Numerical simulation of erosion of elbow by a small amount of granular fluid

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Abstract

By means of the erosion model (DPM) in Fluent, the erosion status of the fluid containing thin particles into the elbow is numerically simulated, and the force of the wall surface is analyzed and the trace of particle particles is traced. The results of numerical simulation show that the erosion mainly occurs at the bottom of the elbow, and at different inlet velocities, the erosion effect of the same diameter particles on the elbow increases with the increase of particle velocity. The simulation results are in agreement with the experimental data, and the simulation method can be used to transport the safety monitoring and process modification of the pipeline containing a small amount of granular fluid.

Keywords

Small particles, Fluid, Erosion, Numerical simulation.

1. Introduction

When the natural gas pipeline conveys the fluid medium, the particles in the fluid inevitably cause the erosion of the wall of the pipe, and the erosion wear is the failure of the material and the equipment. Therefore, we need to accurately predict the most vulnerable parts of the pipeline and the speed of wear, so as to ensure the safe operation of the pipeline[1]. In order to provide technical support for the design of the elbow and the maintenance and use of the actual working conditions, the numerical simulation of the erosion of the wall surface with a small amount of granular fluid passing through the pipe is carried out by using the computer.

2. The Establishment of the Model

2.1 Section Mathematical Model

The flow of sand in the tube is a typical solid liquid two phase flow model, because the object of this study is a fluid with solid particle diameter of 200 microns, so the discrete phase model can be used[2].

Liquid-solid two phase continuity equation:

Liquid phase:

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{1}$$

Solid phase:

$$\frac{\partial \bar{\rho}_p V_i}{\partial x_j} = -\frac{\partial}{\partial x_j} \bar{\rho}'_p \bar{V}'_j \tag{2}$$

Equation of momentum:

$$\rho U_j \frac{\partial U_j}{\partial x_j} = -\frac{\partial p}{\partial x_i} + (\mu + \mu_i)\frac{\partial^2 U_i}{\partial x_j^2} - \frac{1}{\rho}\frac{\partial}{\partial x_j}\overline{u'_i u'_j} + F_{pi} \tag{3}$$

$$\bar{\rho}_p V_j \frac{\partial V_i}{\partial x_j} = -\overline{\rho'_p v'_j}\frac{\partial V_i}{\partial x_j} - \frac{\partial}{\partial x_j}(\bar{\rho}_p \overline{v'_i v'_j}) - \frac{\partial}{\partial x_j}(V_j \overline{\rho'_p v'_i}) - \bar{F}_{pi} + \bar{F}_g \tag{4}$$

k-ω Equation:

$$\frac{\partial}{\partial x_j}(\rho_{uj} k) = \frac{\partial}{\partial x_j}\left[\Gamma_k \frac{\partial k}{\partial xj}\right] + p_k - \rho\varepsilon + \overline{F_{pi} u'_i} \tag{5}$$

$$\frac{\partial}{\partial x_j}(\rho_{uj}\varepsilon) = \frac{\partial}{\partial x_j}\left[\Gamma_\varepsilon \frac{\partial \varepsilon}{\partial xj}\right] + \frac{\varepsilon}{k}(C_{\varepsilon 1} P_k - C_{\varepsilon 2}\rho\varepsilon + C_{\varepsilon 3}\overline{F_{pi} u'_i}) \tag{6}$$

DPM erosion model:

When the DPM model is used, the discrete phase used by Fluent is very thin, so there is no need to consider the collisions between particles. When the erosion model is established, the erosion wear caused by the particle impact on the wall at a smaller impact angle is far greater than that of the wall with a larger angle. The v is relative to the wall of the particles. Velocity, b(v) is a function of this relative velocity; in the simulation process, the speed exponent function is constant 2.6. The final unit of erosion rate is the quality of the worn material / area (time).

2.2 Geometric Model and Grid Partition

The model is shown as shown in Figure 1. Inner diameter D=100mm, Bending radius R=50mm, Each end of the pipe is extended 400mm. After establishing the geometric model in SolidWorks, we import the x_t format into ICEM-CFD and divide it into meshes. The unstructured grid is used. Finally, the number of grids is 143691, as shown in Figure 2.

