Numerical Simulation of Corrugated Inclination Angle on the Performance of Plate Heat Exchanger

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Abstract—Plate heat exchanger is a kind of compact heat exchanger, which has high heat transfer coefficient and compact structure and is easy to wash.In recent years it has been widely used, but also has the disadvantages of big flow resistance.In this paper the numerical simulation is performed by using the CFD soft FLUENT[1]. A 3D geometric model is established and whose mesh is generated. The fields of the temperature, pressure and velocity in the computational domain are simulated. And the effect of the corrugation inclination angle on the heat transfer and flow is analyzed.From the numerical simulation,we can get some conclusions about the corrugation inclination angle .Along with the corrugation inclination angle increases, heat exchange gets better and plate pressure drop decreases. Corrugated plate with inclination angle(70°) is good for the cleaning effect of the high-speed turbulence which can effectively reduce the deposited dirt. If we consider the heat transfer and the resistance, inclination angle should be from 60°to 70°.By this conclusions ,we can get a best inclination angle to design the plate heat exchanger.

Keywords-corrugation inclination angle; plate heat exchanger; numerical simulation; heat transfer; computational fluid mechanics

I. INTRODUCTION

Heat exchangers being one of the most important heat & mass transfer apparatus in industries like oil refining, chemical engineering, electric power generation etc. are designed with preciseness for optimum performance and long service life[2].A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids[3].The plate heat exchanger (PHE) was invented by Dr Richard Seligman in 1923 and revolutionised methods of indirect heating and cooling of fluids. Dr Richard Seligman founded APV in 1910 as the Aluminium Plant & Vessel Company Limited, a specialist fabricating firm supplying welded vessels to the brewery and vegetable oil trades. This has a major advantage over a conventional heat exchanger in that the fluids are In recent years it has been widely used, but also has the disadvantages of big flow resistance. Carla S. Fernandes et al. simulated the production process of yoghurt in the plate heat exchangers. A non-Newtonian fluid model was established and the velocity and temperature field were achieved [4].Flavio C. et al. carried out the simulation calculation of plate heat exchanger used in food engineering, results showed that the flow is mostly laminar. They tested and verified the effectiveness and correctness of the calculation [5]. Kone Grijspeerd et al. did two dimension and 3 dimension numerical calculations on the V-shaped plate heat exchanger. Influence of corrugation shape was attained in the 2 dimension one and the impact of the corrugation angle was attained in the 3 dimension. Finally the optimizational corrugation model was achieved [6].Muley use water and vegetable oil as the heat transfer medium, through the water--water and water--vegetable oil heat resistance experiment ,and he make a research on resistance performance and heat transfer about chevron-type plate heat exchanger[7].Study on heat transfer performance of plate heat exchanger focus on how to improve heat exchange efficiency and reduce the flow resistance, and to seek the best matching of heat transfer and pressure drop. In this paper effect of the corrugation inclination angle, one of the most important parameters of the plate heat exchanger, is studied. In the following sections, numerical simulations will be explored on the flow resistance and heat transfer performance of the plate heat exchanger.

II. NUMERICAL SIMULATIONS ON FLOW AND HEAT TRANSFER CHARACTERISTICS

The sketch of the plate heat exchanger is shown in Fig .1 (Guanmin Zhang researched the effect of inclination angles, separation distance and depth on flow resistance and heat transfer performance of the plate heat exchanger[8].)

According to Koen Grijspeerdt,Birinehi Hazarka,Dean Vucinic[9]and FlavioC.C.Galeazzo,Raquel Y Miura,Jorge A.W.Gut[10]their way of the numerical simulation.We design the heat exchanger.And the computational domain is about 50×100 mm. The corrugation inclination angle is variable in 30°to 80° The depth is 4mm and the separation distance is 10 mm. The type of the elements is Tet/Hybrid. The mesh is shown in Fig .2.

