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A review on performance study of finned tube heat exchanger

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Abstract. The plate Fin-and-tube heat exchangers are one of the most common type of heat exchangers that are widely used in variety industrial applications like space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, aerospace industry and sewage treatment. It is very important to reduce the size, weight and enhance the heat transfer rate of heat exchanger. Fin-and-tube heat exchangers with different geometry and orientations are used to improve the thermal performance. The purpose of this paper is to provide an overview of research works carried out to improve the thermal performance of a heat exchanger by using different parameters like type of fins, orientation, shapes and locations. This review is to help understand how every mentioned parameters influences on improvement of thermal performance.

1. Introduction:

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, aerospace industry and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

Fins are surface extensions widely used in different types of heat exchangers for increasing the rate of heat transfer among a solid surface and surrounding fluid Fins are surface extensions widely used in different types of heat exchangers for increasing the rate of heat transfer among a solid surface and surrounding fluid. Mohammad Sikindar Baba et al [1] experimentally compared heat transfer enhancement and pressure drop in double pipe internally finned tube heat exchanger by using nano fluids and compared these results with plain tube heat exchanger. Results indicates that the heat transfer rate is 80–90% more than plain tube heat exchanger. often geometrically modified fins are incorporated, which besides increasing the surface area density of the heat exchanger, also improve the convection heat transfer coefficient. Some examples of such enhanced surface compact cores include Offset-strip fins, Louvered fins, Wavy fins, Plain fins and Pin fins. Of these, wavy fins are particularly attractive for their simplicity of manufacture, potential for enhanced thermal-hydraulic performance and ease of usage in both plate-fin and tube-fin type exchangers.

Enhancement of heat transfer can reduce the size of heat exchangers, reducing in pressure drop provide higher heat transfer efficiency, and yield savings of operating costs and materials. The enhancement of heat transfer is critically important in industrial applications such as process cooling, refrigeration, chemical processing, air separation, etc. Fins or extended surfaces play an important role to augment the rate of heat transfer. In situations of combined conduction-convection effects, depending on the application, various types of augmented heat transfer surfaces such as rectangular, triangular, trapezoidal fins, Pin fins, wavy fins, offset strip fins, louvered fins and perforated fins are used. It is a well-known fact that any enhancement technique will introduce additional fluid pressure drop, and often the ratio of pressure drop increase is larger than that of heat transfer enhancement. And the heat transfer rate reduces along with the height of the fin, to overcome the above mentioned problems various types of fin arrangements and fin geometries are used.

2. Effect of fins on thermal performance

Fins are used to enhance the heat transfer rate, due to extended surface heat transfer rate is increased as compared to un-finned heat exchanger. To further enhance heat transfer, different shapes can be used to effectively distort fluid flow. However, to avoid large heat transfer area per volume, various types of fins with different orientation are used.

2.1 Rectangular Fins

Plain fins are still popular as they are simple, durable and versatile in applications. Jayaram Thumbe [2] made an analysis of double pipe counter flow heat exchanger using fins attached to inner pipe their results shows that finned configuration gives overall better thermal qualities compared with un-finned heat exchanger. M. Kazemi et al [3] made an investigation to improve the heat transfer rate by using longitudinal fins on heat exchanger tubes by comparing bare tube heat exchanger during phase change. They used triple-fin and double fin located at different angles on the tube surface and compared the result with bare tube. It is observed that by using triple and double fins at an increase in angle of 600 to 1200 for triple fin there is 6 to 22.5 percent reduction in melting time, whereas for double fins at an angle reduction from 1500 to 450 reduces the melting time by 62 percent with respect to the simple heat exchanger, Fig.1 shows triple and double fin heat exchanger. Manish K. Rathod and Jyotirmay Banerjee [4] studied the heat transfer Enhancement in shell and tube latent heat storage unit using longitudinal fins. There is increase in the rate of heat transfer and The percentage reduction in melting time due to provision of fins is approximately by 50%.

