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Performance of finned tube heat exchanger – Review

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***Abstract* - Most of the engineering problems require high performance heat transfer Systems with progressively less weights, volumes, accommodating shapes and costs. Fins are one of the heat exchanging devices that are employed extensively to increase heat transfer rates. The rate of heat transfer depends on the surface area and shape of the fin. In this paper authors discussed various types of heat exchangers such as concentric tube heat exchangers, Cross-flow heat exchangers, Shell-and-tube heat exchanger, compact heat exchanger and types of fins such as straight fin, annular fin and pin fin. We discussed performance of fins and its applications. Also state the effect of fin alignment and tube alignment on the heat transfer performance. In this paper analyzed the heat transfer rate and efficiency for circular and elliptical annular fins.**

***Index Terms* - Fin, Circular fin, Elliptical fin, Heat exchanger, Heat transfer rate.**

I. INTRODUCTION

Fins are commonly used in extended surface exchangers. Conventional fin-tube exchangers often characterize the considerable difference between liquids' heat transfer coefficients. In a gas-to-liquid exchanger, the heat transfer coefficient on the liquid side is generally one order of magnitude higher than that on the gas side. To minimize the size of heat exchangers, fins are used on the gas side to increase the surface area and the heat transfer rate between the heat exchanger surface and the surroundings. Both the conduction through the fin cross section and the convection over the fin surface area take place in and around the fin. When the fin is hotter than the fluid to which it is exposed then the fin surface temperature is generally lower than the base (primary surface) temperature. If the heat is transported by convection to the fin from the ambient fluid, the fin surface temperature will be higher than the fin base temperature, which in turn reduces the temperature differences and the heat transfer through the fin. Exchangers with fins are also used when one fluid stream is at high pressure. The temperature value is limited by the type of material and production technique. All above causes that finned tube heat exchangers are used in different thermal systems for applications where heat energy is exchanged between different media. Applications range from very large to the small scale (tubes in heat exchangers, the temperature control of electronic components).

II. FINS (EXTENDED SURFACES).

When the available surface is found inadequate to transfer the required quantity of heat with the available temperature drop and convective heat transfer coefficient, extended **surfaces** or **fins are used**. This practice invariably is found necessary in heat transfer between a surface and gas as the convective heat transfer coefficient is rather low in these situations.

The finned surfaces are widely used in :

1. Economizer for steam power plant;
2. Convectors for steam and hot-water heating systems;
3. Air cooled cylinders of air craft engines, I.C. engines and air compressors,
4. Cooling coils and condenser coils in refrigerators and air conditioners;
5. Small capacity compressors;
6. Electrical Transformers and motors etc. [1]

Types of fin

Different fin configurations are illustrated in Fig.1. A straight fin is any extended surface that is attached to a plane wall. It may be of uniform cross-sectional area, or its cross-sectional area may vary with the distance x from the wall. An annular fin is one that is circumferentially attached to a cylinder, and its cross section varies with radius from the wall of the cylinder. The foregoing fin types have rectangular cross sections, whose area may be expressed as a product of the fin thickness t and the width w for straight fins or the circumference $2\pi r$ for annular fins. In contrast a pin fin or spine, is an extended surface of circular cross section. Pin fins may also be of uniform or no uniform cross section. In any application, selection of a particular fin configuration may depend on space, weight, manufacturing, and cost considerations, as well as on the extent to which the fins reduce the surface convection coefficient and increase the pressure drop associated with flow over the fins. [2]

