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Survey on Three-Dimensional Performance Analysis of Wavy Fin Tube Heat Exchangers

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***Abstract*- In recent years, thousands of numerical and experimental studies have been performed on heat exchangers with different configurations. Mainly heat transfer and frictional characteristics have been studied in detail with respect to different geometrical parameters in various ranges of Reynolds number. Further these studies have been cross verified with researches already performed in this field. With the advent of new tools like CFD for the study of thermo-hydraulic characteristics, it has becomes easier to understand flow phenomena around the tubes for different rows and also in rest of flow regions. These studies also bring about some correlations so as to easily find the values of Colburn and friction factor for various different geometrical parameters so as to suit to the different industrial conditions and requirements.**

***Index terms*- Heat Exchanger, friction factor, Colburn factor, Reynolds number**

1. INTRODUCTION

A heat exchanger is a device by which thermal energy or enthalpy is transferred between two or more fluids having different temperatures and which are also in thermal contact with each other. The enthalpy can transfer between two or more fluids, between fluid and solid particulates and between fluid and a solid surface which are in thermal contact with each other. Usually in heat exchangers there is no work interaction. The heat exchangers are also adiabatically insulated, so no heat transfer takes place outside the system. The cooling and heating of a fluid, condensation of a single or multi- compound fluid, evaporation of a single or multi-compound fluid are the main applications of the heat exchanger. Generally, high effective heat exchangers are used in cryogenic applications. The effectiveness of heat exchangers used in liquefiers is of the order of 0.96 and above. There will be no liquid yield if the effectiveness of the heat exchangers falls below the design value. But in case of the use of heat exchangers in aircrafts, high effectiveness and performance is not so required rather the aim is to keep the weight and volume of the heat exchanger minimum. These requirements of low volume and weight of the heat exchanger lead to the generation of compact heat exchangers. In general Compact heat exchangers have large surface area density i.e. large surface area to volume ratio which is of the order 700 m2/m3or greater than this value for gas and it should be 300 m2/m3for two-phase streams and liquids.

Extended or finned surface are widely used in compact heat exchangers to enhance heat transfer and reduce their size. The plate fin-and-tube heat exchangers are widely used in variety of industrial applications, particularly in the heating, air-conditioning and refrigeration, HVAC industries. There are many different types of geometry for heat exchangers available and being used. The plate-fin and tube geometry is one of the most common configurations. There are different types of plate-fin geometry, the most common being the plain fin, where the fins are parallel plates attached to a hot element in the form of tubes or some other shape. These fins act as a sink, absorbing the heat out of the hot element with the help of conductive heat transfer. And then dissipating this absorbed heat onto the outside environment which is at a lower temperature.

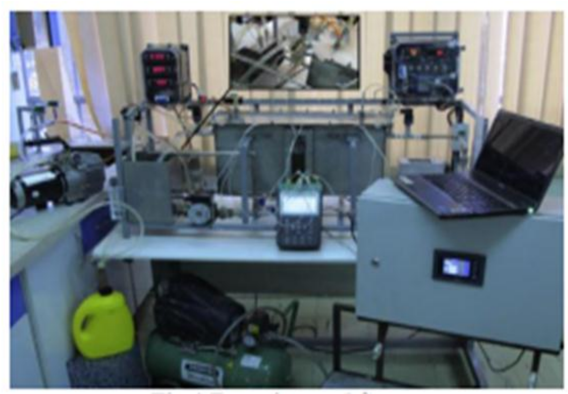
It has also been shown that the performance of heat exchangers can be greatly increased with the use of unconventionally shaped flow passages by Webb [4] and Wang et al. [5]. Some examples of such enhanced surfaced compact cores include plain, perforated offset strip, louvered, wavy, vortex generator and pin. Of these, as shown in Fig. 1, the wavy fins are particularly attractive for their simplicity of manufacture, potential for enhanced thermal-hydraulic performance, and ease of usage in plate fin-and-flat tube heat exchangers[1] The wavy surface can lengthen the path of airflow and cause better airflow mixing. As the wavy surfaces increase the flow path, it also increases the above mentioned surface area, thereby aiding in better heat transfer. The better flow mixing can be attributed to the corrugations existing in the flow channel.

