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Investigation of Pressure Signal and Leak Detection in Pipes by Using Wavelet Transform in Transient Flow †

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Abstract: Leakages in pipes lead to water loss, so leak detection to prevent water loss is essential. Transient flow is a method to obtain a wide range of pipe flow data, but generally, signal data have various noises also related to leakages. One effective way to detect leaks is to use wavelet transform (WT). So, in this study, by conducting laboratory experiments and using WT, the behavior of the signal and the effectiveness of wavelet transform were investigated. Results of the research showed that WT is very effective for leak detection, noise reduction, and signal analysis for transient flow.

Keywords: pipeline leak detection; transient analysis; wavelet transform; leakage

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1. Introduction

Pipelines, which have a vital role in water transmission, are exposed to risks such as leakages due to problems like the aging of pipes, structural loads, inappropriate junctions, etc. [1]. Leakage in pipelines leads to water losses, which can be a relevant fraction of the distributed volumes. Hence, to reduce this consequence and its economic impact, it is essential to take measures; leak detection has been an efficient solution for repairing the pipes and alleviating this problem. For collecting data, acoustic and transient methods are commonly used [2–4]. However, finding a way to increase the efficiency of leak detection and to better use the collected data is very useful. Wavelet transform (WT) is a way to achieve this objective [5]. In other words, in addition to the ability to reduce signal noise, wavelets are also an effective method for finding discontinuities in the pressure signal [6]. Considering that the presence of leaks in pipeline networks leads to discontinuity in pressure wave functions, the effectiveness of the WT method has become more important [7].

The review of the studies that were conducted indicates that there is still a need to further investigate the effectiveness of the wavelet transform in different scenarios. In particular, the use of WT in the presence of the transient flow condition, which is a common method in recent years for collecting data for leak detection, is of special importance. Therefore, this study, by experimental and numerical tests with the transient flow condition and in the presence of different sizes and locations of leaks, aimed to analyze signal and leak detection by using WT.

2. Materials and Methods

2.1. Experimental Tests

In the first stage, the experimental tests were performed using a high-density polyethylene pipeline model located in the Hydraulics Laboratory of the Faculty of Water and

Environmental Engineering, Shahid Chamran University of Ahvaz, Iran (Figure 1). The pipeline model had a 50.5 mm internal diameter, 6.5 mm thickness, and 158 m length.

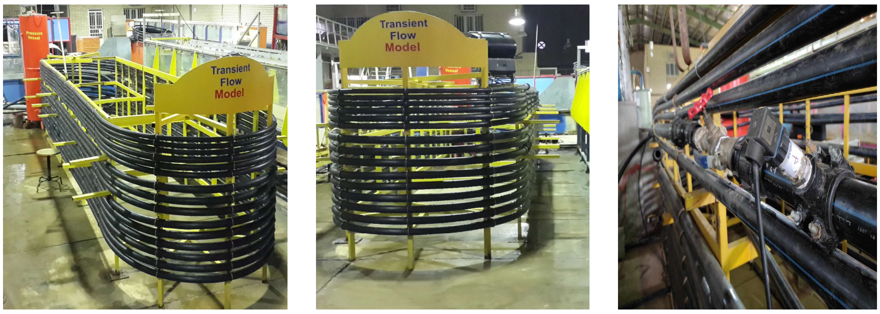


Figure 1. Pipeline model in the Hydraulics Laboratory of the Shahid Chamran University of Ahvaz.

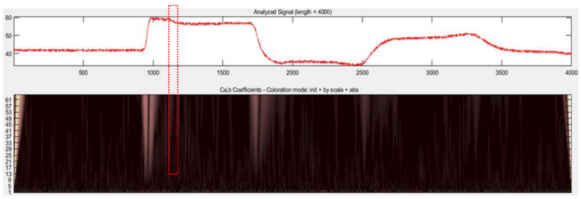
In order to achieve the goals of the current research, a test without leakage and leakage tests with sizes of 6, 7, and 8 mm and distances of 54 and 117 m from the upstream of the reservoir were carried out. The flow rate was 1 L/s. At the downstream end were two ball and globe valves, one to generate transient manually (closing time ≈ 0.05 s) and the other to regulate steady flow, respectively. Data collection was performed at a rate of 1 kHz using the transducer.

2.2. Numerical Tests

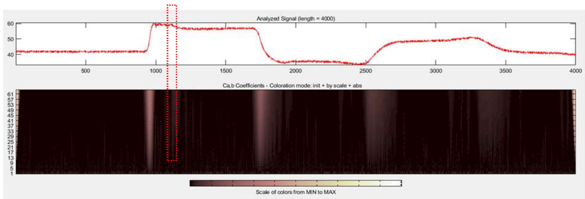
After conducting laboratory tests and collecting the desired data, continuous wavelet transform (CWT) was used. For each scenario, different types of wavelet orthogonal basis functions, such as Haar, Daubechies (db), Symlets (sym), and Reverse biorthogonal (Rbio) wavelets, were examined so that by comparing their results, the most appropriate wavelet was found.

