The flow characteristics of two loop tubes in junction at ends

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Aiming at the flow characteristics of tubes, this work analyzed the different cases of inner flow in loop tubeby CFD, and the cases were determined according to the different radius of tube section. The CFD analysis results show that with the increase of radius, the highest velocity at mixing point decreases with a maximum value of 45.22%, but increase at the outlet with a maximum value of 4.79%. There are nonlinear change of flow velocity at the inlet and outlet, and the velocity in the tubes is layered vertically.

Keywords: Tubes; Loop; Conjunction; CFD analysis.

1. Introduction

The flow in parallel pipes exists widely in boilers, steam generators, heatexchanger, boiling water reactors and other devices [1-4]. To understand such manifold or a geometric structure, a lot work has been done to study the flow distribution among the branches and some other hydraulics characteristics like the static pressure, flow resistance and so on. These hydraulic problem affect the flowing, dynamics, and economics of tubes. This is the point why the global analysis comes into the topology of such manifolds [5-7].

In this paper, it sounds quite natural to look at the fluid motions on a manifold to analyze the tube structure. A diffluence-concourse flow in round tubes is modeled. The inlet flow is constant, after the start, the tube is branched, and mixed before the outlet. The fluid velocity distribution is worked on in this paper.

2. The flow distribution problem in manifold tubes

The flow in manifold tubes is hard to control, it is usually non-uniform. Such performance can cause trouble in engineering. If the pressure distribution in tubes is like, with a constant pressure differential. So the flow in tubes is the same with each other. But the pressure distribution in tubes is always unlike, and the pressure differential is different from each other, so the flow is unlike with the same value. In engineering, there are fluid kinetic energy, pressure energy and fluid resistance in tubes, and the vortex always appears at the dividing and combining manifolds. The nonlinear of tube flow is caused by such factors. In this paper, a manifold with two loop tubes in conjunction at ends is modeled to study the fluid characteristics, shown in Fig.1.

A simple energy control equation can be used to describe the flow in manifolds. At the dividing part,

$$z_0+\frac{p_0}{\rho g}+\frac{\alpha_0 v_0^2}{2g}=z_1+\frac{p_1}{\rho g}+\frac{\alpha_1 v_1^2}{2g}+h_{w0-1} \quad (1)$$

$$z_0+\frac{p_0}{\rho g}+\frac{\alpha_0 v_0^2}{2g}=z_2+\frac{p_2}{\rho g}+\frac{\alpha_2 v_2^2}{2g}+h_{w0-2} \quad (2)$$

At the combining part,

$$z_1+\frac{p_1}{\rho g}+\frac{\alpha_1 v_1^2}{2g}=z_3+\frac{p_3}{\rho g}+\frac{\alpha_3 v_3^2}{2g}+h_{w1-3} \quad (3)$$

$$z_2+\frac{p_2}{\rho g}+\frac{\alpha_2 v_2^2}{2g}=z_3+\frac{p_3}{\rho g}+\frac{\alpha_3 v_3^2}{2g}+h_{w2-3} \quad (4)$$

Where, z0 is the inlet tube, z1 is the tube 1, z2 is the tube 2, z3 is the outlet tube.

