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CFD Analysis of heat transfer and flow behavior of fluid flowing over the straight and twisted square fin

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ABSTRACT

Fins are the extended surfaces which are used to increase the rate of heat transfer for the fluid over the surface. The present research deals with the study of comparative analysis of fluid flow behavior and heat transfer characteristics for a fluid flowing over the straight and twisted square fin. To analyze the thermo-physical properties of fluid flow, a 3-D model of straight and twisted fin was developed using CFD, Ansys fluent v 19.1 module. The developed model of fins was equipped with rectangular encloser with air as a fluid domain and aluminum was used as a material for both the fins. The simulation of both straight and twisted square fin was carried out for same input conditions to analyze the effect of twist on variation of fluid properties and heat transfer rate for fluid flowing over the straight and twisted square fin respectively. The results obtained from the analysis of both straight and twisted fins are compared with each other. The results obtained from the analysis showed that twisted fin improved the heat transfer rate with increase in pressure drop due to turbulence incited by the twist of twisted fin when compared with the straight fin. The results obtained from the cfd analysis of straight and twisted fin is depicted in the form of various contours viz. velocity, pressure, turbulence and temperature.

Keywords:* *ANSYS FLUENT, Twisted Fin, Straight Fin, Turbulence, Flow behavior.

1. INTRODUCTION

Heat exchangers are the devices which are widely used to enhance the rate of heat transfer in many industrial applications such as in thermal power plant, refrigeration and air conditioners, heating and cooling equipments and electronic devices. Heat exchangers are designed to reduced material savings, cost and space. To improve the rate of heat transfer from heat exchangers, fins are employed on heat exchanger. Fins are used to enhance the rate of heat transfer from heated surface to air by increasing the surface area of heated surface. Fins with different shapes and sizes are designed and manufactured and attached to the surfaces to improve the rate of heat transfer from heated surface to surrounding. Several researchers have carried out research in the field of fins to investigate the effect of fin geometry on thermal performance and fluid properties of fluid flowing over the heated surface. The present research deals with the comparative analysis of heat transfer and fluid flow behavior of fluid flowing over the straight and twisted square fin under identical conditions using computational fluid dynamics fluent module. Karan Sangaj el al. [1] analyzed the heat transfer with various shapes of fins viz. circular, rectangular, parabolic, conical and tapered having varying materials such as aluminum, copper, mild steel and stainless steel using ANSYS. It is concluded that pin fins of same shape with copper and aluminum material showed equal heat

transfer. Shyy-woei chang et al. [2] investigated numerically pin fin array with dimples. It is observed that for dimpled pin fin array, the local and average Nusselt number increased with increase in Raleigh's number.
Saroj yadav et al. [3] numerically investigated pin fin models under forced convection with air as a working fluid. It was observed that for pin fins with elliptical and kite shapes showed increase in heat transfer coefficient and Nusselt number. Arun K. Saha et al. [4] investigated numerically performance of heat exchanger with inline array of pin fins. It was observed from simulation that heat transfer enhanced with increase in Gasthof's number. Also, it is observed that at a constant pitch, with decrease in thermal boundary layer there is increase in heat transfer. Xu et al. [5] carried simulation study with tree shaped microchannel heat sink. It was found that the cooling effect of the seven-level tree-shaped microchannel has the best minimal pressure drop. S. G. Khomane et.al.[6] numerically investigated convective heat transfer and flow behavior of fluid flowing over the array of solid and discrete fins mounted on a flat plate. It is concluded that Nusselt number increases with increase in heat input. It is also observed that base temperature for solid fin was more elevated than that of discrete fins.

2. CFD METHODOLOGY

In this proposed work, in order to evaluate the heat transfer and flow behavior of fluid flowing over the straight and twisted square fin, a 3-D geometric model of straight and twisted square fin with similar dimensions were created respectively using cfd, ansys fluent v 19.1. To generate the fluid domain around the straight and twisted square fin, the envelop was generated around the fins as shown in Fig.1 and Fig.2.