These above mentioned heat exchangers are commonly operated with a hot liquid inside the tubes and air on the outside. The heat from the fluid is transferred to the fin by conductive heat transfer. The fins then dissipate the heat onto the environment by convective heat transfer. The dominant heat resistance of almost 80%-90% for an air-cooled heat exchanger is external, which is on the air side as mentioned by Wang et al. [6,7]. There is not much heat resistance in the tube side or the channel where liquid flow takes place. Hence, there should be a greater focus to reduce the heat resistance on the dominant air side. The flow of air between the fins is filled with obstructions in the form of tubes, and also the air is in constant contact with the fins. The same air is the carrier of heat from the fins and there by cooling the fins down. In order to design better heat exchangers and come up with efficient designs, a thorough understanding of the flow of air in these channels is required. Hence this study focuses on the heat transfer and friction characteristics of the air side for wavy fin and tube heat exchanger.

2. LITERATURE SURVEY

Arafat A. Bhuiyan (2013) investigated heat transfer and fluid flow characteristics of a four-row plain fin-and-tube heat exchanger using the Commercial Computational Fluid Dynamics Code ANSYS CFX 12.0. Heat transfer and pressure drop characteristics of the heat exchanger are investigated for Reynolds numbers ranging from 400 to 2000. Fluid flow and heat transfer are simulated and results compared using both laminar and turbulent flow models (k-u) with steady and incompressible fluid flow. Model validation is carried out by comparing the simulated case friction factor (f) and Colburn factor (j) with the experimental data of Wang et al. [1]. Reasonable agreement is found between the simulations and experimental data. In this study the effect of geometrical parameters such as fin pitch, longitudinal pitch and transverse pitch of tube spacing are studied. Results are presented in the form of friction factor (f) and Colburn factor (j). For both laminar and transitional flow conditions heat transfer and friction factor decrease with the increase of longitudinal and transverse pitches of tube spacing whereas they increase with fin pitches for both in-line and staggered configurations. Efficiency index increases with the increase of longitudinal and transverse pitches of tube spacing but decreases with increase of fin pitches. For a particular Reynolds number, the efficiency index is higher in in-line arrangement than the staggered case.

From the early literature on the experimental analysis of thermal–hydraulic performance of Copper–water nano-fluid flow in different plate-fin channels presented by M. Khoshvaght Aliabad (2014) et al., fabricated and tested seven plate-fin channels, including plain, perforated, offset strip, louvered, wavy, vortex generator, and pin. The fluid used for testing was copper–water nano-fluids. The experimental setup is shown in Fig. 1.



1: Experimental Setup

Experimental study on thermal hydraulic performance of a wavy fin-and-flat tube aluminium heat exchanger presented by Junqi Dong (2013) et al., in this experimental investigation a 16 samples with different geometry parameters were tested and the effects of fin height, fin pitch, fin length, wavy amplitude, and wavy length on the heat transfer and pressure drop were studied.

Experimental and numerical investigation of thermal -hydraulic performance in wavy fin-and-flat tube heat exchangers presented by Junqi Dong (2016) et al., experimentally investigated the air flow and heat transfer characteristics over the wavy fin heat exchangers and the results of friction factor and heat transfer performance test data are for fully developed turbulent region of air flow in the wavy fin.

Jose Fernandez-Seara (2013) et al., investigated on the pressure drop and heat transfer characteristics of a titanium brazed plate-fin heat exchanger with offset strip fins by using firstly water on both sides of the heat exchanger and secondly 10-30 wt% ethylene glycol aqueous solutions as working fluids and both the results were compared. The experimental setup is shown in the Fig..2.

