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Flow field analysis of the bypass pipeline of pig receiving trap

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ABSTRACT

In order to study the effect of the structure diameter of the device piping, namely the by-pass pipe of pig receiving trap at the gas station on flow field, the distribution of flow field was simulated and analyzed in the pig receiving trap, and its internal pressure, flow velocity and turbulence kinetic energy changes were analyzed. Besides, the effect of by-pass pipe diameter changes on the flow field was also studied. The results show that the static pressure is four clear regional distributions in the interior of pig receiving trap, namely that the pressure within the main ball tube is maximum, and the pressure inside the small ball tube is second, and that of reducer is the smaller, and pressure of by-pass tube is minimum. Besides, there is obvious vortex at the entrance of by-pass pipe. With the increase of the by-pass pipe diameter, the pressure decreases, and the pressure change rate also decreases. In the interior of the by-pass pipe, with the increase of the diameter, both the velocity and turbulence kinetic energy decrease.

Key Words: Pig receiving trap; Flow field analysis; Bypass pipe; Turbulent kinetic energy; Pressure

1. INTRODUCTION

The application of pigging process is common in gas pipelines, and it has been developing rapidly in recent years, namely that it is widely used in oil, gas, water pipes, and more and more significant effect is obtained. Service life and transmission efficiency of the long-distance pipelines depends largely on the pipe wall and internal cleanliness, and in long-distance pipeline construction and operation, pigging is a very important and risky job [1]. In order to improve the pigging efficiency of gas transmission pipeline, the pig receiver or launcher is set in the first, middle and end pigging station of the pipe, and it is the essential equipment when pipeline pigging operations and pipeline detection[2]. As the device piping of pig receiving trap, the by-pass pipe is used to connect the main ball tube and station pipeline, and fluid is flowed to the station by the bypass pipe when launching or receiving the pig, which can make the gas transmission operation be normal. However, the by-pass pipe diameter size is affected by fluid capacity, and if the by-pass pipe diameter size is not appropriate, it cannot receive gas completely, which make the pig receiving trap easily produce the vibration. Therefore, the study of by-pass pipe structure diameter size is very important.

2. At present, there are a lot of studies about the pigging process and pig receiver or launcher device at home and abroad. Jian-jun Ma etc. [3] studied the application of pigging technology in natural gas pipeline engineering. Jian-Feng Yan etc. [4] studied the pigging process from different aspects, such as the pig type, pigging methods, preparations before pig into the pipe and the encounter failures during pigging process. Yu Wang etc. [5] studied the receiving process of traditional pigging ball and its main problems. Meng-De Wang etc. [6] studied the special equipment safety rules and periodic inspection rules of pressure piping, and combining with domestic technology situation, put forward the necessity of increasing the pig receiver trap in the design of city gas. Ying-Liang Yang etc. [7] introduced the pig transceiver design under the GB150.1 ~ 4-2011 "pressure vessel", ASME31.3 and ASME31.4 standard. However, most of researches have been aimed at pigging process or the design of the launcher and receiver trap, and there is not about the analysis of effect of the by-pass pipe structure diameter on the flow field. Therefore, by the finite element software, the distribution of flow field inside the pig receiving trap, namely the pressure, flow velocity, turbulence kinetic energy changes were analyzed. Besides, the changing rule of the flow field was analyzed when the by-pass pipe diameter D is 200 mm, 250 mm, 300 mm and 350 mm.

2 Mathematical Model

2.1 Computing Method

In Fluent software platform, the flow field of the pig receiving trap was analyzed. As the continuous medium, the gas flows continuously with the whole flow field. There is strong three-dimensional swirl turbulent motion in the gas transmission pipeline, thus the RNG k ~ epsilon turbulence model was used to simulate, and it meets conservation of mass and turbulent kinetic energy equation when the gas flows.

Mass conservation equation is also called the continuity equation, and it can be expressed as: the microelement quality increase in the fluid region unit time is equal to the quality flowing into the microelement at the same time. Mass conservation equation as follows:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho V) = S_m \qquad (1)$$

Where ρ is fluid density, kg/m^3; t is time, s; V is the velocity vector, m/s ; S_m is the quality of the continuous phase, kg.

