Research Progress on Solid Particle Erosion of Elbow Pipe

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Abstract

In the process of natural gas exploitation, high-pressure sand-bearing airflow causes serious erosion wear to pipeline equipment, and according to the actual situation, the damage of the elbow is the most serious. In this paper, the erosion of the elbow by solid particles is taken as the research object. Through literature investigation, the practicability and reliability of CFD in simulating erosion wear of elbow are described, and the steps of erosion prediction by the Euler method are given. The theory and methods of solid particle erosion in the future are prospected by reviewing the research achievements in this field in recent years.

Keywords

Erosion wear; Bend; CFD.

1. Introduction

Petroleum energy is an important strategic resource in the development of the national economy. It plays an important role in agriculture, industry, commerce, transportation, and national defense construction. People's life and social progress cannot be separated from the petroleum industry. With the rapid development of the oil and gas industry and the increasing difficulty of oil and gas well testing and development, fracturing technology is gradually widely used in the exploitation of oil resources. Fracturing process of rock debris and industrial sand can cause excessive sand content in the gas, the gas, and impurities and fracturing fluid at high pressure into the gathering pipeline, gathering equipment caused by wear, congestion, severe cases, even erosion equipment, thereby causing serious consequences, and threaten the safety and stability of the production. Elbow, as a pipe widely used in oil and gas pipeline transportation systems, is vulnerable to erosion and wear of mechanical impurities (such as sand and iron filings) carried in pipeline fluid [1].The direct effect of erosion wear is to reduce the thickness of pipe wall, thus reducing the bearing capacity of pipe, shortening the service life of related equipment, and increasing the risk of pipeline transportation. In serious cases, pipe perforation failure, oil and gas resource leakage, and environmental pollution will be caused, not only causing huge economic losses but also threatening people's production and life safety [2].

2. Erosion wear and computational Fluid Dynamics (CFD)

Research on erosion wear has never been interrupted. Through a large number of experiments, researchers have explored the loss of material surface quality under different flow conditions. By analyzing the results and sorting out the experimental data, the relevant erosion wear mechanism model is proposed. According to different influencing factors of erosion, relevant mathematical models are established [3][4].In modern industrial production, the working environment and geometric structure of the equipment are very different, so the flow of fluid in the equipment becomes more complicated, which makes it difficult to apply experimental research methods[5]. Early erosion wears mechanism research and specific experimental results to explain the material erosion provides certain theoretical guidance, with the development of computational fluid dynamics, gradually formed in the numerical simulation research method, to explore the complex fluid flow condition and changeable geometry structure of erosion, at the same time, as compared with the related experimental results to better explain the internal reasons and make corresponding changes [6][7].

Advances in computational fluid dynamics (CFD) technology promise to provide a design tool for structural optimization based on predicted erosion wear of equipment. In most cases, designers can only reduce erosion wear of equipment by selecting materials and adopting maintenance methods[8]. By using CFD to simulate erosion under different flow conditions, redesigning the geometry, and optimizing the results, erosion wear can be quickly and effectively reduced. The most prominent feature of CFD technology is the ability to determine through simulation where erosion is likely to occur in the equipment. At present, this can be achieved through reasonable parameter setting and a basic understanding of the hedging process, as this function is largely dependent on the well-developed particle dynamics and fluid dynamics. As a commercial software tool in the design process, CFD technology has been able to predict fluid movement phenomena in complex geometric shapes and modify equipment structures according to specific simulation results [9].At present, the main research content of erosion wear abroad is to determine the erosion rate and remaining service life of equipment before failure or complete damage [4].

Erosion wear on material surfaces can be predicted by using the combined Euler-Lagrange method, but the knowledge of particle dynamics and erosion processes near walls remains unsolved. Using the Euler-Lagrange method to simulate erosion requires three stages of the prediction process: 1) Using a viscous or non-viscous model to predict flow field;

2) Particle trajectory calculation through discrete particle dynamics modeling;

3) Use Euler-Lagrange method to determine the erosion wear material removal model.

3. Research Status at home and abroad

In recent years, domestic and foreign scholars have carried out extensive research on the erosion of particulate air or liquid flow employing experiment, theory, and numerical calculation.

In 2011, Zeng Yongjie [10] studied the failure caused by erosion of natural gas elbow based on CFD, studied the flow field (pressure and velocity field) of the elbow, proposed that the surface with the largest radian of the elbow was eroded the most, and put forward some suggestions for avoiding and slowing down the erosion failure of the elbow.

In 2012, Hu Yuehua [11] predicted the law of erosion-corrosion of various special pipe fittings under narrow erosion conditions based on numerical simulation and proposed a series of preventive measures aimed at slowing erosion of typical pipe fittings.

In 2017, Zheng Sijia et al. [12] accurately described the erosion process of the inner wall of a short radius elbow (R= 1.5d) based on 3D imaging technology. CFD was used to carry out the numerical simulation, and it was found that in the process of continuous erosion of pipe wall by particles, the velocity of wall thickness wear diffusion to low Angle was less than that to high Angle center Angle.

In 2018, H Zhu et al. conducted a simulation study on a 90° elbow by using CFD-DPM. Considering the wear speed and anti-erosion effect of the elbow, it was concluded that the 25° elbow was relatively wear-resistant.

In 2020, Li Cang [13] et al. used the E/CRC erosion wear model in FLUENT software to simulate the gas-solid two-phase flow of 90° bend in the gas transmission pipeline. The erosion rate of 90° bend is positively correlated with the influence of factors.

4. Research Prospects

The research conclusion is based on the experience formula of the specific condition of a fitting, narrow scope of application, not hedge corrosion for reasonable interpretation from the mechanism, and form can accurately describe the erosion rate and comprehensive function relation between multiple parameters. For anti-erosion coatings, composite coatings have the advantages of high strength and high toughness of both metal and non-metal coatings. The structure of an anti-erosion pipeline can improve its anti-erosion performance by changing the fluid flow in the pipeline to avoid solid particles directly impacting the vulnerable parts of the pipeline. In the future, the development direction of solid particle erosion theory and anti-erosion method of the elbow is reflected in the following aspects:

1) Enrich and perfect the theoretical model of solid particle erosion of elbow. Based on the basic parameters such as particle incidence Angle, erosion velocity, and target hardness, more new variables affecting erosion are added continuously, such as flow pattern, statistical theory, particle distribution in two phases, particle migration, and so on, to further improve the theoretical model of erosion.

2) For the development and application of the anti-erosion coating on the inner wall of the pipeline, it will be more inclined to develop new materials. The anti-erosion coating of composite materials has the advantages of both metallic and nonmetallic phases and is the direction of future development. Nanomaterials and advanced processing technology can help its development and perfection.

3) For the development and application of pipeline anti-erosion structure, more and more methods and technologies of bionics will be used for reference in the future, and its design will combine interdisciplinary and transfer[1].

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