Numerical study of parallel pipeline homogeneous Flow Model

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Abstract. To research the parallel pipeline system of household solar collector pipelines,we use the FLUENT software to simulate the parallel tubes numerically .We proposed that we can reduce the pressure drop and improve the flow distribution uniformity of parallel tubes by changing the connection angle. Comparing the pressure drop of import and export and branch pipe flow, we calculated the changes of pressure drop and Average flow property. The maximum flow deviation coefficients are decreased obviously under three different mass and flow after change the angel between the pipe and branch pipe, which provides a method to design the parallel pipeline in the future. At the same time, we calculate out that reducing the number of branch pipe can also improve the uniformity of flow distribution.

1. Introduction

Parallel pipeline is an important part of the solar heat exchanger, which uniformity of flow distribution directly affect solar heat collecting efficiency of the heating system. The flow deviation can cause the uneven distribution of heat, not only to reduce the thermal efficiency, but also caused the damage of the heat exchanger.

Many scholars at home and abroad have studied on the flow characteristics of parallel tubes. Bie Yu, Hu Mingfu established a momentum balance method flow based on uniform discrete mathematical model, and proposed that increasing the resistance element can make the appropriate flow uniformity decreases by an order of magnitude. Yang Cheng proposed to increase or decrease the diameter of branch pipe diameter to improve the flow distribution of parallel tubes by numerical simulation. Jorge Facao put forward increasing the outlet pipe diameter greater than the diameter of inlet pipeline, the flow distribution is more uniform,by both experimental and numerical methods.

At present the parallel pipelines most adopt the branch pipe and pipe vertical connection structure, according to the theory of fluid mechanics, when vertical connection local loss coefficient is the largest, but there is no people to carry out related research on the set of connected angel between the pipe and branch pipe of parallel pipelines pressure and flow.

This article simulated on the flat panel solar set of parallel heat exchanger pipelines which is the current market commonly used , calculated the import and export flow uniform effect of parallel piplines with the change of connecting angle and the pipe diameter .

2. Organization of the Text

2.1 Physical Model

Use the common flat plate solar collector parallel pipeline as the object, its geometric model is shown in Figure 1.The parallel pipelines consists of the diversion pipe, bus pipe and 7 branch pipes.

The water from the inlet flow into the diversion pipe, then split-flow through the 7 branch pipes, and outflow from the outlet in the collection pipe after confluence in the bus pipe. Before the simulation, we make the following assumptions:(1)The fluid is incompressible liquid water, and flow in the pipe under a certain temperature; (2) mother pipe and pipe were as a uniform circular pipe, and pipe distributes uniformly;(3) friction coefficients of mother pipe and pipe are equal everywhere; (4) pressure and temperature is unchanged.

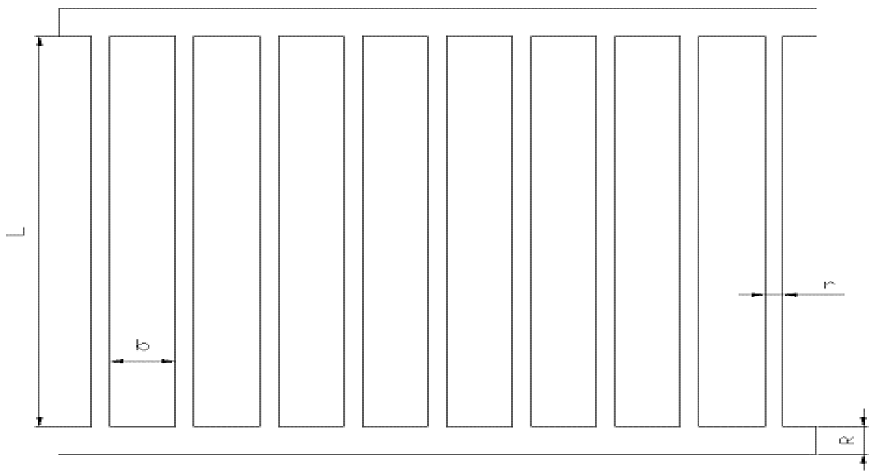

Fig.1 Dull solar energy parallel pipe manifold structure drawing

2.2 Mesh division

We use Gambit to establish the 3D model of parallel tube . the fluid in set of pipe and pipe connection flow is complex, but the straight pipe flow is relatively simple, sowe use unstructured mesh int the connecting between the collecting pipe and pipe which is as shown in Figure 2, and straight pipe section area uses a structured grid to represent. In order to ensure the accuracy,and validate grid independence, we simulate on four groups number of grid when the parallel tube group import mass flow is constant for the 0.04kg/s , and the last two grid pressure difference is less than 1%. Considering the accuracy and computational cost, we choose 3540135 number to calculate.

