CHAPTER 2

LITERATURE REVIEW

There are several developments going on in the field of louvered fin and flat tube compact heat exchangers. Cowell et al (1995) presented an overview of the operating mechanisms in heat transfer surfaces with inclined multi-louvered fins. The performance characteristics of these surfaces are compared with the offset strip fin configuration. On the basis of currently available data, it has been shown that louvered fins are capable of outperforming offset strip fins.

The major focus of the present review includes the correlations for the $f$ and $j$ factors, thermo-hydraulic performance analysis, the parametric analysis and other studies such as effects of vortex generators, flow visualization, frost deposition, dehumidification condition, effects of thermal wake interference, comparison of louvered fin with different fin configurations and use of nanofluids as heat transfer fluids on the louvered fin and flat tube compact heat exchanger.

2.1 CORRELATIONS FOR $f$ AND $j$ FACTORS

The $f$ and $j$ factors being the most important characteristic parameters in the field of the compact heat exchanger, the development of these factors and other studies comparing these factors are reported as the first part of the literature survey.
2.1.1 Experimental Investigation

Davenport (1983) studied the characteristics of a nonstandard variant of the flat tube and corrugated louvered fin. His experimental results revealed that the flow pattern could be characterized in terms of duct directed or louvered directed flows, depending on the Reynolds number. At a low Reynolds number, the boundary layers are so thick that the gap between the adjacent louvers is blocked, and the flow is duct directed in the direction of the fin. At a higher Reynolds number, the boundary layers are thinner, and the flow is almost aligned with the louvers. He considered 32 samples of louvered fins to develop the correlations for the $f$ and $j$ factors.

Achaichia and Cowell (1988) conducted an experiment to find the heat transfer and pressure drop characteristics of a flat tube and louvered plate fin surfaces using a wind tunnel test rig. They proposed heat transfer and friction correlations, using the data bank, consists of several samples of louvered fin heat exchangers with different geometrical parameters, including transverse tube pitch, number of tube rows, hydraulic diameter, ratio of minimum free flow area to frontal area, louver angle, louver pitch and fin pitch. The data cover the Reynolds number range from 120 to 8000 for the heating of air at ambient temperature. They found that $j$ is independent of $Re$, for $Re_{Dh} < 300-1000$, because the airflow is relatively duct directed at a low Re and louver directed at a high Re, which was reported later by Webb and Trauger (1991) also.

Sunden and Svantesson (1992) reported that the louvered surfaces are more efficient than the corresponding smooth surfaces. They developed the correlations for the Colburn $j$ factor and Fanning friction $f$ factor from
their experiments, by varying the louver pitch/fin pitch ratio from 0.26 to 0.91, louver angle from 14° to 34° and Reynolds number from 100 to 700.

Chang and Wang (1997) developed a generalized heat transfer correlation for louver fin geometry, with the aid of a large data bank from the already published literature. This data bank consists of 91 samples of louvered fin heat exchangers with different geometrical parameters, including louver angle, tube width, louver length, louver pitch, fin length and fin pitch. For corrugated louver fin geometry, it is shown that 89.3% of the corrugated louvered fin data are correlated within 15%, with a mean deviation of 7.55%. Later, Chang et al (2000) developed a generalized frictional correlation, using the same 91 samples of louvered fin heat exchangers, used in their earlier study for heat transfer correlation. The proposed correlation gives a mean deviation of 9.21%, and it is shown that 83.14% of the frictional data can be correlated within ±15%.

Wang et al (1999) proposed the general heat transfer and friction correlations for louver geometry, having a round tube configuration. A total of 49 samples of the louvered fin and tube heat exchangers, with different geometrical parameters, including louver pitch, louver height, longitudinal tube pitch, transverse tube pitch, tube diameter and fin pitch, were used to develop the correlations. The proposed correlation described that 95.5% of the Colburn factor and 90.8% of the Fanning friction factors were within ±15%.