Turbulent kinetic energy equation

$$\frac{\partial \rho K}{\partial t} + \frac{\partial \rho u_j K}{\partial x_j} = -\frac{\partial}{\partial x_j}[(\mu + \frac{u_t}{\sigma_k})\frac{\partial K}{\partial x_j}]$$
$$+u_t \frac{\partial u_j}{\partial x_j}(\frac{\partial u_j}{\partial x_j} + \frac{\partial u_i}{\partial x_i}) - \rho\varepsilon \qquad (2)$$

μ , u_t is laminar and turbulent viscosity coefficient respectively; k is the turbulent energy [8].

2.2 Geometric model

Using ProE software for structural modeling, because when making preparations for receiving the pig, all other valves of pig receiving trap will be closed, and only the by-pass pipe valve will be open. The by-pass pipe is used to connect the main ball tube and station pipeline, and when receiving the pig, fluid is flowed to the station, which can make the gas transmission operation be normal. Therefore, on the basis of strict accordance with oil and gas pipelines design drawings of pig launcher & receiver, the model was simplified, and the structure diagram is shown as figure 1. Its structure size is shown in table.

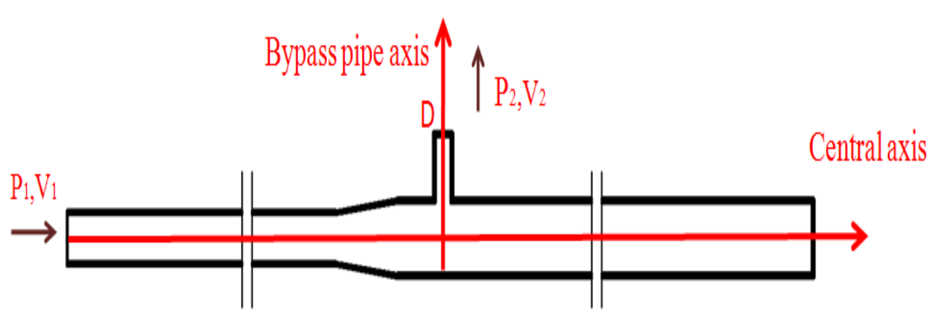


Figure 1 Flow field diagram

Table 1 Model Calculated Parameters

Fluid density /kg·m^{-3}	**Fluid viscosity /10^{-5} Pa·s**	**Receiving trap Length /m**	**Nominal pipe diameter /m**
0.6679	1.085	11.20	0.45
By-pass pipe diameter /m	**Pressure condition/MPa**	**Inlet velocity /m/s**	**Outlet pressure /Pa**
0.25	12	3	101325

2.2 Boundary conditions

Meshed by mesh software, the model has 13019 nodes and 61318 units, and then it was simulated analysis by fluent software. Under the RNG k ~ epsilon turbulence model, the model boundary conditions were set the velocity-inlet (small ball tube entrance), normal temperature, and the inlet velocity is 3 m/s, and pressure condition is 12 Mpa. Methane gas whose density of 0.6679 kg/m^3, and dynamic viscosity is 1.087 x 10-5 Pa·s under standard condition has approximately instead of natural gas. Export condition (exports of by-pass pipe) is set the pressure-outlet, the pressure is 101325 Pa. The wall boundary condition is no slip, and a standard wall function is calculated near the wall region. The model uses finite volume method to establish equations, and solves the control equation combination with the QUICK difference scheme and SIMPLE algorithm. Figure 2 is the finite element model after meshing.

