Using Wireless Vibration Sensors to Study the Impact of Fouling on Fluid-Conveying Pipelines

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Abstract. This paper analyzes the vibration signals on the surface of the fluid-conveying pipelines so as to monitor the state of pipelines, and study the impact of fouling on these pipelines. Wireless acceleration sensors are deployed on pipelines' surfaces to detect the vibration signals under different states. According to the real data from the test experiments, a model is implemented in ANSYS. On this basis, extensive simulation is conducted. The simulation results compare with real test data to verify the efficiency of the model.

Keywords: Vibration signals · Fluid-conveying pipelines
Fouling impact · Wireless acceleration sensors

1 Research Problem

Heat exchanger is a kind of important equipment in petrochemical plants. For the continuous production of industrial enterprises, the safe and stable operation of heat exchanger is of great importance. When using industrial circulating water as the cooling medium for heat exchangers, sediment and dirt are easily produced. When the heat exchanger is in operation, proper vibration will help reduce dirt and severe dirt will reduce heat exchange efficiency. In order to maintain the original efficiency, the speed need to be increased, which will increase the vibration of heat exchanger. According to statistics, the damage of nearly thirty percent heat exchanger is caused by the vibration of the tube bundle.

At present, the structure, heat transfer performance and heat transfer parameters of heat exchange tubes are simulated and studied by some researchers by means of ANSYS and CFX [9]. However, the research results of fault vibration characteristics of the heat exchanger through the commercial simulation software is quite less, because it involves the fluidic and structural two-way coupling, the heat exchanger structure is very complex, resulting in the difficulty of calculation of finite element analysis [2]. Many scholars have done a lot of research on the on-line monitoring and fault diagnosis of heat exchanger [7,10]. However, their

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studies are limited by many factors, e.g., temperature, pressure, petrochemical material flow, and have many disadvantages, e.g. inefficient management, unreliable data, and high labor cost. Considering that petrochemical plants are lacking effective online monitoring system to conduct fault diagnosis for heat exchangers [5,6], this paper aims at proposing a novel method to solve this problem.

2 Solution

A heat transfer tube is one of the basic parts of a circulating water heat exchanger for conveying and controlling liquid or gas. Normally, the tubes of pipe - shell circulating water heat exchange are straight, and the pipes between the two baffles are simply supported single span beams. In order to analyze the blockage of the pipeline, this paper uses a two-way coupling separation model. Through the study of different plugging levels of the model, the law of pipe vibration caused by pipe blockage is determined. The simulation results were as show in Fig. 1. After that, the simulation results compare with real test data which collected by wireless acceleration sensors [3,4], to verify the efficiency of the model. In this paper, the fouling of heat exchanger pipeline was discussed and a new diagnostic method is put forward.

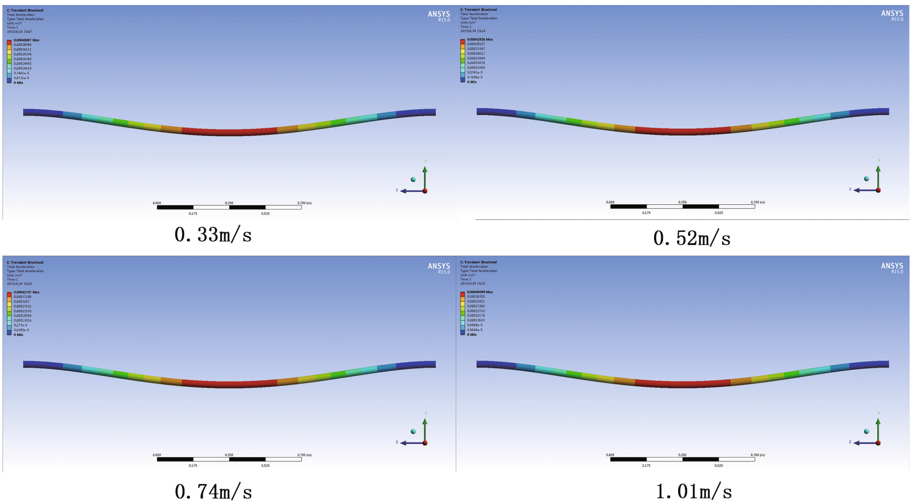
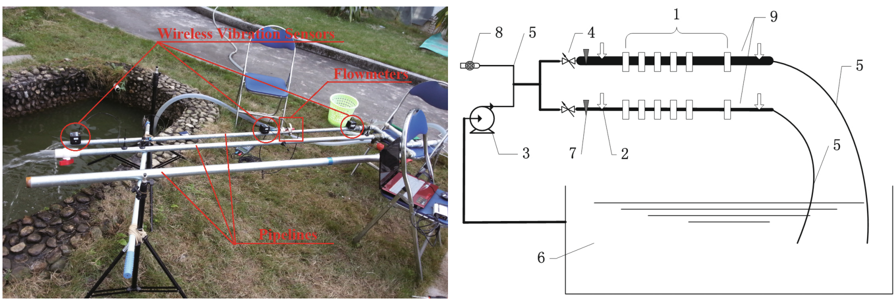


Fig. 1. Through constructing the finite element model of fluid - conveying pipe with different levels of pollution, this paper analyzes the four different degree of clogging (0%, 20%, 40%, and 60% fouling) under the influence of flow speed, direction, and load on pipe wall, wall displacement, the fluid domain of accelerated speed fluid conveying pipeline. It is found that fluid flow velocity and direction varied with the fouling position. In addition, wall load, wall displacement and accelerated speed increased with increasing degree of clogging. Therefore, the pollution of flow pipeline has an effect on the vibration of pipes.

