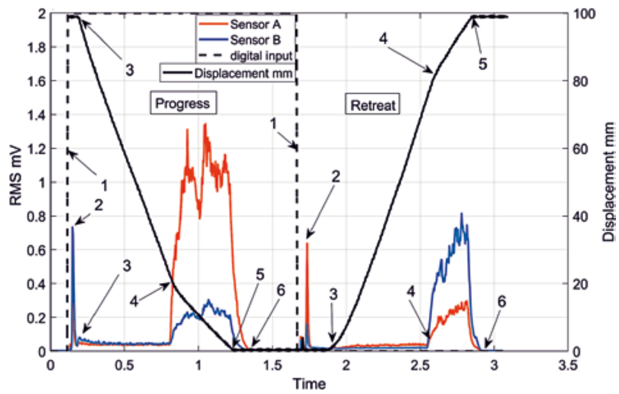

Fig. 4. The relationship between AErms and piston displacement during the time for undamaged cylinder.
Rys. 4. Zależność między AErms a przesunięciem tłoka w czasie dla nieuszkodzonego cylindra.

(1) the valve is opened by the digital input to let the air pass through the port, (2) the impact of the air at the cushion piston, (3) the initiation of movement, (4) the initiation of the damping phase 21.7mm before the TDC, (5) when the cushion piston impacts the cushion cap, and stops, (6) the end of venting air and relaxing and the end of the stroke.

The ratio between maximum AErms from sensor B and the maximum AErms from sensor A in the retreat stroke, determines whether the cylinder is damaged or undamaged.

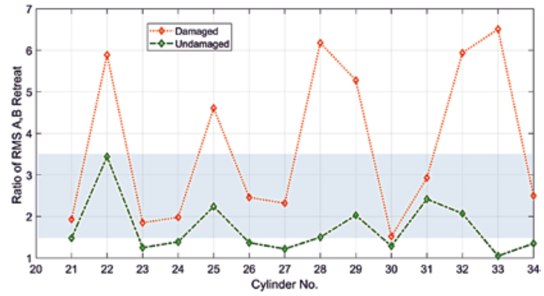

Fig. 5. Comparing between damaged and undamaged cylinders according to the ratio of AErms values.
Rys. 5. Porównywanie uszkodzonych i nieuszkodzonych cylindrów na podstawie wartości AErms.

The high values of AErms ratio indicate that the cylinder is damaged, while the low values indicate that the cylinder is undamaged. However, there is a range of uncertainty lies between them, the range of values that do not give a direct indication to whether the cylinder is damaged or undamaged. In this case, a new criterion should be considered.

The first criterion is the difference between curve B and curve A of the signal's energy in the retreat stroke for one cycle, which is given by the following equation:

$$E_{B-A} = \sum U_{retreat\ B}[i]^2 * \mathrm{dT} - \sum U_{retreat\ A}[i]^2 * \mathrm{dT} \quad (3)$$

Where dT is the value of sampling (in our case 0.004 s), the area between curve A and curve B demonstrates the value of energy.

The value of energy is in inverse proportion to the quality of the cylinder. When $E_{B-A} > 0.5 \cdot 10^{-7}\ V^2 \cdot s \cdot Ohm$ the cylinder is damaged, and when $E_{B-A} < 0.2 \cdot 10^{-7}\ V^2 \cdot s \cdot Ohm$ it is undamaged. The cylinders between $0.2 \cdot 10^{-7}$ and $0.5 \cdot 10^{-7} V^2 \cdot s \cdot Ohm$ are in the uncertainty range. As undamaged cylinders No. 22, 29 and damaged cylinders No. 30, 34 are between the range $0.2 \cdot 10^{-7}$ and $0.5 \cdot 10^{-7} V^2 \cdot s \cdot Ohm$.

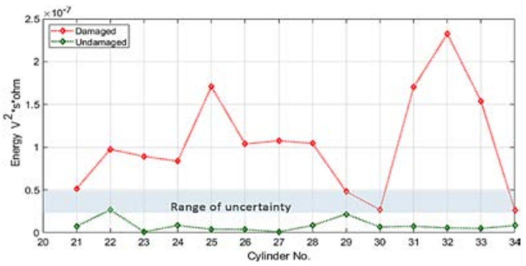

Fig. 6. Comparing between damaged and undamaged cylinders according to the energy values.
Rys. 6. Porównywanie uszkodzonych i nieuszkodzonych cylindrów na podstawie wartości energii.

5. Conclusion

The frequency spectrum, counts and events were not sufficient to identify all defects. The frequency spectrum was replaced later by the AErms during the monitoring of changes in the test results. The last group of measurements discusses the two types of leakage that are difficult to detect by conventional methods and previous study. The determination of diagnostic criteria that evaluate the pneumatic cylinder PS and determine whether the cylinder is damaged or undamaged. There are four criteria to evaluate the cylinder respectively:

- The AErms was normalized; the defect in the cylinder causes a delay in the stroke time, which causes an extension in the damping area. This delay distinguishes between undamaged and damaged cylinder.
- The specific ratio between maximum AErms from the sensor A fixed in the head cap of and the max AErms from the sensor fixed in the rear cap B of the cylinder in the retreat stroke can identify whether the cylinder is damaged or undamaged. When the ratio is bigger than 3.5 the cylinder is damaged if the ratio is smaller than 1.5 the cylinder is undamaged.
- The damaged and undamaged cylinders were distinguished using the difference in energy values present in the signals from the two sensors in the retreat stroke. at signal energy $E_{B-A} > 0.5 \cdot 10^{-7} V^2 \cdot s \cdot Ohm$ the cylinder is damaged, and at $E_{B-A} < 0.2 \cdot 10^{-7} V^2 \cdot s \cdot Ohm$ it is undamaged.

These criteria will be applied to other types of cylinders. Moreover, new criteria will be applied to other types of defects that will improve the mobile diagnostic tool using AE methods.

The Acoustic emission can be applied to detect and locate leaks as long as there is enough pressure fluid acting across the leak.

6. Acknowledgment

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