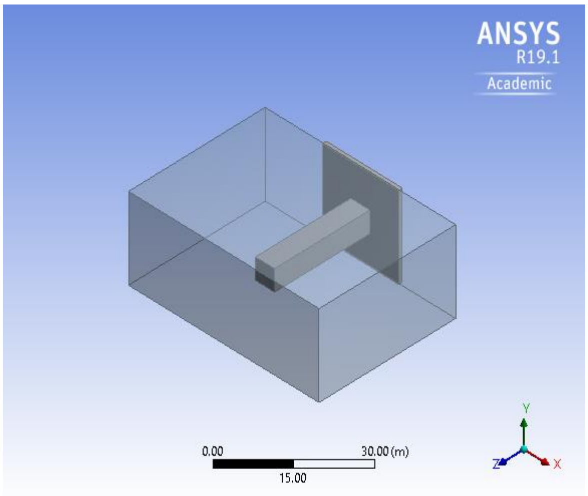

Fig.1: CAD model with Straight fin

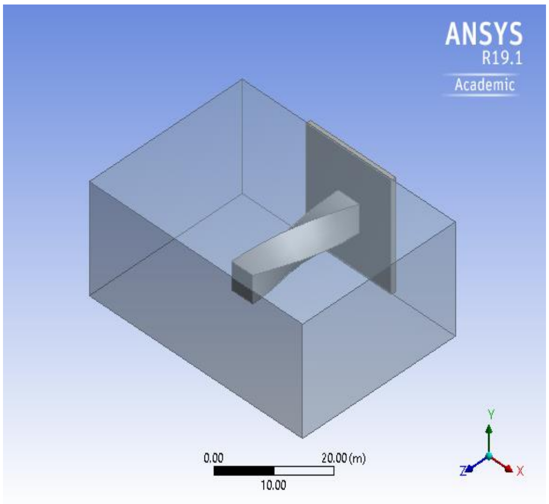

Fig.2: CAD model with twisted fin

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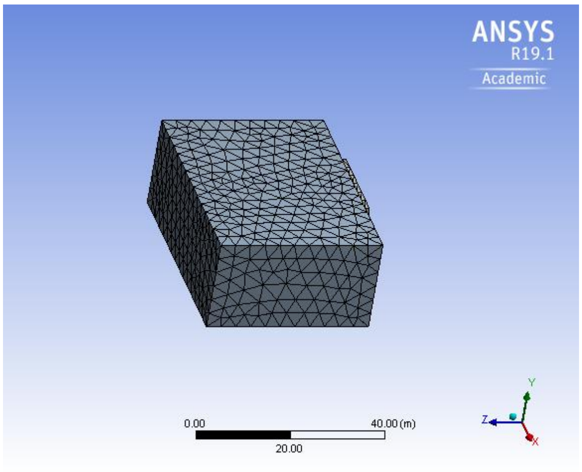

Fig.3: Mesh Generation

As shown in Fig.3, mesh generation was done followed by the geometry creation with 436230 elements and 112232 nodes. After mesh generation, CFD simulation was carried using k-epsilon model with standard wall fin condition after providing boundary conditions in pre solver. The results obtained are visualized in the form of contours.

3. RESULTS AND DISCUSSIONS

The analysis was carried out with air as a working fluid with 300 K temperature and 0.5 m/s velocity as a inlet boundary conditions. The wall temperature of fin was set at 500 K.