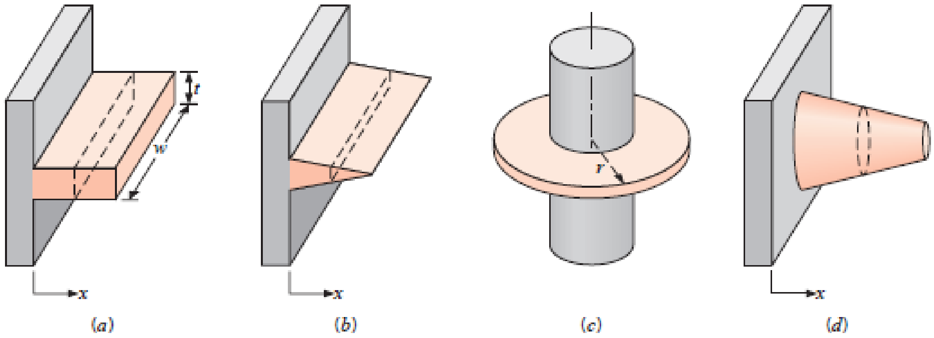

Figure 1. (a) Straight fin of uniform cross section. (b) Straight fin of Non uniform cross section. (c) Annular fin. (d) Pin fin.

Fin Performance

The important fin thermal performance parameters are as under ,

1. Fin Effectiveness
2. Fin efficiency

Fin Effectiveness

Fins are used to increase the heat transfer from a surface by increasing the effective surface area. However, the fin itself represents a conduction resistance to heat transfer from the original surface. For this reason, there is no assurance that the heat transfer rate will be increased through the use of fins. An assessment of this matter may be made by evaluating the fin effectiveness ε_f. It is defined as the ratio of the fin heat transfer rate to the heat transfer rate that would exist without the fin Therefore

$$\varepsilon_f = \frac{q_{fin}}{q_{without\ fin}} \dots\dots\dots\dots\dots (1)$$

Where $A_{c,b}$ is the fin cross-sectional area at the base. In any rational design the value of ε_f should be as large as possible, and in general, the use of fins may rarely be justified unless $\varepsilon_f \geq 2$.

Fin efficiency

Another measure of fin thermal performance is provided by the fin efficiency η_f.The maximum driving potential for convection is the temperature difference between the base (x = 0) and the fluid, $\Theta_b = T_b - T_\infty$. Hence the maximum rate at which a fin could dissipate energy is the rate that would exist if the entire fin surface were at the base temperature. However, since any fin is characterized by a finite conduction resistance, a temperature gradient must exist along the fin and the preceding condition is an idealization. A logical definition of fin efficiency is therefore

$$\eta_f = \frac{q_f}{q_{max}} \dots\dots\dots\dots\dots \quad (2)$$

Where A_f is the surface area of the fin. [2]

III. HEAT EXCHANGER.

In any heat exchanger form, the heat is transferred by all three basic forms: conduction, convection and radiation simultaneously. The intensity of heat conduction is not a challenging problem as usually it can be controlled by the material chosen to build the heat exchanger. Further, radiation is of less concern for heat exchangers operating under moderate temperatures, whereas the intensity of the heat transferred by the convection is the dominant problem particularly on the gas side for the design of the heat exchanger.

A “Heat Exchanger “ is process equipment designed for the effective transfer of heat energy between two fluids; a hot fluid and a coolant. The purpose may be either to remove heat from a fluid or to add heat to a fluid. Notable examples are:

1. Boilers , super heater and a condenser of a power plant.
2. Automobiles radiators and oil coolers of heat engine.
3. Evaporator of an ice plant.
4. Condensers and evaporators in refrigeration units.
5. Water and air heaters or coolers. [3]

Heat exchangers are typically classified according to flow arrangement and type of construction. The simplest heat exchanger is one for which the hot and cold fluids move in the same or opposite directions in a concentric tube (or double-pipe) construction. In the parallel-flow arrangement of Fig.2.a, the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end. In the counter flow arrangement of Fig.2.b, the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends.

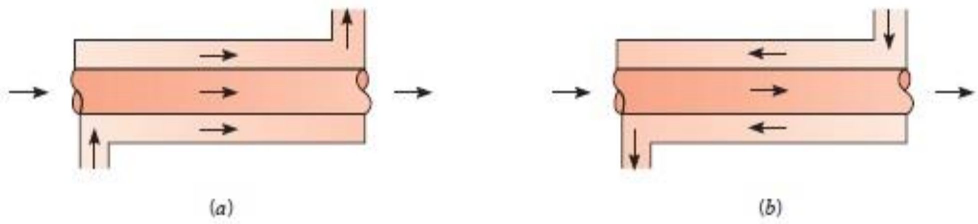

Figure 2.Concentric tube heat exchangers. (a) Parallel flow. (b) Counter flow.