Kim and Bullard (2002 (a)) studied the air-side heat transfer and pressure drop characteristics of multi-louvered fin and flat tube heat exchangers. The air-side thermal performance data were analyzed using the effectiveness-NTU method, for the cross-flow heat exchanger with both fluid unmixed conditions. The heat transfer coefficient and pressure drop data for
heat exchangers with different geometrical configurations, were reported in terms of Colburn $j$ factor and Fanning friction factor $f$, as the functions of the Reynolds number, based on the louver pitch. The general correlations for the $j$ and $f$ factors were developed and compared with the other correlations. The $f$ correlation indicates that the flow depth is one of the important parameters for the pressure drop.

Chang et al (2006) proposed an amendment to the previous correlation developed by Chang et al (2000) for the generalized frictional correlation for louvered fin geometry. The proposed amendment eliminates the discontinuity of the original correlation, and gives a mean deviation of 9.11%, and it is shown that 83.91% of the frictional data can be correlated within $\pm$15%.

Dong et al (2007) performed an experimental study on the air side heat transfer and pressure drop characteristics of 20 types of multi-louvered fin and flat tube heat exchangers. A series of tests were conducted for the air-side Reynolds numbers of 200–2500, based on the louver pitch with different fin pitch, fin height, fin thickness, louver angle and flow length, at a constant tube side flow rate of $2.8 \, m^3/h$. The air side thermal performance data were analyzed using the effectiveness-NTU method. The characteristics of the heat transfer and pressure drop for the different geometry parameters were reported in terms of Colburn $j$ and Fanning friction $f$ factors as a function of $Re_{Lp}$. The general correlations for the $j$ and $f$ factors were derived by the regression analysis and F test of significance. The correlations of the $j$ and $f$ factors predict the test data within a rms error of $\pm$10% and $\pm$12%, and the mean deviations are 4.1% and 5.6%, respectively.
Kim and Cho (2008) experimentally investigated the heat transfer and pressure drop characteristics of heat exchangers having louvered fins. The samples had small fin pitches (1.0 - 1.4 mm), and the experiments were conducted up to a very low frontal air velocity (as low as 0.3 m/s). Below a certain Reynolds number (critical Reynolds number), a fall-off of the heat transfer coefficient curve was observed. The critical Reynolds number was insensitive to the louver angle, and decreased as the louver pitch to fin pitch ratio \( (L_p/F_p) \) decreased. The existing correlations on the critical Reynolds number did not adequately predict the data. The friction factor increased, as the fin pitch decreased and the louver angle increased. A new correlation predicted 92% of the heat transfer coefficient, and 94% of the friction factor within ±10%.

Li and Wang (2010) conducted an experimental study on the air-side heat transfer and pressure drop characteristics for brazed aluminium heat exchangers with multi-region louvered fins and flat tubes. A series of tests were conducted for heat exchangers with different numbers of louver regions, at the air-side Reynolds numbers of 400-600 based on the louver pitch. The air-side thermal performance data were analyzed by using the effectiveness-NTU method. In this study, the correlations of the \( j \) and \( f \) factors are obtained based on geometry parameters, including the number of louver regions, louver angle, fin pitch, fin height, louver height, flow depth, and fin thickness.

It is observed from the above literature, that the researchers have developed the correlations of the \( f \) and \( j \) factors, using their experimental results as a useful tool for engineers to design such heat exchangers.
2.2 THERMO-HYDRAULIC PERFORMANCE ANALYSIS

2.2.1 Experimental Investigation

Lee (1986) experimentally investigated the heat transfer and pressure drop characteristics of an array of plates, aligned at various angles of $\Theta = 20 - 35^\circ$ in the direction of the air flow in a rectangular, straight duct in the range of Reynolds numbers between 350 and 5000. The heat transfer coefficients of the forward and back sides of the plates have been separately determined, and the average coefficient between the two, closely approximates the laminar short duct theory at low Reynolds numbers ($N_{Re,Dh} \leq 1200$), and is nearly independent of the angle of alignment with respect to the air flow direction. However, at higher Reynolds numbers ($N_{Re,Dh} \geq 1500$) the average coefficient deviates significantly from the theory. The pressure drop measurements through the plate array showed, that the streamwise, per-row coefficient $K_p$ is a function of only the plate angle, and is independent of the Reynolds number $N_{Re,Dh}$.

