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THE POSSIBILITY OF APPLICATION THE ACOUSTIC EMISSION METHOD FOR MONITORING FLOW OF WATER WITHIN A BALL VALVE

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Abstract

Acoustic emission method (AE) can be used for the diagnosis of machine parts or apparatus such as, for example, ball valves. This paper presents the methodology and research results of ball valve in fresh water systems. The opening angle of the valve was changed during the research. The flow of water was measured by a magnetically inductive flowmeter. The research was carried out on a laboratory test stand using an acoustic emission set made by Vallen Inc. This set included: 4 channel signal recorder AMSY 6, two measurement modules ASIP-2/S, preamplifier with a frequency range 20 kHz – 1 MHz and the strengthening of 34 dB and AE signal measurement sensor type VS 150M, with a frequency range 100 – 450kHz. The obtained from the AE-System made by Vallen were compared with the results of the AE-System made by Physical Acoustics (PAC). The PAC system includes preamplifier USB AE Node, type 1283 with bandpass 20 kHz – 1 MHz, AE-Sensor R6D, computer with AE Win for USB Version E5.32 software. During the study, the acoustic emission (AE) generated by flowing water was recorded. The following parameters were determined: amplitude, number of events – hits, the effective value of the signal (RMS). Analysis of the results showed that within a specific range of opening angle of the valve the value of the generated acoustic emission in flowing water increases. This is probably associated with the occurrence of cavitation within the valve. This is an undesirable phenomenon and that these opening angles of ball valve should be avoided in the normal operation.

Keywords: *Acoustic Emission (AE), diagnostic, ball valve, cavitation*

1. Introduction

One of the methods for monitoring the flow of water in pipelines is the acoustic emission (AE) method. Acoustic emission is considered as a non-destructive method included in Standard PN-EN 473:2008, described and defined in PN-EN 1330-9:2009 and PN-EN 13554:2011. According to the definition acoustic emission (AE) is an evanescent elastic wave, which is the result of rapid release of the energy stored in the material by propagating a micro-damage (increase in micro-cracks, the movement of groups of dislocations) in the material or by a process (friction, leakage, water flow, cavitation, etc.) [4, 6, 8, 10]. The typical frequency range of the acoustic emission is normally determined within 20 kHz – 2 MHz [5].

Acoustic Emission is a passive non-destructive method. Its main advantages are:

- high sensitivity,
- the possibility of continuously research,
- the possibility to locate the source of the AE signals (damages, leaks, etc.),

– the possibility of carrying out research without having to shut down equipment out of service [2].

The stimulus causing the release of energy and the formation of elastic waves can be: load operation, environment, temperature change, and the processes which are accompanied by AE changes both at the micro and the macro scale, such as: cracks, friction, plastic deformation, corrosion, leaks, structural and phase changes, chemical reactions, delamination, cracking of the fibers and matrix in composites, etc. [1, 7].

The acoustic waves propagate in all directions from the source, thus can be recorded by one or more sensors mounted on an object or component. During the propagation of the AE waves, they are damped by several physical effects. Therefore, the waves can only be detected within a limited distance. These distance dependents on many factors, mainly on properties of the material, the geometry of the object and the level of interference from background noise [9]. An example of AE signal is shown in Fig. 1 and 2.

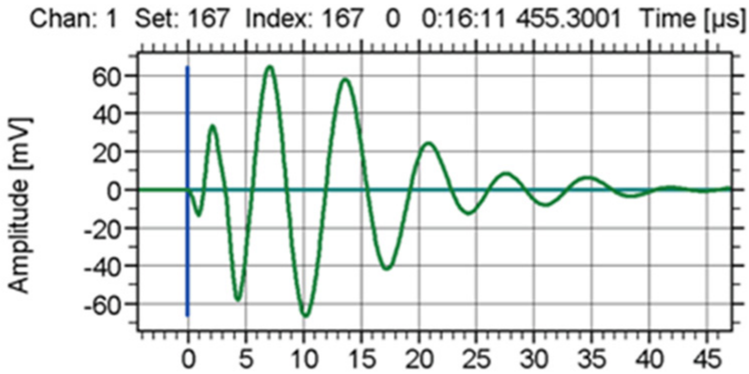

Fig. 1. An example of typical acoustic emission burst signal [5]

