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Measurements and analysis of cavitation in a pressure reducing valve during operation – a case study

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Abstract

This paper proposes a methodology and presents its practical application for evaluating whether a pressure reducing valve (PRV) is under cavitation during its operation in a water distribution system. The approach is based on collecting measurements over a 24-hour period such that high demand and low demand times are included. The collected measurements allow evaluation of four indicators related to cavitation, namely the hydraulic cavitation index, noise generated by the valve, acoustic cavitation index and the spectra of the noise. These four indicators provide sufficient information for diagnosis of cavitation with high certainty.

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pressure reducing valve (PRV), cavitation, hydraulic measurements, acoustic measurements

1. Introduction

Cavitation is a phenomenon related to formation of vapour bubbles inside liquids, in our case water, under conditions where local liquid pressure falls below the vapour pressure under given temperature. If these newly formed bubbles are subsequently subjected to high pressure they ultimately collapse generating pressure shock waves. In case of a plunger valve depicted in Figure 1 cavitation may occur in the narrowing section of the valve between the plunger and its body. If the water velocity is sufficiently high, due to either high flow or small valve opening, the pressure can drop below the water vapour pressure of the water in accordance with the Bernoulli principle. These vapour bubbles are then carried by the liquid downstream where the pressure ultimately recovers to its normal value causing the bubbles to implode and produce high pressure waves. If the bubbles implode in the vicinity of the internal valve surface they are likely to cause damage to the valve wall. The valves should therefore be sized in such a way that the pressure operating points are always above a hydraulic cavitation curve - see Figure 3. In practice, this task may sometimes be difficult to achieve as the operational conditions may change in time due to changes in valve flows and, as a result, the valve can operate under cavitation that may lead to more or less extensive damage. Cavitation damage can be checked by inspecting the valve and downstream pipework, however this may prove to be a costly op-

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eration as it requires taking the valve off-line. There is therefore a clear need for a non-invasive method to assess the valve's operating conditions with respect to cavitation during normal valve operation. However, the level of cavitation is notoriously difficult to assess and a single indicator may not be sufficient to assess the extent of cavitation in the system or conclude with certainty that cavitation is not taking place. For this reason the method proposed in this paper is based on many indicators involving both hydraulic and acoustic variables.

Fig. 1: Cross-section of the VAG plunger valve.

All relevant measurements were collected over a 24-hour period to ascertain that information from high demand (day) and low demand (night) times is included in the data [1]. The experimental set-up was designed to take the measurements of hydraulic variables such as valve inlet and outlet pressures and valve flow, as well as acoustic variables obtained from four acoustic sensors. An accelerometer was placed on the upstream pipe, the valve, and the downstream pipe. Additionally a capacitor microphone was positioned in the air close to the valve. The acoustic sensors were connected to sound recording equipment which measures both the signal level (in dB) and the sound frequency spectra. The collected measurements allowed evaluation of a number of indicators related to cavitation such as the cavitation index σ_{ISA} [2], the noise generated by the valve as a function of valve position, the noise level against the sigma coefficient (acoustic cavitation characteristic), and the frequency spectra of the signals from acoustic sensors at different times. These four indicators were then compared one against another to facilitate the diagnosis of cavitation with high certainty. The experiment is not invasive and comparatively cheap to run. Once the equipment is installed, data collection can be done automatically within a 24 hour period. This paper presents details of the case-study which confirmed the validity of the approach. The paper is organised as follows: Section 2 explains the measurement set-up while Sections 3 to 6 describe and evaluate the respective cavitation indicators. In Section 3 the cavitation coefficient σ_{ISA} is compared against the cavitation curve provided by the valve manufacturer VAG. In Section 4 the measured noise level is compared with the manufacturer noise curve. Section 5 investigates the acoustic cavitation characteristic and, finally, Section 6 analyses the frequency spectra of the signals measured by three accelerometers.

2. Method and measurement setup

The method is illustrated by application to a specific case study with the schematic and position of sensors depicted in Figure 2. Three accelerometers were placed in the rig: first on the upstream pipe, second on the valve and third