3. Results and Discussion

At first, in order to find the appropriate wavelet, its different types, such as Haar, db, and Rbio, were applied to the laboratory pressure data on the time domain obtained from experimental tests without leak and with a 7 mm leak, and the results were compared with each other. Figure 2 shows the results using the Haar and db2 wavelets.



(**a**)

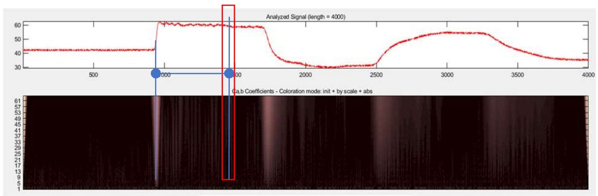


(**b**)

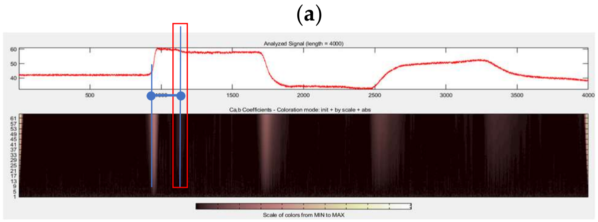
Figure 2. Comparison between data of leak 7 mm at 117 m distance by (**a**) db2 and (**b**) Haar.

According to Figure 2, the performance of the Haar wavelet was better than that of other types of wavelets in reducing noises and finding the location of leaks. The similarity of the basic shape of the Haar wavelet with the shape of the laboratory signal is one of the factors of its superior efficiency. Additionally, disturbances or noises in this wavelet are less than in other wavelets, which, in addition to filtering and reducing side noises, leads to a more accurate understanding of the behavior signal and the extent of leakage. Next, various scenarios were investigated using the Haar wavelet.

In order to check the efficiency of the Haar wavelet in detecting the leakage, under the effect of the distance of the transient flow, two leaks with the same diameter of 6 mm, one at a distance of 54 m and the other at a distance of 117 m from the upstream reservoir, were considered. Figure 3 shows that the results of wavelet transform in leak detection are acceptable in both locations, but it performed better at 117 m (closer to the transient generation location). This means that if the distance between the leak and the measurement section is large, this performance can be uncertain because the cone created by the leak can overlap with system disturbances.



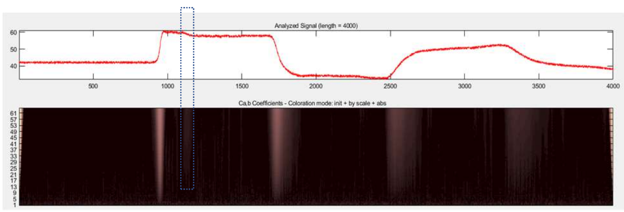
(**a**)



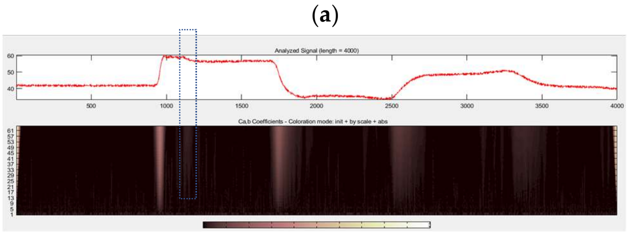
(**b**)

Figure 3. Results of Haar with leak 6 mm for transient generation locations of (**a**) 56 m and (**b**) 117 m.

At a distance of 117 m from the upstream reservoir, two leaks of 6 and 7 mm are shown in Figure 4 in comparison. Given that the transient intensity is the same for both tests, the 7 mm leak had a little clearer and better resolution. With the increase in the size of the leak, the resulting reflection power increased. Reflections from smaller leaks overlapped more with system disturbances but were still detectable with reasonable accuracy by the Haar wavelet. Also found that for a distance of 56 m from the upstream reservoir, two leaks of 6 and 8 mm could be identified.



(**a**)



(**b**)

Figure 4. Results of Haar with transient generation location 117.4 m for leaks of (**a**) 6 mm and (**b**) 7 mm.

4. Conclusions

In this research, the effectiveness of wavelet transform in leak detection was investigated. The scenarios of the sizes and locations of the leaks were investigated in a laboratory. The results showed that the Haar wavelet performed better and made the leakage more clearly visible than using other wavelets, especially at distances close to the transient generation location and for larger leakage sizes.

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Conflicts of Interest: The authors declare no conflicts of interest.

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