THE APPLICATION OF WAVELET IN PETROLEUM PIPELINE DETECTION

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Abstract: The leakage of petroleum can lead to serious economical loss. How to find out leakage spot is the key technology that we will discuss in the paper.
In this paper, we apply wavelet transform to solving the problem. Because the audio signal from the leakage spot is very weak, when the sound spreads to the ends, the signal tested by sensor has been sinked down by other noise signals. It is difficult to get this signal with normal method. But we can amplify the low frequency filtering signal step by step in accordance to the micro-mirror character in wavelet transform. Then, apply correlation method to locate the leakage spot.
Based on wavelet transform theory, we can effectively locate the leakage spot.
We have put this technology into effect and benefit from the technology.

Introduction: In recent years, the petrochemical industry is quickly developing, and the oil transmission. Pipelines pave wide geographic areas in china. The oil transmission pipelines extend in all directions, stagger in length and breadth and lay in the underground. Its distance is long. On the one hand, with using time increasing and the pipeline affected by the geography environment and transmission pipelines condition and so on, the underground oil pipeline happen the phenomena of the welding line rupture, inside and outside nature and the matter corrosion and perforation, which leads to leakage. On the other hand, some man in what are called third party damage want to obtain amazing profits, adopt non-law means frequently stealing oil by drilling hole in oil pipeline which leads to serious economical loss and is likely to cause a corrosion leak in the future on the same time. If we don't find the leak place in the pipelines in time, it easily occurs to the tragedy accidents of the fire, the blast and the environment pollution.

Once a leakage spot is established, at the instant of a breakdown of the pressure boundary (leak), the release of the elastic force couples with the system fluid to create a transient acoustic wave. This acoustic expansion wave travels outward in all directions from the source at the speed of sound for that fluid. In a pipeline, the expansion waves are guided through the fluid by the walls of the pipeline in either direction from the source of the break, to be detected by sensitive acoustic sensors placed at the ends of the pipeline. From times of arrival of the expansion waves at the sensor locations, the location of the leak is determined. The challenge of the technology is to pick up acoustic signal masked by the background noise. The figure 1:

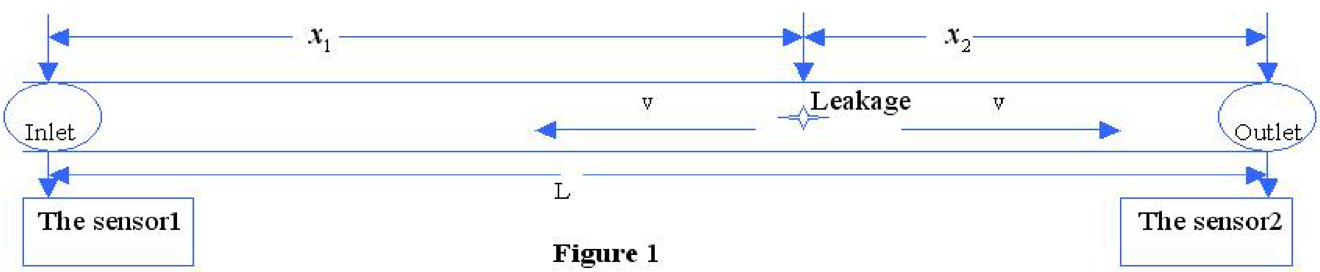

Figure 1

Wavelet transform is a new method of time-frequency analysis, which uses the scale operator replacing the transferable operator of the frequency and transforms the time-frequency plane into the time-scale plane. Its time windows function is changeably characteristic windows. When its frequency portion gets high, the time window is short, and vice versa. Because of its characteristic, wavelet can not only analyze high frequency elements, but also accurately estimate the low frequency elements of the signal. This paper briefly introduces the theory of wavelet transform and its application to detection and location of oil pipelines.

Results: When the pipeline leaks, the acoustic signal travels in either directions from the source of the break. Figure 2 and Figure 3 is the acoustic signal detected by the sensors at the inlet of the pipeline and at the outlet of the pipeline respectively.