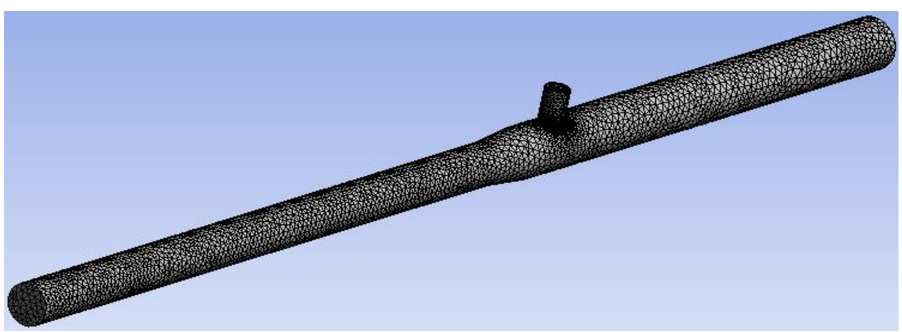


Figure 2 Finite element model

3 Results and Analysis

3.1 Flow Field Distribution

The static pressure nephogram of pig receiving trap is shown in figure 3.The static pressure is four clear regional distributions in the interior of pig receiving trap, namely the small ball tube, reducer, the main ball tube and the by-pass pipe. Within the small ball tube, the pressure is bigger, because the tube structure is uniform, and after the fluid enters the small ball tube, there is just relatively small turbulence. However, in the reducer, due to the structural change slightly, the turbulence intensity increases, and pressure decreases, and then after the fluid arrives at the by-pass pipe, circulation diameter decreases, thus the fluid is squeezed, and energy loss is bigger. Besides, the flow direction changes, namely changing the momentum, thus the fluid pressure loss increases, and the pressure significantly decreases. What’s more, within the main ball tube, just only a little fluid flow, thus the turbulence is very small and the pressure is the maximum.

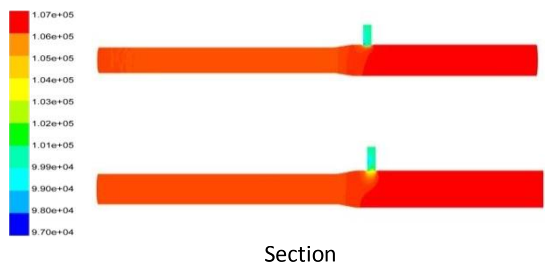


Figure 3 Static pressure nephogram

The velocity nephogram of pig receiving trap is shown in figure 4. The velocity and pressure changes on the contrary, and in the small ball tube, the gas translates stably, and arriving at the reducer, the flow velocity begins to increase. Besides, in the by-pass pipe, the velocity is the maximum and the velocity of the right side is larger than that of the left side, because the flow direction changes, and the diameter changing direction on the left is small, and it of the right side is big, thus the buffer of the region that the diameter changing direction is small is small, and energy loss is great, and the velocity is small.

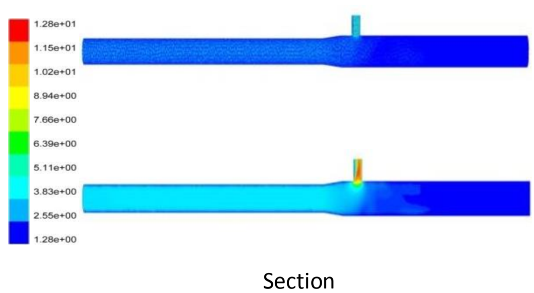


Figure 4 Velocity nephogram

The turbulence nephogram of pig receiving trap is shown in figure 5. There is the turbulent motion beginning at the entrance of small ball tube, because the pipe is gentle, turbulence kinetic energy gradually decreases. At the entrance of by-pass pipe, obvious vortex is produced, and turbulence kinetic energy is great, because the diameter and direction change, the pressure consumption increases, and the turbulence increase.

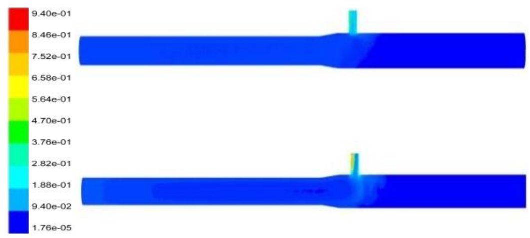
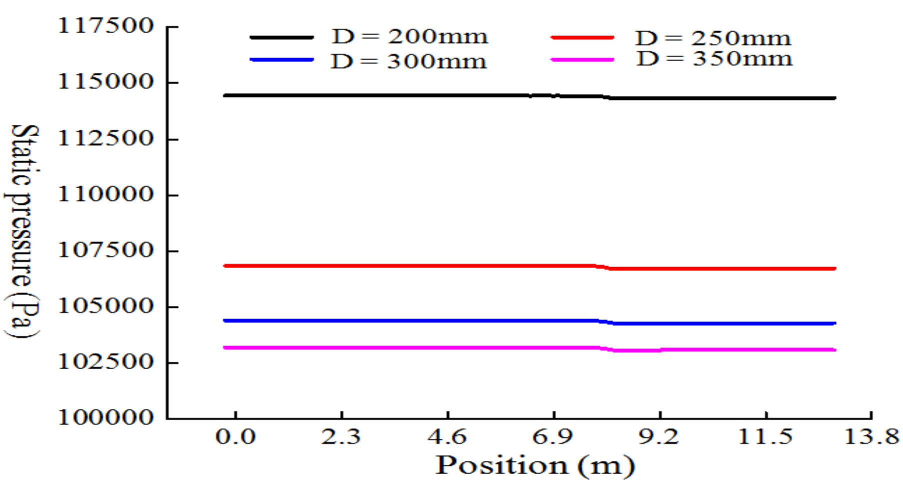


