Determining the location of restriction in formation pressure management systems pipelines with wavelet analysis

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Abstract. This paper provides theoretical foundation for possibility of assessment of pipeline inner surface and detection of macroscopic defects by analyzing the pipe wall oscillations.

1. Introduction

Most of signals of practical importance are represented in the time domain. Often, such representation is undescriptive, as the most important information lies in the frequency range of the signal.

Most often, to move from time domain representation to the frequency domain representation, Fourier transform is used, resulting in spectral representation of the signal.

Fourier transform provides frequency information, i.e., what the rate of each frequency is in the signal, but getting information about a moment when a certain frequency appeared or disappeared is impossible. However, it is not needed in case of a stationary signal.

If a temporal localization of the spectral components is needed, one may turn to a wavelet transform. There are two types of the wavelet transform: a continuous wavelet transform and a discrete wavelet transform [1].

Under the continuous wavelet transform, the signal is multiplied by a function (wavelet) and the transform is performed separately for different temporal segments. Figure 1 shows the continuous wavelet transform.

Smaller scale corresponds to lower frequencies. Thus, in Figure 1 the part of the graph where the scale is closer to zero corresponds to low frequencies. The upper frequency of the analyzed signal is 100 Hz and it appears at the highest scale values at the shift from 750 to 1000. The lowest frequency of the signal is 10 Hz and it appears in the beginning of the shift axis and at the smallest scale values.
Figure 1. A continuous wavelet transform of a non-stationary signal

The continuous wavelet transform requires a large number of computations. Besides, the number of coefficients is much higher than the number of events in the initial signal. In comparison, the discrete wavelet transform is not as computationally-intensive, as the number of discrete wavelet coefficients is the same as the number of signal events.

The analyzed signal is a discrete time series for which there are efficient algorithms of fast wavelet transform, similar to the Fast Fourier Transform. The fast transform algorithms are not feasible for all types of wavelets, so we will use the Daubechies wavelet db2, which supports the fast wavelet transform [2-4].

2. Materials and methods
A low-power impact wave created by a ball valve is used as a valid signal giving the information on the interior space of a metal-reinforced plastic pipe. The signal is amplitude as a function of time (Figure 2).
Figure 2. The original signal resulting from opening a ball valve

Let us subject it to the discrete wavelet transform up to the third level (further decomposition of this signal gives no additional information) (Figure 3).

Figure 3. Discrete decomposition of the signal up to level 3
Let us then consider the signals that include reflected signals: Signal 1 – there is the same wave in the signal as the original (Figure 4); Signal 2 – there is a wave with the inverse frequencies with respect to the original wave (Figure 6); let us subject them to the discrete wavelet transform (Figures 5 and 7).

**Figure 4.** Signalogram obtained in inspecting the water pipeline

**Figure 5.** Discrete decomposition of the signal in Figure 4 up to level 3
**Figure 6.** Signalogram obtained in inspecting the water pipeline

**Figure 7.** Discrete decomposition of the signal in Figure 6 up to level 3
Analysis of the results shown in Figures 2-7 allows for a conclusion that if the signalogram contains no reflections, then the wavelet coefficients oscillate around the horizontal line never digressing too far from it. If a signalogram contains reflected signals, then after the discrete wavelet transform is performed, there is one (Figure 7) or several (Figure 5) segments with significant frequencies. It may be used to diagnose various reflected signals appearing in the signalogram. In addition, presence of the reflected signals is confirmed by standard deviation that is calculated for the wavelet coefficient of the third level (it is significantly larger than that of other coefficients) [5-7].

3. **Content of the method and assessment of its efficiency.**

Let us consider a signal where detection of a reflected signal is problematic (Figure 8).

![Figure 8](image)

**Figure 8.** Signalogram taken at a facility with insignificant restriction of the pipeline section

Let us also subject it to the discrete wavelet transform (Figure 9).

This signalogram is more complex than the ones considered previously. It contains several reflected signals: a signal with the same frequencies as the first wave and a signal with the frequencies opposite to the first wave. It is evident from both the discrete transform of the signal and the energy spectrum obtained from decomposition of the wavelet coefficients.

From the analysis of the results, it follows that the discrete wavelet transform of signalograms allows detecting hidden features of the signals that are undetectable visually. From the analysis of the transform graphs, wavelet coefficient decomposition spectrograms and calculated standard deviation values of the transform coefficients one may estimate presence of certain features in the reflected signal and classify such features [8-12].
Figure 9. Discrete decomposition of the signal in Figure 8 up to level 3

4. Conclusion
This paper is dedicated to optimal detection of constriction of pipeline section with wavelet analysis. At the initial stage, we selected discrete analysis as the optimal method for a large number of points in the original data.

A method has been developed for processing experimental spectrograms with wavelet analysis methods.

It was demonstrated, that application of the wavelet analysis to signal processing when detecting the pipeline restriction in metal-reinforced plastic pipes allows increasing the accuracy of determination of the time intervals between the initial pulse and a signal reflected from an obstacle.

Classification of signal features will allow assessing relative decrease in the pipeline section.

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