Alternatively, the fluids may move in cross flow (perpendicular to each other), as shown by the finned and unfinned tubular heat exchangers of Fig.3. The two configurations are typically differentiated by an idealization that treats fluid motion over the tubes as unmixed or mixed. In Fig.3.a, the cross-flowing fluid is said to be unmixed because the fins inhibit motion in a direction (y) that is transverse to the main-flow direction (x). In this case the cross-flowing fluid temperature varies with x and y. In contrast, for the unfinned tube bundle of Fig.3.b, fluid motion, hence mixing, in the transverse direction is possible, and temperature variations are primarily in the main-flow direction. Since the tube flow is unmixed in either heat exchanger, both fluids are unmixed in the finned exchanger, while the cross-flowing fluid is mixed and the tube fluid is unmixed in the unfinned exchanger. The nature of the mixing condition influences heat exchanger performance.

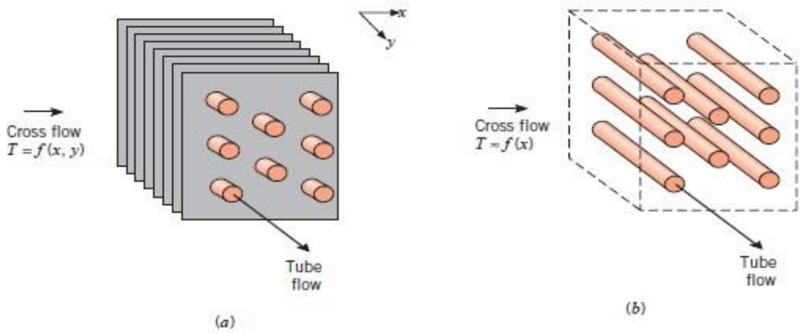

Figure 3.Cross-flow heat exchanger. (a) Finned with both fluids unmixed. (b)) Un-finned with one fluid mixed and the other unmixed.

Another common configuration is the shell-and-tube heat exchanger . Specific forms differ according to the number of shell-and-tube passes, and the simplest form, which involves single tube and shell passes, is shown in Fig 4. Baffles are usually installed to increase the convection coefficient of the shell-side fluid by inducing turbulence and a cross-flow velocity component relative to the tubes. In addition, the baffles physically support the tubes, reducing flow-induced tube vibration. Baffled heat exchangers with one shell pass and two tube passes and with two shell passes and four tube passes are shown in Fig 5.a and Fig 5.b respectively. [4]

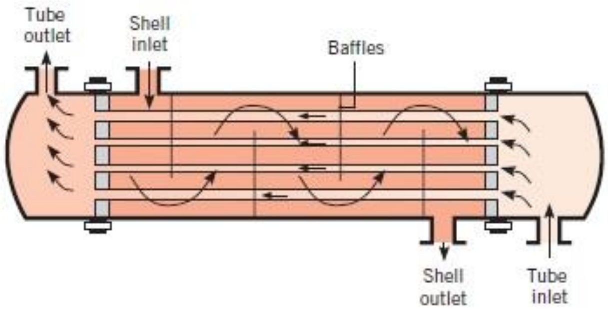

Figure 4. Shell-and-tube heat exchanger with one shell pass and one tube pass (cross-counter flow mode of operation).