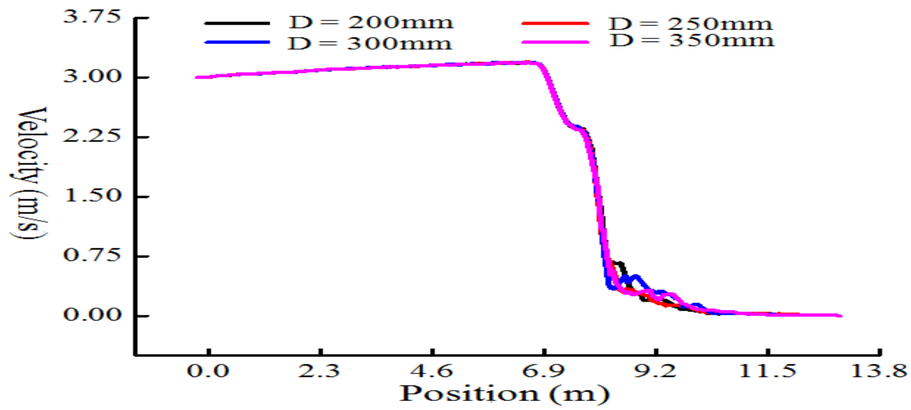
Figure 5 Turbulence nephogram

3.2 Effect of the by-pass pipe diameter

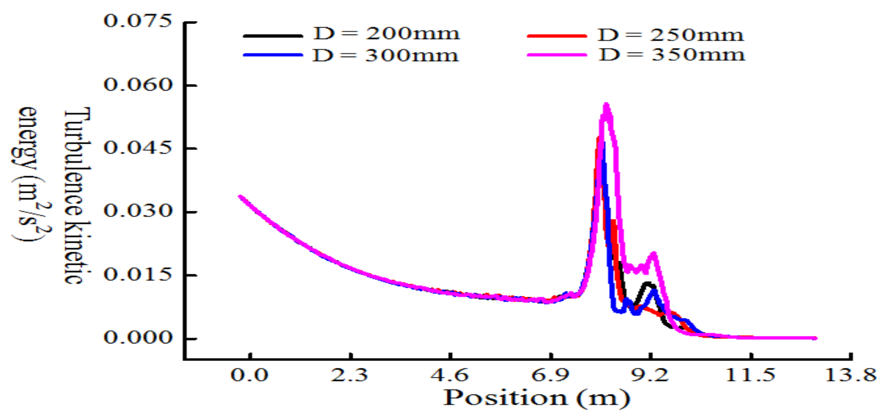
On the central axis, the change curves of the pressure, flow velocity and turbulence kinetic energy are shown in figure 6. In figure 6a, on the center axis, the pressure change is stable, and with the increase of the by-pass pipe diameter, the static pressure decreases, and the pressure change rate also decreases. In figure 6b, on the center axis, the diameter change of the by-pass pipe has a little effect on flow velocity. In figure 6c, in the position 8.1m, turbulence kinetic energy increases obviously, and with the increase of diameter, the turbulence kinetic energy increases, but the change is small.



