Study on Internal Flow Field of the Three-phase Separator with Different Entrance Components

Ping Yu\textsuperscript{a}, Shilei Liu\textsuperscript{*}, Yaohua Wang\textsuperscript{a}, Wei Lin\textsuperscript{a}, Zhihui Xiao\textsuperscript{a}, Chao Wang\textsuperscript{a}

\textsuperscript{a}College of Mechanical Science and Engineering, Jilin University, Changchun, 130025, China

Abstract

Apply Fluent to simulate the internal flow field of the three-phase separator with different entrance component as baffle-type, upper holes box type or lower holes box type. Then get the internal flow field velocity vector diagram of the three different situations. The result shows that the fluid motion is more stable when pass through the lower holes box type entrance component.

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Keywords: separator; entrance component; flow field

1. Introduction

With the increase of the water ratio in oil deposit and the emergence of alternative energy sources such as oil shale, the application of the three-phase separator increase gradually. After years of development, lots of new kinds of three-phase separator are appeared. And the performance is improving. But there are still some problems, mainly is poor universal, large equipment, low separation efficiency. One of the effective methods to solve the above problem is to select appropriate internal components and install them reasonably.

Entrance component is one of the basic components in the three-phase separator. It has two major functions: One is to change fluid speed, absorb certain of kinetic energy, thus reduce the impact to the flow field of the separator; the other is to achieve a certain degree of separation\cite{1}. This paper used the CFD...
method, applied Fluent to study the internal flow field of the three-phase separator with different entrance component as baffle-type, upper holes box type or lower holes box type. Provide some reference for choosing entrance component.

2. Solving domain meshing under different entrance component

According to the issue, the three-phase separator in this paper is relatively small. Specific dimensions are as follows: the cylinder body length is 874 mm, Both ends of the hemisphere diameter are 286mm, entrance diameter is 34mm, gas export diameter is 20mm, water export diameter is 20mm, oil export diameter is 20mm. The baffle-type entrance component is semicircle, radius is 100mm, thickness is 10mm, located 150mm at the rear section of the entrance. The holes box wall thickness of the upper holes box type entrance component is 10mm, bore diameter is 20mm. The structure of the lower holes box type entrance component is the same as the upper holes box type entrance component. But the installation position in separator is different. The structure of the baffle-type entrance component, upper holes box type entrance component and lower holes box type entrance component are shown in figure 1.

![Fig. 1. (a) Baffle-type entrance; (b) Upper holes box type; (c) Lower holes box type](image)

Apply the preprocessor Gambit 2.3 of the Fluent 6.3 to mesh the computational domain of the three-dimensional model. In order to get a higher quality of the grid, this paper used the unstructured adaptive grid. Grid type is TGrid. Interval Size is set to 5. Figure 2 shows the resulting grid.

![Fig. 2. (a) Baffle-type entrance; (b) Upper holes box type; (c) Lower holes box type](image)

The data produced by three kinds of entrance component grid partition is shown in table 1:

Table 1. The statistical data of entrance component grid partition.

| Entrance component name | Calculated regional total volume $m^3$ | Total grid | The biggest grid volume $m^3$ | Minimum grid volume $m^3$ | The biggest grid area $m^2$ | Minimum grid area $m^2$ |
|-------------------------|----------------------------------------|------------|-------------------------------|---------------------------|---------------------------|--------------------------|
3. Design conditions

3.1. Computation model

In this issue the flow of the oil, gas and water in the three-phase separator belongs to the turbulent flow. And there is no strong swirl. So the standard $k-\varepsilon$ model will be used as turbulence model. The control equations of the standard $k-\varepsilon$ model consist of continuity equation, momentum equation, energy equation, $k$ equation, $\varepsilon$ equation and turbulent dynamic viscosity $\mu$ function[2]. Mixture model will be used as multiphase flow model. To build the mixture model, the control equations need to include continuity equation, momentum equation, energy equation, second phase of the volume fraction equation and relative speed algebraic expression[3].

3.2. Boundary Conditions

Three-dimensional fluid simulation types of entrance boundary conditions in Fluent6.3 include inlet-vent, intake-fan, mass-flow-inlet, velocity-inlet and pressure-inlet[4]. In order to make the three-phase separator more stable, entrance boundary condition is set to velocity-inlet. The design requires that the mixture stay in separator for 10 minutes, The Inlet velocity is $v = 0.53 m/s$. The specific set of the entrance boundary conditions are shown in table 2.

| Name of boundary conditions | Numerical set |
|-----------------------------|---------------|
| operating pressure          | 690kPa        |
| inlet velocity              | $0.53 m/s$    |
| volume fraction of oil      | 45%           |
| volume fraction of gas      | 25%           |
| volume fraction of water    | 30%           |

4. The simulation results and analysis
The structure of horizontal oil-gas-water three-phase separator is symmetrical about the plane \( X = 0 \). Therefore, \( X = 0 \) cross-section is selected as the research section. Apply Fluent6.3 to simulate the internal flow field of the three-phase separator with different entrance component as baffle-type, upper holes box type or lower holes box type. The internal flow field velocity vector diagrams are shown in figure 3 (a), (b), (c).

Fig. 3. (a) Baffle-type entrance component; (b) Upper holes box type; (c) Lower holes box type

Velocity vector in \( X = 0 \) cross section shown in figure 3 shows that: speed reduced and direction changed when the liquid flow into the separator. The reason is that space volume suddenly increased and the speed of inertia reduced.

Baffle-type entrance component makes entrance fluid can’t directly impact the flow field of separate areas. But the fluid will produce relatively serious primary vortex in the separate areas after impact the baffle due to the cross-section effective flow area relatively reduced. The influence to the flow field of separate areas is relatively large.

Both of the upper holes box type and lower holes box type entrance components reduce the generation of primary vortex effectively. But they will produce a certain secondary vortex below or above the holes box. The influence to the flow field of separate areas is less than the baffle-type entrance component. But the separation of gas and liquid is slightly weakened.

Compare Figure 3 (a), (b), (c) we can get that the fluid motion in separate areas of the three-phase separator is more stable under lower holes box type entrance component.

5. Conclusion
Compared with the baffle-type entrance component, the holes box type entrance component reduce the generation of primary vortex. Though it will produce little secondary vortex, the influence to the separate areas is relatively small.

The flow pattern in the separate areas is more stable under lower holes box type entrance component.

Acknowledgment

This issue “Design of the Oil Shale Surface Acquisition System” comes from the special project of the Ministry of Education and the Ministry of Finance: country's potential oil and gas resources (oil shale exploration and exploitation) research projects(serial number of the project: OSR-06-04).

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