

Optimization of Fins Used in the Heat Exchanger Tubes

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ABSTRACT: The concept of heat transfer through annular fin of rectangular profile is one of the methods for improving heat transfer rate by natural convection in heat exchangers. Radial fins are used in heat exchange devices to enhance the heat transfer rate. Temperatures vary with the geometry of the fins and along the fluid flow direction. The fin geometry has the affects on the flow direction and causes the temperature changes. Numerical analyses are carried out to examine finned tube heat exchanger.

KEYWORDS: Extended surfaces, Heat Transfer, optimization, Temperature distribution, Heat exchanger.CFD

I. INTRODUCTION

Annular fins find various applications in heat exchangers, in specialized installations of single and double-pipe heat exchangers, in electrical apparatus, on cylinders of air cooled internal-combustion engines, etc. In a conventional heat exchanger heat is transferred from one fluid to another through a metallic wall. The rate of heat transfer is directly proportional to the extent of the wall surface, the heat transfer coefficient and to the temperature difference between one fluid and the adjacent surface. If thin metals (fins) are attached to the surface extending to one fluid so total surface for heat transfer is thereby increased. Many of the basic engineering data for modeling systems comes from measurements of heat capacity and thermal conductivity. Fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems. Annular fins are used extensively in heat exchange de-vices to enhance the heat transfer rate. For various fins can dissipate different amounts of heat because of the different shape and geometry. The goal of fin optimization is to find the shape of the fin which would maximize the heat dissipation for a given fin volume. Computational fluid dynamics (CFD) has become grate role

in recent years for the analysis of heat transfer in different conditions

II. DETAILS OF EXPERIMENT

Experimental analysis was done on the heat exchanger (Finned tube heat exchanger) model, inside and outside convection heat transfer coefficients are estimated by passing preheated air through the tube and over the tube by the help of draught fan. Temperatures at the fin tip and base are checked by thermocouple.

A. Specifications of Finned Tube Heat Exchanger

Inner diameter of bare tube: 0.051m

Outer diameter of bare tube: 0.064m

Tube material: Aluminum

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Length of Intercooler: 0.163m

No. of fins: 14

Fin material: Cast Iron

Thickness of each fin: 2.73×10^{-3} m

Type of fins: Radial fins of rectangular cross section

Height of fin: 11.325×10^{-3} m

B. Experimental Observation

Temperatures at different positions of fin are measured by using infrared thermocouple

Table 1: Temperature of fins in($^{\circ}$ C)

Sl.No.	Temp ($^{\circ}$ C)
1	77
2	76
3	76.2
4	75
5	75.6
6	76.3
7	76.8
8	77
9	75.5
10	75.3
11	73.8
12	74
13	73.6
14	70

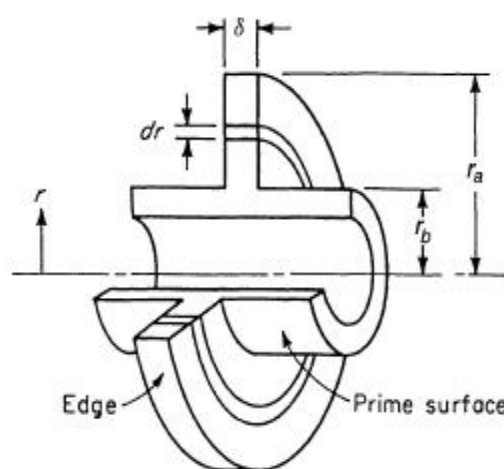


Fig .1. Radial fin of rectangular profile

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Estimation of inside convective heat Transfer coefficient

Mean temperature of air inside the intercooler = 80°C

Discharge (Q) = $C_d a_0 \sqrt{2gHa}$

Where = C_d coefficient of discharge of orifice meter = 0.62

$$a_0 = \frac{\pi}{4} d_0^2$$

$$H_a = \frac{\rho_{water}}{\rho_{air}}$$

$$d_0 = 20 \text{ mm}$$

$$a_0 = 3.14 \times 10^{-4} \text{ m}^2$$

$$Q = 0.62 \times 3.14 \times 10^{-4} (\sqrt{2 \times 9.81 \times 0.025})$$

$$Q = 3.79 \times 10^{-3} \frac{\text{m}^3}{\text{s}}$$

$$V_{\text{air inside}} = \frac{Q}{a_i}$$

$$a_i = \frac{\pi}{4} d_i^2$$

$$d_i = 51 \times 10^{-3} \text{ m}$$

$$V_{\text{air inside}} = 1.85 \text{ m/s}$$

$$Re = 7788.33$$

Dittus-Boelter equation for fully developed flow is considered for evaluation of inside convective heat transfer coefficient