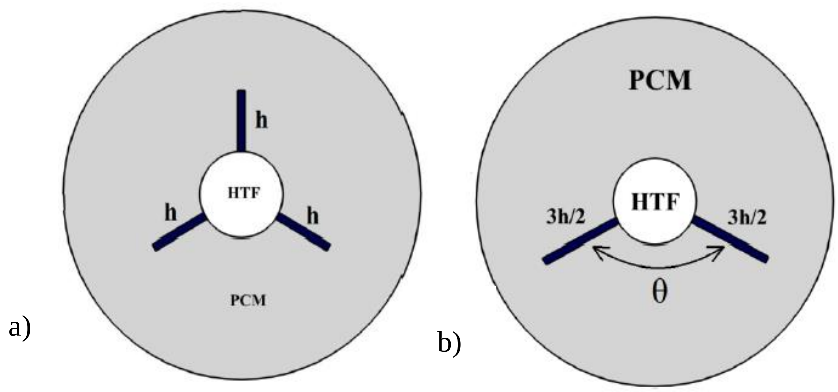

Figure1. Finned tubes a) Triple and b) double fin heat exchanger

Further enhancement of heat transfer in heat exchanger is carried out by using rectangular dwarf fins in this experiment Umesh et al [5] fig.2 shows the arrangement of rectangular dwarf fins. In this experimental analysis they compared the experimental data between full length and dwarf fins shows about 28% enhanced heat transfer coefficient as opposed to the full length fin array with 25% saving in material. At same time by saving the material alternate dwarf fins enhances the heat dissipation rates due to largest increase in the Nusselt number and at the same time decreases the cost of fin materials.

a) b)

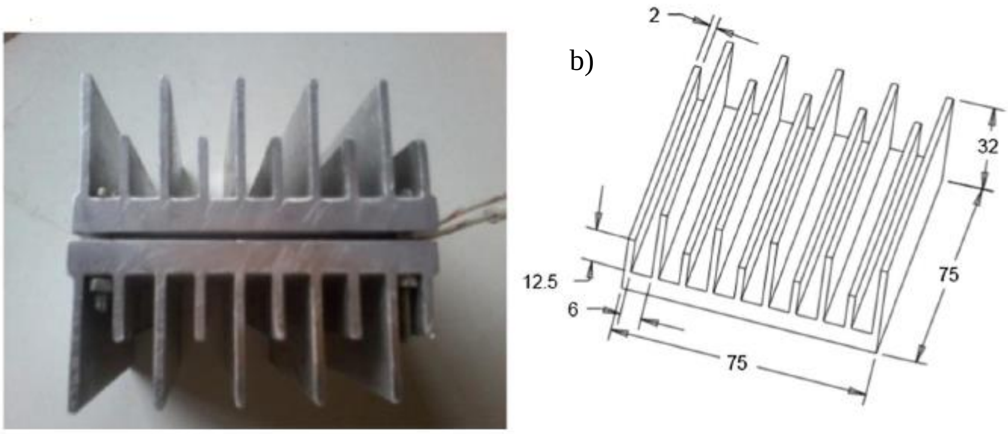

Figure2. Heat sink.a) Dwarf finsb)Dwarf fin dimensions

M.Anishi and B.Kanimozhi [6] made an attempt to enhance the heat transfer rate by surface modification of rectangular fins using different notches fig.3 shows the different types of notches formed on rectangular fins. Heat transfer from longitudinal fins with circular notch, triangular notch and without notch in a horizontal rectangular channel with uniform heat flux boundary condition at the bottom surface has been studied experimentally. From the experiments the heat transfer coefficient was obtained between 10.343 to10.552 for circular notched fin, 10.085 to 10.299 for triangular notched fin and 9.688 to 9.767 for without notched fins, among these triangular notched fins gives more heat transfer co efficient for the same heat inputs.

a) b) c)

