Simulation of acoustic wave natural gas pipeline

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Abstract

In this paper, the sound field of the 3D model is jointly simulated by various softwares, and then the simulation data is imported into the programmed system to make up for the deficiency of the 2D model signal (data) and to deepen the subsequent simulation research on the sound source simulation. Software-based, hardware-based principles, reduce costs, and enhance system flexibility. Specifically, the simulation experiments and indoor experiments on the detection and location of natural gas pipeline leakage in medium and low-voltage towns are also provided. It also provides some references for the realization of “virtual and real synchronization” of pipeline inspection, that is, the leakage signal that is not easy to be tested in the field, and the prior data and knowledge are obtained by simulation. Thus, when the actual leakage signal is captured, the detection and positioning system reacts immediately.

Keywords

Pipeline leakage, acoustic wave method, detection, simulation.

1. Introduction

The main purpose of this thesis is to make a modest contribution to the national pipeline industry and explore a new way to detect and locate the leakage of urban natural gas pipelines at low cost. Analyze the sound source and propagation characteristics of natural gas leaks, and program the detection and location program to calculate the location of the leak. Finally, an online system for real-time detection of the safe operation of urban natural gas pipelines is established. Based on the three-dimensional model of the pipeline, this paper systematically studies the leak detection and location of urban natural gas pipelines through the combination of simulation and experiment.

2. Basic theory of pipeline leak detection and location

Fluid mechanics and aeroacoustics are the basis of the simulated sound source. Using these two theories combined with the corresponding software, the leakage flow field and sound field of the pipeline are simulated and analyzed. The theory of sound wave propagation explains the propagation process of the leak signal and indicates what factors affect the sound wave transmission. Wavelet transform and wavelet denoising theory provide a theoretical basis for removing noise from acoustic signals collected by sensors. The cross-correlation analysis theory solves the problem of the transit time of the leakage signal of the urban natural gas pipeline (the time difference of the leakage sound signal to the first end sensor). The principle of time delay positioning illustrates how the natural gas pipeline leakage in the town is positioned.

2.1 Basic equations of fluid mechanics

The Navier-Stoke equation (referred to as the N-S equation) is derived from rigorous mathematics and is the basis for describing the state of motion of all fluids. The vector form is:

$$\frac{\partial \vec{u}}{\partial t} + (\vec{u} \bullet \nabla)\vec{u} = \vec{f} - \frac{1}{\rho}\nabla p + \nu\nabla^2\vec{u} \quad (1)$$

Where is the vector velocity of the micro-element in the flow field, m/s; is the unit mass force acting on the micro-element, N; is the density of the micro-element, kg/m3; is the pressure Pa acting on the micro-element; kinematic viscosity m2 /s; is a Hamiltonian with dual properties of vector and differential; it is a Laplacian operator.

The energy conservation equation is also a universal law of the material world, which can derive the energy equation of the fluid.

$$\rho \frac{d}{dt}\left(e + \frac{1}{2}\boldsymbol{u} \cdot \boldsymbol{u}\right) = \nabla \cdot \left(\boldsymbol{\Sigma} \cdot \boldsymbol{u}\right) + \rho \boldsymbol{u} \cdot \boldsymbol{f} - \nabla \cdot q \quad (2)$$

Among them, the fluid internal energy per unit mass, J; refers to the heat passing through the unit cross section per unit time, that is, the heat flux, J / (m2 · s); is the mathematical representation of the stress tensor, that is, the stress state. Each of the formulae (2-7) is for a unit volume mass fluid.

3. signal processing method

3.1 Analysis of various acoustic signals in large pipeline systems

There are various kinds of acoustic signals in the pipeline operation, which can be roughly divided according to whether the sound can be perceived or the frequency. The infrasound wave (frequency less than 20Hz), audible wave (frequency 20 to 20kHz), ultrasonic wave (frequency 20kHz to 1GHz), microwave ultrasound (Frequency is greater than 1 GHz) [82]. According to the position of the sound wave signal source and the pipeline, it can be roughly divided into two categories, the external acoustic signal of the pipeline and the acoustic signal of the pipeline system. Since this paper mainly analyzes various types of acoustic signals from the perspective of piping systems, the second classification method is adopted.