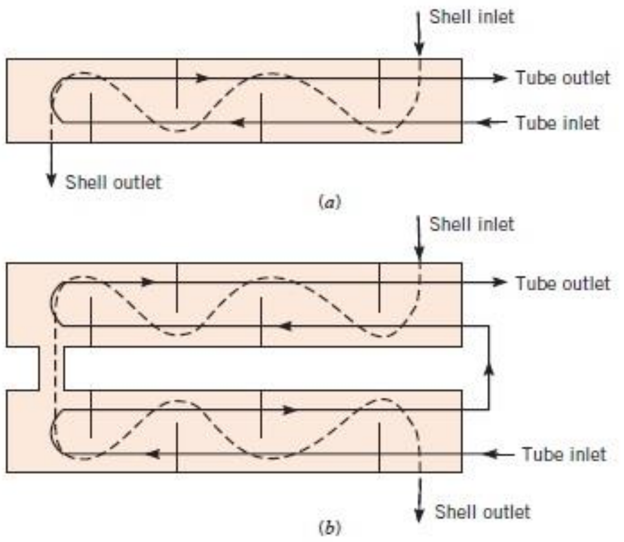

Figure 5.Shell-and-tube heat exchangers. (a) One shell pass and two tube passes. (b) Two shell passes and four tube passes

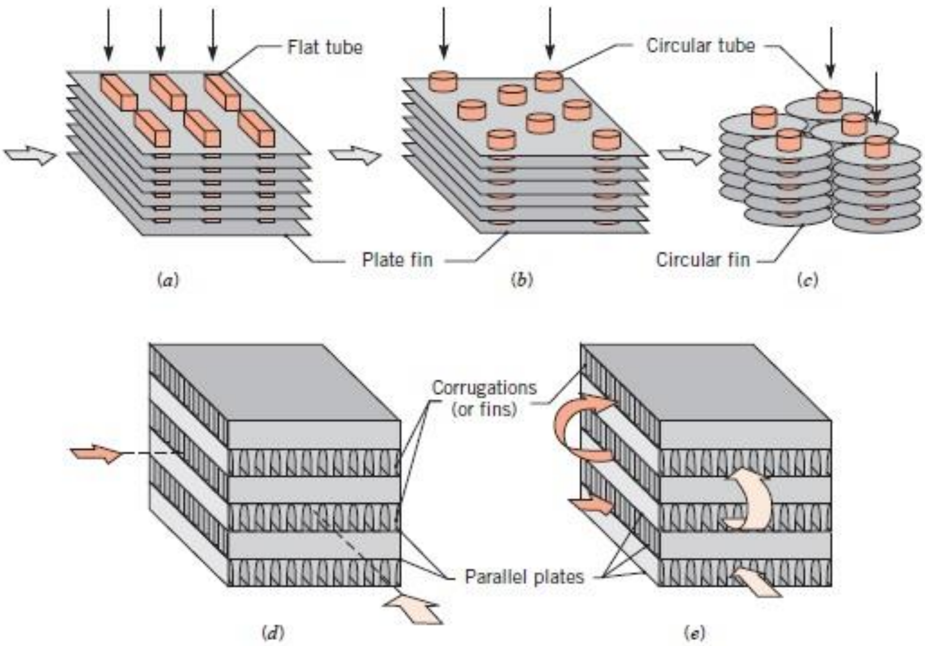

Figure 6. Compact heat exchanger cores. (a) Fin–tube (flat tubes, continuous plate fins). (b) Fin–tube (circular tubes, continuous plate fins). (c) Fin–tube (circular tubes, circular fins). (d) Plate–fin (single pass). (e) Plate–fin (multipass).).

A special and important class of heat exchangers is used to achieve a very large (≥400 m^2/m^3 for liquids and ≥ 700 m^2/m^3 for gases) heat transfer surface area per unit volume. Termed compact heat exchangers, these devices have dense arrays of finned tubes or plates and are typically used when at least one of the fluids is a gas, and is hence characterized by a small convection coefficient. The tubes may be flat or circular, as in Fig 6.a and Fig 6. b, c respectively, and the fins may be plate or circular, as in Fig 6.a, 6.b and 6. c respectively. Parallel-plate heat exchangers may be finned or corrugated and may be used in single-pass (Fig 6.d) or multipass (Fig 6.e) modes of operation. Flow passages associated with compact heat exchangers are typically small ($D_h \leq 5$ mm), and the flow is usually laminar. [5]