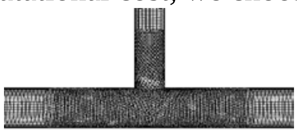

Fig. 2 Header and branch attachment point grid chart

2.3 Boundary conditions

After the Definition of boundary conditions, we input grid file into fluent. Due to the fluid motion of isothermal, we chose not to the energy equation, but to adopt the fluent to solve the three-dimensional N-s equations. And the fluid flow in the shunt and confluence region is complex, so the standard turbulence model is adopted, and we use the simple pressure correction algorithm for computing. We calculated under three situation when inlet mass flow is 0.04 kg / s, and 0.08kg/s 0.06kg/s respectively.

2.4 Evaluation index of average flow

In order to evaluate the pipe flow distribution uniformity of parallel ,we definite the uneven flow distribution coefficient:

$$\eta_i = nm_i / \sum_{i=1}^{n} m_i$$

themaximum flow deviation coefficient is defined as:

$$\Delta\eta = (\eta_{\max} - \eta_{\min}) \times 100\%$$

2.5 Changing the angle of pipe and pipe connection point

static pressure distribution of diffluenceand confluence parent tube will affectthe flow distribution in the parallel tube group directly .According to the theory of fluid mechanics, reducing the angle between the branch and the parent tube, local resistance can be reduced, which will result that the static pressure changes of the tube decreases. Based on this ,we put forward a method by changing the angle of pipe and pipe connection point to improve the parallel the uniformity of flow distribution.

We take the step length is 5 degrees, keep the length of pipe as a constant,. And calculated the import and export pressure difference and flow uniformity by changing connecting angle from 90 degrees to 30 degrees, . For convenience, we definite the inclination as branch pipe and a collecting pipe angle.

When Mass flow is 0.04kg/s ,the flow of each branch pipe and the maximum flow deviation factor are as table 1 shown. We can figure out that the maximum flow deviation coefficient gradually decreases as the angle between branch pipe and the vertical increases. The maximum flow deviation coefficient decreases by 4.27%than the vertical connection , and flow uniformity decreases by 47.2% compared with 90 degrees

Table 1

θ / o	The mass flow of each branch pipe (kg/s)							The maximum flow deviation coefficient
90	0.005765	0.005659	0.005582	0.005612	0.005702	0.005858	0.006102	9.04%
85	0.005799	0.005641	0.005601	0.005606	0.005694	0.005843	0.006090	8.50%
80	0.005819	0.005658	0.005599	0.005606	0.005664	0.005847	0.006084	8.43%
75	0.005868	0.005682	0.005589	0.005582	0.005655	0.005812	0.006046	8.07%
70	0.005857	0.005685	0.005597	0.005587	0.005657	0.005804	0.006047	8.00%
65	0.005879	0.005706	0.005595	0.005590	0.005653	0.005788	0.006025	7.57%
60	0.005910	0.005730	0.005613	0.005585	0.005633	0.005759	0.005966	6.63%
55	0.005926	0.005707	0.005614	0.005599	0.005655	0.005770	0.005949	6.09%
50	0.005901	0.005731	0.005628	0.005602	0.005632	0.005740	0.005929	5.70%
45	0.005897	0.005734	0.005643	0.005612	0.005646	0.005741	0.005894	4.97%
40	0.005893	0.005728	0.005637	0.005611	0.005636	0.005722	0.005890	4.92%
35	0.005884	0.005733	0.005638	0.005609	0.005648	0.005724	0.005868	4.80%
30	0.005880	0.005729	0.005643	0.005607	0.005638	0.005728	0.005861	4.77%

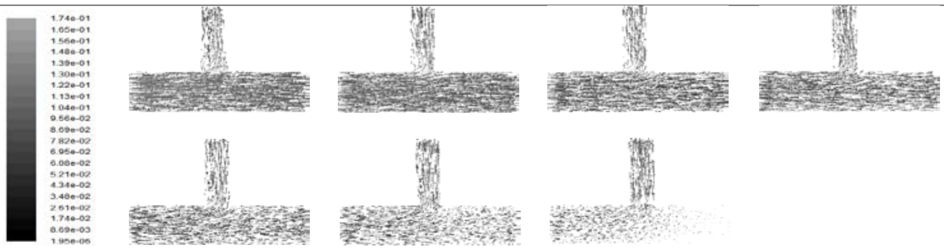

Fig.3

Parallel tubes in the shunt of fluid velocity and static pressure will have obvious change. Branch and the parent tube of the shunt velocity vector diagram as shown in Figure 3 connected vertically , the former four tubes in shunt exist certain vortex area, and the vortex area gradually disappeared as the the flow rate of the fluid decreases . the vortex will increase the flow resistance. branch pipe and the vertical direction angle for the velocity vector diagram is as shown in Figure 4 shunt 60 degrees, there is no obvious vortex area and branch pipe inlet velocity distribution is more uniform compared with 90 degree .