a Static pressure



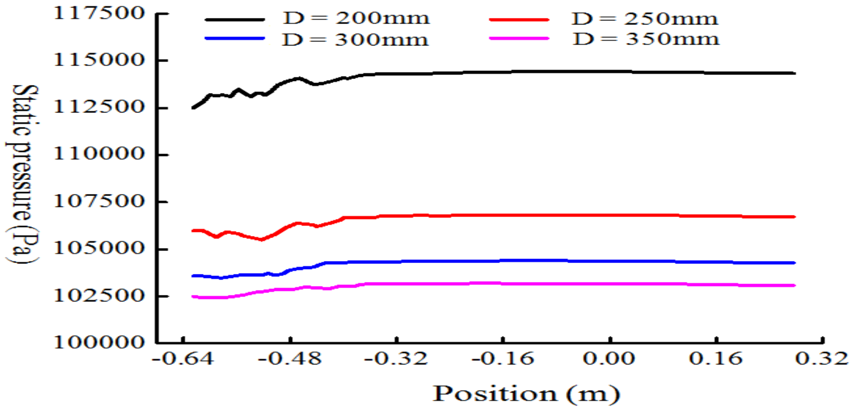
b Velocity



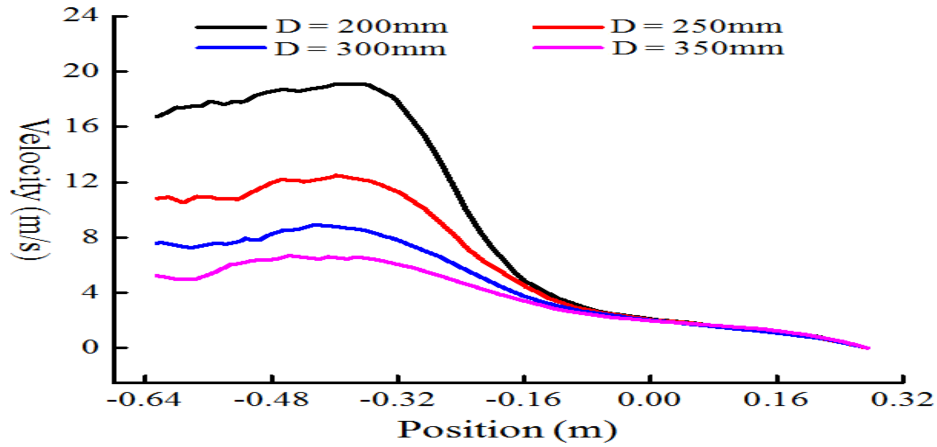
c Turbulence kinetic energy

Figure 6 Change curves of the flow filed on the central axis

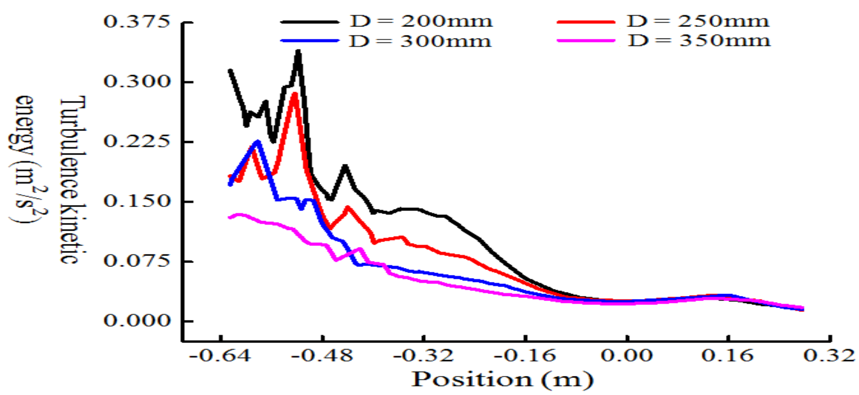
On the axis of the bypass pipe, the change curves of the pressure, flow velocity and turbulence kinetic energy are shown in figure 7. In figure 7a, in the position 0.4 m ~ 0.64 m (the by-pass pipe), there is a range of fluctuations of the pressure, and with the increases of by-pass pipe diameter, the pressure decreases, and the pressure change rate also decreases. In figure 7b, in the position -0.16m, the velocity begins to increase, and with the increases of by-pass pipe diameter, the velocity decreases, and the velocity change rate also decreases. In figure 7c, in the position -0.1m, the turbulence kinetic energy begins to increase, and in the position0.4 m ~ 0.64 m (the by-pass pipe), the turbulence kinetic energy increases obviously, and its fluctuation is larger. With the increases of by-pass pipe diameter, the turbulence kinetic energy decreases.



a Static pressure



b Velocity



c Turbulence kinetic energy

Figure 7 Change curves of the flow filed on the bypass pipe axis

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4 Conclusion

(1) The static pressure is four clear regional distributions in the interior of pig receiving trap, namely that the pressure within the main ball tube is maximum, and the pressure inside the ball tube is second, and that of reducer is the smaller, and pressure of by-pass tube is minimum. Besides, there is obvious vortex at the entrance of by-pass pipe, and the turbulence kinetic energy is greater.

(2) With the increase of the by-pass pipe diameter, the pressure decreases, and the pressure change rate also decreases. Besides, in the interior of small ball tube and main ball tube, the diameter change has a little effect on the velocity and turbulence kinetic energy. In the interior of the by-pass pipe, with the increase of the diameter, both the velocity and turbulence kinetic energy decrease, and the velocity change rate also decreases.

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