IV. Application of Heat exchanger.

Not only are heat exchangers often used in the process, power, petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, alternative fuel, and manufacturing industries, they also serve as key components of many industrial products available in the marketplace. [6]

Heat exchangers are commonly used in practice in a wide range of applications, from heating and air-conditioning systems in a household, to chemical processing and power production in large plants. Heat exchangers differ from mixing chambers in that they do not allow the two fluids involved to mix. In a car radiator, for example, heat is transferred from the hot water flowing through the radiator tubes to the air flowing through the closely spaced thin plates outside attached to the tubes. [7]

V. Conclusion.

Effect of Fin pitch on the fin performance by plate type fins.

Experimentally investigated by Praveen pandey, Rozina Praveen, S.N.Mishra, for an Effect of fin pitch on the fin performance using plate type fins. They take three plate type fins attaching to a flat base plate. Three fin pitch settings 1cm, 2cm, 3cm were employed under free and forced heat transfer conditions. The heat transfer area was kept the same. The fin performance parameters heat transfer coefficient, base temperature and temperature profile along the length of the fin were studied and compared for different cases. The experiment set up which they are using is as shown in Fig 7. [8]

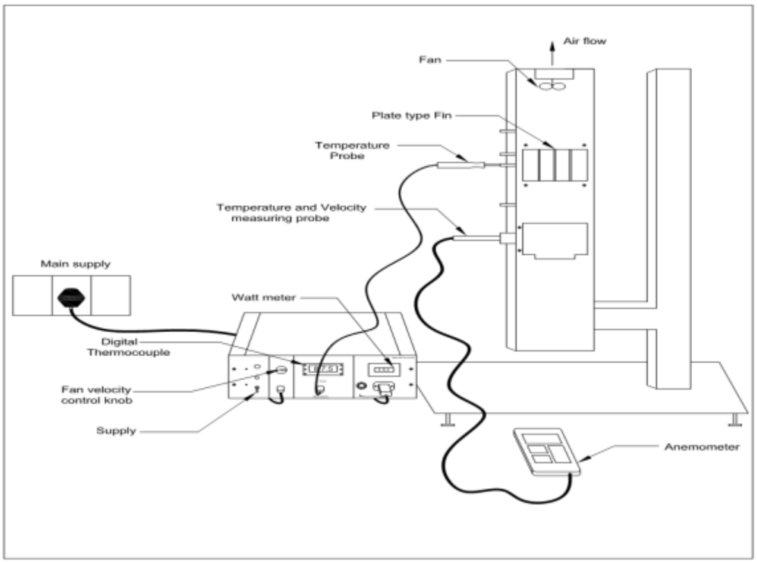

Figure 7.Schematic Diagram for the Experimental Setup

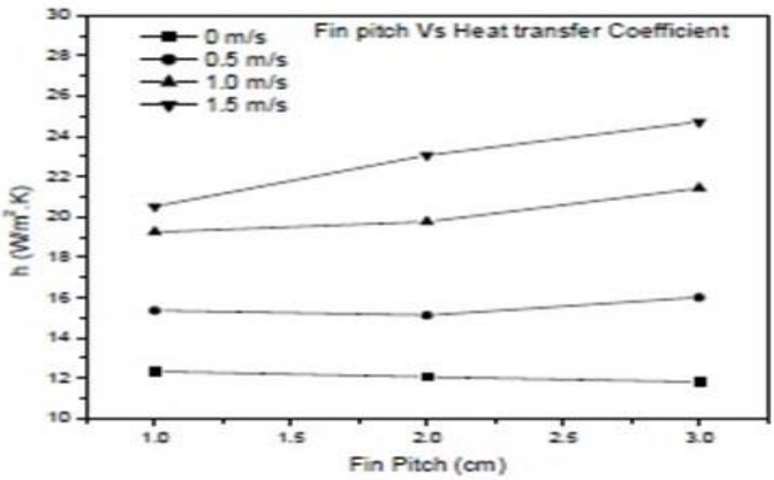

Figure 8. Effect of fin pitch and heat transfer coefficient

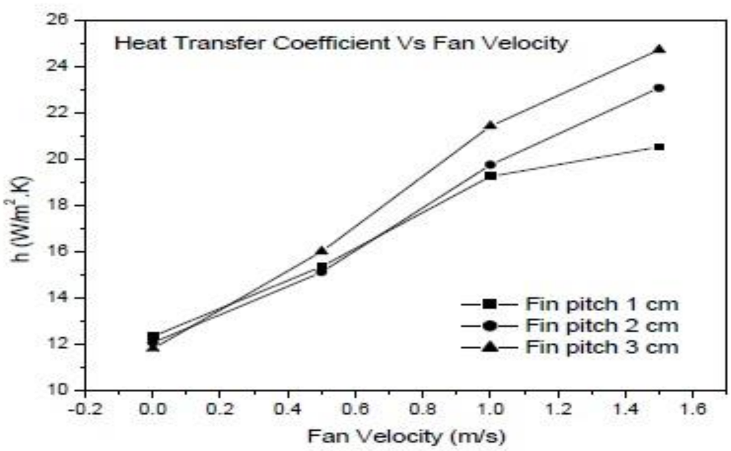

Figure 9. Effect of fan velocity and heat transfer coefficient.

The conclusions are summarized as