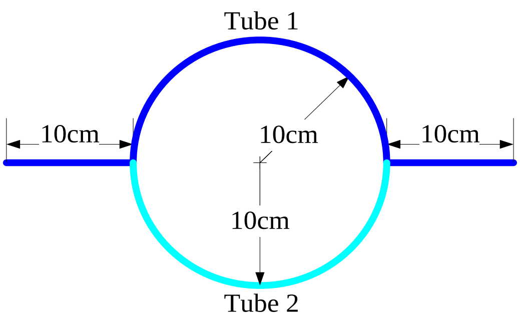


Figure.1 The analysis tubes flow model

2.1 Modeling and flow analysis of tube

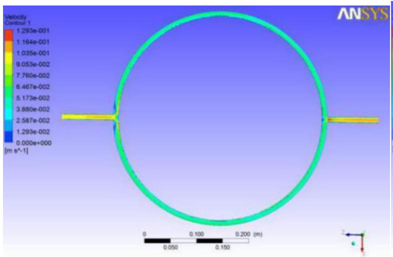
The inlet mass flow is constant 5 g/s,with constant temperature 25°C, and the tube wall is adiabatic. The analysis substance is water, with its default setting. The tube dimension is shown in Fig.1, and the radius of two tubes are shown in Table.1, so the analysis cases are done.

Table1 Analysis cases

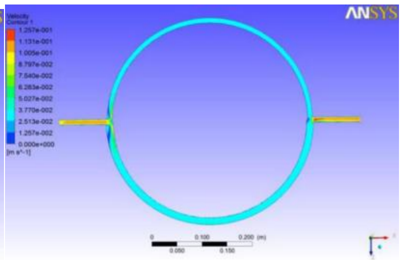
case	r-tube1	r-tube2
1	5mm	5mm
2	5mm	7mm
3	5mm	9mm
4	5mm	10mm

3. CFD Calculation and Analysis

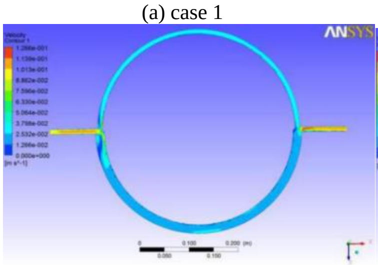
CFD analysis is available by ANSYS software, the tubes are modeled directly and the flowing parameters are set. The velocity distribution cloud is shown in Fig.2. There are velocity changes in the inlet branches, and the lowest velocity region is beside the inlet.