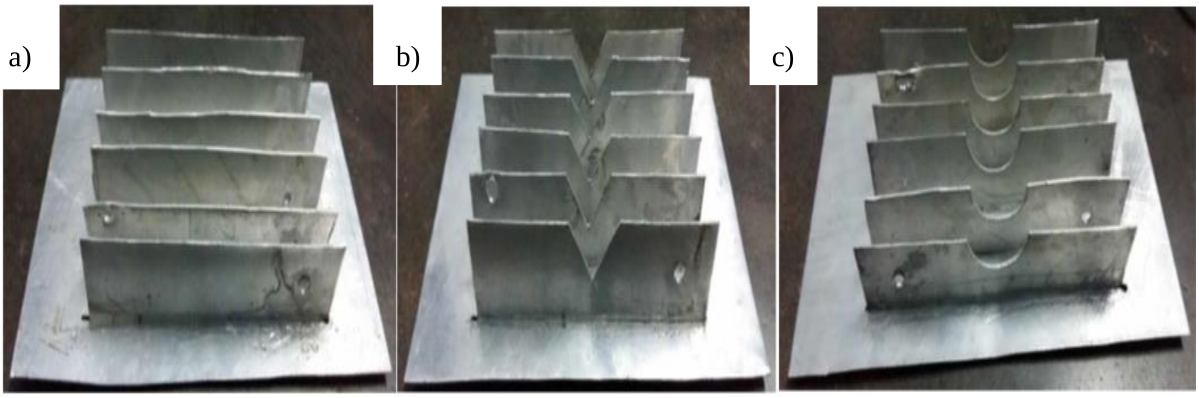

Figure 3. Fins. a)Rectangular fin array without notch. b) with triangular notch. c) with circular notch

Ashish Dixit & Anil Kumar Patel [7] made an experimental investigation on heat transfer characteristics of a plate fin having grooves of various configurations on two broad faces. Transverse grooved, inclined grooved, V-grooved, and multi-V-grooved fins are used in their analysis as shown in fig.4. They collected heat transfer data by varying Reynolds number from 1500 to 5000, and these results are compared with that of a smooth conventional fin to gauge the heat transfer performance of modified fin.

The maximum enhancement in Nusselt number corresponds to the inclined groove fin, whereas the highest value of grooved fin effectiveness is obtained for the multi-V grooved fin. Nakul Sreedhar and George Varghese [8] made an analysis of Longitudinal Fin Patterns in a Concentric Double Tube Heat Exchanger using LMTD and CFD Techniques In their analysis. y located fins are placed externally, internally and both external and internally to the inner tube and compared all three cases with bare tube heat exchanger . There is a increase in heat transfer rate in externally placed fins compared to other cases. Shiva Kumar et al [9] numerically studied the heat transfer performance in finned tube heat exchanger by using different fin configurations like rectangular, triangular and parabolic profiles, for constant mass flow rate of cold fluid and varying hot fluid flow rate rectangular finned tubes showed an average improvement of 6.1% over the triangular and 9.2% over parabolic finned tube. Similarly, For a constant hot fluid flow rate and varying cold fluid flow rate, it showed an improvement by 2 and 5% over the triangular tube and parabolic finned tube respectively.

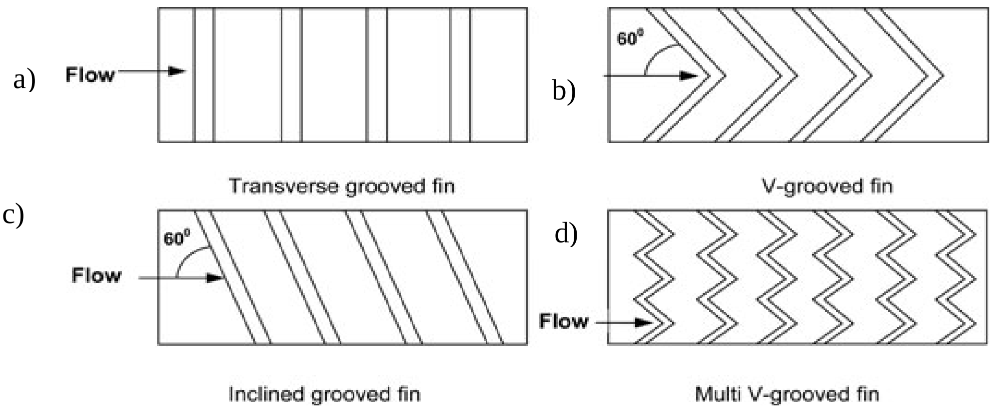

Figure 4. Various grooved Fin Configurations. a) Transverse groove. b) V-Groove. c)Inclined groove. d)Multi V-groove

