Comparison of the Performance of Helical and Normal Pin Fins

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Abstract

In many engineering applications, fin arrays are used as a method to increase heat transfer rate from a surface. The amount of heat transfer depends on film coefficient of the coolant fluid (e.g. air) which is a function of the flow regime. More turbulence in air flow results in higher amounts of heat transfer. Therefore, causing turbulence in air flow is desirable in many cases. A practical way to cause turbulence in air flow which is passing through an array of fins, is using helical fins instead of straight normal fins. In this paper, the performance of helical and normal fins, which are attached to a surface with a high temperature, is evaluated using numerical simulation. It should be noticed that the pitch length of helical fins must be in an appropriate range in order to obtain better functionality. We have done CFD analysis on several models of helical pin fin arrays with different pitch lengths, the optimum amount of pitch length is found. The results show that helical pin fins with specific optimum pitch length could be used to increase the amount of heat transfer significantly.
Keywords: Heat transfer, CFD analysis, Helical fins.

Introduction

The knowledge and science of air-side heat transfer enhancement plays a key role in designing procedures of many engineering applications. By taking a glance to the existing literature, even though the case of a single fin attached to a horizontal surface has not been studied sufficiently, lots of attention has been given to the case of the fins array and their size. Commonly, densely packed fins are used in order to increase heat transfer coefficient by increasing air-side surface area. For instance, Starner and McManus (1963) who measured heat transfer coefficient from constant temperature fins on a vertical base, did one of the earliest studies in this field. They found that the suitable orientation of the fins depends on their lengths. Harahap and McManus (1963) analyzed horizontal fin arrays using the length of the fin as a variable and concluded that the shorter lengths result in higher average convection coefficients. Using a two-dimensional analysis, Chung and Iyer (1993) approximately determined the optimum aspect ratios of longitudinal rectangular fins and cylindrical pin fins. In following of researches on the physical features of fins, the optimization of straight fins has been considered in some details by Gardner (1964). Duffin (1959) proposed an optimum profile for longitudinal fins. Also, Fabbri (1997) presented a genetic algorithm which was able to optimize the heat transfer through longitudinal fins, whose lateral profile was described by a polynomial function, considering a constant convective heat transfer coefficient. With the aim of efficiency enhancement, lots of attention have been paid to installation of fins, beside their geometrical design. In this regard, Aihara et al. (1990) have done extensive experiments on the vertical rectangular fin arrays and it was found that fin spacing is very important for effectiveness, which is a function of Rayleigh number. Jones and smith (1970) studied the variations of the local heat transfer coefficient for isothermal vertical fin arrays and suggested a preliminary design method for maximum heat transfer. In many cases, heat transfer mainly occurs through convection and radiation. For a wide range of temperatures, Rammohan and Venkateshan (1996) made an interferometric study of heat transfer by free convection and radiation from a horizontal fin array with great emphasis on the significance of the mutual interaction between free convection and radiation. Yüncü and Anbar (1998) carried out an experimental investigation on natural convection heat transfer from rectangular fin arrays on a horizontal base for effects due to fin spacing, fin height and temperature difference between fin base and surroundings. Heat transfer also strongly depends on the material of fins. Van Fossen (1982) utilized different materials for circular pin fins and described the Reynolds number dependence of the results, along with comparisons with available relevance for constant property conditions. Temperature difference between surfaces and air is one other cause for heat transfer. Hereof Simoneau and Van Fossen (1984) measured pin surface heat transfer coefficients as the test section gas temperature varies between 260 and 290 and described the effect of changing the number of pin rows. Also, Chyu et al. (1999) measured surface mass transfer coefficients using naphthalene-sublimation measurement techniques considering temperature of ambient air and surface.

Although many researches have been done on the performance of fin arrays, there is still room to discuss heat transfer characteristics of these types of fins such as the performance of helical pin fins and their relation with their height. The objective of this paper is to study the thermal performance of helical pin fins on a plate with constant temperature, in comparison with normal pin fins.

Modeling and Simulation

In this section, the process of modeling and simulation of pin fins and helical pin fins is presented.

Normal Pin Fins

Figure 1 shows the SolidWorks model of pin fins in normal shape. Dimensions of this models is presented in Table 1. It is considered that the fins which are attached to a square plate, are all made of Aluminum 7178-T6.

