Computational analysis of Heat Transfer enhancement in Fin and Tube Heat Exchanger using Rectangular Vortex Generators

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1. INTRODUCTION & OBJECTIVE

In present work the effects of attack angle of rectangular vortex generators (RVGs) on flow structure and heat transfer characteristics in a fin-tube heat exchanger, having block shaped rectangular vortex generators mounted on the fin surface have been analyzed by means of the solution of complete Reynolds average Navier-Stokes equation to study basic mechanism of localised flow structure and the heat transfer augmentation. Three dimensional numerical simulations are performed to examine the heat transfer rate and pressure drop in a fin-and-tube heat exchanger with block shaped rectangular vortex generators. In present analysis effect of angle and location on heat transfer enhancement has been carried out. The heat transfer enhancement by using inclined block vortex generator is more useful for low and moderate Reynolds numbers.

These vortex generators can be mounted on the fin surfaces by either welding, punching or embossing. These vortex generators induce stream wise longitudinal vortices. These vortices disrupt the growth of the thermal boundary layer and serves to bring about heat transfer enhancement between the fluid and the fin surfaces.

The geometrical configuration considered in this study is representative of a single element of the tube exchanger and periodic and symmetry condition is applied .Air is taken as the working fluid. The flow regime is assumed to be turbulent because, usually the fin spacing is small and the mean velocity is such that the Reynolds numbers of interest are below the critical Reynolds number. The constant wall temperature thermal boundary conditions are considered. The finite volume method is used to discretize the governing equations. The convective terms and diffusive terms of the momentum equations are discretized using a weighted average second order upwind scheme and central differencing scheme respectively. The pressure terms are discretized by first order forward differencing scheme. After discretization, the equations are solved by a numerical procedure based on Standard k-epsilon model. The computations are also performed at different angles of attack (30º, 45º and 60º) and for Reynolds numbers (1000 to3000) with and without vortex generator. It is observed that the heat transfer increases with the increase in the angle of attack and Reynolds number. The block shaped vortex generator is stamped behind the tube at three different angles and beside the tube with same pair of angles.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The effect of block shaped RVG at 30^0 on heat transfer rate and pressure drop placed behind the plate fin and tube heat exchanger comparing with baseline case is as shown.

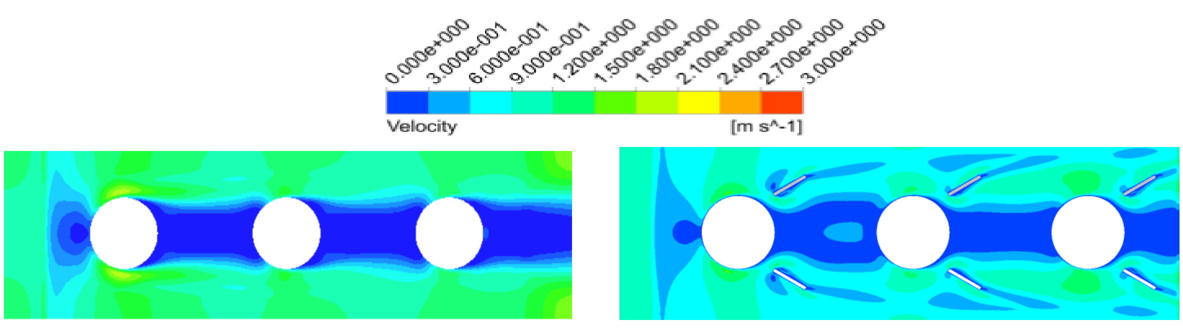

Fig.1: Velocity contours for baseline, rectangular vortex at 30^0 placed behind the tube

Here from the above four contours of velocity in Fig.1.2.the changes regarding to separation point and wake region can be seen clearly. When RVG having angle of attack deg-30 is used the strength of vortex is increased gradually. The larger vortex strength will bring higher-momentum fluid into wake region which shift the separation point towards right i.e. delaying the flow separation on the tube which result in reduced wake size. The longitudinal vortices generated by RVG at 30^0 rearrange the temperature distribution and the flow field, which result in increase in heat transfer performance of heat exchanger.

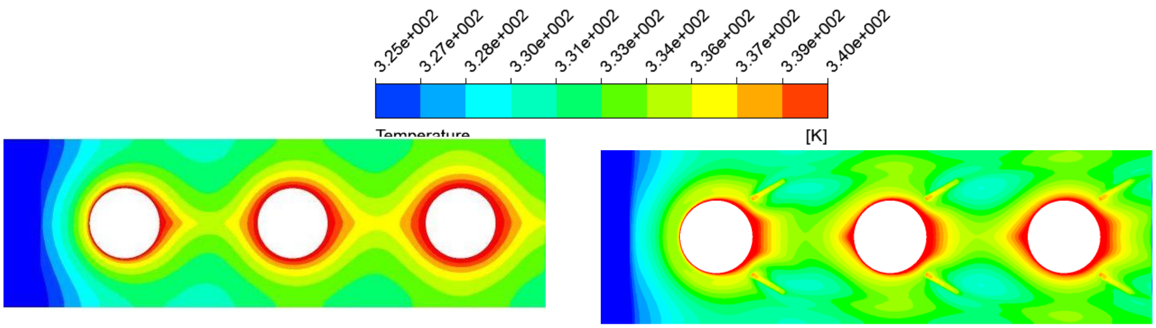

Fig. 2: Temperature contours for baseline, rectangular vortex at 30^0 placed behind the tubes

As flow approaches the block shaped RVGs, longitudinal vortices are generated. The combination of tube and RVGs forms a converging passage due to which flow is accelerated into the wake region which mixes the fluid in the recirculation zone and this leads to decrease the thickness of wake region between the tubes. As Reynolds number is increased from 1000 to 3000 the fluid in the recirculation zone mixes in a good manner and this effect is more pronounced when angle of attack is increased. The percentage increase in average heat transfer coefficient $\overline{h}$ value for rectangular VGs at 30^0 is from 11.13% to 33.29% from baseline case. The change in pressure loss for rectangular type VGs at 30^0 is from 10.64% to 35.58% in comparison to baseline case.

However in further studies this angle of vortex generators will be increased to deg-45 and deg-60 both behind and beside the tubes and the effect will be studied and compared with the help of heat transfer coefficient and pressure drop.

REFERENCES

1. A.M. Jacobi, R.K. Shah, Heat-transfer surface enhancement through the use of longitudinal vortices – a review of recent progress, Exp. Thermal Fluid Sci. 11 (1995) 295–309

2. C.C. Wang, C.J. Lee, C.T. Chang, S.P. Lin, Heat transfer and friction correlation for compact louvered fin-and-tube heat exchangers, Int. J. Heat Mass Transfer 42 (1999) 1945–1956.

3. G. Biswas, N.K. Mitra, M. Fiebig, Heat-transfer enhancement in fin-tube heat exchangers by winglet type vortex generators, Int. J. Heat Mass Transfer 37 (1994) 283–291.

4. J.M. Wu, W.Q. Tao, Numerical study on laminar convection heat transfer in a rectangular channel with longitudinal vortex generator, Part A: verification of field synergy principle, Int. J. Heat Mass Transfer 51 (2008) 1179–1191.