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Optimization of Flat Plate Heat Exchanger Tube by using Different Geometrical Shape

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Abstract: A plate fin heat exchanger is a type of heat exchanger design that uses plates and finned chambers to transfer heat between liquids. It is often classified as a compact heat exchanger to emphasize the relatively high ratio between the heat transfer surface and the volume. The main objective of the present work is to configure a optimum design of plate fin tube heat exchanger using Computational fluid dynamic approach and maximizing thermal performance. There are total five designs of plate fin and tube heat exchanger are used in present work and CFD analysis have been performed in it to get maximum heat transfer. It has been observed from CFD analysis that the maximum heat transfer can be achieved from plate fin and tube heat exchanger with elliptical tube arrangement inclined at 30° with 22.92% more heat transfer capacity as compared to circular tube plate fin heat exchanger. So that it is recommended that if the plate fins and tube heat exchanger with inclined elliptical tube used in place of circular tube arrangement, better heat transfer can be achieved.

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I. Introduction

A plate fin heat exchanger is a type of heat exchanger design that uses plates and finned chambers to transfer heat between liquids. It is often classified as a compact heat exchanger to emphasize the relatively high ratio between the heat transfer surface and the volume. The plate fin heat exchanger is widely used in many sectors, including the aerospace one, due to its compact size and light properties, as well as cryotechnics, where its ability to facilitate the transfer of heat is used with small differences in temperature.

Plate heat exchangers in finned aluminum alloy, often called welded aluminum heat exchangers, have been used in the aviation industry for over 60 years and have been adopted in the cryogenic separation sector. Air in chemical plants such as the processing of natural gas during the Second World War and immediately afterwards. They are also used in railway engines and motor vehicles. The stainless steel fins have been used in aircraft for 30 years and are currently being established in chemical plants.

II. Design of plate-fin heat exchangers

Originally designed by an Italian mechanic, Paolo Fruncillo. A finned plate heat exchanger is made up of layers of corrugated sheets separated by flat metal plates, generally in aluminum, to create a series of finned chambers. Separate flows of hot and cold liquid through alternating layers of the heat exchanger and are closed at the edges by side bars.

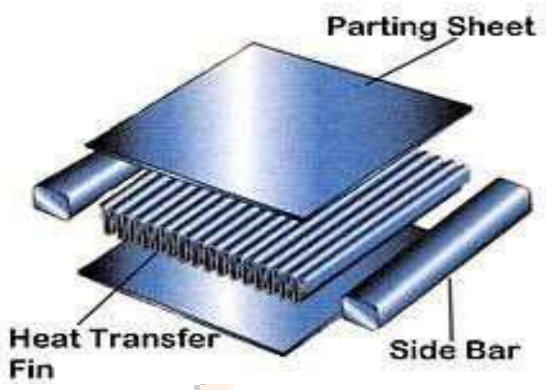

Figure 1: Principal Components of a Plate Fin Heat Exchanger

The heat is transferred by a current through the fin interface to the separation plate and through the subsequent series of fins in the nearby liquid. The fins are also used to increase the structural integrity of the heat exchanger and resist high pressures while providing an expanded surface for heat transfer. There is great flexibility in the design of plate fin heat exchangers, as they can work with any combination of gas, liquid and two-phase liquids. Heat transfer between different process flows is also considered, as a large number of heights and types of fins are available as different entry and exit points for each flow. The main four types of slats are: smooth, referring to simple triangular or rectangular designs with straight wings; Herringbone pattern with fins arranged laterally to provide a zigzag path; and notched and perforated, which refer to cuts and perforations in the fins to increase flow distribution and improve heat transfer.

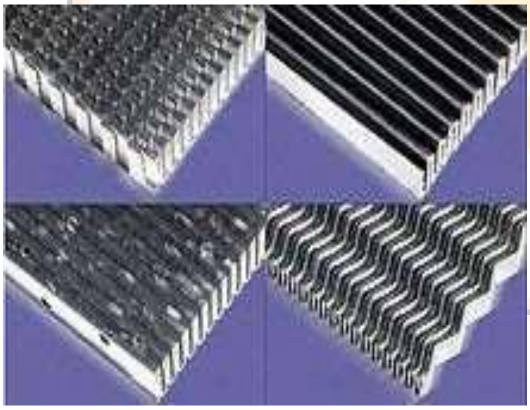

Figure 2: Different Fin Structures for Plate Fin Heat Exchangers

A disadvantage of finned plate heat exchangers is that they tend to be contaminated due to their small flow channels. Furthermore, they cannot be cleaned mechanically and require other cleaning procedures and adequate filtration to operate with potentially polluting flows.

III. Literature Review

C.Mahesh et al. This article aims to optimize the performance of finned plate heat exchangers by drilling through the FLUENT software. The widespread use of the heat exchanger concept has ensured many dimensional deviations and has shown that changes in dimensional parameters affect performance. It is therefore important to understand how the geometry of a compact heat exchanger can affect its performance. Consequently, a study of the parametric influence on the overall performance for the types of heat exchangers (smooth fin, circular fin and perforated elliptical fin, offset fin with and without perforation) is modeled and simulated in the same boundary conditions (low Reynolds number).