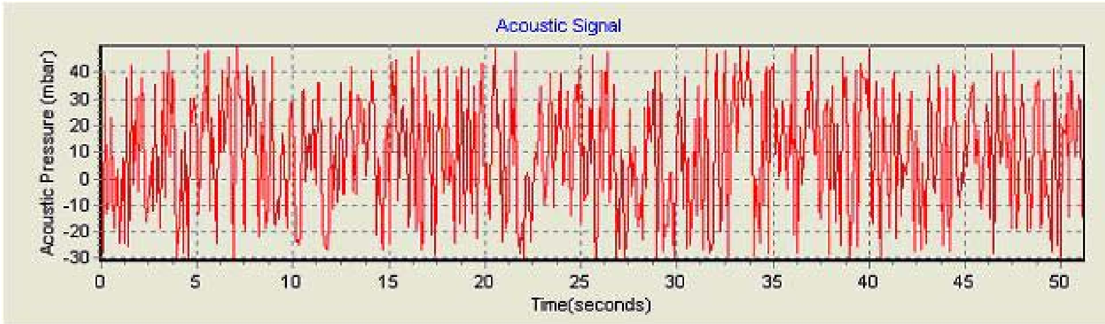

Figure 2: The inlet original signal

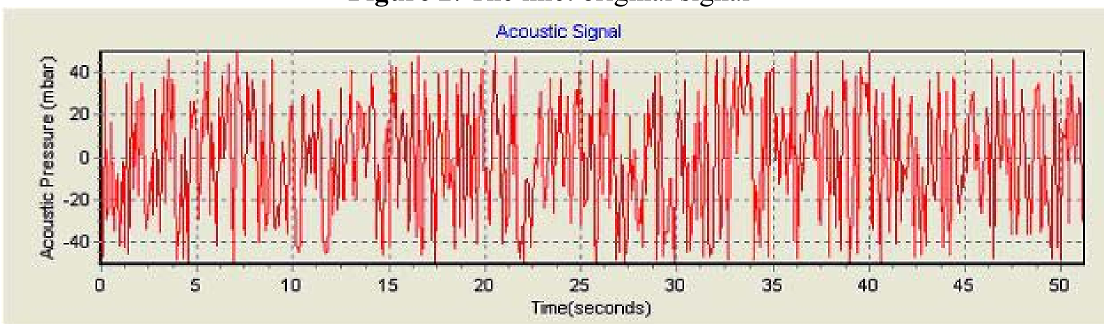

Figure 3: The outlet original signal

After wavelet transform, apparent gorges can be seen, according to the distance between the two gorges, we obviously know the time interval Δt that the acoustic signal arrives at the inlet and outlet. According to the figure 1 theory, we can locate the leak by the orientation formula what is as follow.

$$x_1 = \frac{L + v * \Delta t}{2}$$

Where: x_1: the leak site

v: the velocity in the raw oil

Δt: the time interval

Discussion: 1. The basic theory of wavelet transform

Wavelet transform is mathematical tool what is applied to time frequency analysis in recent years, which is different from the Fourier transform what can not regulate distinguishable ratio and show off local signal ability. The wavelet transform is the localizingly analyzable method what can change the size and shape of time and frequency windows.

$L^2(R)$ multiple scale analysis space sequence $\{V_m\}_m \in z$, when m is big enough to approach to $L^2(R)$, for any $f \in L^2$, $f_m \approx f$, f_m is the projection of the f on the V_m. Among $h_{1-n}\Phi(2x-n)_j, \Phi$ is the cell of the $\{V_j\}, \Psi_{j,n}$ is the standard orthogonal radix of the w_j. $\Psi(x)$ and V_{j+1} is given respectively by the formulas what are as follows:

$$\Psi(x) = \sum_{n \in x} (-1)^n h_{1-n} \Phi(2x - n)_j \tag{1-1}$$

$$V_{j+1} = V_j \oplus W_j \tag{1-2}$$

When m becomes zero and f_0 equal f, its result is as follows:

$$V_0 = \sum_{j=-1}^{-N} W_j \oplus V_{-N} \tag{1-3}$$

$$f_0 = \sum_{k=1}^{N} g_{-k} + f_{-N} \tag{1-4}$$

For $f_0 \in V_0$ and $\{C_n^0\}_{n\in x} \in I^2$: $f_0 = \sum_{n\in x} C_n^0 \Phi_{0n}$, $C_n^0 =< f, \Phi_{0n} >$

According to (1-4): $f_0 = f_{-1} + g_{-1}$

$f_{-1} = f_{-2} + g_{-2}$

…

$f_{-k} = f_{-(k+1)} + g_{-(k+1)}$

$f_{-k} = \sum_{n\in x} C_n^k \Phi_{-k,n} \quad , g_{-k} = \sum_{n\in x} d_n^k \Psi_{-k,n}$.