Cuevas et al (2011) tested a whole heat exchanger with a hydraulic diameter of 2.3 mm. A glycol–water mixture (60/40 in volume) circulates through the tubes at flows ranging from 100 to 7800 l/h and at a supply temperature of 90ºC. This fluid is cooled with the ambient air at a temperature of 20ºC, and at frontal air velocities varying between 0.5 and 7 m/s. The thermo-hydraulic performance of the heat exchanger is compared with the classical correlations given in the literature, for the heat transfer and the friction factor calculation. For laminar regimes ($Re < 2300$) on the glycol–water side, there was a good agreement between the experimental and theoretical results. However, the Nusselt numbers measured in the transition zone were 0.59 times the ones predicted by the Gnielinski correlation. As for the friction factor, the difference between the measured and the calculated values was 0.89 for the transition zone. On the air side, the identified heat
transfer coefficient was 1.34 times the one predicted by the Chang and Wang correlation (1997).

2.2.2 Experimental and CFD Analysis

Springer and Thole (1998) described a methodology used for designing an experimental model of a two-dimensional louvered fin geometry, scaled up by a factor of 20, that allows for flow field measurements. The particular louver geometry studied for these experiments had a louver angle of 27°, and a fin pitch to louver pitch ratio of 0.76. The measured flow field confirmed that, in fact, the flow is louver directed for this geometry at $230 \leq Re \leq 1016$. Differences in the flow field for Re=230 as compared with Re=1016 were detected, both by the mean and time-resolved velocity measurements. For the Re=1016 case, the mean velocities indicated, that wakes leaving the set of louvers located one and two louvers upstream were still evident, while for the Re=230 case, the mean velocities indicated, that only the wake from one louver upstream was evident.

2.2.3 CFD Analysis

Atkinson et al (1998) presented a detailed evaluation of two and three dimensional numerical models of flow and heat transfer over louvered fin arrays, in compact heat exchangers. Two 3D models are described, both of which incorporate the effects of the tube surface area and fin resistance on the overall heat transfer rate. Both these features lead to a lowering of the predicted heat transfer rate per unit area compared with the 2D model, and as a result, the 3D models give predictions of the overall heat transfer in better agreement with the experimental observations.
Cui and Tafti (2002) studied the flow and heat transfer in a three-dimensional geometry of a multi-louvered fin. The geometry includes the angled part of the louver and its transition to the flat landing along the fin height. The flow on the angled louver is characterized by span wise vortex structures, which are shed from the separated shear layers on the top and bottom surface of the louver. A high energy compact vortex jet forms in the vicinity of the louver junction with the flat landing, and is drawn under the louver. The top surface experiences large velocities in the vicinity of the surface, and exhibits high heat transfer coefficients. Although the flow slows down at the flat landing, the large induced velocities on the top surface increase the heat transfer coefficient on the tube surface.

Perrotin and Clodic (2004) presented the results of 2D and 3D CFD models of compact louvered heat exchangers, for the determination of the heat transfer and pressure drop characteristics and local information analysis. The 2D and 3D steady simulations are performed and compared to the experimental results and correlations of the literature. The 2D CFD approach allows one to study in detail, the 3 main phenomena involved in the louvered array, which are the flow configuration (ducted or flat plate), the thermal wake effects of the upstream louvers, and the flow unsteadiness that occurs at higher Reynolds numbers.

Malapure et al (2007) presented a numerical investigation of the fluid flow and heat transfer characteristics of louvered fins and flat tube in compact heat exchangers. Three-dimensional simulations of single and double row tubes with louvered fins were conducted. Simulations were performed for different geometries with varying louver pitch, louver angle, fin pitch and tube pitch and for different Reynolds numbers. Conjugate heat transfer and conduction through the fins are considered. The air-side performance of the heat exchanger is evaluated by calculating the Stanton number and friction
factor. The local Nusselt number variation along the top surface of the louver is calculated, and the effects of the geometrical parameters on the average heat transfer coefficient are computed. Design curves are obtained, which can used to predict the heat transfer and the pressure drop for a given louver geometry.