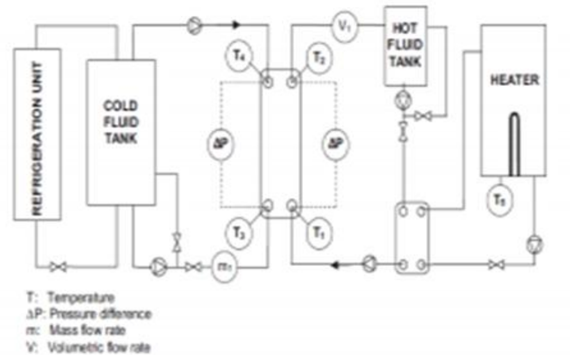


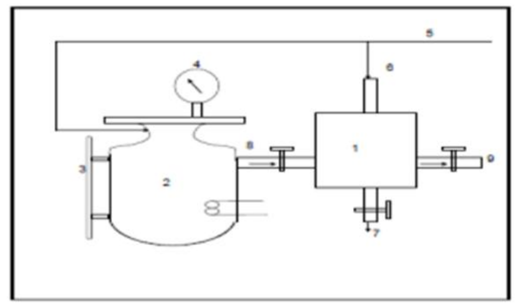
Fig 2: Experimental Setup

Giovanni lozza (2005) et al., showed the performance of various fin configurations in air cooled condenser and liquid coolers to enhance the heat transfer capabilities of the devices the results showed louvered fin geometry had the best heat transfer rate but the pressure drop was high.

S.M. Pesteei (2005) et al., investigated experimentally study of the effect of winglet location on heat transfer enhancement and pressure drop in fin-tube heat exchangers the results showed a reasonable amount of increase in the heat transfer with addition of winglet type vortex generators.

Ting Ma (2011) et al.,conducted an experimental study on investigation of a novel bayonet tube high temperature heat exchanger with inner and outer fins where the numerical results showed that the inner fins and inner tube both should not be welded together and the mass flow rate and the inlet temperature on the fuel gas side have a reasonable effect on the heat transfer rate and effectiveness, and the pressure drop ratios are mainly affected by the mass flow rate rather than the inlet temperature.

Design and experimental analysis of spiral tube heat exchanger by Jay.J. Bhavsar(2013) et al., a spiral tube heat exchanger was fabricated and experimental analysed and was compared with a shell and tube heat exchanger and the results showed the spiral tube heat exchanger had a better heat transfer rate with an increase in pressure drop compared to shell and tube heat exchanger. Performance analysis of cross flow plate fin heat exchanger for Immiscible system using ANN by M.Thirumarimurugan(2010) et al., the results such effectiveness and overall heat transfer were obtained experimentally and simulation results were also obtained by using ANN general regression it showed the predicted results obtained by the ANN approach are close to the experimental results. The experimental setup used for this experiment is shown in Fig. 3.



1 Cross flow heat exchanger,
2 Steam generator,
3 Level indicator,
4 Pressure guage,
5 Cold liquid,
6 Cold liquid inlet,
7 Cold liquid outlet,
8 Steam inlet,
9 Steam outlet

Fig 3: Experimental Setup

Experimental determination of correlations for mean heat transfer coefficients in plate fin and tube heat exchangers by Dawintaler (2012) experimental determined the heat transfer coefficient for a cross flow plate fin and tube heat exchanger and correlation were developed for the this type of heat exchanger the result show increase in heat transfer and as well as increase in pressure drop.

3. CONCLUSION

Several previous studies have been performed on plate and tube fin heat exchangers, the geometrical parameters have been varied for different range of Reynolds number which brought us some important conclusions. Heat transfer increases whereas pressure drop decreases with increased fin pitches and vice versa. Heat transfer is directly proportional to fin thickness. The louver fin has higher values of f and j factor compared to wavy and plate fin configurations. The number of tube rows has negligible effect on fictional and heat transfer characteristics. The effect of number of tube rows on heat transfer is prominent at low Reynolds number values. Heat transfer is always higher in staggered tube arrangement than that of in-line arrangement. Heat transfer is higher for highly conductive material at high Reynolds number values. The pressure drop for staggered arrangement is always higher than that of in-line arrangement. Plate and flat tube-fin heat exchanger have higher heat transfer with wing type vortex generator than that of plate and round tube-fin configuration with VGs. VGs embedded fins helps in reduction of fin area by 25% as compared to plain fin heat transfer area.

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