1. In free convection heat transfer condition, the effect of change in fin pitch on fin performance is not significant. There was no noticeable change in the fin base temperature and convection heat transfer coefficient with the change in fin pitch.

2. In forced convection condition, the effect of fin pitch on fin performance is more pronounced at higher air flow velocities over the fin surface. At 0.5 m/s velocity, the convection heat transfer coefficient value increased by about 5 percent when the fin pitch setting is changed from 1cm to 3cm. When the velocity is increased to 1m/s under similar condition, the increase is about 11 percent. Further, when the velocity is increased to 1.5m/s, the increase in convection heat transfer coefficient value is about 20 percent, which is a significant increase. The increase in heat transfer coefficient value is also manifested by a corresponding decrease in the fin base temperature.

Effect of Fin and Tube alignment on heat transfer performance.

The experimental data carried out by Yonghan Kim, Yongcham Kim and Daesik Sin for the effect of fin and tube alignment on the heat transfer performance of finned-tube heat exchangers with large fin pitch that can be used in the optimal design of finned-tube heat exchangers with large fin pitch.

In this study, six types of Heat exchangers with a discrete flat plate fin (type 1,3,4), a continuous flat plate fin(type 5,6), and a discrete wavy fin (type 2) tubes were tested by varying the air flow rate.both the effects of number of tube row, fin pitch, and fin type and the influences of tube and fin alignment on the heat transfer performance are investigated. The different fin configurations which they used are shown in fig 10 . [9]

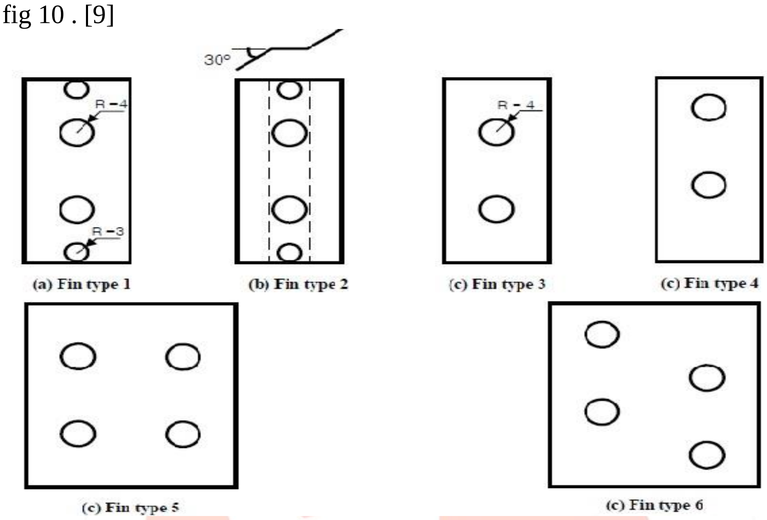

Figure 10.Fin configurations of the evaporator coil.