G. Harish et al. This article aims to optimize the performance of plate fin heat exchangers by drilling using the FLUENT software. The widespread use of the heat exchanger concept has ensured many dimensional deviations and has shown that changes in dimensional parameters affect performance. It is therefore important to understand how the geometry of a compact heat exchanger can affect its performance. Consequently, a study of the parametric influence on the overall performance for the types of heat exchangers (smooth fin, circular fin and perforated elliptical fin, offset fin with and without perforation) is modeled and simulated in the same boundary conditions (low Reynolds number). From the results, the behavior of the heat transfer, the Nusselt number, the factors j and f are analyzed and all the parameters of the different types of heat exchangers with plate fins are compared.

Jan Skočilas et al. This article is about a CFD (Computational Fluid Dynamics) simulation of the heat transfer process during a turbulent hot water flow between two chevron plates in a plate heat exchanger. For digital detection, a three-dimensional model was designed with the simplified geometry of two cross-wave channels provided by herringbone plates, taking into account the inlet and outlet openings. The influence on the main flow parameters of the angle of inclination of the shaft with respect to the direction of flow was taken into consideration. An analysis of the temperature distribution on the plates was carried out and areas with higher heat losses and lower intensity of the liquid flow were shown.

Dawid Taler & Paweł Ocłon et al. Finned tube heat exchangers operate in a cross flow arrangement. Numerical studies on the performance of these heat exchangers encounter difficulties in correctly predicting the total temperature difference on the gas side because the resistance of the thermal contact between the fin and the tube is unknown. Local measurements of its value are difficult to make. This article presents a modified method for estimating the average thermal resistance of the contact in a plate heat exchanger with fins and tubes. The proposed calculation method is based on CFD simulations and experimental measurements and allows an accurate prediction of the entire temperature difference on the gas side in a heat exchanger.

Karthik Pooranachandran at el. In the present work an experimental study is conducted to analyze the heat transfer properties of a compact heat exchanger with fins and elliptical tubes, which is used as a cooling device in an internal combustion engine. The experiments are carried out by placing the cooler in an open wind tunnel. The digital temperature drop on the air side is compared with that of the experimental values. The current calculation method confirms a good agreement between the experimental and numerical results.

J.N. Mao at el. Due to the complex mechanical turbulence caused by the micro-flap fins in relation to the problems of thermal interaction between the air and the refrigerant side, the distribution of the air flow in such a compact air-refrigerant heat exchanger with tube with fins is perceived as a composite and uneven behavior. The results show that a poor distribution of the air flow affects the condensation capacity, the pressure drop of the refrigerant and the theoretical electrical consumption of the fan. The reduction in maximum capacity and the increase in maximum pressure drop are respectively 6% and 34% for these types of poor air flow distribution.

Arafat Ahmed Bhuiyan et al. The purpose of this numerical study is to study the effect of heat transfer and the characteristics of the pressure drop in a four-row, four-row finned tube heat exchanger, which allows for an offset and arrangement of the tubes. coated with smooth and wavy fins for laminating ($400 \leq ReH \leq 1200$) and turbulent flow areas ($1300 \leq ReH \leq 2000$) using the commercial digital fluid dynamics code code ANSYS CFX-11. The turbulence model k-ω was used for the transition flow. The results are presented in the form of rationalized diagrams, velocity vectors and temperature and pressure distributions.

Y. Zhu et al. A computational fluid dynamics program (CFD), FLUENT, was used to predict the flow of fluid and the heat transfer in the heat exchanger channels with plate fins with smooth fins and serrated fins. The results of the calculations showed that the local heat transfer coefficients for cold and hot liquids in the heat exchangers with smooth or serrated fins had the maximum values at the inlet. The local heat transfer coefficients and the local pressure values for hot and cold liquids have changed abruptly on each toothed rib offset surface. The thickness of the boundary layer on the serrated ribs was thinner than the smooth ribs. The local heat transfer coefficient and the pressure drops of the liquids in the fin heat exchanger were greater than the fin heat exchanger.

IV. Methodology

A plate fin heat exchanger is a type of heat exchanger that uses plates and fin chambers to transfer heat between liquids. The plate fin heat exchanger is used in many sectors, including the aerospace one, thanks to its compact size and luminous properties, as well as cryogenics, where its ability to facilitate the transfer of heat to small temperature differences are used.