2.2 Triangular fins

Further enhancement of heat transfer in heat exchanger will be carried out by using different types of fins, Ammar M. Abdulateef [10] analysed experimentally and numerically by using rectangular and triangular fins in triplex tube heat exchanger by using phase change materials. Two types of extended surfaces were used, namely the longitudinal and triangular fins in various configuration were numerically and experimentally studied fig.5 shows the two types of fins with different arrangements. A significant enhancement was observed using internal, internal-external, and external triangular fins at 14%, 16%, and 18% respectively, compared to longitudinal fins configuration. Consequently, the external triangular finned tube has been considered the most efficient for the brief solidification PCM (630 min). The total energy released for the both types of fins were compared. The simulation results were agreed well with the experimental results. Mathanraj [11] experimentally investigated the heat transfer rate in double pipe heat exchanger by using triangular fins as shown in fig.6. They compared the experimental results with plain tube heat exchanger the heat transfer coefficient for triangular finned tube is increases approximately by 1.5 times that of plain n tube heat exchanger, by using triangular finned tube heat exchanger the LMTD value decreases from 33.580C to 29.50C, Overall heat transfer coefficient (U) increases from 798.901 W/m^2.k to 1137.419 W/m2.k and effectiveness increases from 0.405 to 0.505 when compared with plain tube heat exchanger. B. Yu [12] experimentally studied heat transfer and pressure drop characteristics in entrance and fully developed regions of triangular wave like finned tube heat exchanger, they conducted the experiments for two cases: one is by blocking the inner tube (no air flowing through it) and the other one is by unblocking the inner tube of heat exchanger (air flowing through it). For fully developed region, the results were obtained for Reynolds number range of 9 x 102 to 3:5 x 103. It has been found that the wave-like fins enhance heat transfer significantly with the blocked case than unblocked case.

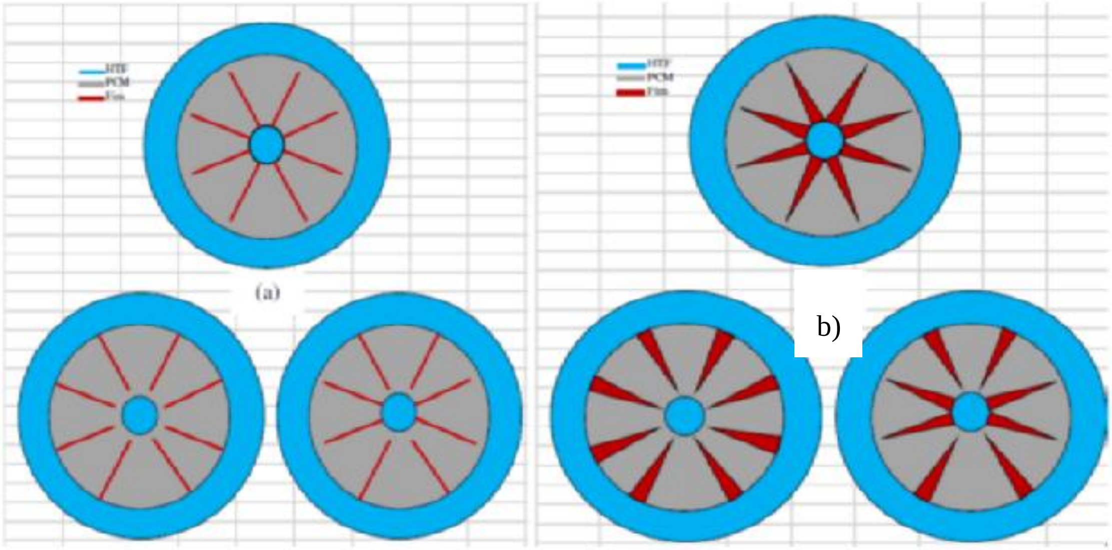

Figure 5. Physical configuration of triple tube heat exchanger. a) rectangular . b) triangular longitudinal fins

