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Numerical Simulation Of Fluid Flow And Heat Transfer Of Supercritical Pressure

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Abstract— **In this paper, Fluent software turbulence model *k*-w SST proposed near the critical temperature of the water flow and heat transfer numerical simulation, comparative analysis of the spiral bellows and smooth tube axial direction speed, temperature, on the wall distribution of temperature were studied. And the effect of inlet temperature, inlet velocity of axial velocity and temperature distribution were analyzed. The study found that in the proposed critical temperature region, spiral bellows inside the center exhibits a low speed gradually increased along the wall, close to the wall when the change occurred at the trend decline.**

Keywords—component; supercritical pressure, turbulence model k-w SST, spiral bellows

I. INTRODUCTION

Terms of thermal efficiency, supercritical unit were significantly higher than subcritical unit, can better save energy, but also can play a role in reducing pollution. Supercritical state, in the vicinity of the proposed critical temperature, water physical properties (density, specific heat, thermal conductivity, viscosity), and other parameters change severely [1], the corresponding heat transfer rules change. Study on the supercritical pressure fluid flow and heat transfer of more and more [2-6], but less velocity changes of the temperature of the inner tube in the axial direction. In this paper, under supercritical pressure, flow and heat transfer in the case of a vertical upward flow of fluid within the heat pipe to simulate, understand the changes in temperature and velocity within the tube axial direction, factors affecting the flow of heat transfer analysis.

II. CALCULATION MODELS AND METHODS

II.1GEOMETRIC MODEL

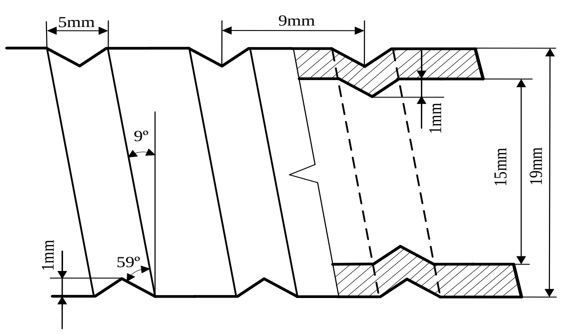


Figure 1: a schematic view of spiral bellows geometry

Spiral bellows structure calculated using the (19 × 2000mm, thickness 2mm, the pitch of 9mm, the thread width 5mm, thread groove depth 1mm), as shown in figure. In this paper, in order to reduce the amount of calculation, the wall thickness is ignored, and will shorten the length of 400mm. By contrast the smooth pipe wall thickness is also ignored, reduced to a 15 × 400mm fluid domain. Z direction (vertical direction) to the direction of fluid flow (referred axial direction), and the remaining two directions is called radially.

II.2 MESHING

Gambit software using geometric modeling and meshing, meshing using Cooper way, under turbulent state, we need to encrypt the grid near the wall. According to the first layer of mesh boundary layer height calculation of setting the near wall region, keeping y^+ <1. Grid computing spiral bellows number is 343980, the number of grid computing smooth tube to 210245.

II.3 MATHEMATICAL MODEL

Heat transfer fluid flowing in the pipe to meet mass, momentum, energy conservation equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \qquad (1)$$

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v} \vec{v}) = -\nabla p + \nabla \cdot \left[(\mu_1 + \mu_t) \left((\nabla \vec{v} + \nabla \vec{v}^T) - \frac{2}{3} \nabla \cdot \vec{v} I \right) \right] + \rho \vec{g} \qquad (2)$$

$$\frac{\partial \rho h}{\partial t} + \nabla (\rho h \vec{u}) = \nabla \cdot \left[(k_{eff} \nabla T) + \vec{u} (\mu_1 + \mu_t) \left((\nabla \vec{v} + \nabla \vec{v}^T) - \frac{2}{3} \nabla \cdot \vec{v} I \right) \right] \qquad (3)$$

Where: k_{eff} is the effective turbulent heat transfer coefficient. Turbulence model *k*-w SST using equation model, with its turbulent kinetic energy dissipation rate equation