Figure 3: Steps of Expected Methodology

Geometrical parameters for the plate fin tube heat exchanger models:

Parameters	Values
Tube diameter fin collector outside diameter, D (mm)	9.87
Longitudinal tube pitch, L_l (mm)	27.45
Transverse pitch, L_t (mm)	31.65
Fin Pitch, F_p (mm)	3.21
Fin Thickness, F_t (mm)	0.20
Number of tube row, N	4
Fin and tube arrangement	In line, staggered

CFD Analysis of plate fin with various shape and angles of heat exchanger

Figure 4: Meshing of plate fin with elliptical tube inclined at 30° heat exchanger

Figure 5: Different boundaries of Plate fin with elliptical tube inclined at 30° heat exchangers

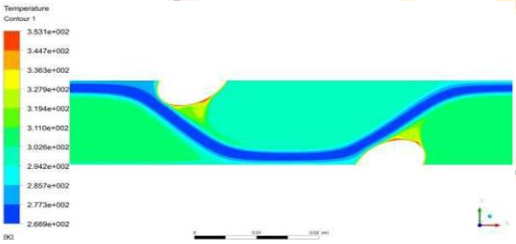

Figure 6: Temperature distribution over the plate fin with elliptical tube inclined at 30° heat exchanger

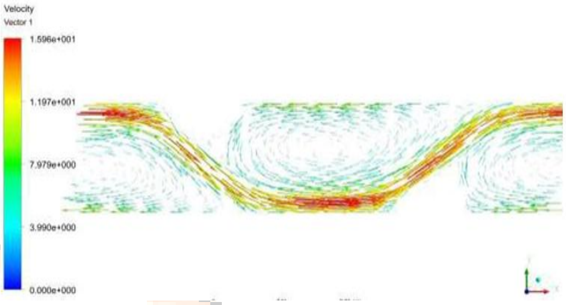

Figure 7: Velocity vector diagram of air flowing through the plate fin with elliptical tube inclined at 30° heat exchanger

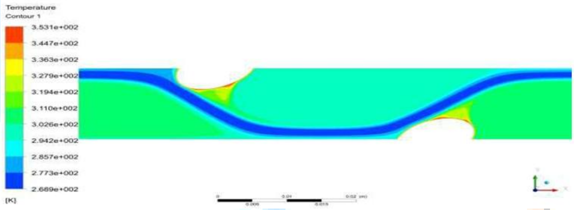

Figure 8: Temperature distribution over the plate fin with circular tube heat exchanger

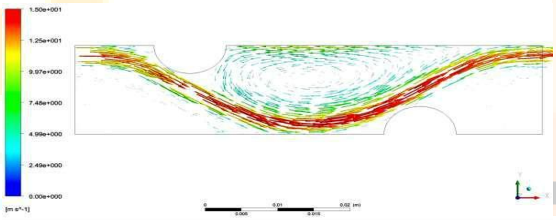

Figure 9: Velocity vector diagram of air flowing through the plate fin with circular tube heat exchanger

Figure 10: Velocity distribution over the plate fin with elliptical tube inclined at 45° heat exchanger

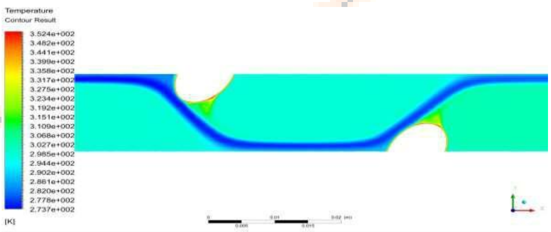

Figure 11: Temperature distribution over the plate fin with elliptical tube inclined at 60° heat exchanger

V. Result and Discussion

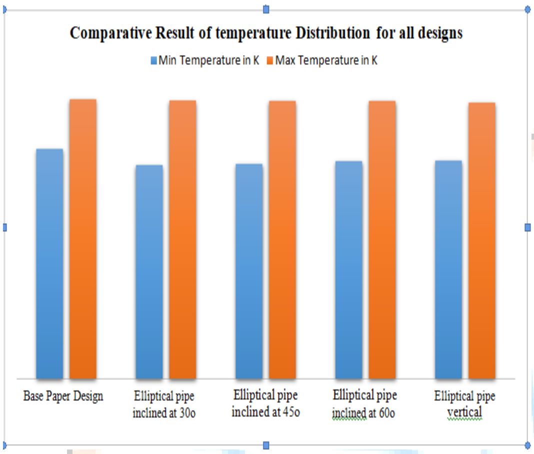

Figure 12: Comparative Result of temperature Distribution for all designs

From the above results, it was observed that the maximum and minimum temperature for the design of the base paper (plate fin and tube heat exchanger with circular tube arrangement) was 351.38 K and 289, 26 K per exchanger finned and tube heat exchanger with elliptical tube arrangement. An inclination of 30 ° was observed at 349.68 K and 268.77 K for fin and tube heat exchangers with an arrangement of 45 ° inclined elliptical tubes at 349.02 K and 270.03 K for heat exchangers heat with fins and tubes with an arrangement of elliptical tubes inclined at 60 ° 349.04 K and 273.48 K and for heat exchangers with fins and tubes with an arrangement of the elliptical tube inclined at 90 ° (vertical ellipse) were observed 347.29 K and 274.29 K, respectively.

From the above conclusions, it has been observed that the maximum heat transfer can be obtained from a plate and tube fin heat exchanger with an elliptical tube arrangement inclined by 30 ° with a heat transfer capacity of 23.22% more than a circular plate heat exchanger. Therefore, it is recommended to obtain the heat transfer of the mix if using the plate fins and the tube heat exchanger with an inclined elliptical tube instead of the circular tube arrangement.

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