3 Experiment

From the turbulence model, the normal fluid transportation pipeline model is established by means of ANSYS and CFX. The paper studies the vibration of the pipeline under different ow velocity through the study of the pipeline vibration by ANSYS and CFX. On this basis, the pipeline model of with different blockage levels is established, and the vibration of the pipeline is studied on the premise of the same ow velocity [1,8].

In order to verify whether it is feasible and correct to establish the finite element model of fluid transportation pipeline using ANSYS and CFX, this paper presents an experimental analysis of an experimental model under a given working condition. In this paper, two different diameters of pipeline are used to simulate the vibration produced by the fluid with different inlet velocities. Many high precision wireless sensors are installed at the same data observation point, and computer simulation is carried out to collect vibration signals simultaneously. The experimental facilities were as shown in Fig. 2.



(a) Main components of experimental equipment

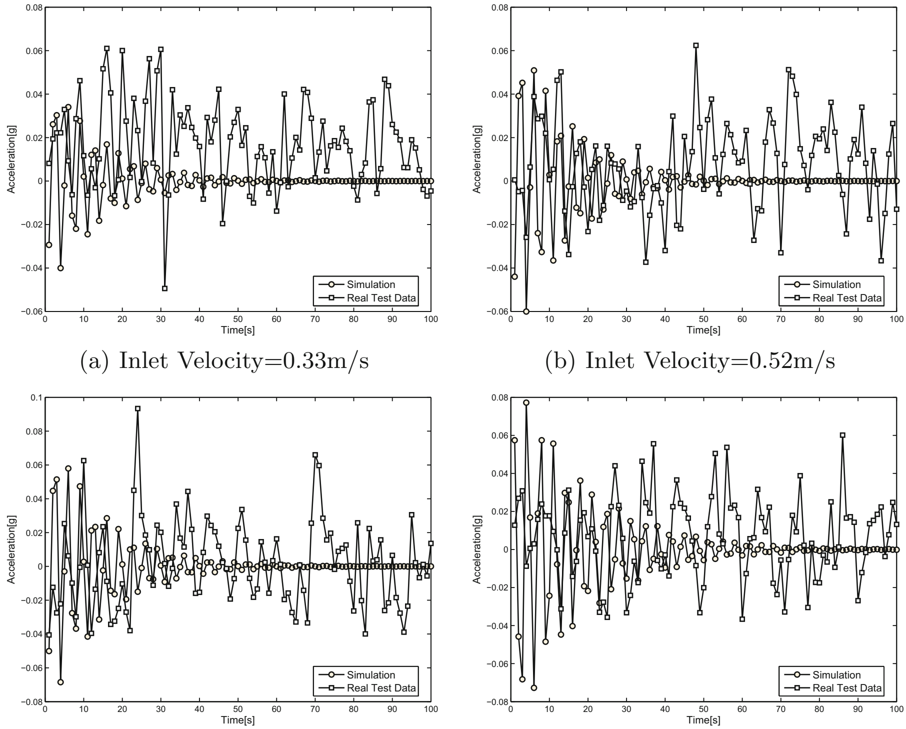
(b) Schematic diagram of real test

Fig. 2. 1-wireless vibration sensors, 2-flow meters, 3-pumb, 4-water valve, 5-flexible pipeline, 6-pool, 7-press instrument, 8-tap water inlet, 9-pipelines.

4 Conclusion and Open Issues

The experimental study was carried out in two different fluid - convey pipes. As shown in Fig. 3, through comparing the simulation model with the real test data of the non-fouling fluid-conveying pipeline in the same working condition, the validity of the simulation model is proved.

The finite element model of fluid-conveying pipeline under fluid-solid coupled interaction was established by ANSYS finite element analysis method. On the basis of this model, finite element analysis is carried out in the pipeline of different velocity and degree of clogging. In addition, a series of pipeline vibration experiments were performed under the same normal conditions. The results



(a) Inlet Velocity=0.33m/s

(b) Inlet Velocity=0.52m/s

(c) Inlet Velocity=0.74m/s

(d) Inlet Velocity=1.01m/s

Fig. 3. Taking the vibration data of the pipeline (DN20) center as an example, the data of the finite element analysis and the actual experiment are basically similar, and the speed is 0.52 or 0.74 m/s. The acceleration speed data is 0.33 m/s. In the same orders of magnitude, the maximal acceleration speed of ANSYS simulation increases with the increase of inlet velocity.

show that the simulation data is basically consistent with the actual test data, only a small amount of data does not match.

4.1 Open Research Issues as Future Work

1. Vibration test experiments have been conducted with non-fouling fluid-conveying pipelines, but without fouling pipelines. Designing such fouling pipelines to make test experiments is still an open issue.
2. Vibration signals generated by other running equipment will affect the signal collection on the target equipment. Distinguishing the signals which collected from pipelines and other equipment in highly noisy environment is still an open issue.

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