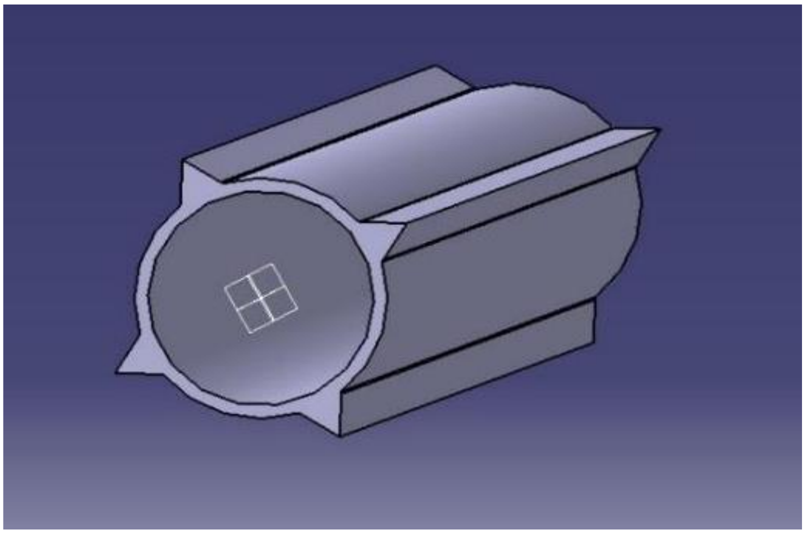

Figure 6. Triangular finned tube

2.3 Trapezoidal fins.

Balaram Kundu [13] verified shell and tube heat exchanger fitted with longitudinal fins of rectangular and trapezoidal shape by using kern's method. Fig.7 shows the arrangement of trapezoidal fins fitted to shell and tube heat exchanger. In this analysis rectangular and trapezoidal fin shapes longitudinally attached to tubes, when the results were compared between these two fins, in trapezoidal fins heat transfer was less than the rectangular fins by keeping the outer shell diameter, number of passes tube pitch layout as constant. But when the total volume of the fins over tube was kept constraint only, using the trapezoidal fins the heat transfer rate is enhanced in comparison with rectangular fins. The pressure drop is also decreased much more than that of rectangular fins.

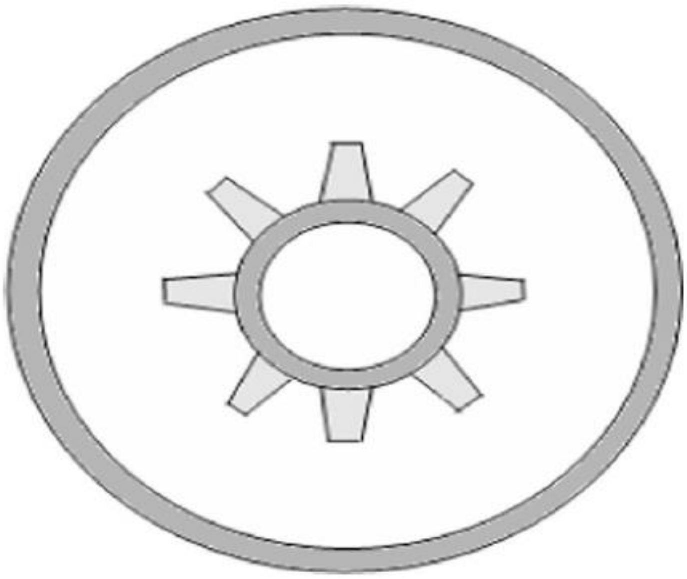

Figure 7. Shell tube heat exchanger attached with trapezoidal fins

Z. Iqbal [14] considered laminar forced convection on the shell side fined double pipe with triangular fins in their analysis. Here study flow in fully developed region of the finned annulus is subjected to constant heat flux boundary condition. Genetic algorithm has been employed as the optimizer and finite element as the flow solver. Optimal values of the configuration parameters are sort out of their specified respective ranges. A comparison of present optimal configuration of triangular fins with those of trapezoidal fins makes triangular fins a better choice in respects.