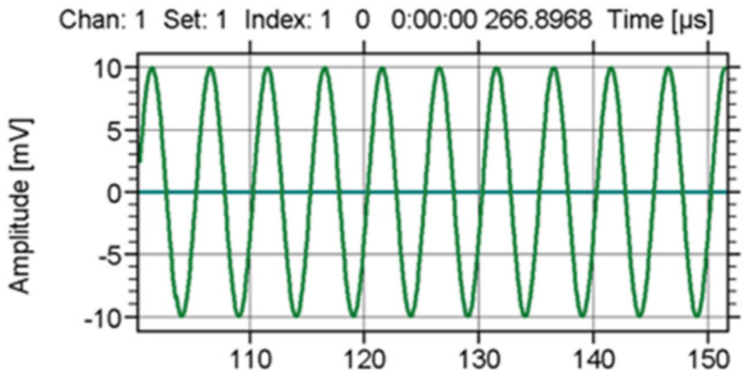

Fig. 2. An example of typical acoustic emission continuous signal [5]

According to PN-EN 1330-9: 2009, AE signal can be characterized by parameters such as: amplitude, frequency, energy, rise time, duration, number of exceedances of the threshold of discrimination – hits, RMS of the signal, etc.

The article presents the possibility of using acoustic emission method for monitoring flow of water within a ball valve with optimizing the angle of opening that valve for avoiding cavitation.

2. Research methodology

The research was carried out at the centrifugal pump test stand of the Technische Hochschule Mittelhessen, Faculty of Mechanical Engineering, and Laboratory for Fluid Flow and Fluid Flow Machines [8]. The test stand includes water tank, valves, pipes, pressure and flow meters, the pump and its drive. The accuracy of the used meter are less than or equal to 0.5% of the final valve. The test stand has a water circulation, which starts at the vertical water tank. Except the hydraulic system, there were two acoustic emission systems: Vallen system and Physical Acoustics Company (PAC) system see Fig. 3.

