Air Side Performance and Heat Transfer Characteristics of Wavy Fin-and-Tube Heat Exchanger

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Abstract:- In this study, air side performance of fine-and-tube heat exchanger is enhanced by modifying fin shape to Wavy fin, fin angle and also material. The conventional resistance on air side is maximum up to 85% of total resistance. This resistance should be minimizing to enhance the heat transfer rate. Wavy fins are particularly attractive for their simplicity of manufacture and potential for enhanced thermal –hydraulic performance. Here performance of wavy-fin and tube heat exchanger is calculated for different temperature and wave angle. Here thermal analysis is taken for steady state for two cases. we get the maximum heat flux is 43344 w/m^2 and minimum 116.5 w/m^2 for fin angle 17.5^0 and water inlet temperature 80^0 c.

Keywords: Wavy fin; Wavy fin-and-tube heat exchanger; Thermal analysis;

I. INTRODUCTION

Extended or finned surfaces are widely used in compact heat exchanger to enhance the heat transfer and reduce the size. Common among these are automobile radiators, charge air coolers, automobile air-conditioning evaporators and condensers to meet the demand for saving energy and resources. In these applications, the heat transfer is normally limited by the thermal resistance on the air side of the heat exchangers. Therefore, various augmented surfaces have been developed to improve air side heat transfer performance. Typical fin geometries are plain fins, wavy fins, offset strip fins, perforated fins and multi-louvered fins, which, besides increasing the surface area density of the exchanger, also improve the convection heat transfer coefficients. Of these, wavy fins are particularly attractive for their simplicity of manufacture and potentials for enhanced thermal-hydraulic performance. The air side thermal hydraulic performance of wavy fin and round tube heat exchangers have been studied by many researchers [1-4].

A lot of experimental and numerical studies have been conducted on airside heat transfer performances of wavy fin and circular tube heat exchangers. Wang et al. [1,2] made extensive experiments on the heat transfer and pressure drop characteristics of wavy fin and tube heat exchangers. Wongwises and Chokeman [3] experimentally investigated the effects of fin pitch and number of tube rows on the air side performance of herringbone wavy fin and tube heat exchangers. Jang and Chen [5] numerically studied the heat transfer and fluid flow in a three-dimensional wavy fin-and-tube heat exchanger. Manglik et al. [6] analyzed the effects of fin density on low Reynolds number forced convection in three-dimensional wavy-plate-fin compact channels by numerical simulation. Jones and Russell [7], Saboya and Sparrow [8], Rosman et al. [9] and Ay et al. [10] demonstrate that there exists a great variation of the heat transfer rate on the fin surface of the plate fin-and-tube heat exchanger. This also implies that the heat transfer coefficient on the fin surface is very nonuniform and the actual steady-state heat transfer coefficient on the fin surface should be the function of position. But it is very difficult to measure the local heat transfer coefficient on the fins, because for this purpose the local fin temperature and local heat flux are needed. The study of the distributions of the local heat transfer coefficient and fin efficiency on the fin surface is an important task to design high-performance heat exchangers because the results can be used to point out the areas where the enhancement is mostly needed and effective. Mao Yu Wen and Ching Yen Ho [11] present the information of an experimental design on the elements of the fin and tube heat exchanger. In this study the three different types of the fin design were proposed (plate fin, wavy fin, and compounded fin) and investigated. The heat transfer coefficient, the pressure drop of the air side, the Colburn factor (j), and fanning friction factor (f) against air velocity (1-3 m/s) and Reynolds number (600-2000) have been discussed in this paper. Shital B. Salunkhe and Dr.Rachayya R.Arakerimath [12] lists the Reynolds number, Prandtl number these relations are used to calculate the values of heat transfer coefficient and Nusselts number for forced convection. In this paper they are comparing different material fins heat transfer coefficient and Nusselts numbers. The main purpose of this study is to show the performance of different material fins to improving heat transfer.

Here in this study, the performance of fin and tube heat exchanger is enhanced by wavy fin augmentation technique and thermal analysis of same .