2.4 Wavy fins.

L. Sheik Ismail [15] analysed the Thermo-hydraulic design of compact heat exchangers (CHEs) is strongly dependent upon the predicted measured dimensionless performance (Colburn factor j and Fanning friction factor f vs. Reynolds number(Re) of heat transfer surfaces. Also, air (gas) flow mal-distribution in the headers, caused by the orientation of inlet and outlet nozzles in the heat exchanger, affects the exchanger performance. Three typical compact plate-fin heat exchangers have been analysed using fluent software for quantification of flow mal distribution effects with ideal and real cases. The headers have modified by providing suitable baffle plates for improvement in flow distribution. Three offset strip fin and 16 wavy fin geometries used in the compact plate-fin heat exchangers have also been analysed numerically. For the validation of the numerical analysis conducted in the present study, a rectangular fin geometry having same dimensions as that of the wavy fin has been analysed. The results of the wavy fin have been compared with the analytical results of a rectangular fin and found good agreement.

Yidan Song [16] has considered three dimensionless variables such as the channel space, the wavelength ratio and the amplitude ratio of two wavy walls are considered to find the optimal configuration of wavy-fin channels for the compact heat exchanger applied in a heat recovery system of a micro turbine fig.8 shows wavy fin channel. The results shows that the new generation of wavy fin channel can help to reduce the pressure drop by more than 54% and to enhance the heat transfer rate by around 26%.

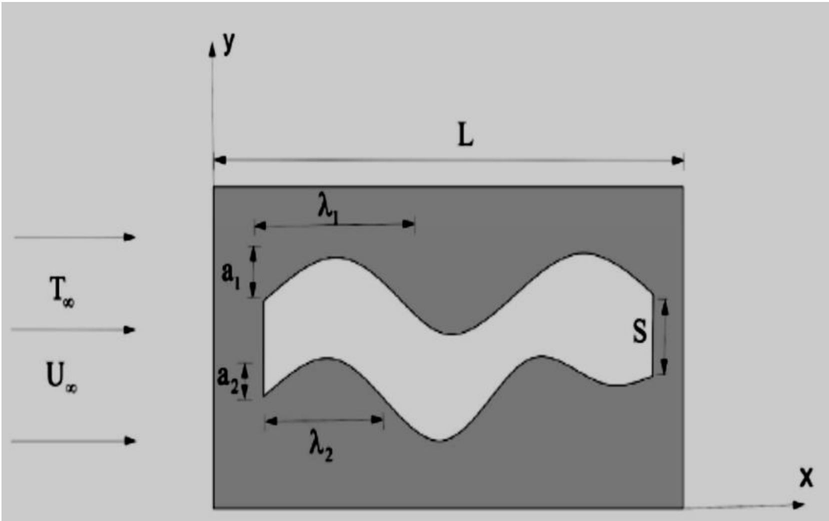

Figure 8. Schematic of wavy fin channel

Ratnesh Raj [17] experimentally measured heat transfer and pressure drop characteristics in doubly enhanced tube heat exchanger the fig. 9 shows the doubly enhanced tube used for the analysis they compared the bare tuburee heat exchanger. They used Ethylene Glycol and water as working fluids in their analysis.by considering constant pumping power, the maximum tube-side heat transfer enhancement was 6% with Ethylene Glycol in the laminar regime, and 18% with water in the turbulent regime. On a constant heat duty basis, the maximum reduction in pumping power was 23% with Ethylene Glycol in the laminar regime and 54% with water in the turbulent regime. The overall heat transfer enhancement (UAeff) enhanced/(UAeff) smooth based on the overall heat transfer coefficients was measured as 116% with water in the turbulent flow regime.