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left(\Gamma_k \frac{\partial k}{\partial x_j}\right) + \tilde{G}_k - Y_M + S_k \quad (4)$$

$$\frac{\partial}{\partial t}(\rho \omega) + \frac{\partial}{\partial x_i}(\rho \omega u_i) = \frac{\partial}{\partial x_j}\left(\Gamma_k \frac{\partial \omega}{\partial x_j}\right) + G_w - Y_w + D_w + S_w \quad (5)$$

II.4 CALCULATION CONDITIONS

Where: Γ_k and Γ_ω represent the effective diffusion coefficient, σ_t and σ_ω represent the turbulent Prandt number, the transport equation $\tilde{G}_k$ and G_ω denote turbulence generation items, Y_k and Y_ω represent the turbulent dissipation rate items.

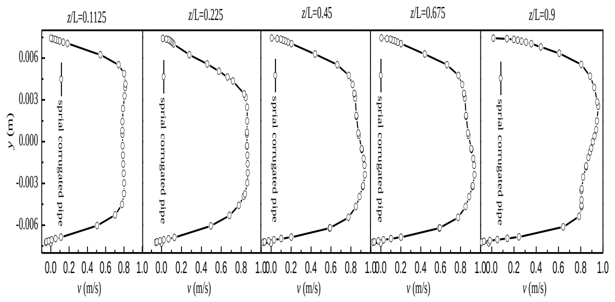
Selection Fluent software turbulence model *k*-w SST to simulate spiral bellows. Entry conditions for speed entrance, the wall is constant heat flux conditions, given the heat flux q = 0.4 MW/m^2, the outlet is set to pressure outlet, the outlet pressure 26 MPa (actual pressure), gravitational acceleration g = 9.8 m/s^2, physical properties parameters according to REFPROP software to get the value, according to the way a given polynomial interpolation.

III. COMPARISON AND ANALYSIS RESULTS

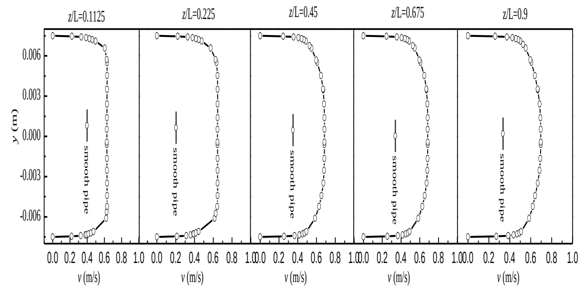
Comparative results will be compared mainly along the axial direction of the velocity distribution and temperature distribution under the bellows and smooth spiral tube in the axial direction and velocity and temperature and different inlet velocity and inlet temperature.

III.1SMOOTH PIPE SPIRAL BELLOWS CONTRAST

Inlet velocity v = 0.6 m/s, the wall heat flux q = 0.4 MW/m^2, an inlet temperature of T = 600 K, respectively spiral bellows and smooth tube numerical simulation, taken along the flow direction of their cross-sectional axis 5 analyze the velocity and temperature.