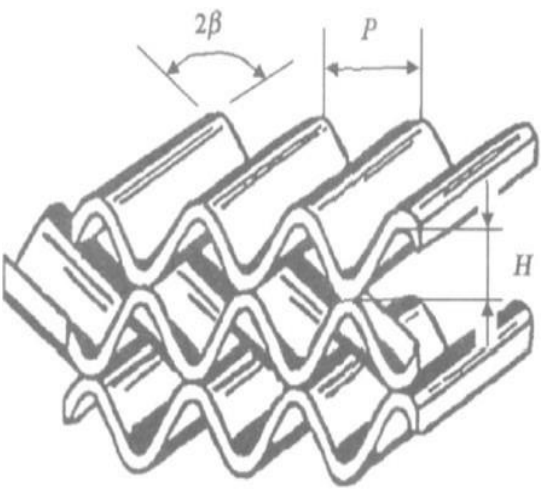


Figure 1. Computational domain of the corrugation plate

β - inclination angle, P – separation distance, H - depth

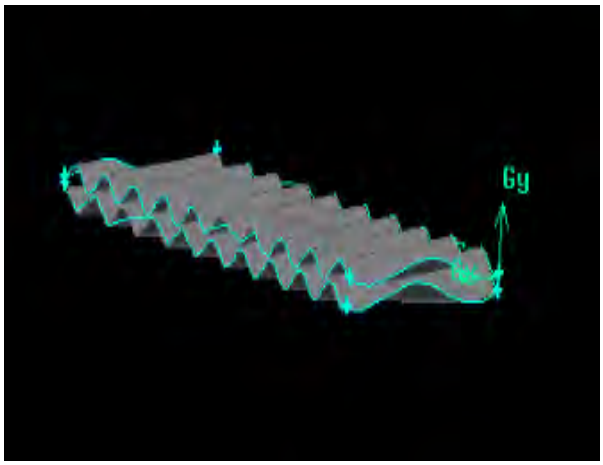


Figure 2. Mesh of the flow channel of the heat exchanger

III. BOUNDARY CONDITIONS AND METHODS

Inflow boundary condition is set as velocity-inlet where the velocity is 0.5 m/s. The working fluid is water, and the temperatures is set as 300 K. Outflow boundary condition is set as pressure-outlet where the pressure is 0.10133MPa. The RNG k −ε turbulence model was selected for turbulence computation. The following simplification and assumptions are introduced in the process of numerical simulations: (1) The working fluid is incompressible Newton fluid. (2) Gravity and the buoyancy induced by density difference are ignored. (3) Thermal effect induced by viscous dissipation is neglected.

IV. RESULTS AND ANALYSES

The following is the analysis of the results of the numerical simulation. And it is divided into four aspects.

A. *The temperatures of the flow channel with six different inclination angle are shown in Fig .3*

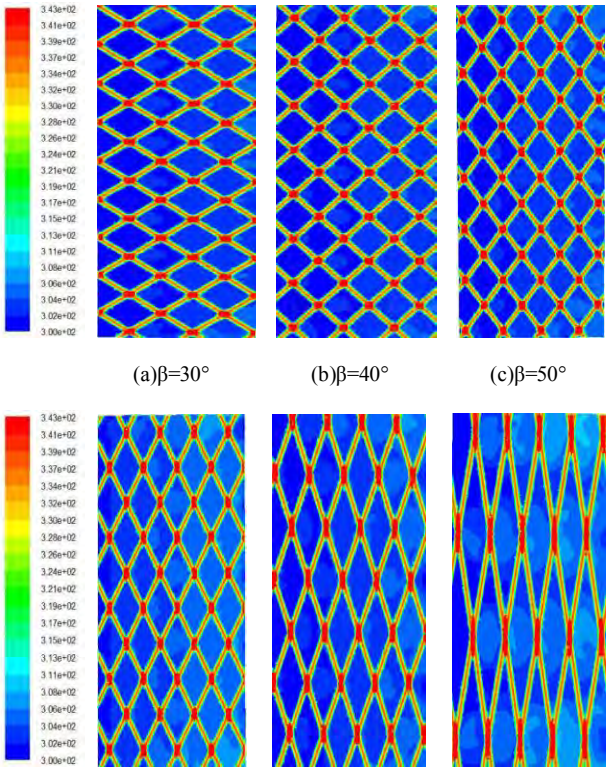
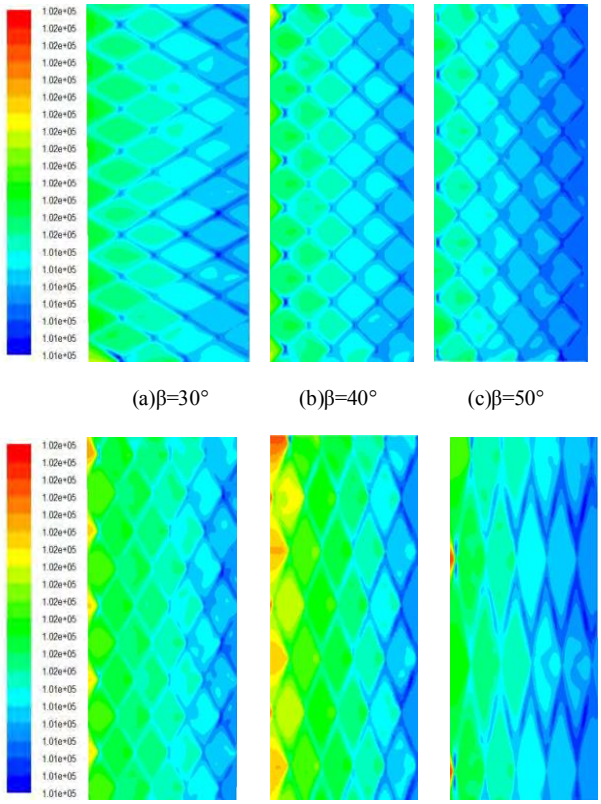


Figure 3. The temperatures of the flow channel with six different inclination angle

From the figure can be observed.When β is small ,contacts for fluid side collision is strong.Heat transfer is enhanced,but in the back to the fluid side heat transfer is slightly poor.If β<70°,The fluid distribution tends to be uniform with the increase of β.The fluid flow which is along the corrugation is reduced. the turbulence intensity is increased.Heat transfer is more uniform and sufficient.If β>70°,the contacts are reduced ,and heat transfer is no longer uniform. Heat exchange effect began to deteriorate .