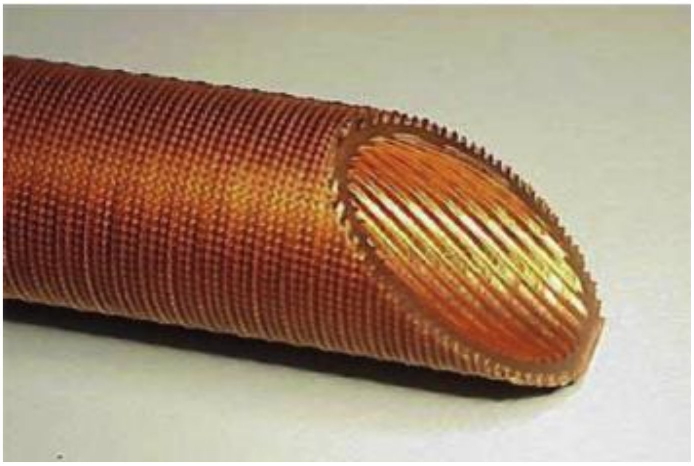

Figure 9.Doubly enhanced tube

Wen-Tao Ji [18] evaluated and summarised on single phase heat transfer enhancement for laminar and turbulent pipe flow in heat exchanger. The thermal–hydraulic performance of liquid flow and heat transfer in double pipe heat exchanger with internal integral-fins, twisted tape inserts, corrugations, dimples, are used in this comparison. The comparison results shows that internally-finned tubes as shown in fig.10 yield the best thermal–hydraulic performance compared with the other three types of tube, whose heat transfer rate augmentation over plain tube is more than the increase of friction factor at the same flow rate. Fahimeh Khanmohammadi [19] numerically investigated the heat transfer rate and fluid flow characteristics inside the tube with internal fins of various geometry and the obtained results shows that both heat transfer rate and friction factor of finned tubes are significantly higher than those of plain tube. Maximum values of Nusselt number friction factor for case with wavy fins are 510 and 779% higher than those for plain tube. Longfei Wang l[20] numerically studied the heat transfer performance and flow characteristics of a single-pass, stationary channel with wavy ribs and compared with V shaped ribs by considering the rib height, rib round radius and rib angle, As a result, wavy ribs with high rib height and large rib round radius perform better in increasing heat transfer and decreasing pressure drop. In comparison between 45^0 V-shaped ribs and wavy ribs shows that ribbed wall Nu/Nu_0 and ribbed wall area improve by 7–37% and 28–52%, respectively, without friction loss increasing. It is concluded that the wavy rib appears to be an effective method of heat transfer improvement in internal cooling channels. Özden Ağra et al,.[21] numerically investigated the passive heat transfer enhancement techniques they compared the heat transfer performance and concluded that there is higher heat transfer coefficient in helically finned tubes than smooth tubes and corrugated tubes.

a)

b)

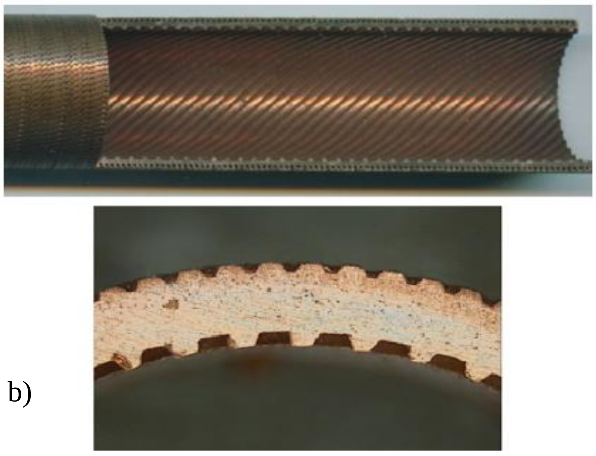

Figure 10. Internal helically finned tube. a)cut section. b) cross section

2.5 Special fins.

Kuen Tae Park [22] experimentally investigated natural convection heat transfer on vertical cylinder by using branched plate fins as shown in fig.11, They compared thermal resistance of branched fins for various branch angles with plate fins and found that the thermal resistance is reduced up to 36% than cylinder with plate fins for 100,000 < RaL < 600,000. Therefore, branched fins have potential for use in cooling equipment in various heat transfer applications.

