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LEAK MEASURING SYSTEM OF COMPRESSED AIR IN PIPELINE

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Abstract: *The new innovative measurement method of compressed air leakage flow rate in compressed air pipeline is proposed. The methods can be used to measure compressed air leakage in any place of compressed air pipeline: in main line, distribution line and connection line. The controlled air flow through the throttle valve is directly measured by flow meter. The proposed measurement methods of compressed air leakage in pipeline are independent of receiver and compressor parameters, which is not the case with traditional method measuring leaks by emptying the receiver. A device for the automatic measurement of leakage flow rate in compressed air pipeline.*

Keywords: Compressed Air, Leakage Flow Rate Measurement, Energy Efficiency.

1. Introduction

Leakage is usually the largest source of energy waste associated with compressed air usage. Leakage can occur at a number of points in a compressed air pneumatic pipeline system. There are many various ways of determining or measuring the quantity of compressed air leaking out (Dudić et al., 2012; Huang Liang et al., 2010; Radgen and Blaustein, 2001; Shibata et al., 2009; Souza et al., 2000). For compressors that have on/off controls or load/unload controls, there is an easy way to estimate the amount of leakage in the system. This method involves starting the compressor when there are no demands on the system (when all the air-operated end-use equipment is turned off). Leakage can be estimated in compressed air pipelines by emptying the compressed air receiver. Compressed air leakage measurement method based on the controlled flow in branch line. The diagram of the air leakage measuring circuit in compressed air pipelines based on the controlled flow in branch line is shown in Fig. 1.

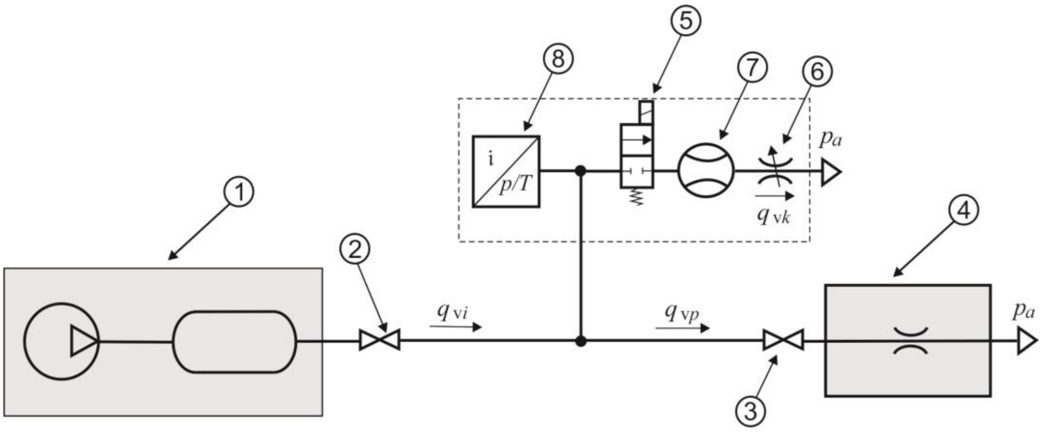

Fig. 1: Diagram of the air leakage measuring circuit based on the controlled flow in branch line: 1 – compressor and receiver, 2, 3 – shut-off valve, 4 – leak point in pipeline, 5 – switching valve, 6 – adjustable throttle valve, 7 – flow meter, 8 – dual pressure and temperature sensor.

The new measurement method of compressed air leakage in pipelines based on the controlled flow consists in determining the relation between air leakage flow rate q_L in leak point of pipeline (4) and the

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controlled air flow rate q_{vc} in adjustable throttle valve 6, directly measured by flow meter (7) in branch line. The formula used to calculate air leakage flow rate based on the controlled flow in branch line (Dindorf and Woś, 2014):

$$q_L = q_{vc} \frac{\ln\left(\frac{p_{Lu}}{p_{Ld}}\right) t_{Lc}}{\ln\left(\frac{p_{Lcu}}{p_{Lcd}}\right) t_L - \ln\left(\frac{p_{Lu}}{p_{Ld}}\right) t_{Lc}} \qquad (1)$$

where:

p_{Lu}, p_{Ld} – upstream and downstream absolute pressure during leakage without the controlled flow,

p_{Lcu}, p_{Lcd} – upstream and downstream absolute pressure during leakage with the controlled flow.