B. *The pressures of the flow channel with six different inclination angle are shown in Fig .4.*



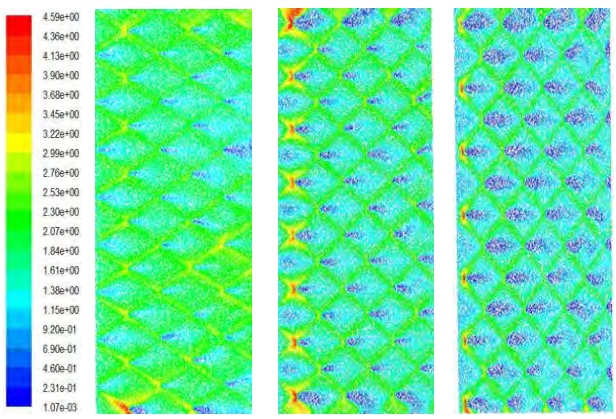
(a)β=30° (b)β=40° (c)β=50°

(d)β=60° (e)β=70° (f)β=80°

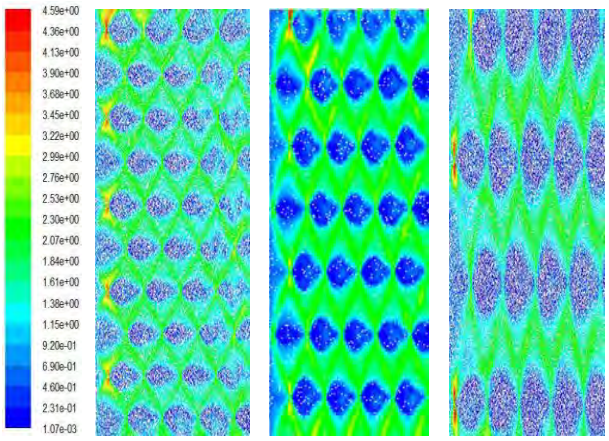
Figure 4. The pressures of the flow channel with six different inclination angle

One can see that The structure of the pressure field is similar to the corrugated plate which are stacked.And it's structure likes a gird.with the increasing of β The pressure gradient increases.This is mainly due to the fact that the component of the tangential force and the main current are inverse.This makes the pressure loss increased(when the corrugation inclination angle is variable in 30°to 70°).

C. *The velocity of the flow channel with six different inclination angle are shown in Fig .5.*



(a)β=30° (b)β=40° (c)β=50°



(d)β=60° (e)β=70° (f)β=80°

Figure 5. The velocity of the flow channel with six different inclination angle

One can see that the corrugation inclination angle carries huge implications on internal flow of the heat exchanger.If it is small,the fluid is mainly in the ripple tank.The distributing of the fluid is not uniform.The turbulence is small.Heat exchanging is bad.If the corrugation inclination angle increases,the fluid likes three-dimensional turbulent .And vortex density becomes bigger. The heat transfer effect is improved obviously.

D. *The pressure drop versus inclination angle is shown in Fig. 6*

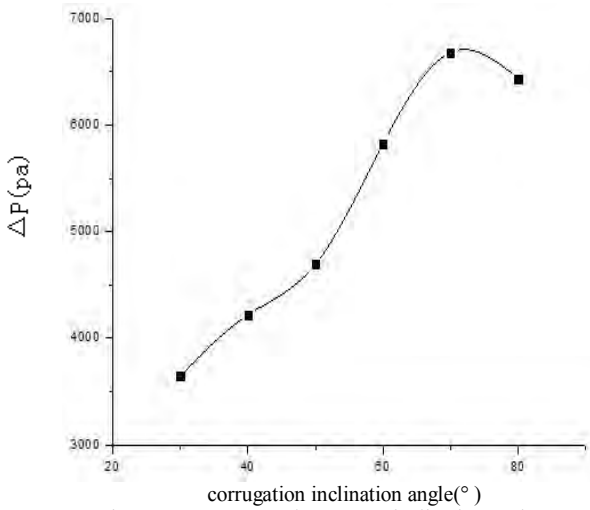


Figure 6. Pressure drop versus inclination angle

Along with the corrugation depth increases, heat exchange gets better and plate pressure drop decreases.

V. CONCLUSIONS

The contacts are best for heat transfer. The role of spoiler of the contacts makes the highest degree of fluid turbulence around them, thus heat transfer is enhanced.

Along with the corrugation inclination angle increases, heat exchange gets better and plate pressure drop decreases. Corrugated plate with inclination angle(70°) is good for the cleaning effect of the high-speed turbulence which can effectively reduce the deposited dirt. If we consider the heat transfer and the resistance, inclination angle should be from 60° to 70°.

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