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Technical Note

Monitoring the presence of water and water–sand droplets in a horizontal pipe with Acoustic Emission technology

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ABSTRACT

Monitoring of multiphase flow is a process that has been established over several decades. This paper demonstrates the use of Acoustic Emission (AE) technology to detect and monitor moving water and water–sand droplets in a horizontal pipe. The experimental investigation considered two types of droplets, water and water–sand with average droplet volumes ranging from 1 ml to 5 ml. The experimental findings show good correlation between AE energy, droplet volume and the superficial gas velocity (V_{SG}).

1. Introduction

In oil/gas production and transportation pipelines, pipe bursts or leaks are often attributed to corrosion/erosion which can cause significant material damage. One reason for corrosion/erosion in a natural gas pipeline is the presence of droplets (water/water–sand) in the flow due to entrained liquid. These droplets will strike the internal wall of the pipe and/or accumulate at the bottom of the pipe with further water droplets accelerating corrosion of the internal wall of the pipe [1]. Also, sand–water droplets might cause an increase in the quantity of accumulated sand at the bottom of a pipe. This leads to a drop in the transportation efficiency of the system and reduces the capacity of the pipeline. Therefore, to maintain trouble-free operation of the pipeline monitoring techniques (intrusive/non-intrusive) must be employed.

Boulesteix et al., [2] performed detection and tracking of droplets in an air–water horizontal pipe by processing images obtained in the centre of the pipe using a high-speed camera. Further, their visual observations showed that collision between drops, and even droplet break-up, is a frequent phenomenon that had a significant effect in the reduction of droplet size. As widely known the droplet erosion is defined as the loss of original material due to the repeatable droplets impact on the material surface [3]. Thus, monitoring the characteristics of droplets inside pipes may lead to significant contribution in predicting the droplet erosion phenomena.

Arabnejad et al. [4] developed a model to calculate erosion resulting from liquid droplet impact on internal pipe walls used in oil and gas industry under specific flow conditions. The main goal was to predict erosion failures in production and transportation facilities due to the impingement of liquid droplets. This would lead to lower costs of erosion inspection and maintenance. The collected data of material loss for several oil field materials such as stainless and carbon steel utilizing specimens that were mounted on a rotating flywheel and impacting liquid jets are combined with the American Society for Testing and Materials (ASTC) G73 guideline to develop the model. The results from this model have been compared to data provided in the literature for droplets impacting specimens utilizing different materials, droplet sizes and velocities. Authors concluded that, the model presented in this study will be improved as more data and information becomes available.

Bordás et al., [5] conducted an experimental study to determine droplet velocity and diameter distribution using shadow-graphy. Shadow-graphy is an established imaging measurement method characterised by its ability to directly observe collision and coalescence processes. Observations have shown that shadow-graphy can be indeed applied to a quantitative investigation of collision events.

The great challenge for corrosion/erosion engineers is to determine more precisely the flow conditions leading to corrosion/erosion within the oil and gas industry. Given that entrained water/water–sand is not always easy to detect there is a drive to develop non-intrusive technologies to monitor the presence of droplets.

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The authors explore the use of the AE technology as one such solution.

Acoustic Emission (AE) is defined as the class of phenomena whereby transient elastic waves are generated by the rapid release of energy from localized sources within a material [6]. The elastic waves, typically in the frequency range from 100 kHz to 1 MHz propagate through the material and can be detected by an AE sensor [7]. Several recent publications have shown that AE technology can offer reliable quantitative information about the process being monitored though there are challenges in application [8,9]. The application of AE technology in multiphase flow monitoring is gaining attention given the advantages such as the ability to be fitted non-intrusively to pipes or containers [10–12].

Whilst some studies have showed AE technology is sensitive to sand particle movement [12] and bubble collapse [13] this study presents an experimental investigation into the applicability of AE as a non-invasive tool for detecting water/water–sand droplet impact on pipe walls, this is in addition to correlating AE activity with droplet quantity for varying superficial gas velocities (V_{SG}). The latter (V_{SG}) is defined as the volumetric flow of gas divided by the cross-sectional area of the pipe. The basis of this investigation evolves from the premise that entrained water/water–sand present in the form of droplets can be detected using AE technique by capturing the energy generated when these droplets impact the internal pipe wall.