4. Simulation analysis of acoustic signal of pipeline leakage

This chapter first explains the significance of simulating leaky acoustic signals, and then briefly introduces the principle of model similarity, paving the way for the replacement of actual prototypes. Finally, through a variety of software joint simulation of the acoustic signal of the pipeline leakage, the main process is the internal flow field of Fluent simulation pipeline, the flow field data is imported into Virtual.Lab Acoustics simulation sound field, and the sound field data is imported into LabVIEW to synthesize the leakage sound signal.

4.1 Leakage flow field analysis

In order to finally analyze in ANSYSFLUENT, first establish a three-dimensional physical model. The parameters of the PTC Creo design elbow are: inner diameter 50mm, scanning center line total length 400mm, wall thickness 3mm. Figure 3-1 is a flow path model of the extracted gas flow region. Then, the structural mesh of the curved tube is divided in the ICEM as shown in Fig. 3-2, and the BLOCK at the leakage port is reasonably divided (BLOCK is divided by the bottom-up stretching method). Finally, the finite volume method is used to numerically discretize the governing equations in Fluent, and the SIMPLE algorithm is used to implement the calculation. Specifically

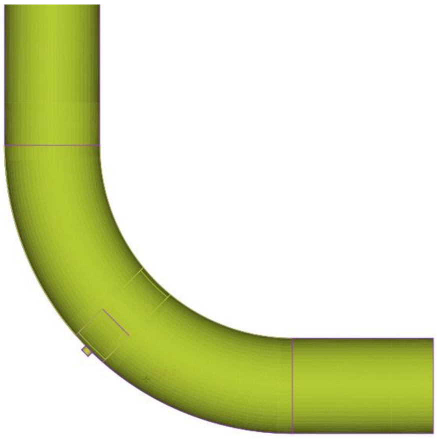
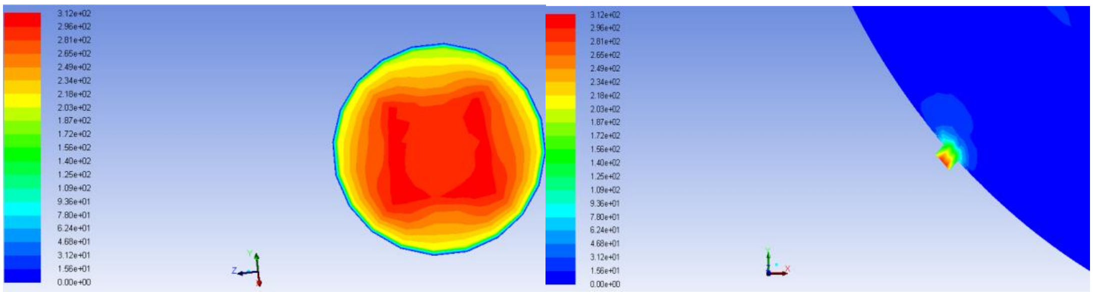