$$Nu = 0.023 Re^{0.8} Pr^{0.3}$$

$$Nu = \frac{h_i d_i}{k}$$

C. Estimation of Outside Convective Coefficient

Film temperature of air = 50 °C

Properties of air are evaluated at 50 °C,

Density (ρ) = 1.093 Kg/m³

Kinematic viscosity (ν) = 17.95×10^{-6}

Thermal conductivity (K) = 0.03047 W/m.K

Prandtl number (Pr) = 0.692

flow across cylinders is considered for evaluation of outside convective heat transfer coefficient

$$Nu = C Re^m Pr^{0.333}$$

$$Re = \frac{V_{\infty} D_e}{\nu}$$

D_e = equivalent diameter of the fin

$$= \frac{A_{fin} A_{tube}}{\pi \times \text{projected perimeter}}$$

$$A_{fin} = \frac{\pi \times (d_f - d_o) (d_f + d_o)}{4}$$

$$= \frac{\pi \times (0.104 - 0.064) (0.104 + 0.064)}{4}$$

$$= 5.27 \times 10^{-3} \text{ m}^2$$

$$A_{tube} = \pi \times d_i \times L_i$$

$$= 18.69 \times 10^{-3} \text{ m}^2$$

$$\text{projected perimeter} = \pi \times d_f = \pi \times 0.1040$$

$$= 0.3267 \text{ m}$$

$$D_e = 0.04668 \text{ m}$$

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$$Re=7788.33$$

For the calculated Reynold's number, the value of C and m are referred from the heat transfer data book as,

$$C=0.193$$

$$m=0.618$$

$$Nu=0.193(6111.97)^{0.618}(0.6974)^{0.333}$$

$$h_0=26.32 \frac{W}{m^2 \cdot ^\circ C}$$

D. Optimization of Fins

Three different radial fin profiles are used for the fin shape optimization.

The shapes of fins, used in simulations, are shown in Fig. 2 (a)-(c).

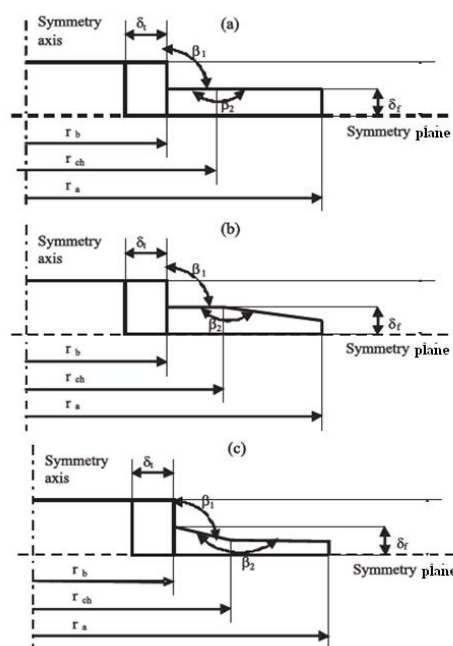


Fig .2. Radial fin Profiles (a),(b),(c)

Table 2: Tube and Fin Dimensions

Parameters used for fin dimension	Fin version		
	a	b	c
r_a (m)	0.032	0.032	0.032
r_b (m)	0.052	0.052	0.052
R_{ch} (m)	-	0.042	0.042
δ (m)	0.005	0.005	0.005
β_1 (deg)	90	90	92
β_2 (deg)	180	179	182

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Each fin operated as a part of the heat exchangers and the initial thermal as well as flow Conditions are the same for all fins:

$$\epsilon = \frac{m_f (T_{OUT} - T_{IN})}{V_f} \rightarrow \max$$

Temperature difference of the fluid is found out by numerically and solid volume is also calculated for different profiles for finding the appropriate optimization function for different profiles

