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TITLE

Detection and quantification of valve through leak from the analysis of acoustic emission (AE)

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ABSTRACT

Based on literature studies of acoustic emissions (AE) from leaking valves the basic behaviour of such emissions is described. Some important factors affecting the scaling of the emissions are discussed briefly.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1		
GROUP 2		
SELECTED BY AUTHOR	Acoustic emissions	Akustiske emisjoner
	Valves	Ventiler
	Leak	Lekkasje

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1 Introduction

There exists some publications on the use of acoustic emission (AE) to detect leaky valves. Most of the literature is experimental and reports results from measurements of AE under various conditions. Publications that discuss the origin of the AE point to the occurrence of turbulent flow [1]. This typically occurs for Reynolds numbers, *Re*, larger than 1000.

$$\mathrm{Re} = \frac{\rho V L}{\mu} \tag{1}$$

Here ρ is the fluid density [kg/m^3], V the mean fluid velocity through the leak [m/s], L a characteristic length [m] and μ the dynamic viscosity of the fluid [$Pa \cdot s$]. The characteristic length, L, is usually taken from the leak diameter.

Lighthill presented equations for the sound power from quadrupoles in turbulent flow [2]. For high pressure drops along the leaks a chocked jet can also occur [3], [4]. Depending on the size of the leak, as well as the pressure and velocities involved the emitted sound will often be in the ultrasonic frequency range. One advantage of this is that the emitted sound is easier to separate from any background noise present, which is often in the sub sonic and sonic frequency range. It seems like there is a common understanding that the detection of the presence of a leak is quite feasible using AE, but that the quantification of the leakage rate can be difficult.

Kaewwaewnoi [1] presents theoretical predictions of the AE of leaky valves on the basis of the theory presented by Lighthill. The correlation between the predicted and measured AE seems quite good. Kaewwaewnoi is apparently working on a PhD on the topic of leaky valves [5].

The equations given by Kaewwaewnoi, based on the theory by Lighthill, do not include interaction with nearby hard surfaces. An extension of Lighthill’s theory, including interaction with hard surfaces, is included in the so called Curles equation. Curles equation is for instance presented in a compendium by Mats Åbom [6], containing material for lectures in Flow Acoustics, and in [7]. The equations given by Kaewwaewnoi neither describe the effects of supersonic[1] jets. As Shack et al. [3] describe, the transition from a subsonic to a supersonic jet, changes the relation between the flow through a leak and the corresponding sound generation considerably. Shack states that in a subsonic jet the sound power is proportional to the seventh power of the velocity at the leak throat. In a supersonic jet, on the other hand, the sound power is proportional to the mass flow through the leak.

Some discussions of a few important topics related to AE from leaky valves are presented below.

2 Sources of acoustic emission

As mentioned above, turbulent flow is usually identified as the main source of AE from leaky valves. In water and other liquids cavitation may sometimes be a major contributor to AE [8], [9]. It might thus be necessary to separate gas (compressible) and liquids (non-compressible) when developing an analysis technique for AE signals related to leaky valves.

3 Measurements of AE

Piezoelectric accelerometers are usually used for the measurement of ultrasonic AE. It is critical that the transducers are attached correctly to the valve or piping. The position of the transducers is also very important. The aim is to pick up the AE as effectively as possible and with as little

[1] Supersonic jets are also referred to as choked or under-expanded.

background noise as possible. The level of the AE can be affected by the mechanical resonances of the valve/piping system. This further enhances the importance of finding the best position for the transducers.

4 Factors affecting the level of AE

The factors affecting the level of the AE can be divided into two main groups:

1. Factors affecting the internal level
2. Factors affecting the coupling to the walls of the valve and pipes, and the transmission to the outside

The factors in the second group above can further be divided into two groups:

a. Properties of the flow medium affecting the coupling to the valve and pipe walls
    - Typically density of medium
b. Properties of the valve and pipes
    - Valve and pipe material and thickness
    - Geometry and dimensions of valve and pipes

Amongst the factors in group 1 above are:

- Medium density
- Sound velocity in flow medium
- Pressure (both difference and absolute level may affect the AE level)
- Temperature
- Leak rate
- Viscosity
- Size and geometry of leak

The factors that have been studied the most are pressure, leak rate and size and geometry of the leak [1, 10]. Pressure, leak rate and leak size seem to correlate positively with AE.

The scaling of AE with geometry and dimensions of valve and piping hasn't been discussed very thoroughly in the literature. The main approach when it comes to analyzing the effect of geometry and dimensions seems to be to measure the AE and assessing changes in level [1], [11]. For ultrasonic frequencies the effect of geometry and dimensions on the transmission of internally generated sound might be little. However, the geometry and dimensions will most likely affect any sound generated through interaction between the leaking medium and valve or pipe walls[2]. In publications discussing noise emissions from valves as a problem on its own, some discussions on how internally generated sound is transmitted through the piping can be found [12]. This can be useful in understanding any effects of geometry and dimensions of valves and pipes that might exist.