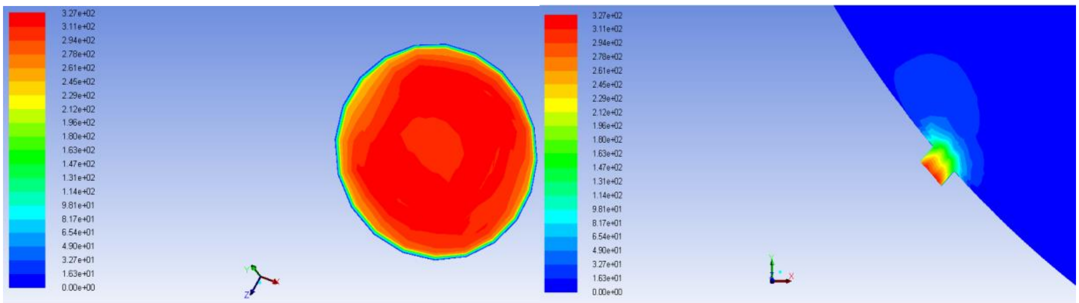
Fig .1Natural gas elbow model

4.2 Fluent solves the flow field

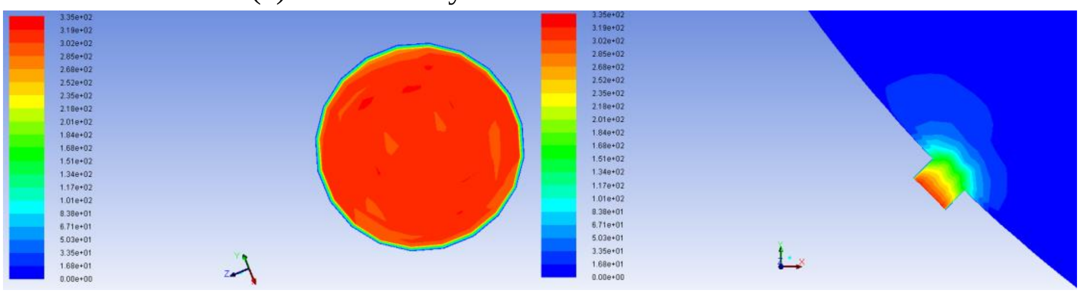
When the pipeline suddenly breaks down, the pressure difference between the inside and the outside of the pipeline at the breakage hole is large, and the fluid at the leak hole is ejected at a high speed to form a turbulent pulsation containing many vortices. Outside the leaking hole area of the pipe, the pressure difference changes relatively stably, so the focus is on the flow field pressure and velocity changes at the leak hole, which is the main source of sound generation. Figure 1-2 shows the velocity cloud at the leak.



(a)Flow velocity near a small hole at 0.1MPa



(b)Flow velocity near a small hole at 0.2MPa



(c)Flow velocity near a small hole at 0.3MPa

Fig. 2 Velocity cloud map at the leakage hole

From the cloud map:

(a) Figure 1-2 a) The flow velocity outside the leak hole area is stable at about 15m/s, and the leak hole is nearly 320m/s. It indicates that the fluid velocity is abrupt near the leak hole, and the larger the value is, the more the growth rate is more than 20 times. The color of the cloud near the center of the leaking hole is dark red, and the color near the rounded edge is light blue. The numerical center (300m/s) is significantly larger than the round side (0m/s).

(b) It is known from Fig. 1-2(c) that the entire circular surface at the exit of the leak hole is almost red, and the value reaches a peak of 335 m/s, but it can be noticed that the velocity at the boundary layer is small, where the dipole is mainly generated by pressure pulsation. Sub sound source.

(c) Figure 3-3 (a) ~ Figure 1-2 (c) shows that when the pipeline operating pressure is from 0.1 to 0.3 MPa, the peak near the center of the leak hole increases, from 312 m / s to 335 m / s. . Due to the bending, the fluid separates here, the velocity inside the elbow decreases, the outer velocity increases, and the fluid tends to flow from the outside to the inside. When the fluid flows through the leak hole, the fluid is turned to the outside again, and the direction of fluid movement is complicated.

5. Summary

This chapter mainly analyzes the benefits of simulation and the similarity principle of the model. Then the simulation process of the total signal z2 is described, including the flow field simulation and sound field simulation of the leaked sound source signal, and the synthesis of the useful signal n (ie, the sound field simulation data) and the noise signal m. Based on the theory and principle of the second chapter, a variety of software co-simulation methods are used to simulate and analyze the sound source characteristics when the gas pipeline leaks.

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