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Monitor of Leakage in Long-distance Pipeline Based on Detecting Theory of Abrupt Change

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ABSTRACT

Leaks in pipelines give rise to hydraulic parameters changing with the time at inlet and outlet. This fact leads to a new method of finding leaks. After the leaks present, inlet discharge increases abruptly comparing with the steady flow situation, whereas inlet pressure, outlet discharge and pressure decrease abruptly. Thus, the theory of abrupt change is used to on-line detect the abrupt points of hydraulic parameters at inlet and outlet of the pipeline to detect leak. The presence of abrupt points indicates there are leaks in pipelines. The technique has been successful in detecting leaks from a laboratory pipeline.

KEY WORDS: Pipeline; abrupt change; leak; detection.

INTRODUCTION

Long-distance pipeline, one of the most important transportation means, has been widely utilized around the world. However, leak in pipelines often occurs owing to different reasons, which causes much larger economic loss and environmental destruction. Therefore, it is necessary to study the leak detection methods to minimize damage.

The researchers have developed many leak detecting methods during the past of a few years. Developed detecting methods are divided into two groups: direct leak detection methods and hydraulic methods. Direct leak detection methods are including the observational method, pig-based leak detection method, acoustic leak detection method etc. Hydraulic methods are including reflected wave method, transient model method, mass balance method, pressure gradient method etc. Each of these methods for finding leaks has its advantages and disadvantages in different circumstances. However, traditional methods are not suitable for the long-distance pipeline due to their expensive price, difficult maintenance and the influence on normal running, etc. especially, the random characteristics of hydraulic parameters causes a large error. So, a statistical analysis method is introduced in this paper for the purpose of minimizing the error. That is the motivation of this paper.

Firstly, this paper analyses the law of hydraulic parameters changing at inlet and outlet of pipeline during the leak, valve opening and closure condition happened according to numerical analysis result. Secondly, a new leak finding method is developed. Finally, the new method is used to a laboratory pipeline to detect the leaks.

GOVERNING EQUATIONS FOR UNSTEADY FLOW MODEL

The unsteady flow behavior of a fluid in a pipeline can be described using conservation of continuity and momentum. The unsteady pipe flow equations with leakage are (Wang, Lambert, Simpson and Liggett, 2002)

$$\frac{\partial H}{\partial t}+\frac{Q}{A}\frac{\partial H}{\partial x}+\frac{a^2}{gA}\frac{\partial Q}{\partial x}+\frac{a^2}{gA}Q_L\delta(x-x_L)=0 \tag{1}$$

$$\frac{\partial H}{\partial x}+\frac{1}{gA}\frac{\partial Q}{\partial t}+\frac{Q}{gA^2}\frac{\partial Q}{\partial x}+\frac{fQ^2}{2DgA^2}-\frac{QQ_L\delta(x-x_L)}{gA^2}=0 \tag{2}$$

in which x = distance along the pipeline; t = time; H = piezometric head; Q = flow rate in the pipeline; a = wave speed; g = gravitational acceleration; Q_L = leak discharge; f = friction factor; A = pipe cross-sectional area; D = pipe diameter; x_L = position of leak

$$\delta(x-x_L)=\begin{cases}\infty; & x=x_L\\ 0; & x\neq x_L\end{cases} \text{ and } \lim_{\varepsilon\to 0}\int_{x_L-\varepsilon}^{x_L+\varepsilon}\delta(x-x_L)dx=1.$$

Leak discharge is expressed by the orifice equation

$$Q_L=C_dA_L\sqrt{2g\Delta H_L} \tag{3}$$

$$\Delta H_L=H_L-z_L \tag{4}$$

where Q_L = flow rate through leak; C_d = orifice discharge coefficient; A_L= leak area; ΔH_L = pressure head at the leak; H_L = piezometric head at leak; z_L = pipe elevation at leak; .

Eqs.(1) and (2) are solved using the method of characteristics(Wylie