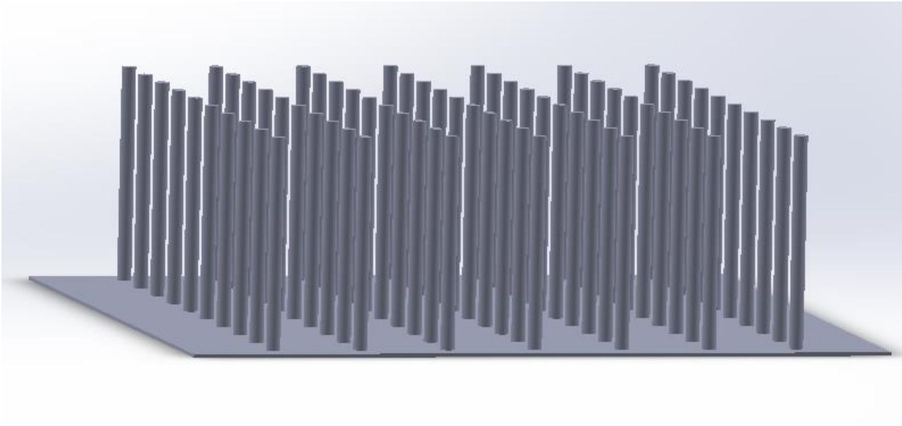

Figure 1. SolidWorks model of normal fin array on plate

Table 1. Dimensions of the model presented in Figure 1

Board thickness (mm)	8
Board area (mm^2)	10000
Fins height (mm)	50
Cross section radius of fins (mm)	1.5
Longitudinal pitch (mm)	10.5
Transverse pitch (mm)	12.5

Helical Pin Fins

SolidWorks model of pin fins in helical form is displayed in Figure 2. Pitch length of helical fins is 10 mm, maximum transverse deflection of fins is 1.5mm and the total length of helical fins is 50mm. The material assigned to the parts shown in Figure 2 is also Aluminum 7178-T6. Thermal conductivity of this specific alloy is 125 W/m.K.

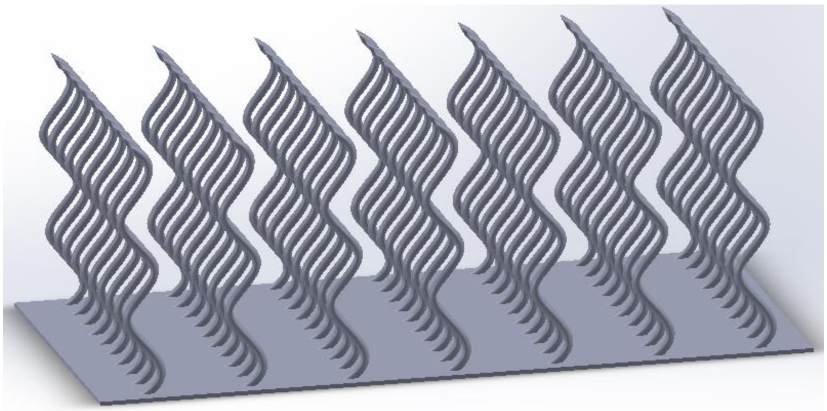

Figure 2. SolidWorks model of helical fin array on plate

Numerical Analysis

Numerical analysis, which is performed on both geometries presented in Figures 1 and 2, consists of two steps, which are described in sections below. The specification of the Hardware and Software is shown in Table 2.

Table 2. Specifications of the simulation equipment

PC	Hardware	Intel ® Core ™ i7-2600, 3.4 GHz CPU, 16GB RAM
	Software	Windows 8.1 Pro 64-bit, SolidWorks 2014, ANSYS 16

Performance Assessment of Normal and Helical Pin Fins

CFD analysis is performed on both normal and helical fin arrays using FLUENT software in order to investigate the effect of helical shape of fins on the amount of heat transfer. Boundary conditions of the simulation are velocity inlet with an air flow of 8m/s and a temperature of 300K, pressure outlet with zero gauge pressure, and far-field for other boundaries. Also the temperature of the plate below the fins is 350K.

Mesh refinement is done on the fin arrays to achieve a high accuracy. Also, independency of number of elements is verified for each case. The results of energy and k-ϵ equations converged and temperature profile on the fins is extracted.

Finding the Optimum Pitch Length of Helical Pin Fins

In this step of simulation, the optimum pitch length of helical pin fins is found, which results in maximum heat transfer for 50mm length of fins. Five other models similar to Figure 2 but with different pitch lengths is created. For each model, total length of the fins is kept constant at 50mm but the pitch lengths were set 1.25, 2.5, 5, 7.5, 10, 12.5 and 15mm.

Results and Discussion

For the first step, the CFD analysis shows that helical fins are more efficient than normal fins. The minimum temperature on top of the normal fins is about 317 k but the temperature on the upper-side of helical fins is 308K. Figure 3 shows the temperature profile of fins for both normal and helical shapes.