(a) spiral bellows



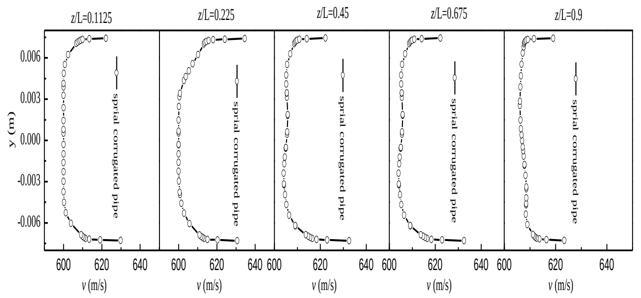
(b) Smooth Pipe

Figure 2: spiral tube axial bellows and smooth speed changes

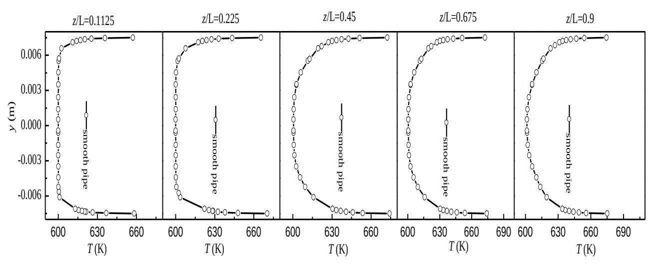
Figure 2 shows the variation of spiral bellows and smooth tube axial velocity. As can be seen from the figure, in the inlet section, spiral bellows and smooth tube axial velocity near the pipe center position remained unchanged, after flowing a distance, the axial velocity radial change began to appear, smooth round after the pipe flow stability. Its axial velocity distribution of basic axisymmetric shape does not change. Helically corrugated tube axial velocity is greater than the smooth tube axial velocity, the heat boost. Compared with the smooth tube, spiral bellows axial intermediate section in the flow velocity distribution is essentially the same, but the speed at one side of the tube exhibits a greater axial velocity, and in the cross-sectional velocity increases after the region has moved to the other side of the tube, since every integer number of cycles to be selected cross-section, so there should be such a change because of the impact of the effect.

Figure 3 shows the variation of spiral bellows and smooth tube axially temperatures. As can be seen from the figure, in the inlet section, spiral bellows and smooth tube temperature in a central location near the tube remained unchanged, after flowing a distance, radial axial temperature changes began to show, in a smooth tube after the import segment, the temperature in the axial direction does not change the basic distribution symmetrical shape.

Compared with the smooth tube, spiral bellows in temperature distribution in the cross section asymmetry along the flow direction, the asymmetry is more pronounced.



(a) spiral bellows



(b) smooth tube

Figure 3: Spiral bellows and smooth tube axial temperature change

III.2 INLET VELOCITY OF IMPACT

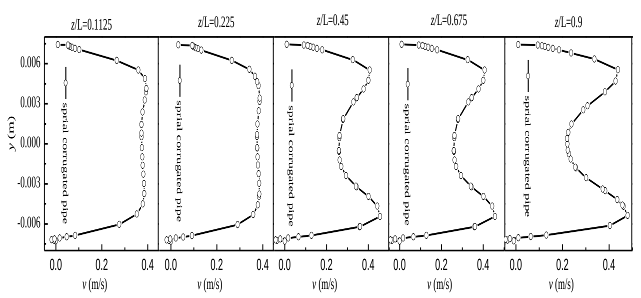


Figure 4: Spiral bellows v = 0.3 m/s axial velocity change

Take the inlet velocity v = 0.3 m /s, the wall heat flux q = 0.4 MW/m^2, an inlet temperature of T = 600 K. Numerical simulation of velocity and temperature distribution is as follows.

Figure 4 shows the spiral corrugated pipe inlet velocity v = 0.3 m/s axial velocity changes. As can be seen from the figure, the v = 0.3 m/s, the speed of the import segment in the control center changed little, while flows to the middle of the pipe section location, speed pipe center decreased, while in the center and near the tube wall zone appears faster than the velocity of the fluid around the area, and has been increasing along the pipeline, from the center to the wall of the pipe direction, the speed decreases rapidly after the first increase.

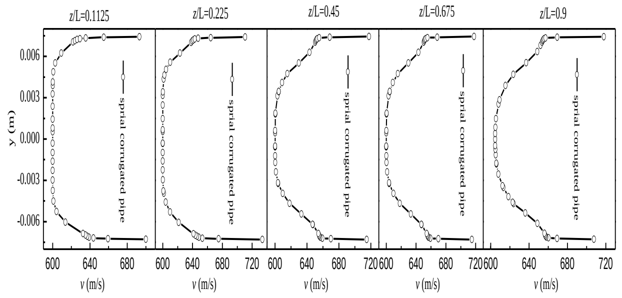


Figure 5: spiral bellows v = 0.3 m/s along the axial temperature change

Figure 5 shows a helical bellows inlet velocity v = 0.3 m/s temperature changes in the axial direction. As can be seen from the figure, in a direction close to the center of the pipe wall, it presents a substantially parabolic temperature distribution in the near wall region, rapid temperature rise. Inside you can see, at a temperature of presenting parabolic trends range, the temperature will rise to pseudo-critical temperature, the viscosity of the fluid at this time a sharp decline sharply reduced density, buoyancy of flow and heat transfer plays an important role, control the axial velocity profile can be seen, the temperature reached the axial velocity increases proposed critical temperature distribution area appears.