Li et al (2010) proposed a new type of aluminum heat exchanger with an integrated fin and micro-channel. The air-side heat transfer and flow characteristics of the integrated fin and micro-channel heat exchanger were systematically analyzed by a 3D numerical simulation. The effect of flow depth, fin height, fin pitch and fin thickness at different Reynolds numbers was evaluated by calculating the Colburn factor $j$ and Fanning friction factor $f$. A parametric study method was used to analyze the fin designed parameters affecting the performance of the heat exchanger. The results show that the contribution ratio of the fin geometries in the descending order are the flow depth, fin pitch, fin height and fin thickness. The air-side performance of the integrated fin and micro-channel heat exchanger is compared with that of the multi-louver fin micro channel heat exchanger, and the wavy fin micro-channel heat exchanger.

Khaled et al (2011) developed an analytical approach using the basic equations for modelling heat transfer through heat exchangers, to determine the thermal performance of cross-flow air-cooled heat exchangers, as a function of the flow statistics of the upstream cooling air. A two-dimensional computational code is also developed to calculate the heat-exchanger performance, in relation to the airflow topology upstream of the heat exchanger, induced by its integration in complex environments, such as the car underhood compartment. Finally, it has been shown that an increase in the non-uniformity (represented by $r$) of the upstream velocity distribution increases the heat-exchanger water-outlet temperature and thus decreases its thermal performance.
2.3 PARAMETRIC ANALYSIS

The literature pertaining to the various geometrical parameters that enhance the heat transfer performance, which include the fin pitch, louver pitch, louver angle, flow length and inclination angle of the heat exchanger, are summarised in this section.

2.3.1 Fin Parameters

2.3.1.1 Experimental investigation

Springer and Thole (1999) made detailed flow field measurements in the entry region of several louvered fin geometries, whereby the louver angle, ratio of the fin pitch to louver pitch, and Reynolds number were varied. The results indicated that larger fin pitches resulted in lower average flow angles in the louver passages and longer development lengths. Larger louver angles with a constant ratio of fin pitch to louver pitch resulted in higher average flow angles and shorter development lengths. As the Reynolds number increased, longer development lengths were required, and higher average flow angles occurred, as compared to a lower Reynolds number case.

Kim and Bullard (2002 (b)) carried out an experimental study of the air-side thermal-hydraulic performance of brazed aluminium heat exchangers, under dehumidifying conditions. For 30 samples of louvered fin heat exchangers with different geometrical parameters, the heat transfer and pressure drop characteristics, for the wet surface were evaluated. The test was conducted for the air-side Reynolds number in the range of 80-300, and a tube-side water flow rate of 320 kg/h. The dry and wet bulb temperatures of the inlet air for heat exchangers were 27 and 19°C, respectively and the inlet water temperature was 6°C. The airside thermal performance data for cooling and dehumidifying conditions were analysed, using the effectiveness-NTU method for cross-flow heat exchanger, with both the fluids unmixed.
Qi et al (2007) used the Taguchi method, which is a well-known parametric study tool in engineering quality and experimental design. This study analyzed five experimental factors (flow depth, ratio of fin pitch and fin thickness, tube pitch, number of louvers, and angle of the louver) affecting the heat transfer and pressure drop of a heat exchanger with corrugated louvered fins, using the Taguchi method. The results show that the flow depth, ratio of fin pitch and fin thickness, and the number of the louvers, are the main factors that influence significantly the thermal hydraulic performance of the heat exchanger with corrugated louvered fins. Therefore, these three factors are considered as the major factors for an optimum design of a heat exchanger.

Yang et al (2007) studied the thermal–hydraulic performance of heat sinks having plate, slit, and louver fin patterns. The comparison of the associated heat transfer performance and the effect of fin spacing was made. The results indicated that the enhanced fin patterns like louver or slit fin operating at a higher frontal velocity and at larger fin spacing, were more beneficial than those of plain fin geometry. The heat transfer performance of the louvered fin is usually better than that of the slit fin, but is accompanied by higher pressure drops. However, it is found that the pressure drop for the slit fin is comparable to the louver fin geometry, when the fin spacing is reduced to 0.8 mm. This is associated with the appreciable rise of the entrance/exit loss (form drag) caused by the slit fin geometry.