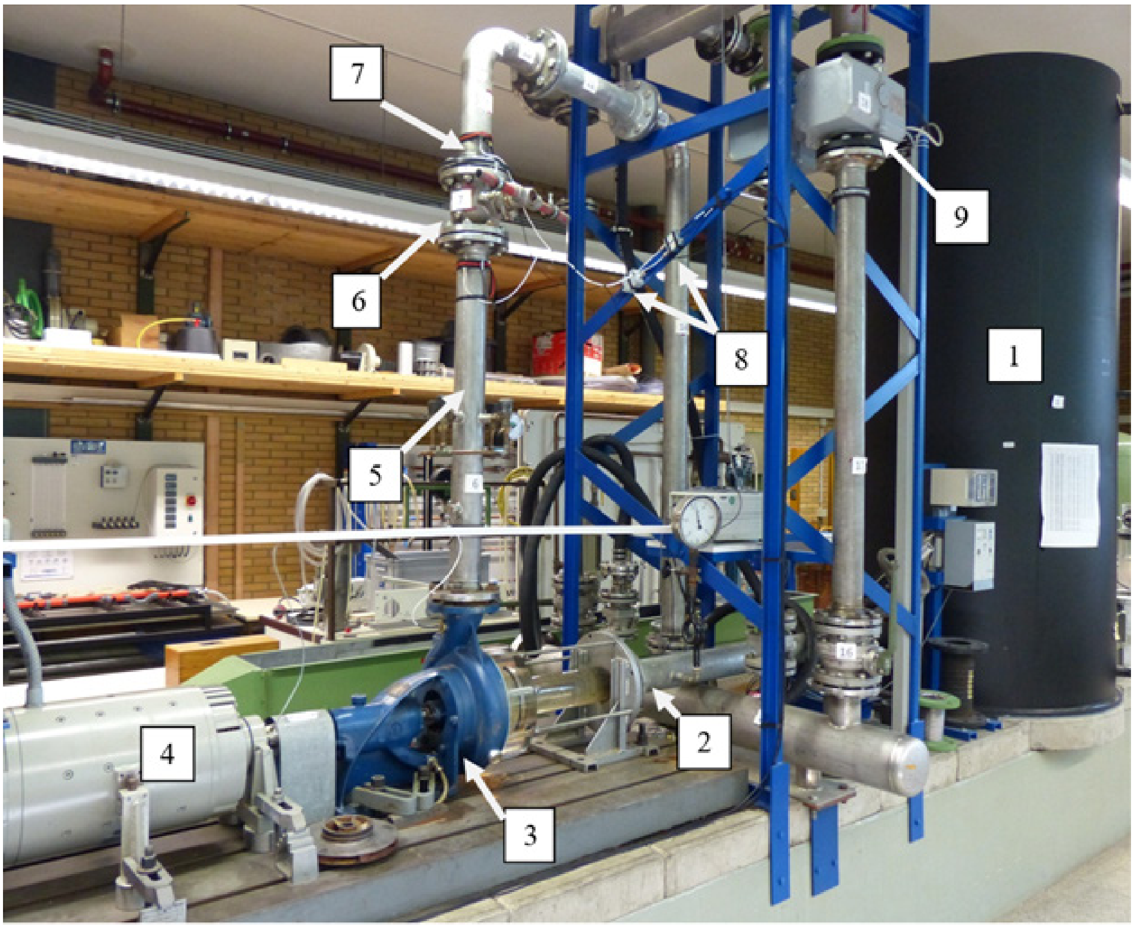

Fig. 3. General view of laboratory stand: 1 – water tank, 2 – suction pipe, 3 – centrifugal pump, 4 – electric swivel-motor with torque- and revolution counter, 5 – discharge pipe, 6 – ball valve, 7 – AE sensors, 8 – AE preamplifiers, 9 – magnetically-inductive flow meter

Research AE accompanying the circulation of water was performed using a set consisting of 4-channel signal recorder type AMSY 6 and two measuring modules ASIP-2/S from Vallen System. The set includes pre-amplifier with a frequency range of 20 kHz – 1 MHz and the strengthening of 34dB and a sensor signal measurement AE, VS 150M, with a frequency range of 100-450 kHz. The system includes a data-recording module – 8MB per channel and software [3]. For recording AE data was used Vallen Acquisition software and for analysing VisualAE software.

The data obtained from Vallen System was compared with results of PAC system. That system consists of preamplifier USB AE Node, type 1283 with bandpass 20 kHz – 1 MHz, AE-Sensor R6D, computer with AE Win for USB Version E5.32 software for recording and analysing AE data.

Between the sensors and the surface of pipe, the coupling fluid was used.

The research was carried out with constant revolution of the pump of 1395 rpm. The measurements of acoustic emission were recorded while the change of water flow rate was approximately 5 m^3/h.

During the study, the AE generated by flow of water in the pipeline after ball valve carried out on a test, recorded a number of parameters, which were analysed. These parameters were e.g.: amplitude, number of events – hits, energy, RMS of the signal. To compare continuous AE, which is chiefly stochastic, is needed an energy equivalent parameter. For comparing the results of the two systems, the parameter Root-Means-Square (RMS) was chosen. For each flow rate, the time of recording the AE parameters lasts 10 s.

3. Research results

Average values of RMS of acoustic emission generated by flow of water within the ball valve were presented in Tab. 1. These results were obtained with different angle of valve opening and thereby different flow rate of water.

Tab. 1. The average values of RMS of acoustic emission depending on the flow of water within a ball valve

Number of measurement	Flow rate Q [m^3/h]	Angle of valve opening α [°]	Vallen System RMS [V]	PAC RMS [V]
1	94.75	90 (totally open)	0.1652	0.0497
2	89.17	83	0.6004	0.1476
3	83.13	78	0.6093	0.1866
4	79.33	76	0.7559	0.2520
5	74.00	72	0.8719	0.3787
6	69.79	69	2.5703	0.5612
7	64.21	66	2.8849	0.7593
8	59.20	64	5.5060	1.0278
9	53.87	62	5.9552	1.2690
10	48.96	58	5.8973	1.4775
11	43.93	57	6.1443	1.6316
12	38.90	54	7.0246	1.7416
13	29.97	49	6.9152	1.7528
14	24.52	45	7.5227	1.7023
15	19.78	44	7.249	1.6316
16	15.00	39	5.9488	1.2975
17	9.90	36	3.4603	0.9708
18	4.89	30	0.3378	0.4571
19	0.00	0 (totally closed)	0.0168	0.0026

Average values of RMS of the signal generated by flow of water obtained from two AE systems are different according to their strength. One of the reasons for that situation is that there are different parameters of strengthening the signal in preamplifiers and the different transfer functions of the two AE measurement chains. Because values of RMS from both systems were not at the same level only the percentage of maximum RMS were compared. Taken this into account the shapes of curves obtained by two systems were similar. Comparing the characters of AE signals are shown in Fig. 2.