2. Experimental setup and test methodology

The experimental investigation presented involved assessing the AE technology's ability to detect the presence of varying droplet volumes ranging from 1 ml to 5 ml in a horizontal pipe within a V_{SG} range of 9–11 ms^{-1}. The multiphase flow facility employed for this investigation is shown in Figs. 1 and 2 and was constructed of ABS plastic (class E) pipes of 0.05 m internal diameter with a total pipe length of 32 m. A Perspex window was inserted for observation adjacent to the steel pipe (test section) from where AE measurements were taken. The test section was positioned about 30 cm downstream of the droplet injection point, and the flow was considered to be fully developed by the time it reached this section. The injection point is the position where a stream of droplets is continuously fed into the flow loop. The diameter of the droplet was assumed to be equivalent to the diameter of the injection nozzle. The number of droplets per volume investigated, 1 ml, 3 ml, and 5 ml was 14 ± 1, 39 ± 2 and 67 ± 3 droplets respectively. The first type of droplet consisted of water only and the second type was a homogeneous mixture of water and sand produced by mixing 2 g of sand in 10 ml of water. The droplets were injected into the pipe using a syringe.

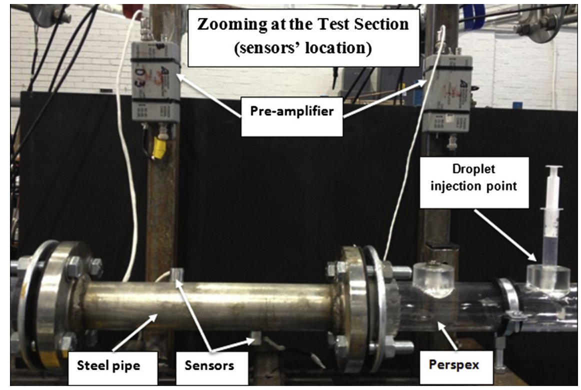

Fig. 2. Test section of two-phase flow facility.

Acoustic Emissions were detected with a calibrated broad bandwidth piezoelectric transducer (Physical Acoustic Corporation type WD) with an operating frequency of 100 kHz–1 MHz. Two type WD AE sensors were employed and located at the bottom and top of the steel pipe test section. It was envisaged that the placement of the sensor at these locations would provide some information on the impact region within the steel pipe as the closer the impact is to a sensor the higher the AE energy at that sensor. The acoustic sensors were connected to a data acquisition system via a preamplifier, set at 40 dB gain. The system was set to acquire AE waveforms at a sampling rate of 5 MHz. The background noise level of the acquisition system was ascertained by measuring the AE response at the pre-amplification of 40 dB without any threshold. Based on this observation a threshold was selected to ensure that the acquisition system only acquired AE activity associated

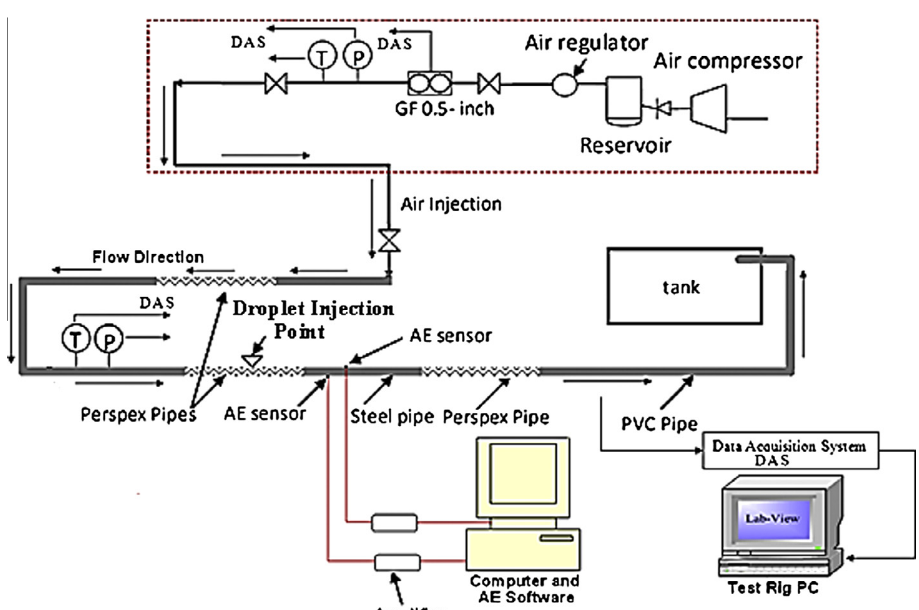

Fig. 1. Schematic diagram of two-phase/three-phase test facility.