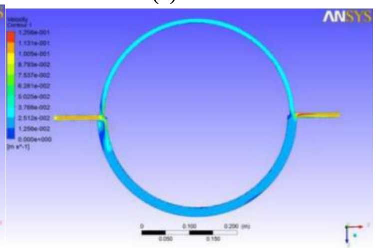
(a) case 1



(b) case 2



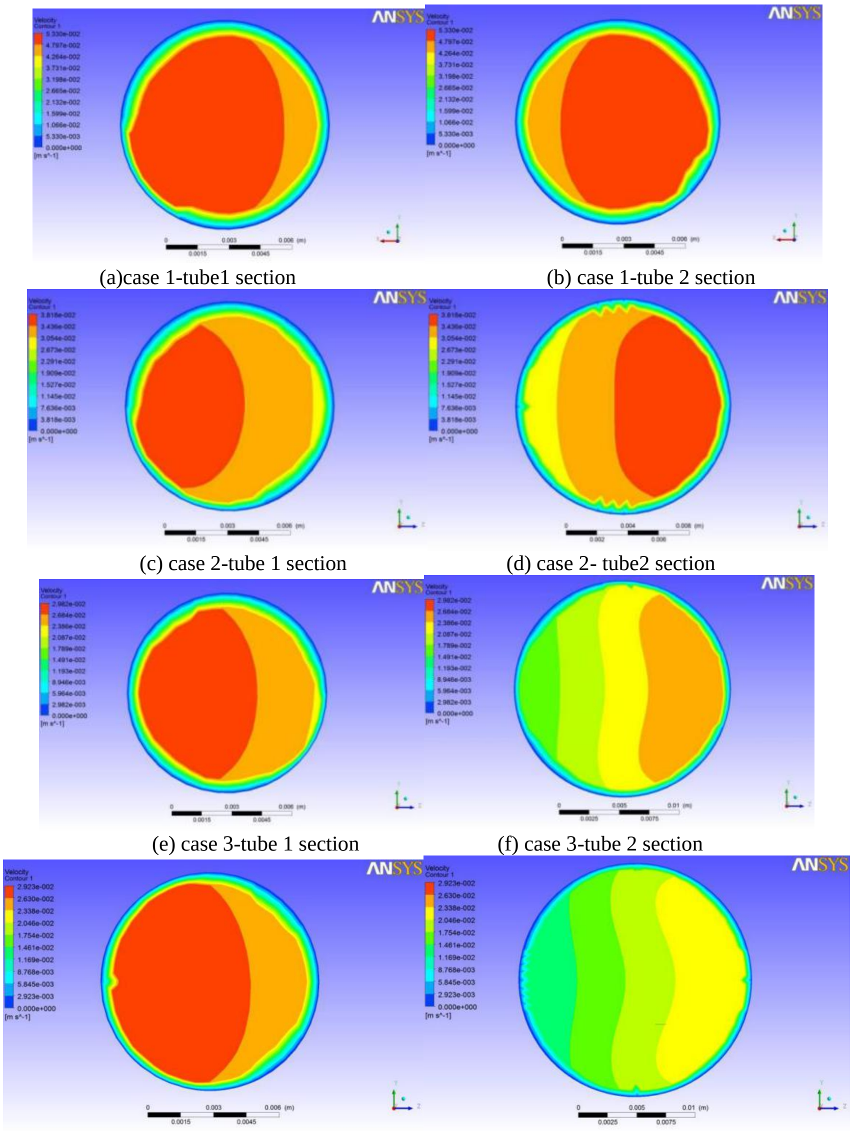
(c) case 3



(d) case 4

Figure.2 The inner velocity cloud of tubes in horizontal plane

At the starting of branch tubes, there are a flow region with minimum velocity, and such region of tube 2 is broadened with the increase of tube 2radius. Before the outlet, the two flow mix at the concourse point, and there are highest velocity point just after the concourse. At this time, the highest velocity is 12.93mm/s, 12.57mm/s, 12.66mm/s and 12.56mm/s for case 1, case 2, case 3 and case 4 respectively. And the velocity of mixing point is always more than the branching point, the velocity varies non-linearly in such tubes.



(a)case 1-tube1 section (b) case 1-tube 2 section

(c) case 2-tube 1 section (d) case 2- tube2 section

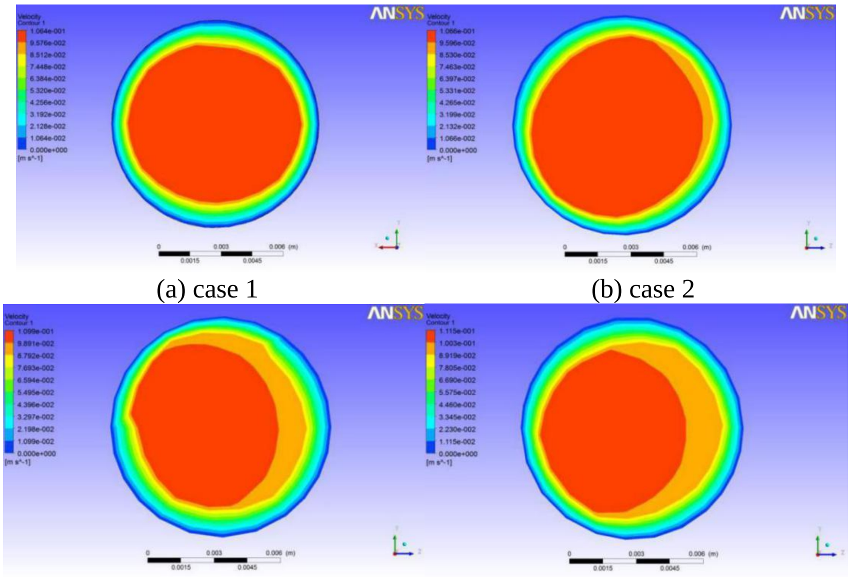
(e) case 3-tube 1 section (f) case 3-tube 2 section

(g) case 4-tube 1 section (h) case 4-tube 2 section

Figure.3 The inner velocity cloud of tubes in middle section plane

The velocity of middle section of two tubes of each case are shown in Fig.3, and the fluid velocity of different cases is apparent. There are symmetry velocity distribution when the tube 2 has the same radius with tube 1 in case 1, and the highest velocity of such region is 5.33 mm/s, both with a high velocity region located outwards.

