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Experimental investigation into the influence of backfill types on the vibro-acoustic characteristics of leaks in MDPE pipe

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Abstract

Pipe leak location estimates are commonly conducted using Vibro-Acoustic Emission (VAE) based methods, usually using accelerometers or hydrophones. Successful estimation of a leak's location is dependent on a number of factors, including the speed of sound, resonance, backfill, reflections from other sources, leak shape and size. However, despite some investigation into some of the aforementioned factors, the influence of backfill type on a leak's VAE signal has still not been experimentally quantified. A limited number of studies have attempted to quantify the effects of backfill. However, all of these studies couple other variables which could be equally responsible for their observed changes in leak signal. There have been no controlled studies where one variable can be directly compared to one another (i.e. all variables remain constant, only changing backfill type). The aim of this paper is to better characterise the influence of backfill on a leak's VAE signal by individually isolating all variables. For the first time, this paper demonstrates the influence of backfill on leak VAE signal by keeping all other variables consistent. It was found that the backfill type had a strong influence on the frequency and amplitude of leak signals, which is likely to have a significant impact on the accuracy of leak location estimates.

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Keywords: Leak detection; water distribution systems; backfill; acoustics.

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1. Introduction

Leaking water distribution systems (WDS) cause both economic and environmental problems [1]. In some countries leakage can be as high as 50 %, especially in older distribution networks [2], where high water losses result in massive losses in revenue. Leakage has been reported by McMahon et al. [3] to cost the UK government £7bn annually due to street works and damage costs.

Nomenclature

τ_{delay}	Delay in arrival time (seconds) between sensor 1 and 2
d	Distance between sensor 1 & 2 (m)
c	Leak VAE signal wavespeed (m/s)
L_1, L_2	Distance from leak and sensors 1 and 2 (m)
$R_{x_1x_2}$	Cross correlation between leak signals
$E[\cdot]$	Expectation operator

Leaks are commonly found using the cross correlation technique. As the water discharges through the leak hole, it creates a Vibro-Acoustic Emission (VAE) which propagates along the pipe wall and through the water column. Accelerometers or hydrophones are normally placed at some distance from the leak (Fig. 1), recording the VAE produced by the leak, which is often termed the "leak signal". The leak location can then be found using Eq. 1, where d is the distance between the two accelerometers or hydrophones and c is the wavespeed of the leak signal:

$$L_1 = \frac{d - c\tau_{delay}}{2} \quad (1)$$

where τ_{delay} describes lag in arrival time between accelerometer 1 and 2, which is calculated from the peak in the cross correlation function using Eq. 2.

$$R_{x_1x_2} = E[x_1(t)x_2(t + \tau_{delay})], \quad (2)$$

where $E[\cdot]$ is the expectation operator. τ_{delay} is shown by:

$$\tau_{delay} = \tau_2 - \tau_{1.} \quad (3)$$

where τ_1 and τ_2 describes the arrival time at accelerometer 1 and 2 respectively.

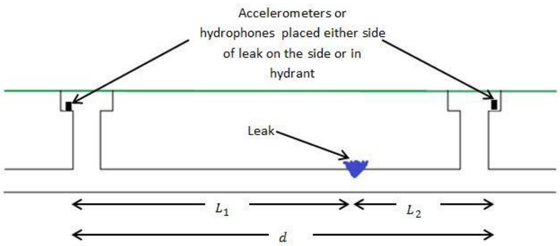

Fig. 1. Leak location schematic.

Although highly successful on metallic pipe, the cross correlation technique is less effective on plastic pipe as leak signals on plastic pipe tend to have a lower signal to noise ratio and do not propagate as far due to the viscoelastic