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Online monitoring method of hydrate agglomeration in natural gas pipelines based on acoustic active excitation

Zhigang Qu [a,*], Huayang Wang [a], Yang An [a], Huanhuan Yue [a], Jian Li [b], Yu Zhang [b], Yanfen Wang [a], Tingting Yue [c], Weibin Zhou [a]

[a] College of Electronic Information and Automation, Tianjin University of Science & Technology, No. 1038 Dagu Nanlu, Hexi District, Tianjin 300222, PR China
[b] State Key Laboratory of Precision Measuring Technology & Instruments, Tianjin University, Tianjin 300072, PR China
[c] Beijing Electric Power Economic Research Institute, No. 15, Guanganmen Station West Street, Xicheng District, Beijing 100055, PR China

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ABSTRACT

Natural gas hydrate, which forms and agglomerates under the condition of low temperature and high pressure, can easily affect production or even lead to serious accidents. In order to prevent hydrate agglomeration in a pipeline, the industries generally add seriously excess inhibitor with experience, which causes serious environmental pollution and huge costs. However, due to the uncontrollable production and environmental conditions, hydrate plugging in a pipeline still occurs. According to the issues above, the method, for hydrate agglomeration online monitoring in a natural gas pipeline based on acoustic active excitation, has been presented in this paper. The method is to monitor and locate the hydrate agglomeration in a pipeline in order to take measures in time. Both the modeling and the experimental results show that the method can monitor and locate the hydrate agglomeration online at different locations with good accuracy.

1. Introduction

With the continuous deterioration of the environment and excessive consumption of the resources, natural gas, a clean and environment friendly energy source, has been seen as a promising alternative energy source in the future [1]. Compared to other fossil fuels, natural gas has relatively lower carbon intensity and higher fuel efficiency in power production [2]. The growth rate of annual global demand of natural gas is expected to over 10% from 2007 to 2035 [3]. Natural gas will exceed coal to be the world's largest energy source after 2030. Flow assurance, which ensures safe transportation through a pipeline, is of crucial importance. However, how to keep the pipeline unobstructed is a considerable puzzle in the area of natural gas industry. A main reason of blocking the pipeline is the natural gas hydrate which can form under normal transportation environment [4].

Natural gas hydrates (also known as flammable ice) usually are ice-like crystalline substances that are composed by methane and water, and can burn in air to form water and carbon dioxide [5,6]. Hydrates can form in natural gas pipelines under suitable conditions (usually high pressure and low temperature) with little hindrance and often lead to serious obstructions in pipelines.

To ensure the flow assurance, different measures have been employed to prevent the hydrate formation in pipelines, which either reduce the water amount in the pipeline or destroy one of the essential conditions for hydrate formation. Currently, in the oil and gas industry, the most applied measure to prevent hydrate blockage is to inject hydrate inhibitors into the pipelines. Most popular hydrate inhibitors are: (1) Thermodynamic inhibitors (THIs) [7]; (2) Low-dosage hydrate inhibitors (LDHIs) [5]; (3) The combination of THIs and LDHIs. However inhibitors can lead to huge cost and environment pollution [8]. Even so, accidents still happen led by hydrate blockage due to the complex environment changes along pipelines, which can cause serious safety and financial loss [9,10].

An hydrate early warning system has been developed by Heriot-Watt University [11,12], in which a test sample need to be taken from an well or transport line, then sound velocity and electrical conductivity in the sample are measured and input to a trained artificial neural network (ANN). The output of the ANN can estimate whether hydrate is forming or not. However, the system can only work offline and cannot detect leakages in gas pipelines.

University of North Dakota reported a transient analysis method to locate and characterize the plugs in gas wells [13]. In

* Corresponding author.
E-mail address: zhigangqu@tust.edu.cn (Z. Qu).

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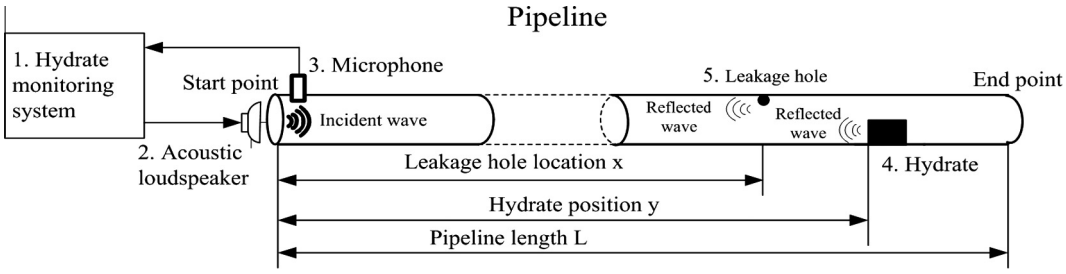

Fig. 1. Measurement principle.

principle, this method can estimate the location and the size of a blockage, however, concrete methods don't come forward and cannot detect gas leakages as well. Also the localization accuracy depends on the dimensions of the deposit.