If the water flow ranges between 15 and 55 m³/h, approximately over 80% of the maximal by both systems recorded RMS Values are generated. This flow rate occurred by a revolution of the pump of 1395 rpm and an opening angle of the ball valve in the range of 40-60°.

Generally, the main task of a valve is to generate a pressure loss for reducing the flow rate, by energy dissipation. If the valve is totally opened the pressure loss is nearly zero. In case of a totally closed valve the pressure, loss is infinite. In the present case, the ball valve must produce a great pressure loss at a low flow rate and a low-pressure loss at a high flow rate.

One can calculate the power of the pressure loss of the ball valve P_{pl} [W] by multiplication of the caused pressure loss within the ball valve Δp_{bv} [Pa] and the flow rate through the valve $\dot{V}$ [m³/s], according to the following equation.

$$P_{pl} = \Delta p_{bv} \cdot \dot{V} \,. \tag{1}$$

By normalizing the power of pressure loss on its maximum value, we earn the "power of pressure loss [%]". The curve is shown in the following Fig. 3.

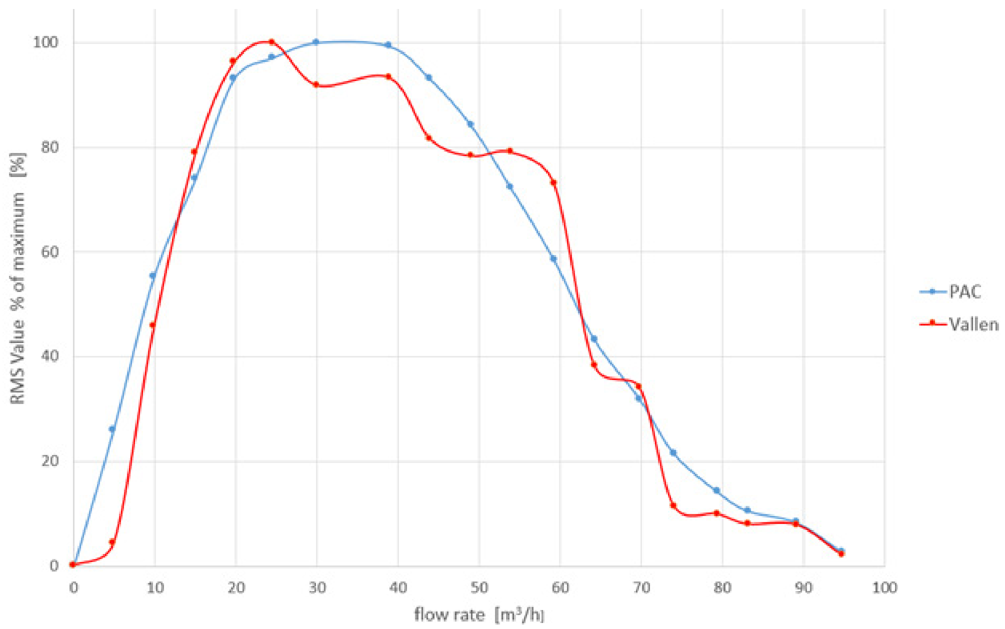

Fig. 2. Comparing the results of AE research obtained by PAC (Physical Acoustic Company) and Vallen system