Zhang and Hrnjak (2010) focused on the quantification of the effects of geometry (i.e. fin pitch 12-22 fpi and louver pitch 1.4-2.8 mm) on defrost and refrost times. Eight heat exchangers differing in louver pitch and fin spacing are studied. A series of tests were conducted to find out the best geometry. The effects of geometry on heat transfer (thermal performance) and pressure drop for air face velocities of 0.9, 2 and 3 m/s were determined and used for comparison.
Li et al (2011) conducted a series of tests on an integrated fin and micro-channel heat exchanger for different flow depths, fin heights, fin pitches and fin thicknesses, to determine their effect on the air-side thermal hydraulic performance. The heat transfer coefficient and pressure drop for heat exchangers with different geometrical configurations were reported, in terms of the Colburn factor $j$ and Fanning friction factor $f$, as functions of the Reynolds number. The air-side heat transfer and flow characteristics of the integrated fin were compared with those of the multi-louver fin and the wavy fin.

Sanaye and Dehghandokht (2011) performed the multi-objective optimization of the parallel flow condenser by applying the Genetic algorithm technique. The design parameters (decision variables) were the hydraulic diameter of the flat tube with multi-pass channels, length of flat tube, and the height of the louvered fin. Among the design parameters, fin height had the least, and the hydraulic diameter had the most influence on the heat transfer rate and pressure drop. With a change in the fin height from its minimum to the maximum value, the condenser heat transfer rate decreased by 0.3% and the pressure drop increased by 1.3%. With the change in the hydraulic diameter from its minimum to the maximum value, the condenser heat transfer rate increased by 17.4% and the pressure drop decreased by about 90%.

Vaisi et al (2011) experimentally investigated the air-side heat transfer and pressure drop characteristics of the flow over louvered fins, in compact heat exchangers. The test samples consist of two types of fin configurations, such as symmetrical and asymmetrical. A series of tests were conducted to examine the geometrical parameters of louver pitch, louver arrangement and number of louver regions. The calculated results indicate that a symmetrical arrangement of louvered fins provides a 9.3% increase in
heat transfer performance, and a 18.2% decrease in the pressure drop over the asymmetrical arrangement of louvered fin. Also, for a constant rate of heat transfer and pressure drop, a 17.6% decrease in fin weight is observed for the symmetrical arrangement of fins, and this is followed by a considerable decrease in the total weight and cost of the heat exchanger.

2.3.1.2 Experimental and CFD analysis

Lyman et al (2002) carried out a study to provide a method for analysing the heat transfer data from large-scale experiments. The large-scale experiments included nine different louver models, which included three louver angles with each louver angle having three different fin pitches. One of the goals of this study was to determine a method to discern the flow and thermal field effects on the louver heat transfer. To discern these effects, the louver heat transfer coefficients were analysed, in which bulk and adiabatic wall temperatures were used as the reference temperatures.

Oliet et al (2007) have performed parametric studies on automotive radiators, by means of a detailed rating and design heat exchanger model developed by the authors. The first part of the analysis focused on the influence of the working conditions on both the fluids (mass flows, inlet temperatures), and the impact of the selected coolant fluid. Following these studies, the influence of some geometrical parameters is analysed (fin pitch, louver angle) as well as the importance of the coolant flow layout on the radiator global performance. This work provided an overall behaviour report of automobile radiators working at the usual range of operating conditions, while significant knowledge-based design conclusions have also been reported.