5 Gas vs. liquids (compressible vs. non-compressible)

As mentioned above there might be some differences between the behaviour of gases and liquids when it comes to AE from leaky valves. As was shown by Kaewwaewnoi [1], gas exhibits more prominent peaks than liquids (see Figure 1 and Figure 2). The AE spectra from liquids are more broadbanded. Whether this is related to different onsets of turbulent flow, cavitation or interaction with the surrounding valve/pipe walls is not clear.

[2] As described by Curles equation mentioned in section 1.

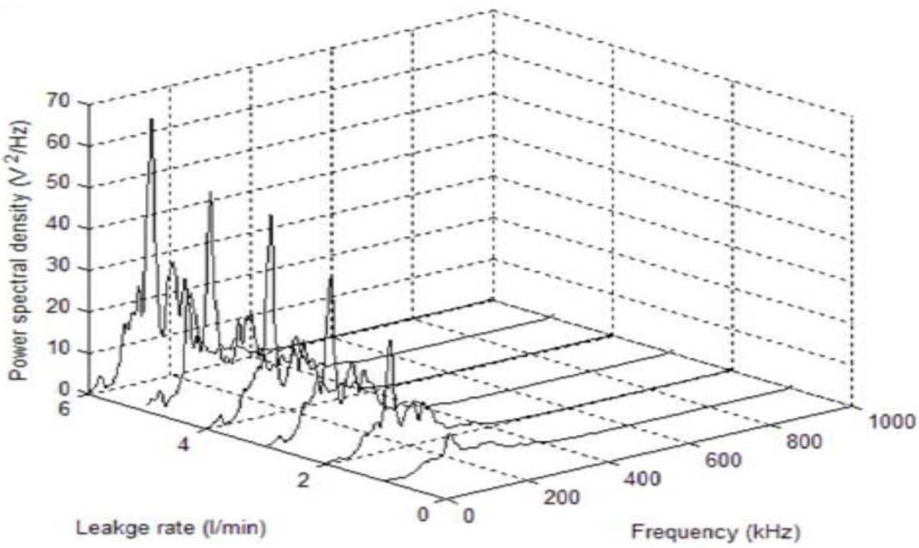

Figure 1: Example of AE spectra from a compressed air leakage (from [1]).

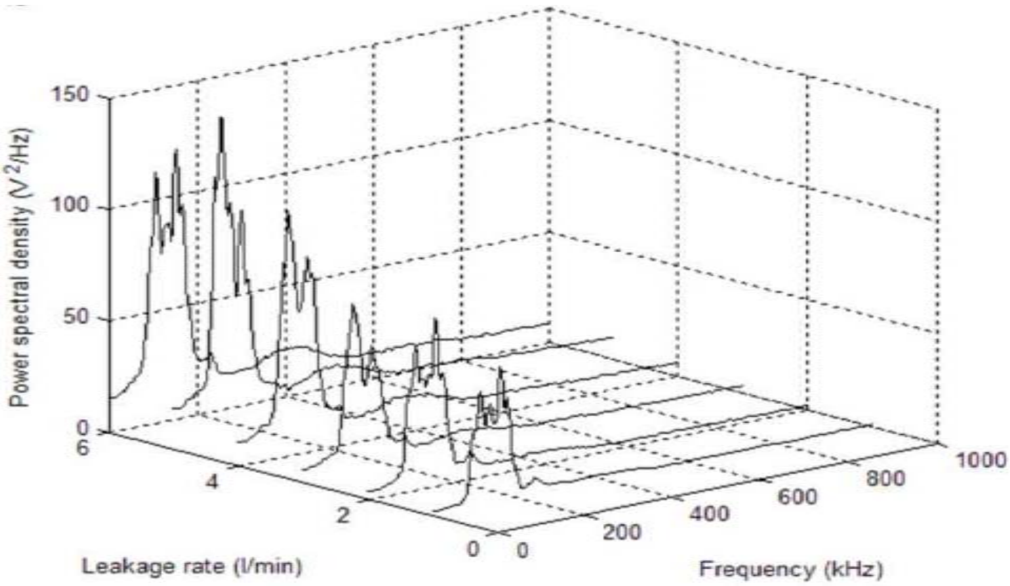

Figure 2: Example of AE spectra from a liquid valve leakage (from [1]).

6 Additional interesting references

The following two references were not obtained, but based on their abstracts they are believed to contain interesting information: [13], [14].

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