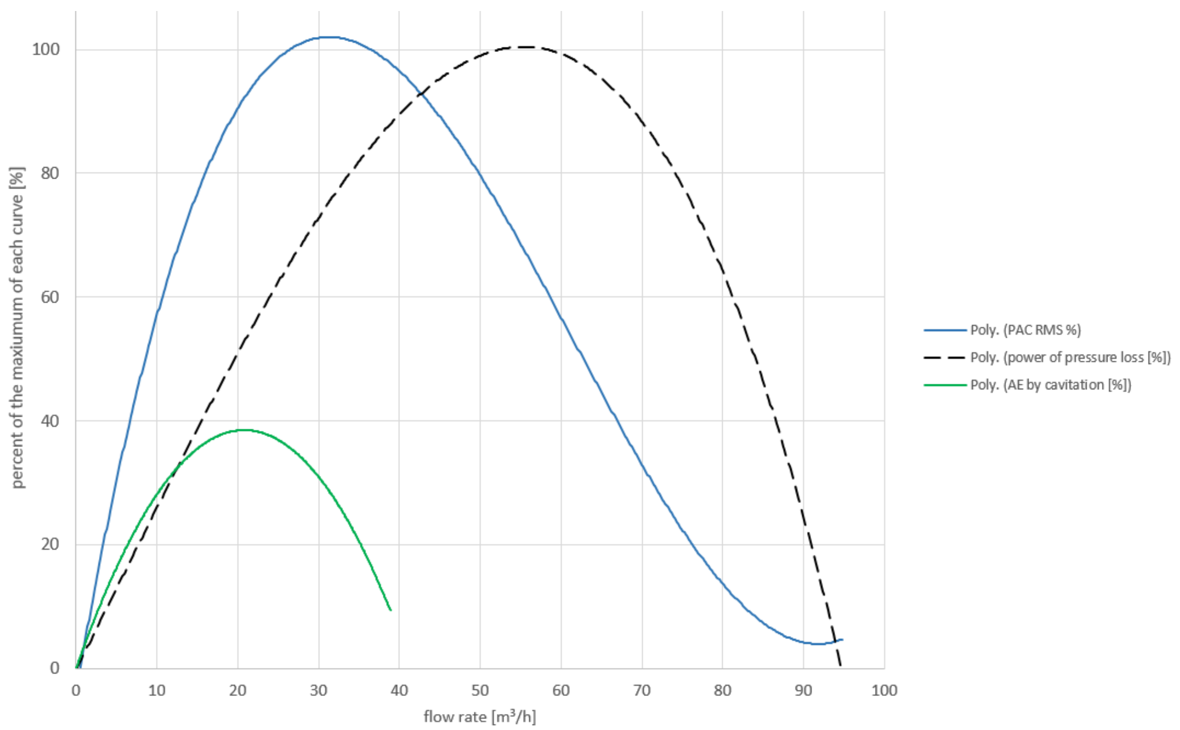

Fig. 3. Approximated curves of measured AE by PAC (the same as shown in Fig. 2), the calculated power of pressure loss and the qualitative course of the additionally generated AE by implosion of cavitation bubbles

In the present case, the power of pressure loss has its maximum within the flow range around 55 m³/h.

From the acoustic emission point of view, the power of pressure loss only takes into account the generated acoustic emission by the turbulent flow, flow separation and vortices through the ball valve. After the author's opinions, the deviation of the maxima (RMS and power of pressure loss) can only be caused by additional generated acoustic emission waves due to the implosions of cavitation bubbles. The difference between the curve of the power of pressure loss and the curve of the measured RMS value correlate with the strength of the cavitation implosions, see curve "AE by cavitation [%]" in Fig. 3.

4. Summary

Correct selection of flow parameters in the installation, such as revolution of pump or angle of opening the valve has a very large impact on the correctness of work and its reliability. The choice of these parameters based on data provided by the manufacturer of the devices or designer of whole hydraulic installation may prove to be insufficient. During work, geometry of parts of installation could change due to e.g. corrosion or sediments. The material, e.g. valve balls or valve housings, can be damaged especially because of cavitation. The strength of these damages depends on the resisting of the material against cavitation erosion and the strength of the cavitation itself. In addition, a cavitation free flow stresses the material, but less according to cavitation.

It is possible to assess the correctness select the flow parameters based on e.g.: temperature distribution – thermography methods, vibration, acoustic emission, etc.

In the research, acoustic emission method was used. It allows defining the parameters at which the flow of water in the installation is more or less stable. AE is a possibility to control the process continuously and enables the operator to be informed about additional circumstances for example the danger of occurring damage of part of the installation.

The application of acoustic emission for monitoring flow of water in the hydraulic installation allowed determining the flow rate in which there is normal or abnormal work. In research, two systems of acoustic emission were used: Vallen System and Physical Acoustics Company system. The most useful parameter within the range of all parameters recorded during the test was RMS Value of the AE signal.

The maximum values of RMS recorded by both AE systems were probably caused by turbulent flow, flow separation, vortices and cavitation within the ball valve. The cavitation has a great influence on the course of the measured AE. Cavitation is undesirable, causes noise and damages of the installation components.

Due to the results of the measured AE, it is not possible to separate exactly the range of flow rate in which cavitation occurs. However, as on can see in Fig. 3, the flow rates at which the maxima of the cavitation curve and the RMS curve occur differs only by 10% of the maximum flow rate.

Both acoustic emission systems could be used for monitoring the water flow in the hydraulic installation.

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