Table 3: Optimization function

Air velocity $V_{IN} = 3 \left(\frac{m}{s} \right)$			
FIN PROFILES			
	(a)	(b)	(c)
$\Delta T(^{\circ}C)$	29.38	28.61	28.93
$V_f(m^3)$	2.25×10^{-5}	1.16×10^{-5}	7.41×10^{-6}
$m_f \left(\frac{kg}{s} \right)$	3.79×10^{-3}	3.79×10^{-3}	3.79×10^{-3}
ϵ	4948.89	9347.57	14796.85

III. RESULT AND DISCUSSION

The heat flux depends on the temperature difference between the tube and air temperatures. In reality, these temperatures vary along the cross section of the air stream and along the fluid flow direction. All results are calculated considering the air flow and its streamline deviations caused by the geometry configuration and compared with the actual result of circular fins of rectangular cross sections. The model allows considering the heat transfer in three directions.

The results illustrate how the fin dimensions influence the defined optimization function for a specified air rates. The best results, among three profiles, are received for profile (c) for higher inlet air velocities. In that case, optimization value ϵ is higher than profiles (a) and (b). The same conclusion may also be reached with the flow analysis. Evaluated the streamlines for all three models, the influence of fin shape on mass flow distribution is seen from ANSYS FLUENT. The examples are demonstrated from Fig 5.4 to 5.36 for same air inlet velocities. The air that comes through the heat exchanger flows over the fin

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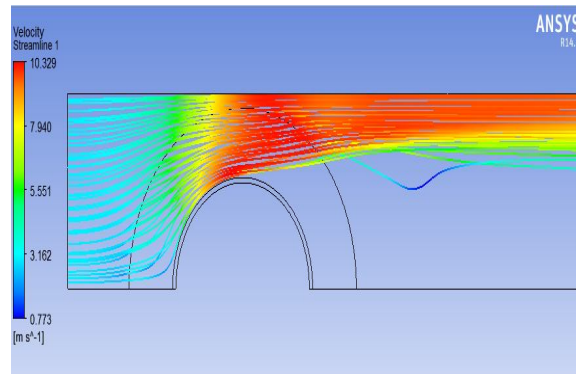


Fig .3. Air streamlines for fin profile (a)

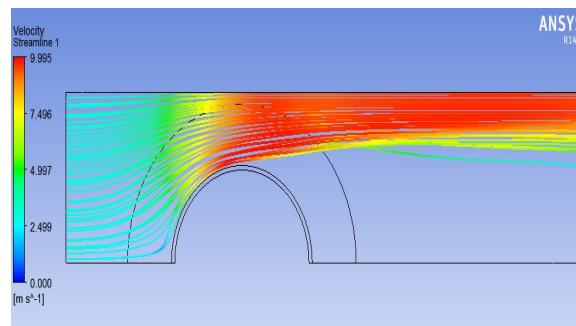


Fig .4. Air streamlines for fin profile (b)

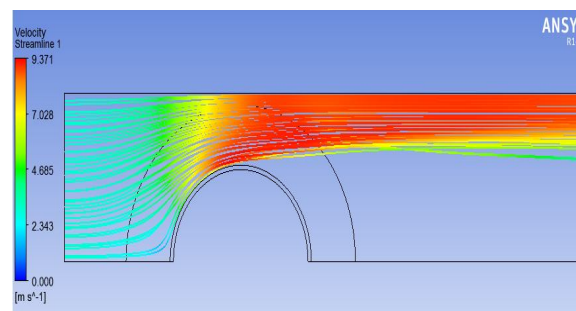


Fig .5. Air streamlines for fin profile (c)

IV. CONCLUSIONS

The rate of the heat transfer does not depend only on wall surface dimensions, heat transfer coefficient and the temperature difference between the fluid that surrounds the plate and the plate surface temperature. The air velocity and the fin shape are also essential because the fin profile influences the flow direction. For heat exchangers, built with many fins and designed for real industry, it is important to pay attention to and calculate the heat transfer considering the fluid flow and flow paths.

It should be also mentioned that if the fin is positioned into an air stream, the flow applies to a force from the fin tip surface in the direction of the oncoming flow (drag). The resistance of the body results in a pressure drop. The fin and tube surface orientation also modifies the resistance of the body that results in a pressure drop.

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