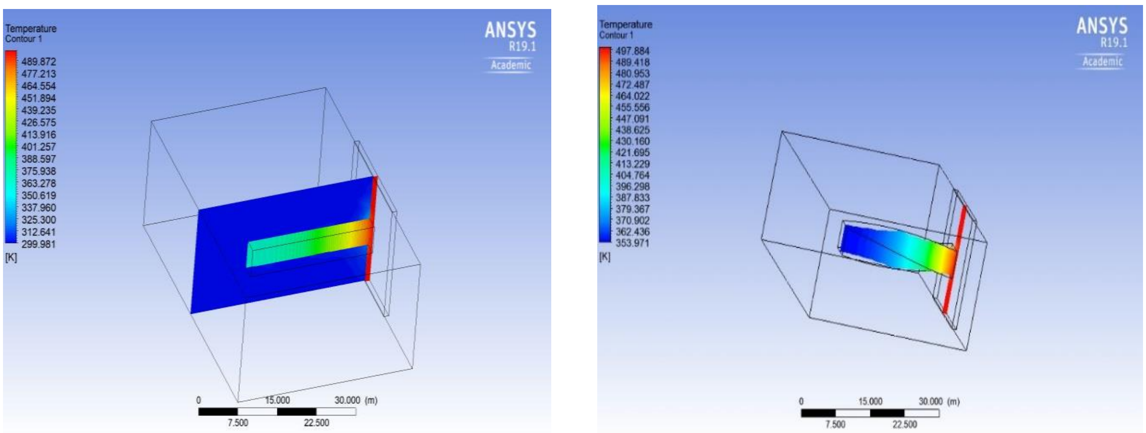

Fig.4: Surface temperature distribution for Straight and twisted fin

Fig.4 indicate the surface temperature distribution across the straight and twisted fin due to conductive heat transfer throughout the fin. It is observed that the temperature distribution across the twisted fin is slightly higher when compared with the straight fin.

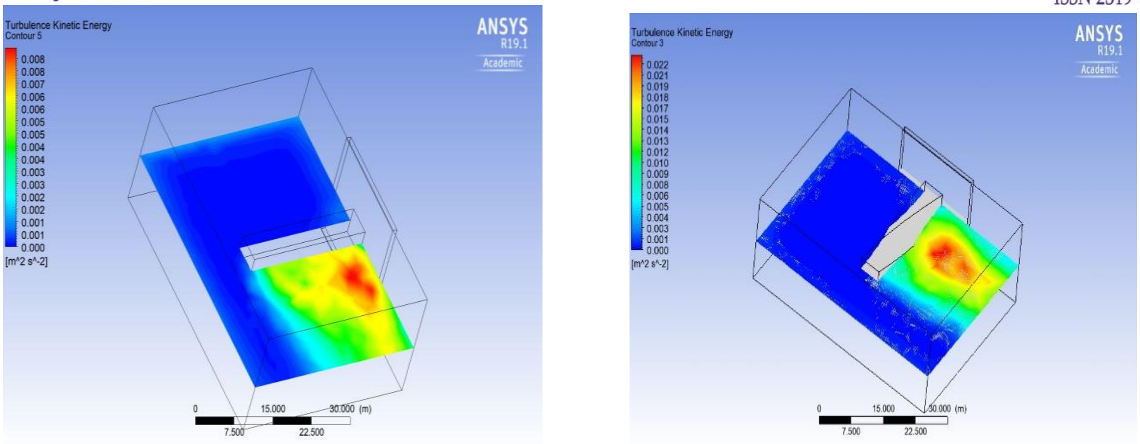

Fig.5: Turbulence kinetic energy contour for Straight and twisted fin

Fig.5 indicate the turbulence kinetic energy for the fluid flowing across the straight and twisted fin. It is observed that twisted fin generates higher turbulence for the fluid flowing over it as compared to straight fin. This is due to the fact that twist generate the greater swirl for the fluid while flowing over the fin.