With the increase of tube 2 radius, the high velocity of tube 1 and tube 2 decrease in case 2, the high velocity region of tube 1 shrinks largely, both with the highest velocity region of 3.82 mm/s in case2.



(a) case 1 (b) case 2

(c) case 3 (d) case 4

Figure.4 The outlet velocity cloud of tubes

For the case 3, there is only one highest velocity region of 2.98 mm/s in the tube 1, the maximum velocity in tube 2 is only 2.68 mm/s. The distribution is the same in case 4 with highest velocity 2.92 mm/s in tube 1, and 2.34 mm/s in tube 2.

From the velocity distribution clouds, it is well known that the velocity layered vertically. The highest velocity of tube section decrease with 28.33%, 44.09% and 45.22% for case 2, case 3 and case 4 than that of case 1. As for the highest velocity of tube 1 and tube 2 in the same case, it is the same for case 1 and case 2, but for case 3 and case 4 there are a large differences of 10.07% and 19.86% between tube 1 and tube 2.

The velocity distribution at outlet is shown in Fig.4, the highest velocity region moves left with increase oftube 2 radius. The highest velocity is 10.64mm/s, 10.66mm/s, 10.99mm/s and 11.15mm/s for case 1, case 2, case 3 and case 4 respectively. The largest increase is 4.79%.

4. Conclusion

Aiming at thediffluence-concourse flow characteristics of round tubes, the different cases of tube inner flow are analyzed by CFD with the increase of tube radius.

The velocity is nonlinear in cases. With the radius increase of tube 2, the velocity in it decrease and the largest decrease is 45.22% in analysis cases between case 1 all with radius 5mm and case 4 with one radius 5 mm and one radius 10mm. But the outlet velocity is not the same, the highest velocity is 11.15mm/s in case 4, more than case 1 with 4.79%.

The velocity distribution cloud also show the symmetry change into asymmetry with the increase of tube 2 radius. So the manifold of tubes in fact would affect the inner flow filed distinctly.

Acknowledgements

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References

[1]. Yoshihiko Mitsumatsu. Helicity in differential topology and incompressible fluids onfoliated 3-manifolds. Procedia IUTAM, (2013)7:167-174.

[2]. Celso Recalde, Cesar Cisneros, Carlos Avila, etc. Single phase natural circulation flow through solar evacuated tubes collectors on the equatorial zone. Energy Procedia, (2015)75:467-472.

[3]. J. Zhou, S. Wang, L.Gao, etc. Study on Flow Instability inside Multiple Parallel Pipes of DirectSteam Generation, Energy Procedia (2015)69:259-268.

[4]. Yang Cheng, Liu Hongzhao, Yuan Daning. The flow characteristics analysis and uniform flow rates model designation for parallel tubes. Acta Energiae Solaris Sinica, (2015),36(7):1573-1578.(In Chinese)

[5]. BIE Yu, HU Ming-fu, MAO Wen-yuan, etc. Mathematical model for uniform flow distribution in manifolds. Journal of Chinese Society of Power Engineering,(2011),31(4):279-284.(In Chinese)

[6]. J.T. Ottesen. Valveless pumping in a fluid-filled closed elastictube-system: one-dimensional theory with experimental validation. Mathematical Biology, (2003)46:309-332.

[7]. LUO Yong-hao. Experimental study of applying a swirl generator to control the flow distribution in manifolds. Power Engineering, (2000), 20(4):750-753.(In Chinese)