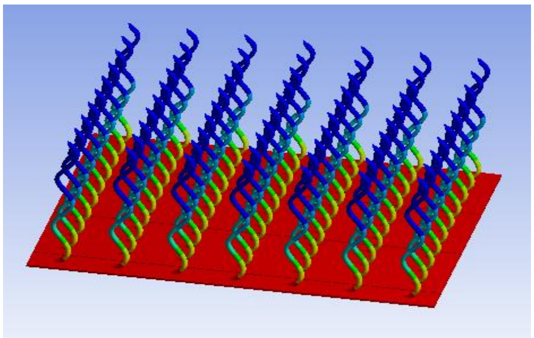

Figure 3a. Temperature profile on helical fins

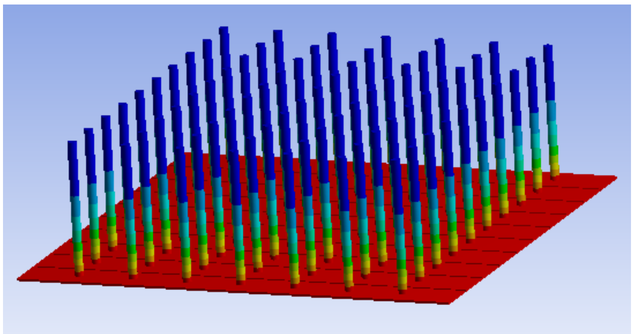

Figure 3b. Temperature profile on normal fins

Figure 3. Temperature profile on helical and normal fin arrays

Helical shape of the fins shown in Figure 3a, causes more turbulence in air flow, thus makes a raise in Nusselt number as a result of increase in the Reynolds number, thereby increasing film coefficient and the cooling process of the plate is faster.

For the second step, CFD analysis shows that the optimum pitch length to reach maximum heat transfer is 5mm. Figure 4 displays the results of this step of simulation.

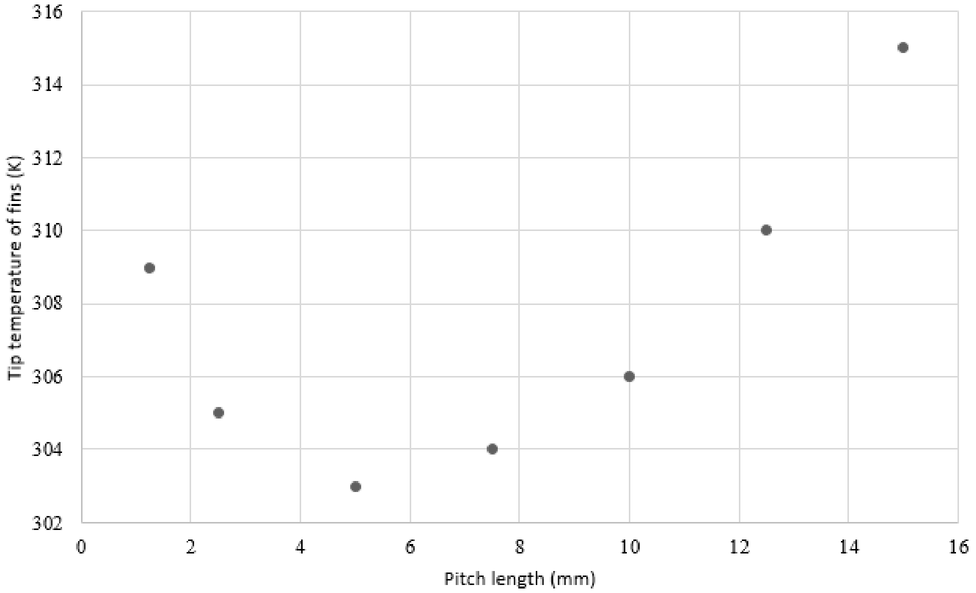

Figure 4. Tip temperature of fins

It can be concluded from Figure 4 that fins with excessive pitch lengths are less efficient, because if the pitch length increases, while the total length of the fin is kept constant, its shape will eventually turn into a normal fin, therefore turbulence caused in air flow will be less intense and the amount of heat transfer will be lower.

On the other hand, too much decrease in the pitch length of fins, while the total length of the fin is constant, restricts air flow between the fins, therefore heat is not properly transferred.

Regarding to above statements, an optimum pitch length of fins must exist, which gives an optimum amount of heat transfer. According to Figure 4, the optimum amount of pitch length is 5 mm, which resulted in lowest possible temperature on tip of the fins.

Conclusion

In this paper, performance of helical and normal pin fins is compared. In this regard, helical and normal pin fins with different geometrical dimensions are modeled and CFD analysis is performed on them. First, it is confirmed that helical fins are more efficient than normal fins. Then, the optimum amount of pitch length of helical fins is found. Results show that if the pitch length is too high, the fin will be more like a normal fin and its efficiency will deteriorate. When the pitch length is too low, air flow is restricted and the efficiency of fins will be reduced. Therefore, the pitch length of the helical fins must be in a certain range for proper functionality. It is found that fins with a pitch length of 5 mm have the maximum efficiency. In a word, owing to the aforementioned elucidations, it can be concluded that generally, helical fins have more efficiency than normal fins, but it would be perfect if the pitch length of helical fins were chosen near to the optimum amount that results in maximum efficiency, which, for the geometry considered in this paper, is about 10% of total length of fin.

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