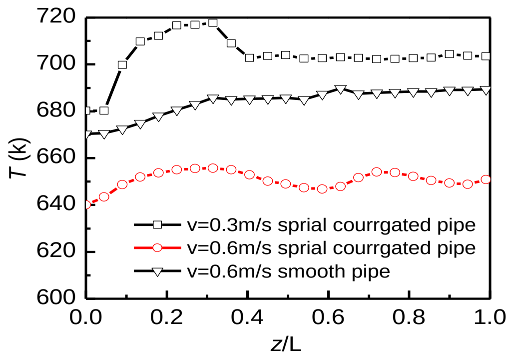


Figure 6: axial wall temperature change

Figure 6 shows the variation of the wall temperature along the axial direction. As can be seen from the figure, the inlet v = 0.3 m/s, the flow in the first half of the wall temperature first increases and then decreases, then essentially unchanged. Inlet velocity v = 0.6 m/s, the axial direction, the wall temperature change in volatility, but the change is better entrance v = 0.3 m/s when the variation is large, the flow in the second half did not occur after a relatively stable wall temperature, still in the small-scale fluctuations which, after the speed increases the wall.

III.3 EFFET OF INLET TEMPERATURE

Take the inlet velocity v = 0.6 m/s, the wall heat flux q = 0.4 MW/m^2, an inlet temperature of T = 630 K, temperature and velocity distribution of the numerical simulation shown in figure 7 and figure 8.

Figure 7 shows the inlet velocity v = 0.6 m/s temperature variation in the axial direction of s spiral bellows. As can be seen, the temperature profile exhibits a substantially lower middle, both sides of the high trends, along the axial direction; the temperature is gradually increased, in the radial direction, an asymmetric temperature distribution, a greater temperature gradient in a position close to the wall. Compared with figure 3 can be found at the inlet temperature, the temperature range in the radial direction is increased, the temperature distribution of the asymmetric type enhancement.

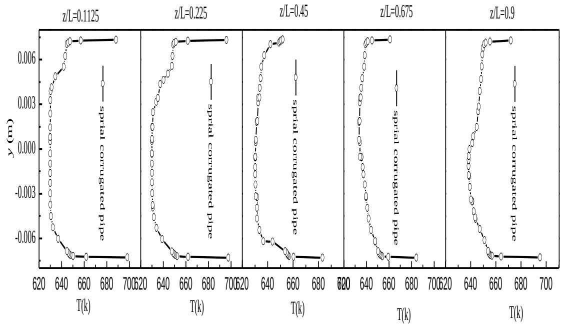


Figure 7: spiral bellows v = 0.6 m/s along the axial temperature distribution

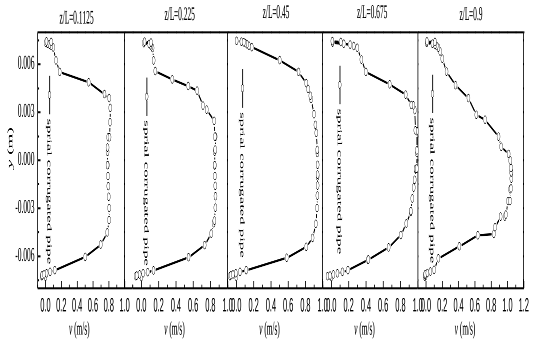


Figure 8: spiral bellows v = 0.6 m/s axial velocity distribution

Figure 8 shows the inlet velocity v = 0.6 m/s variation of axial velocity spiral bellows. As can be seen, on one side of the spiral bellows, the presence of the wall of the inlet section located close to a position of relatively small velocity gradient along the direction of flow, where disappeared reappears after this region. Along the flow direction, velocity control center position changes in the radial direction increases. Comparison can be found in Figure 2, when the inlet temperature increases, the axial velocity is increased slightly.

IV CONCLUSION

The same conditions, helically corrugated pipe wall temperature significantly lower than the smooth tube. Spiral bellows, with the increase of inlet velocity, the wall temperature is lowered. In the proposed critical temperature region, spiral bellows inside the center exhibits a low speed gradually increased along the wall, close to the wall when the change occurred at the trend decline.

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