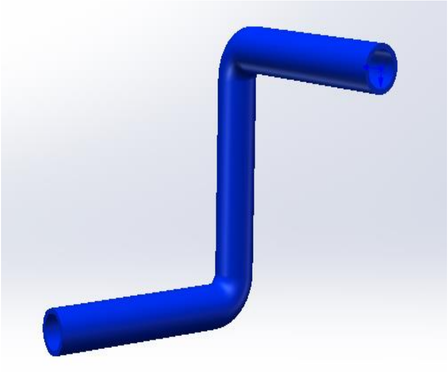

Fig. 1 Pipe Bending Model

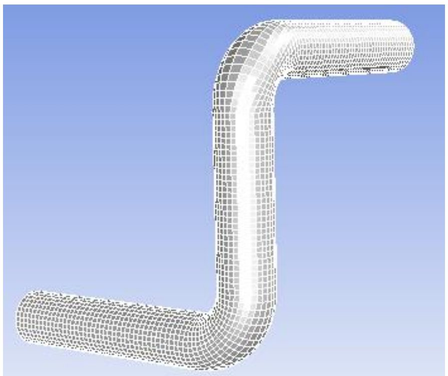

Fig. 2 Model Grid

3. Numerical Simulation

3.1 Initial Condition

Regardless of the impact force between sand and sand in the fluid, it is considered that the particle size is uniform, the density is 1500kg/m3, the mass flow of the sand is 1kg/m3, and the corrosion of the pipe wall is neglected. The particle fluid flows vertically from the bottom pipe mouth to the 10m/s velocity, the exit assumes the outflow boundary, considers the turbulent, isothermal and steady condition in the solution process, and ignores the force and viscous shearing force caused by the pressure gradient of the fluid around the particle.

3.2 Computing Method

Using Fluent16.0 to simulate three-dimensional numerical simulation of the sand flow in the elbow, using the k-ε standard two-way solution, using the type separation solver, the control equation is discrete using the finite element volume method, and the liquid-solid coupling adopts SIMPLE algorithm[3]. The Lagrangian method is used to track the particles in the flow field, then the wear quantity of the elbow is calculated in different working conditions, and the water is the continuous phase, and the sand is the discrete phase.

3.3 Boundary Condition

The sand grains are divided into 4 different conditions under the same diameter and different inlet speed. When setting boundary conditions, we should pay attention to the difference of boundary conditions.

(1) The continuous medium in the elbow is water and the dispersed phase is sand.

(2) Boundary conditions for fluid exit: set to ‘Outflow’.

4. Calculation Results and Comparison

4.1 Tracking of Particle Motion Trajectory and Prediction of Erosion Site

Through the 800 iteration calculation, the results show that all the parameters are convergent, and the trajectories of sand grains in the bend pipe are shown in Figure 3 and pipe pressure diagram 4.