Table 1. Test conditions

	Parameter Value
Inlet air temperature	3
Inlet air relative humidity	(%) 60
Airflow rate (CMM)	0.8, 1.1, 1.4, 1.7
Refrigerant inlet temperature	33 ºC
Refrigerant mass flow rate	150 (kg/hr)
Longitudinal tube space	27, 30, 33 (mm)
Fin type Discrete flat plate, Continuous flat plate, Wavy Fin pitch	7.5, 10.0, 12.5, 15.0 (mm).
Number of row	1, 2, 3, 4
Fin and tube alignment	In-lined, Staggered

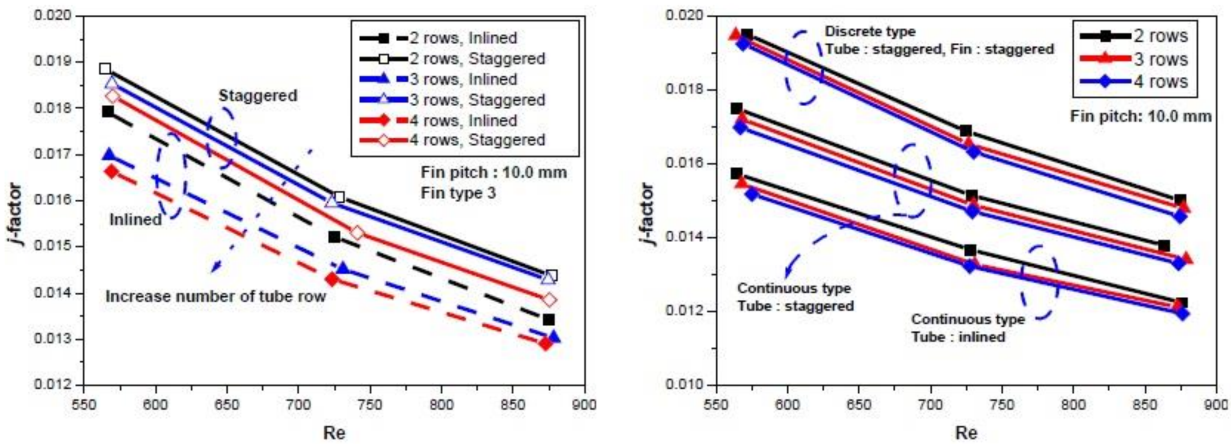

Figure 11. (a) Effect of fin alignment on the heat transfer performance with an increase of tube row. (b) Effect of Tube alignment on the heat transfer performance with an increase of tube row.

The conclusions are summarized as:

- The staggered fin alignment shows 7% higher heat transfer coefficients than the in-lined alignment, which effects are maintained regardless of number of tube row.
- The wavy shape discrete fin can improve the heat transfer performance by approximately 3%.
- The continuous flat plate finned-tube shows lower heat transfer performance than the discrete flat plate finned-tube.

Analysis of the heat transfer rate and efficiency for circular and elliptical annular fin.

The schematic diagram of the experimental apparatus used by N.Nagarani and K.Mayilsamy for the estimation of heat transfer on annular fin at one tube as shown in Fig 12 a and 12 b. The annular circular and elliptical fin made of aluminum is vertically mounted on the circular tube. The circular fins have the outer diameter of 99 mm, thickness 1mm and the space between the fin is 5mm. Length, diameter and thickness on the horizontal circular pipe made of aluminum are 400 mm,32 mm and 3 mm. Electrical heating coil with 0.5 kW capacity is kept inside the tube. Size of the box is 500 x 300 x 300 mm. [10]

Figure 12.a.Experimental setup for circular fin   Figure 14.b Experimental setup for Elliptical fin

Finally, they concluded that Elliptical fin efficiency is more than circular fin. If space restriction is there along one particular direction while the perpendicular direction is relatively unrestricted elliptical fins could be a good choice.

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