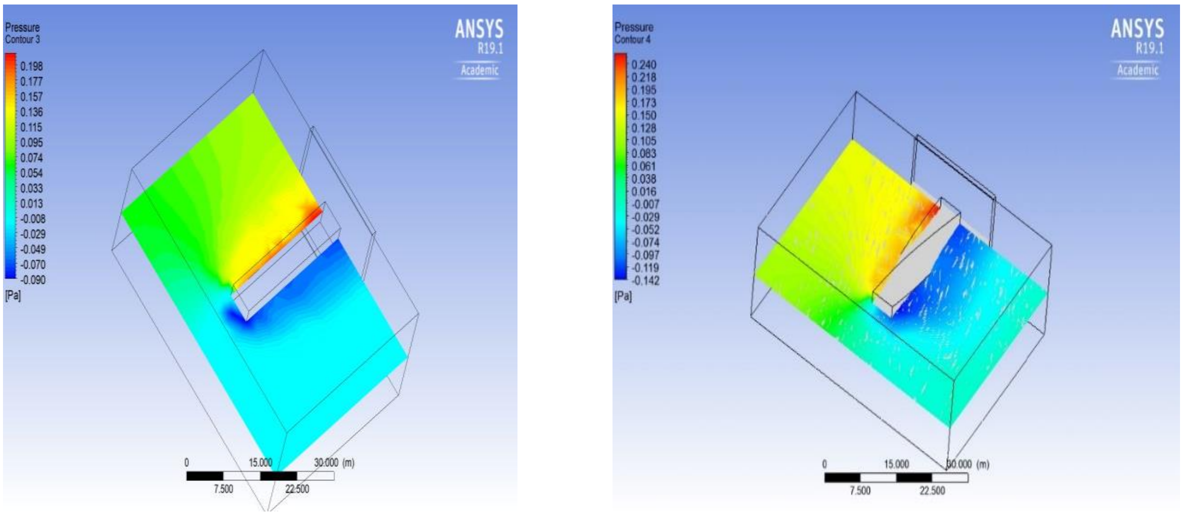

Fig.6: Pressure contour for Straight and twisted fin

Fig.6 illustrate the pressure distribution for the fluid flowing across the straight and twisted fin. It is observed that pressure drop for fluid flowing over the twisted fin is greater than the straight fin. This is because of increase in turbulence for twisted fin compared to straight fin. It is observed that the average pressure drop for the fluid flowing over the twisted fin is greater than 0.65% when compared with straight fin for the identical boundary conditions.

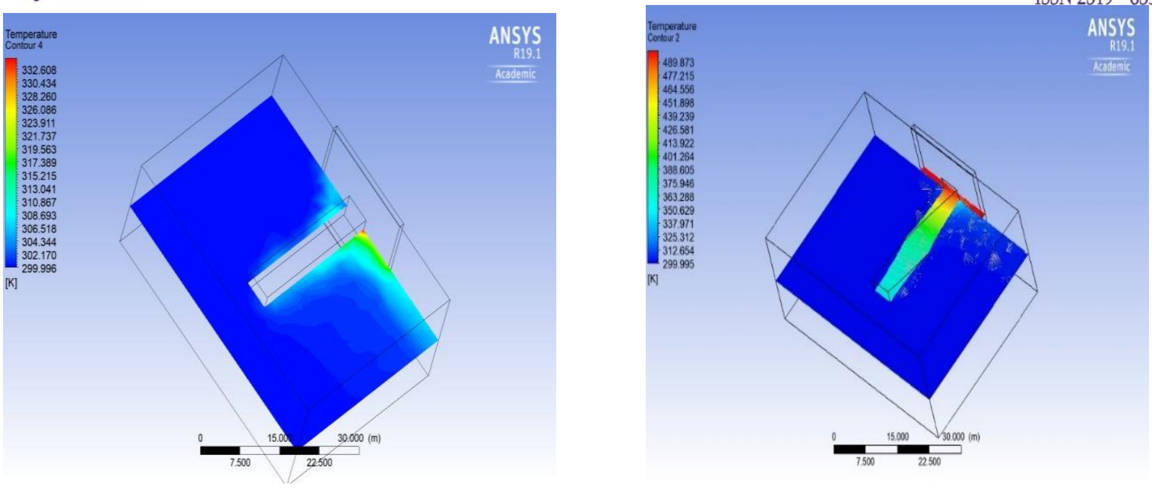

Fig.7: Temperature contour for fluid flowing over Straight and twisted fin

Fig.7 illustrate the temperature distribution for the fluid flowing across the straight and twisted fin. It is observed that temperature of fluid leaving the twisted fin is greater than the straight fin. This is because of turbulence created by the twisted fin which in turn increases the convective rate of heat transfer for the twisted fin as compared to straight fin. It is observed that the average rate of heat transfer for twisted fin is greater than 1.35% when compared with straight fin for the identical boundary conditions.

4. CONCLUSIONS

The present research deals with the numerical analysis of heat transfer and flow behavior of fluid flowing over the straight and twisted square fin. The result obtained from this research indicates that twisted fin increases the turbulence kinetic energy resulted in the increase in pressure drop for the fluid flowing over the fin compared with the straight fin. It is observed that for the identical boundary conditions twisted fin enhances the rate of heat transfer with increase in pressure drop for the fluid as compared to the straight fin.

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