II. EXPERIMENTAL

EXPERIMENTAL SET-UP

Fig. 1 shows the schematic diagram of the wind tunnel used in the study. Air and hot water were used as working fluids. The main components of the systems were the heat exchangers, water flow loop, air supply, instrumentations and data acquisition systems. The wind tunnel system was designed to suck room air over the finned side of the heat exchangers by a 15 kW centrifugal fan. The speed of the fan could be adjusted by a frequency inverter. The tunnel was a rectangular duct 270 x 220 mm in cross-section. To minimize heat loss to the surroundings, the tunnel surface was insulated with a 10 mm thick glass wool layer. Being supported by stands of perforated steel plate, the tunnel system was kept 75 cm above the floor level of the laboratory. The inlet and exit temperature across the air side of the heat exchangers were measured by two T-type thermocouple meshes. The inlet measuring mesh consists of eight thermocouples while the exit mesh contains sixteen thermocouples. These thermocouples were pre-calibrated which have an accuracy of 0.1 ^{0}C. The measuring points were located at positions as described in the ASHRAE standard. These data signals were individually recorded and then averaged. The air pressure drop across the heat exchangers and the nozzles were, respectively, measured by precision differential pressure transducers, whose accuracies were 0.4% and 0.25%. The model of the two differential pressure transducers is WIDERPLUS-DP and C268. The air flow measuring station was a multiple nozzle code tester based on the ISO 5167 standard. The hot water flow loop consisted of a storage tank, a 100 kW electric heater, a centrifugal pump, a control unit and a flow meter. The purpose of this loop was to transfer heat to the air flowing through the heat exchangers. The temperature of the hot water in the water tank was measured by pre-calibrated RTDs (Pt-100 X) and was controlled by the temperature controller. Its accuracy was within 0.1 ^{0}C. After heating the water to the required temperature, the hot water was pumped out of the storage tank, delivered to the heat exchanger and then returned to the storage tank. The water temperatures at the inlet and outlet of the heat exchanger were measured by two per-calibrated RTDs (Pt-100 X) which have an accuracy of 0.1 ^{0}C.

Air inlet multiple nozzle plate Honey cone strengtheners variable exhaust fan system T/C inlet temperature measuring station air outlet pressure tap (inlet) difference pressure tap nozzle test unit inlet temperature tap water pressure tap (outlet) outlet temperature tap water T/C outlet temperature measuring station data acquisition system Setting means hot water tank Static pressure taps water pump.

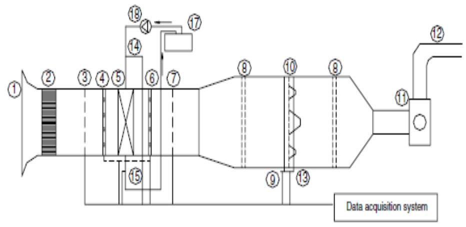

Fig. 1 Schematic diagram of the wind tunnel test apparatus

TEST HEAT EXCHANGER

The schematic diagram of the wavy fin-and-tube heat exchanger is shown in Fig. 2 which has three rows round tubes in staggered arrangement. The tube outside diameter D_c is 10.55 mm , fin pitch is vary between 2-3.2 mm , fin thickness 0.2 mm. Wavy angle vary – 0^0 ,10^0,15^0 ,17.44^0, 20^0 . Air flow direction length is 43.3 mm and wave amplitude is 1.5 mm. Transverse pitch is 25 mm and longitudinal pitch is 21.7 mm. Material selection is most important parameter for fin and tube heat exchanger. Copper tube and aluminium fins are commonly used in fin and tube type heat exchanger. Copper tube generally manufacture from any of five alloys – C10200, C10300, C12000. This is the purest forms of copper which contain 99.9% (min.) copper and 0.04 % phosphorus. Generally fins are made from aluminium. Aluminium 1100 has strong corrosion resistance. They are sensitive to high temperature ranging between 200 to 250^0 C also it have excellent forming characteristics. It contains 99% (min) aluminium and 0.12% copper. Also we are going to study aluminium fin and aluminium tube exchanger.