Thamir K. Ibrahim [23] investigated heat transfer performance by using perforated fins under the forced convection during their study circular, rectangular, triangular shapes are made on plain fin surface as shown in fig12. By providing perforation to the fins will help in enhancing the heat transfer by creating the higher turbulence intensity at the perforated area. This increases the turbulence intensity which is related to the shape or geometry of the perforations itself. Power supplied to base plate is 150W and 100W respectively. The highest temperature different of the fin is with the circular perforation shape which is 51.29% when compared the temperature at the tip of the fins with the temperature at the heat collector followed by the rectangular perforation shape with 45.57% .then followed by the triangular perforation shape by 42.28% then lastly the non-perforated fins by 35.82%. The perforations of the fines show a significant effect on the performance of forced convection heat transfer

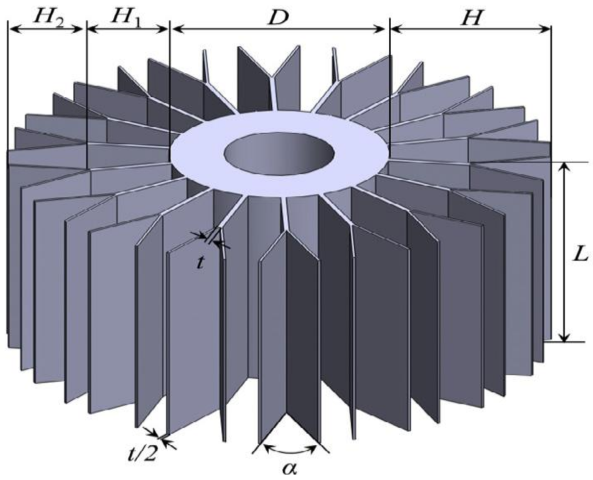

Figure 11. Branched fins on vertical cylinder

Koichi Nakaso, et al[24] are numerically investigated to estimate the heat transfer rate and the pressure drop for various geometries of the heat exchanger. Based on the numerical results, the Nusselt number and pressure drop are formulated for practical applications. By using fins the overall heat transfer rate raised by 15–50% due to increase in heat transfer area. Similarly, the pressure drop increased by 10–15%. If the power for the blower was proportional to the pressure drop, the ratio for the power of the blower increased 10–15%.

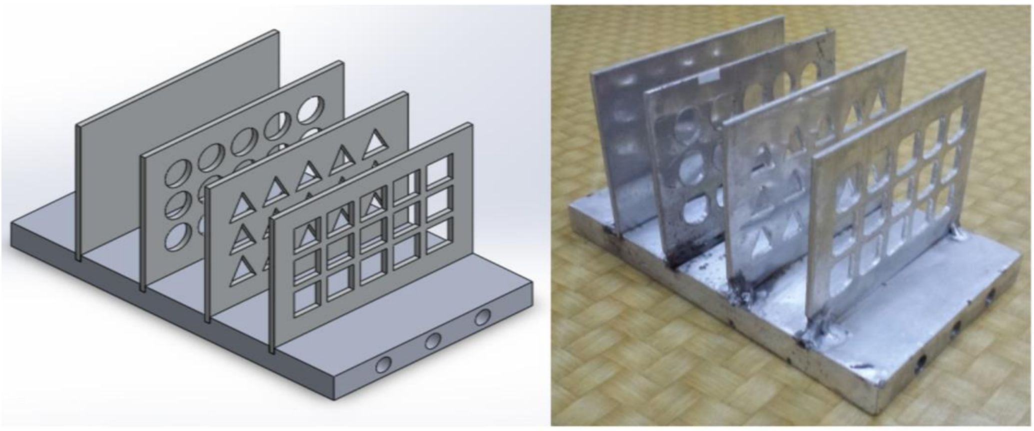

Figure 12. Perforated fins heat sink design and heat sink assemblies

3. Conclusion.

To enhance the heat transfer various types of fins were used in this review paper. Different fin geometries like rectangular, triangular, trapezoidal fins, Pin fins, wavy fins, offset strip fins, louvered fins and perforated fins are used in order to analyse the heat transfer rate and pressure drop measurement, various parameters like fin pitch, orientation, height and different types grooves used to study heat transfer rate, Pressure drop, Nusselt number friction factor Rayleigh number. Research works on variety of fins showed that, it improves the heat transfer by increasing the exposed area to allow more heat transfer and as well as disturbing the flow to produce turbulence and causing bulk fluid mixing. It was clear that standard wavy and rectangular fins provided better heat transfer but increased in pressure drop.

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