Kalaiselvam et al (2009) analyzed the heat transfer and pressure drop characteristics of a tube-fin heat exchanger in an ice slurry HVAC
system. Ice slurry is a suspension of crystallized water based-ice solution with a freezing point depressant like ethylene glycol. The numerical analysis was conducted, by simulating the ice slurry tube flow region and air flow region of the tube-fin heat exchanger, in the air-handling unit of the HVAC system. For the simulation, six different louver patterns with 10 to 55 louver angles were considered. The design of the tube-fin heat exchanger for optimal heat transfer and pressure drop characteristics was also determined, with the optimization parameters like the louver angle, fin pitch, and ice slurry flow velocity.

2.3.1.3 CFD analysis

Leu et al (2001) conducted a numerical investigation of the air side performance of a fin and tube heat exchanger, having circular and oval configurations. The geometrical parameters of the louver angle, louver pitch and louver length are examined. For a fixed louver length (6.25 mm) and louver angle (14°), a 10% decrease in the heat transfer performance is observed, and a 41% decrease in the pressure drop is seen for the oval tube configuration. The calculated results indicate that the pressure always decreases with the increase in the louver angle. Both the heat transfer performance and friction increase with the louver length, and the rate of the increase of heat transfer performance is about the same as the increase in the pressure drop.

Zhang and Tafti (2003) studied the effect of the Reynolds number, fin pitch, louver thickness, and louver angle on the flow efficiency in multi-louvered fins. The results showed that the flow efficiency is strongly dependent on the geometrical parameters, especially at low Reynolds numbers. The flow efficiency increases with the Reynolds number and louver angle and decreases with the fin pitch and thickness ratio. A characteristic flow efficiency length scale ratio is identified, based on the geometrical and
first-order hydrodynamic effects, which together with the numerical results is used to develop a general correlation for flow efficiency.

Hsieh and Jang (2006) proposed successively increased or decreased louver angle patterns and carried out 3-D numerical analysis on the heat and fluid flow. Five different cases of successively increased or decreased louver angles (+2°, +4°, -2°, -4° and uniform angle 20°) were investigated. For cases A (+2°), B (+4°), C (-2°) and D (-4°), the maximum heat transfer improvement interpreted by \( j/j_0 \) are 115%, 118%, 109% and 107%, and the corresponding friction factor ratios \( f/f_0 \) are 116%, 119%, 110% and 108%, respectively, where \( j/j_0 \) and \( f/f_0 \) are the Colburn factor ratio and friction factor ratio between successively variable louver angles and uniform angle, respectively. It is also shown that the maximum area reduction for case B can reach up to 25.5%, compared to a plain fin surface. The present results indicated that the successively variable louver angle patterns applied in heat exchangers could effectively enhance the heat transfer performance.

Hsieh and Jang (2012) studied the effects of the fin pitch, fin collar outside diameter, transverse tube pitch, longitudinal tube pitch, number of longitudinal tube rows, louver height, louver angle, fin thickness, and louver pitch, on the fin performance of the louver finned-tube heat exchanger by the numerical method. The parameters of louver finned-tube heat exchangers are optimized by the Taguchi method. The results show that the fin collar outside diameter, transverse tube pitch and fin pitch, are the main factors that influence significantly the thermal hydraulic performance of the heat exchanger. Therefore, these three factors are considered as the most important factors for an optimum design of a heat exchanger.
2.3.2 Inclination Angle of the Heat Exchanger

2.3.2.1 Experimental investigation

Kim et al (2001) studied the effect of an inclination angle from the vertical position on the air-side thermal hydraulic performance for a multi-louvered fin and flat tube heat exchanger. For a heat exchanger with a louver angle of 27°, a fin pitch of 1.4 mm and a flow depth of 20 mm, a series of tests under dry and wet surface conditions were conducted for the air-side Reynolds numbers of 100 - 300. The inclination angles from the vertical position were 0°, ±30°, ±45° and ±60°. The heat transfer performance under both dry and wet conditions was not influenced significantly either by the inclination angle (-60°<θ<60°), or by the presence or absence of an upstream duct, while the pressure drops increased consistently with the inclination angle. The heat transfer coefficients and pressure drops for the wet conditions revealed the importance of the role of condensate drainage.