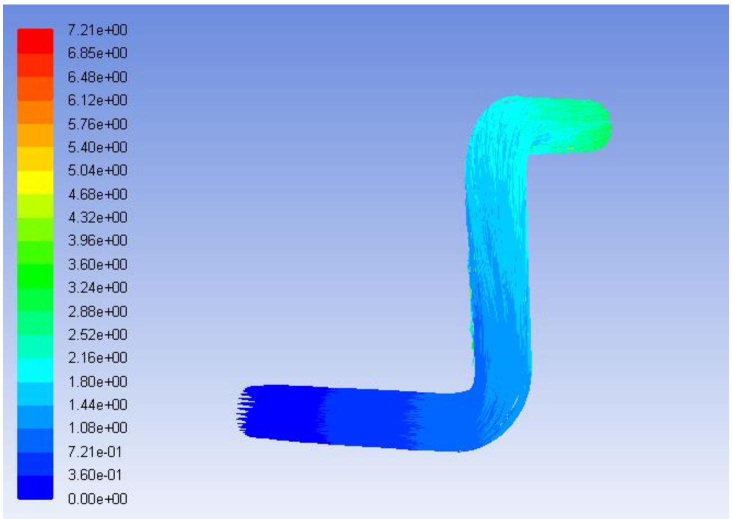

Fig. 3 Particle Trajectory Map

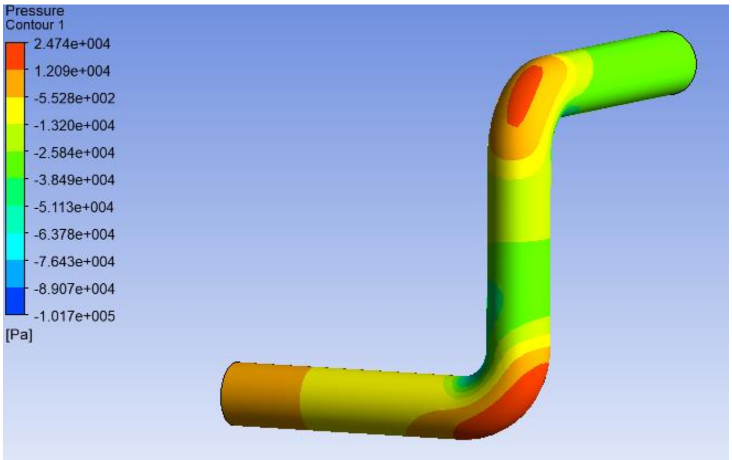

Fig. 4 Pressure Cloud Map

From the trajectory of the sand and the pressure cloud on the wall of the elbow, the erosion occurs mainly in the bottom inner surface of the elbow, as shown in Figure 4. Because when the sand from the inlet with the fluid at a certain speed inflow, due to the inertia, sand in the elbow curvature changes in the part of a certain angle impact on the wall, resulting in the area of wear than other parts of the larger.

4.2 Effect of Particle Inlet Velocity on Corrosion

Under the above 4 working conditions, the elbow bend is divided into 2 section sections according to FIG. 5 (Region A, B), after the fluent in the back-treatment of the wall, elbow parts and a, B section of the section, you can get at different inlet speed of each section of the average erosion rate of comparison chart.

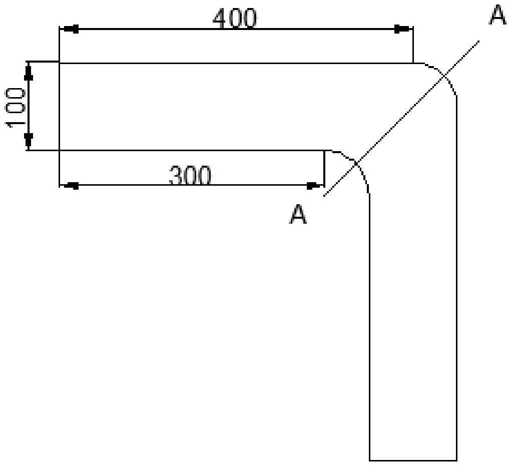

Fig. 5 Section Diagram of Bend Pipe

Figure 6 shows the erosion rate of the sand grains with the same diameter at different inlet velocity to the wall of the elbow. It can be obtained from the figure that when the diameter of the sand grain is fixed, the greater the inlet velocity is, the erosion rate of the elbow increases significantly[4].

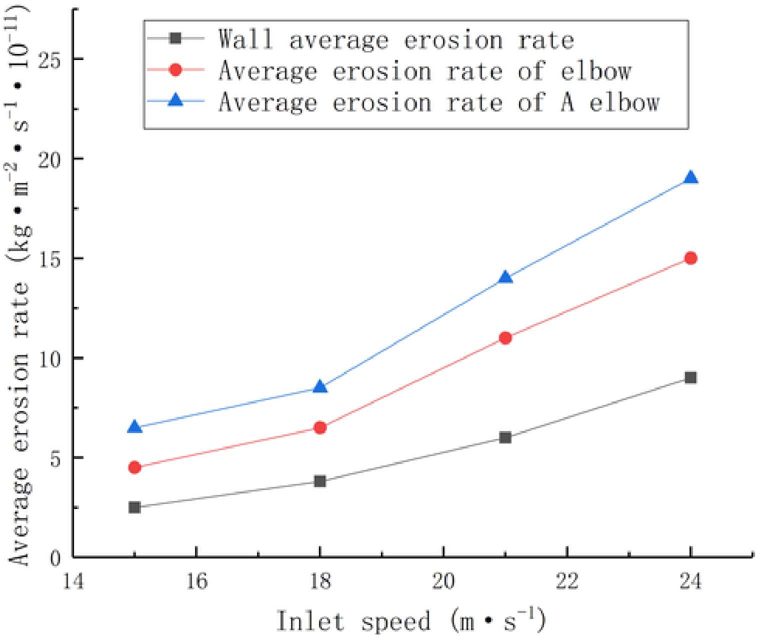

Fig. 6 Comparison of the Average Erosion Rate of the Elbow at the Same Particle Size and Velocity

5. Calculation Results

(1) The serious erosion in the pipeline is the part where the curvature of the pipe is changed, and the second part of the elbow is the most serious.

(2) The particle diameter is unchanged, and the erosion effect of the particles on the elbow increases with the increase of the fluid velocity.

(3) According to the conclusion, it can be applied to the actual production to improve the erosion phenomenon in the solid-liquid two phase flow pipeline.

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