As a result, we obtain multi-scale and 1D wavelet decomposing formula:

$$C_n^k = \frac{1}{\sqrt{2}} \sum_{j\in x} C_j^{k-1} h_{j-2n} \qquad d_n^k = \frac{1}{\sqrt{2}} \sum_{j\in x} C_j^{k-1} g_{j-2n} \qquad \text{k=1,2,…}$$

That is:
$$\begin{array}{ccccccccc} C^0 & \rightarrow & C^1 & \rightarrow & C^2 & \rightarrow & C^3 & \rightarrow \bullet\bullet\bullet \rightarrow & C^N \\ & \downarrow & & \downarrow & & \downarrow & & & \downarrow \\ & d^1 & & d_2 & & d^3 & & & d^N \end{array}$$

c^0, c^1, Λ, c^N denotes the low frequency elements of the signal f being been decomposed, at the same time d^1, d^2, Λ, d^N denotes its high frequency elements.

2. The filter method basing on wavelet transform

In accordance with wavelet transform theory, wavelet transform has band-pass filter function, the signal can be decomposed to different frequency band. The different scale parameters determine on the different filter frequency band or wavelet subspace, in addition the wavelet subspace confirmed by the orthogonal wavelet transform is not intersection. Consequently, for containing the ensuring noise signal, which can be divided into different frequency band by wavelet transform, when the useful elements and the noise show apart characteristic on the frequency domain. As a result the useful signal and the noise will be divided, and the noise signal on the frequency domain will be turned into zero, finally the signal that does not contain noise will be restructured. For frequency resolving power demand that is very high, the frequency band will be decomposed smaller by using wavelet packet and acquiring better filtering effect. For the white noise among the original signal, because the white noise frequency band is very wide, the noise is difficult to be filtered by the conventional method. For the stochastic noise, the signal decomposed by wavelet packet remains requiring frequency band signal and deletes the other frequency band elements. If the decomposed floor is the more and frequency band carved up is the narrower, as a result, the small is the remaining frequency band containing the noise element. The filter effect is better. On the process of the signal analyzed and the equipment state inspected and diagnosed, especially the equipment comes into being initial stages, the incident characteristic signal is often merged by other signal and noise, Consequently, which brings some difficulties for diagnosing work. For the question, using traditional method is extremely difficult to extract weak signal, however, the wavelet transform is a much effective method for extraction features of weak signal and improving the ratio of signal to noise. The results show that we can extract weak signal by wavelet transform, according to the incident frequency characteristic.

In practice, as long as we know h(k) what is the orthogonal filter coefficient, we can decompose and restructure the acoustic signal by algorithm. The paper adopts the orthogonal wavelet of Daubechies. Corresponding filter coefficients are as follows:

Table 1 the orthogonal filter coefficient: h(k)

k	h	k	h
0	0.0778520540850037	7	0.0806126091510774
1	0.3965393194818912	8	-0.0380299369350104
2	0.7291320908461957	9	-0.0165745416306655

3	0.4697822874051889	10	0.0125509985560986
4	-0.1439060039285212	11	0.0004295779729214
5	-0.2240361849938412	12	-0.0018016407040473
6	0.0713092192668272	13	0.0003537137999745

3. The acoustic velocity v

The velocity v is related to temperature and density of the medium, as well as the elasticity of the pipe material. To facilitate oil movement, the raw oil is often heated at each station, especially in cold weather. Due to the non-temperature distribution, the wave velocity is not constant. Consequently, the actual formula for estimating the location of the weak is much more involved than one might anticipate. As a result, v function becomes as follows:

$$v(t)=\sqrt{\frac{K(t)/\rho(t)}{1+\frac{K(t)}{E}\frac{D}{e}C_1}}$$

where: K: the liquid bulk elasticity coefficient

ρ: the liquid density

E: the elasticity model quantity of the pipeline material

D: the pipeline diameter

e: the pipeline wall thickness

c_1: the modify coefficient

Conclusions: The oil pipeline detection based on wavelet transform is applied to the Liao oil field in China, which obtains a good economic effect.

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