Kim et al (2002) investigated the effect of air inlet humidity condition on the air-side heat transfer and pressure drop characteristics for an inclined brazed aluminium heat exchanger. For a heat exchanger with a louver angle of 27°, fin pitch of 2.1 mm and flow depth of 27.9 mm, a series of tests were conducted for the air-side Reynolds numbers of 80-400, with a variation in the inlet humidity condition. The heat transfer data were obtained only for the wet condition, while the pressure drop data were measured for both dry and wet conditions. The inlet air temperature and relative humidity range were 12°C and 60-90%, respectively. The inclination angles (θ) from the vertical position are 0, 14, 45, and 67° clockwise. The inclination angles affect the sensible heat transfer coefficient moderately for the wet condition, and the pressure drops for both the dry and wet conditions increase systematically with the inclination angle. The heat transfer and pressure drop characteristics under the wet condition are not influenced substantially by the air inlet.
humidity for $\Theta \leq 45^\circ$. The effect of the louver directions at the inlet and outlet of the inclined heat exchanger on the performance, is also addressed.

Nuntaphan et al (2007) studied the effect of the inclination angle on the louvered fin and tube heat exchanger subject to the natural convection condition. It is found that the inclination angle plays an important role on the performance of the louvered fin and tube heat exchanger. The performance of the heat exchanger is associated with the interactions between the fin, louver, tube, and inclination angle. The heat transfer performance generally decreases with a rise in the inclination angle. This decrease of the heat transfer performance is due to the blockage of the fin and its reversed heat dissipating direction against the rising air. However, at an inclination angle of 30-45\(^\circ\), a considerable increase of heat transfer performance is seen. This is because, an appreciable amount of air flow was directed by the louver, causing a “louver-directed” phenomenon, as seen in forced convection. With a further increase of the inclination angle, the blockage effect caused by the fin is so strong as to offset the “louver-directed” phenomenon. Unlike that shown in forced convection, the heat transfer performance decreased with the number of tube rows.

2.4 INFERENCES FROM THE LITERATURE REVIEW

It is understood from the literature survey that various researchers have performed experimental investigation to predict the heat transfer and pressure drop characteristics of the louvered fin and flat tube compact heat exchanger, using the $f$ and $j$ correlations. However, in these correlations, all the geometrical and flow parameters were not considered. In some situations, the variations in some parameters that are omitted in the correlations have a very significant effect in influencing the heat transfer and pressure drop characteristics. Under such circumstances, these correlations fail to predict the performance accurately.
Today several commercial softwares are available in the market for various engineering, medical and other applications. In recent years, the popular softwares such as Fluent, CFX, Star CD, etc. are being used to analyse the flow and heat transfer characteristics in various applications. However, the results obtained from these softwares are capable of providing reliable results only after several research outputs, along with the intricacies of a particular application incorporated in the softwares. Hence, in the present research, an attempt is made to assess the performance of one of the popularly used CFD softwares (Fluent) for analysing the thermo-hydraulic performance of a compact heat exchanger.

Also, it is found from the literature survey that all the research works on the compact heat exchanger focussed on analysing or improving the performance of the air side heat transfer coefficient, as the resistance offered by the tube side fluid is very minimal. Hence, in the present work, an attempt is made to analyse whether the improvement in the heat transfer co-efficient of the tube side fluid enhances the overall heat transfer performance or not, by analysing the compact heat exchanger, varying the mass flow rate of the tube side fluid.

2.5 SPECIFIC OBJECTIVES

The specific objectives of the present research are formulated as given below:

- To investigate the performance of the louvered fin and flat tube compact heat exchanger, through experiments using the wind tunnel test rig.
To investigate the effects of the mass flow rate of water in the tube side, on the overall heat transfer performance of the heat exchanger.

To compare the accuracy of the existing correlations available in the open literature with the results of the present experimental investigation.

To carry out the CFD analysis using the commercially available software for a similar configuration used in the experimental investigation.

To validate the results of the CFD analysis with the results of the experiments.

To analyse the effects of the various parameters on the heat transfer and pressure drop performance of the present heat exchanger (test radiator) using the CFD analysis, and also develop a new heat transfer and friction correlation based on the results of the CFD analysis.