With a new indirect method compressed air leakage is estimated by measurement of pressure ratio in a two time intervals (Fig. 2a):

1. For the air leakage without the controlled flow the valve switching (5) (Fig. 1) is closed and the pressure ratio p_{Lu}/p_{Ld} in time intervals t_L is measured.
2. For the air leakage with the controlled flow the valve switching (5) (Fig. 1) is open and the pressure ratio p_{Lcu}/p_{Lcd} in time intervals t_{Lc} is measured.

a) b)

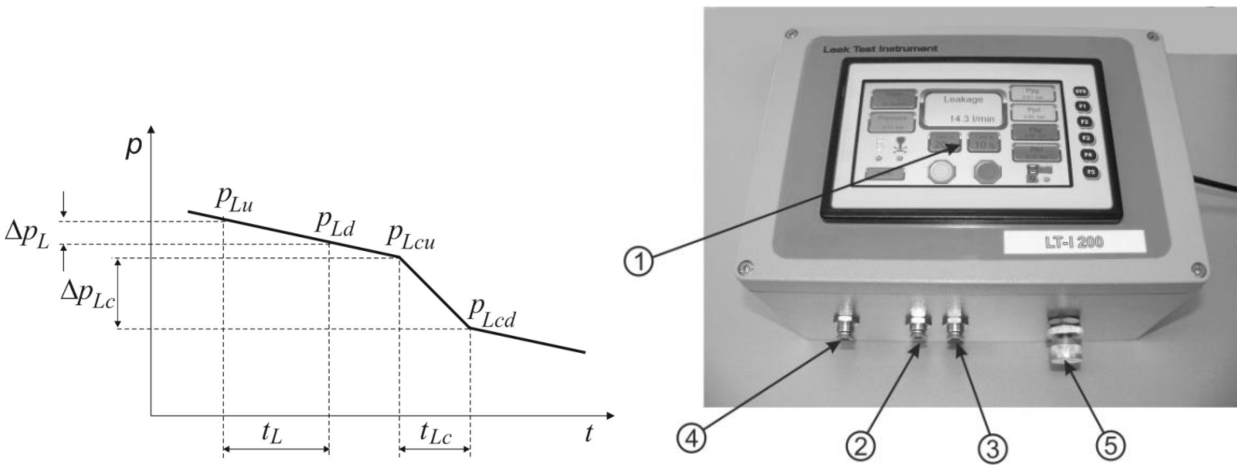

Fig. 2: Pressure change in two time intervals in compressed air pipelines during the air leakage measurement based on the controlled flow in branch line, b) View of the device type LT-I 200 for measuring of leakage flow rate in compressed air systems: 1 – touch panel, 2 – pneumatic connector for direct measurements of the air flow rate, 3 – pneumatic connector for indirect measurements of the leakage flow rate, 4 – output of pneumatic line, 5 – knob of the throttle valve.

2. Leak Test Instrument

The portable compact measurement device type LT-I 200 for automatic measurement of leakage flow rate in compressed air pipeline is shown in Fig. 2b. This measuring procedure makes it possible to measure the determination of leakage flow rate in the test installation in a fully automatic way. The device (Fig. 2b) is configured with membrane keyboard and touch screen (1) on the front panel. The touch screen device has the basic functions for measuring the leakage in compressed air systems: F1 - measuring the mass flow rate, F2 - measuring the pressure, F3 - measuring the leakage in the compressed air. Pneumatic connection (2) allows direct measurement of mass flow rate of compressed air. Connection (3) is used for automatic measurement of the indirect method of leakage. Pneumatic throttle valve (5) is used to determine the controlled leakage flow rate qvc. This instrument after introducing the initial operating parameters such as: times tL, tLc, the intensity of the controlled leakage flow rate qvc performs automatic procedure for measuring and computing. As a result, we obtain directly, the value leakage flow rate qL of compressed air system. A block diagram of the measurement system shown in Fig. 3. The measurement system MS is designed to work with a measuring device MD that reads the voltage input signals of the measuring transducer (1) (uT, up), the thermal flowmeter (2) and generates a voltage signal that controls proportional throttle valve (3). The measuring system MS consists of a calculation block of leakage (4), a block forming the reference signal (5) a calculation block of flow rate (6), the feedback block (7), the controller block (8), and a block that limits the set signal (9). The way of measuring leakages that uses the measuring system MS includes: calibration, measurement without controlled flow and measurement of controlled flow (Takosoglu et al., 2014, 2016). During the calibration of the measurement path of constant time of t_L of polytropic pressure drop across the choke valve is defined (3). On the basis of the measurement the pressure pi in the pneumatic system, the critical pressure to the limit range of critical flow is determined. It is reasonable to agree the critical flow in the throttle valve (3), because the air flows into the atmosphere. By measuring the time constant T_p, the pressure pi in the pneumatic system and the critical pressure p_{cr} selected measurement time t_{Lc} controlled. Block (6) determines the flow rate through the valve q_{Lc} (3) on the base of pi measurement. It is possible to determine the gas flow rate through the valve q_{Lc} (3) on the base of the measurement using the thermal flowmeter (2).