Southwest Petroleum University provided a partial blockage detection solution for the natural gas pipelines [14]. This method employed the transient flow model and the relevant analytical solution previously proposed for partially plugged trunk natural gas pipelines. Nevertheless, it's only a theoretical method based on the Tikhonov regularization without actual experiments.

The Research center of Norway national oil company [15] used an ultrasonic technique for on-line monitoring of solid deposition in radial directions of a pipe. However, this method is suitable for a very short range and cannot be used for a long pipeline.

An acoustic pipeline blockage detection method has been reported [16,17]. However, the research for hydrate monitoring has not been reported.

In order to detect and locate hydrate formation inside a pipeline, this paper presents a method based on acoustic active excitation, which is able to monitor and locate hydrate blockages at multiple locations online. Furthermore the method can be applied to monitor leakages in a gas pipeline, which is not covered by this paper.

2. Measurement principle and experimental facilities

2.1. Measurement Principle

Fig. 1 shows the schematic configuration of the measurement system. A loudspeaker placed at the start point of the pipeline is

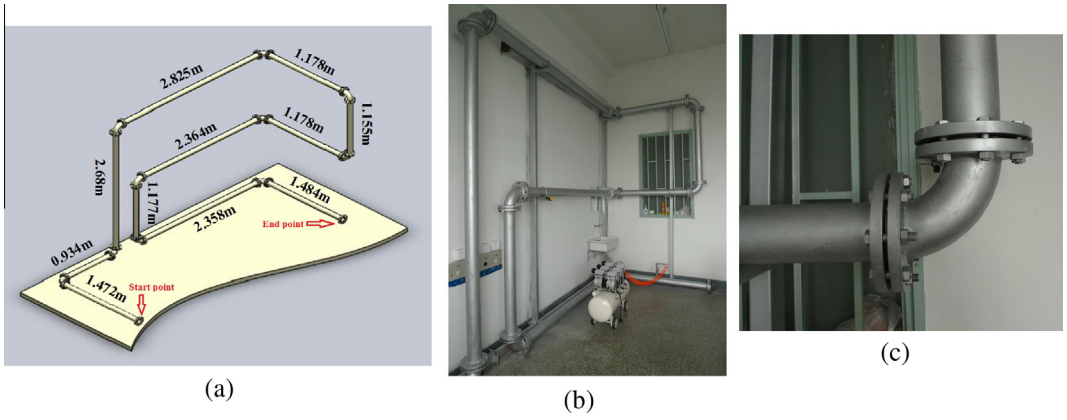

Fig. 2. (a) Test pipe schematic diagram. (b) Pipe with the pump. (c) Details of a bend.

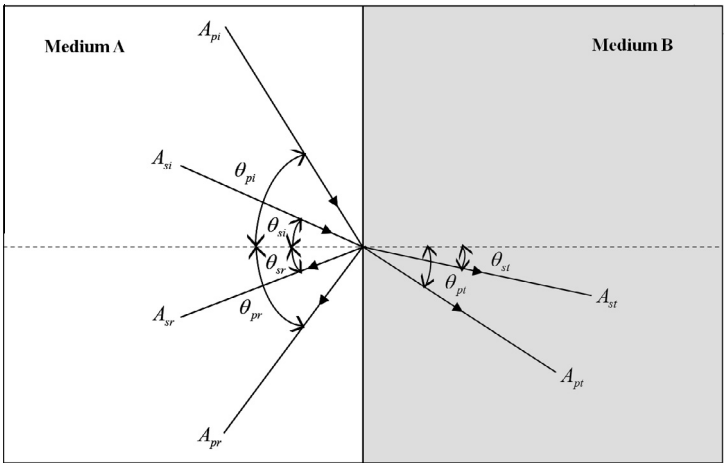

Fig. 3. Description of acoustic wave incident with angles.