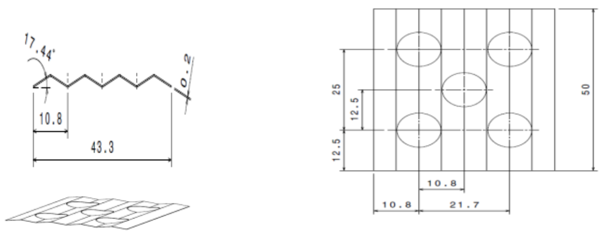

Fig.2. Wavy fin and tube exchangers

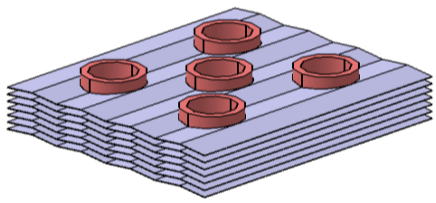

Fig.3. Physical model

III. THERMAL ANALYSIS

The thermal analysis for 2 models has been taken. The thermal analysis is done with steady thermal conditions. The boundary condition applied are a constant for all the models with inlet temperature 60 ^{0} c and 80 ^{0} c for the tube and the convection with all standard air properties. The heat flux for all the 6 models are tested and it is found that addition of heat properties increases the heat flux for the system. Here during the analysis the material selected is copper tube and aluminium fins. The standard properties of copper and aluminium are selected by default as the material is selected. In thermal analysis we are going to consider two cases one is fin angle 15^0 with inlet temperature 60^0 c and fin angle 17.5^0 with inlet temperature 80^0 c . Analysis is carried out for these two cases.

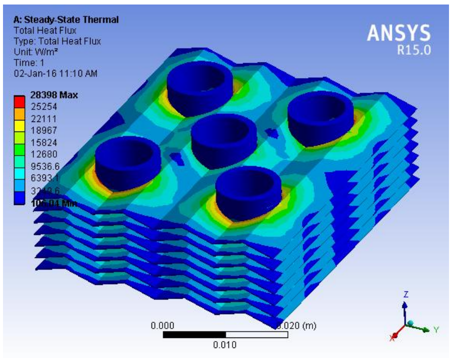

Fig.4. Thermal analysis of fin angle 15^0 and inlet temperature 60^0 c

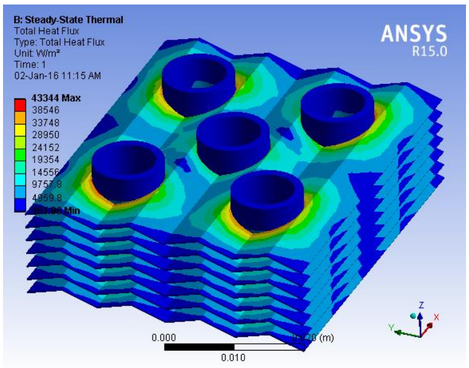

Fig.5. thermal analysis of fin angle 17.5^0 and inlet temperature 80^0 c

IV. RESULTS

The result shows that for case 2 we get maximum heat flux is 43344 w/m^2 and minimum heat flux is 161.5 w/m^2 . for case 1 we get maximum heat flux is 28398 w/m^2 and minimum heat flux is 106.5 w/m^2. From the analysis we get that heat flux varies with temperature and fin angle. In comparison with two cases 17.5 degree angle is better than 15 degree angle.

V. CONCLUSION

1. The present research study is related to performance enhancement of fin and tube heat exchanger. On the basis of literature review, Wavy fin increases the surface area density of the heat exchanger and also improve the convection heat transfer coefficient.

2. Wavy fins are particularly attractive for their simplicity of manufacture and potential for enhanced thermal –hydraulic performance.

3. The air side thermal hydraulic performance of wavy fin and tube heat exchanger depends on geometry of wavy fin such as wavy angle , fin pitch, flow length ratio etc.

4. The thermal analysis results shows that for case 2 we get maximum heat flux is 43344 w/m^2 and minimum heat flux is 161.5 w/m^2 . For case 1 we get maximum heat flux is 28398 w/m^2 and minimum heat flux is 106.5 w/m^2.

5. From the analysis we get that heat flux varies with temperature and fin angle. In comparison with two cases 17.5 degree angle is better than 15 degree angle.

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