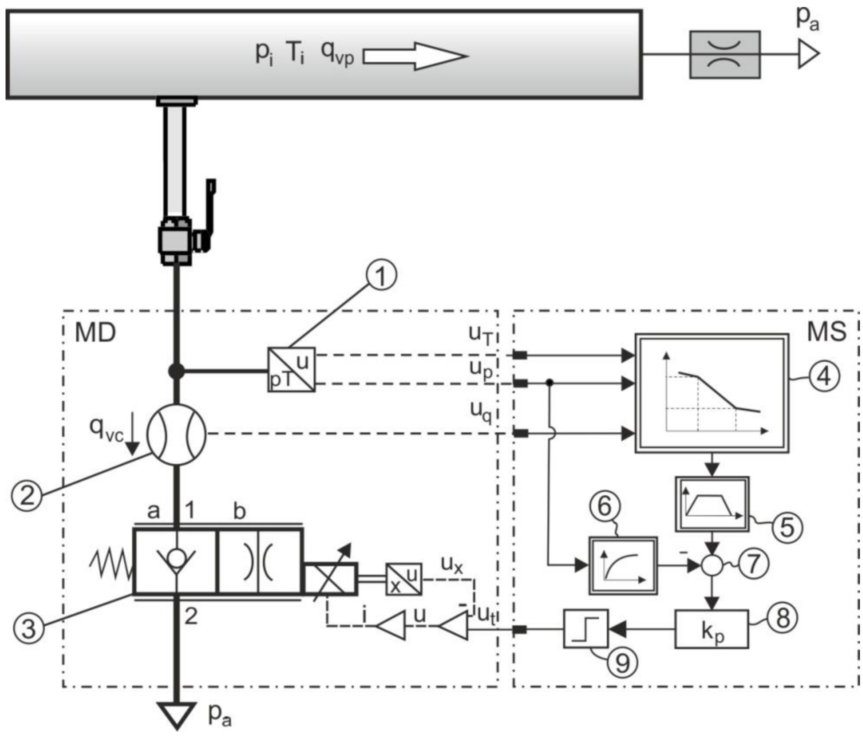

Fig. 3: The schematic diagram of a measurement system.

During measurements without leakage of controlled calculation block (4) during t_L measures the pressure p_{Lu} upper and lower pressure p_{Ld}, when the valve (3) is closed and on this basis, the pressure drop is determined $\Delta p_L = p_{Lu} - p_{Ld}$ caused by the leakage of compressed air in the pneumatic system. When measuring controlled flow calculation block (4), during t_{Lc} measures the pressure p_{Lcu} upper and lower pressure p_{Lcd}, when the valve (3) is opened and on this basis the pressure drop is determined $\Delta p_{LC} = p_{Lcu} - p_{Lcd}$ due to leakage of compressed air in the pneumatic system and the flow of compressed air to the atmosphere through an adjustable throttle valve (3). To carry out controlled flow, there was a block forming the reference signal (5) that generates a voltage of limited duration at the inlet valve (3). To keep the measuring time a constant flow rate q_{lc} by the throttle valve (3), feedback block (7) determines the adjustment error, the controller (8) generates a voltage signal limited to the value of by the block (9). Time pulse voltage determined for controlled measurement time t_c is determined in the range of $T = t_c = 5 - 50$ s. The minimum measurable leakage depends on the measuring range of the flowmeter mounted in the device. The Fig. 4 shows an example of waveforms of pressure changes.

3. Conclusions

An indirect method of measuring the leakage of compressed air in the pneumatic system is a method which is independent from the parameters of the tank and the compressor, as in the case of standard indirect methods of measuring the leakage. Including the elements of the measuring device to the pneumatic system does not require dismantling or modifying the installation. It is enough to connect the measuring devices to proper places where the compressed air is received. With the use of this method, the leakages might be measured at any time and in any place of the pneumatic installation: in the main pipeline, distribution cables or wires connecting the receivers (machines, equipment, tools).

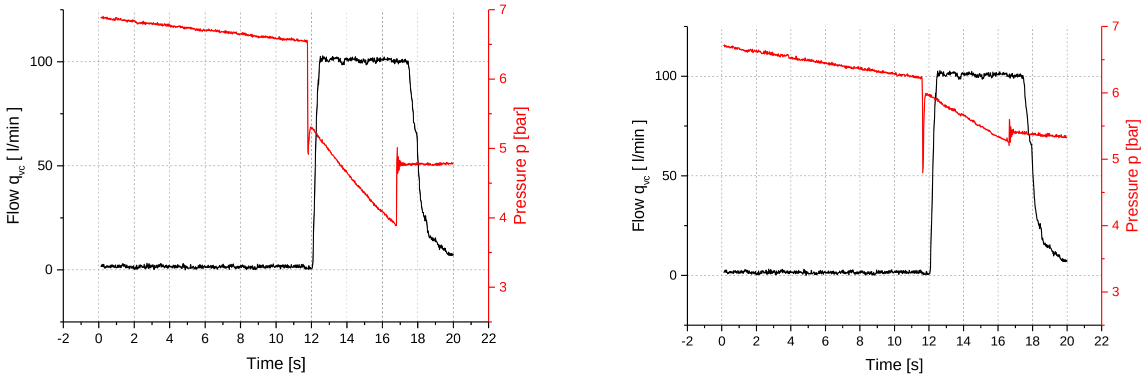

Fig. 4: Diagrams of flow rate measurement q_{VC} and pressure drop Δp.

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