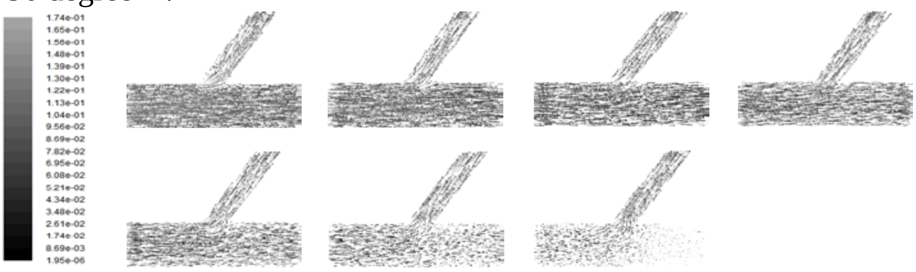

Fig.4

Under three different mass flow, the fitting curve of maximum flow deviation coefficient with angle is shown as figure 5.

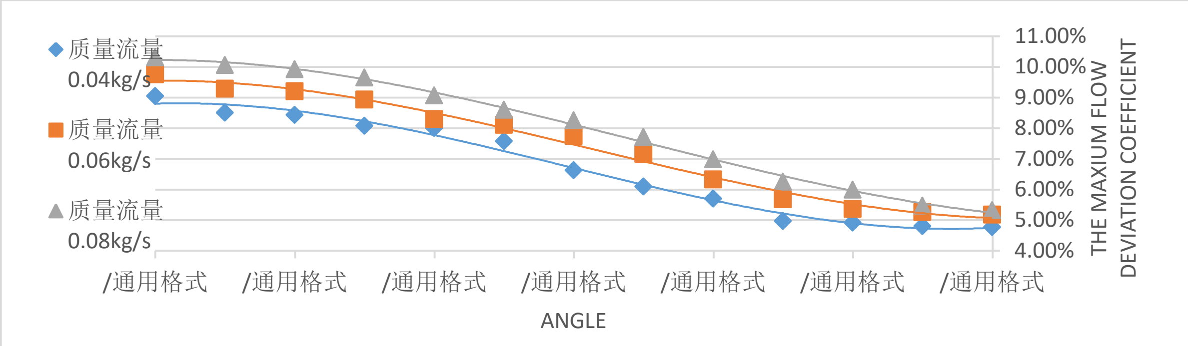

Fig. 5 fitting curve

3. Summary

This article simulated on a solar set parallel heat exchanger tube group in the current marketi , and put forward a new method by changing the connecting angle between branch pipe and collecting pipe to reduce the pressure difference between import and export and improve the parallel pipe flow uniform distribution . The main conclusions are as follows:

(1) by using fluent ,we calculatedthe branch flow and the maximum flow deviation coefficient when the connecting angle between branch and the parent tube changes of under three kinds of mass and flow. The vertical connection shunt exists a vortex area, when the connection angel is 60 degrees, outflow has no obvious vortex area, and the branch pipe of the inlet velocity distributes more uniformly.

(2) the results show that when the mass flow is 0.04kg/s and pipe parent angle of 30 degrees compared with 90 degrees ,the maximum flow deviation coefficient reduces 4.27%, flow uniformity ascend 47.2% compared with vertically connected . The same as when the mass flow is 0.06ks/s 0.08kg/s which prove changing the connecting angel is practical and efficient to improve the uniformity of flow.

4. Acknowledgements

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5. References

[1]. Cheng Yang，Hongzhao Liu，Taining Yuan．Analysis of fluid characteristics and design of uniform flow model of parallel pipe group[J]. Journal of solar energy，2015，36（7）：1573-1578．

[2]. Xiaoli Wei，Zhengqing Miao.Experimental study on flow characteristics of Z type and U type collection box parallel pipe group ［J］. Power energying，2008，28（4）：514—518.

[3]. Mingfu Hu，Yu Bie，Jianghua Bu.Flow distribution model of solar collector array [J]. Journal of solar energy，2011,32（1）：60-65.

[4]. Zhengqing Miao，Tongmo Xu.Flow characteristics of single phase fluid in a collection box ang parallel pipe screen system[J].Journal of Shanghai Jiao Tong University，2000,34(9)：1206-1210.

[5]. Jore Facao.Optimization of flow distribution in flat plate solar thermal collectors with riser and header arrangements [J].Solar Energy,2015,120:104-112.

[6]. Zhengqing Miao,Ziping Tian,Enlu Wang. Study on flow characteristics of single phase fluid in power plant boiler [J]. Power energying, 1998,18 (2):46-49.