"I admitted that I have read this report and my opinion this report are fulfillment the scope and quality for the Bachelor Degree in Mechanical Engineering (Thermal Fluid) graduation."

Signature :

Supervisor : Dr. Mohd. Yusoff Bin Sulaiman

Date : 30/5/06

PERFOMANCE OF DIFFERENT TYPES OF HEAT EXCHANGER DESIGNS

ELIZABETH DIMAH ANAK MULA

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Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

"I admitted that this project is written by me and is own effort and that no part has been plagiarized without citations"

Signature :

Name : Elizabeth Dimah Anak Mula

Date : 21th May 2006

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Thanks God with his permission and guidance I have finally finished my Final Year Project II in a whole semester period. This thesis is the result of the work that I have made in a whole semester.

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ABSTRACT

This thesis presents a performance of different heat exchanger of existing and new design of heat exchanger. This project was mainly focus to measure the heat transfer performance of heat exchanger. The experiment data collected by set up instrument on heat exchangers test rig. For this project, the heat transfer performance measured for car radiator as a compact heat exchanger. Each car radiator has different characteristics such as number of louvers, number of fins, fin thickness, surface area and area density. Besides that, comparison of the heat transfer performance for heat exchanger also can determine by design the new car radiator. Some basic consideration of design the heat exchangers are considered while design the car radiator such of, type of material, number of tube rows, diameter and length of tube. Literature review use as a guide to do the project.

ABSTRAK

Tesis ini menerangkan mengenai corak prestasi bagi pengubah haba. Perbandingan prestasi dilakukan terhadap rekabentuk yang sedia ada dengan rekabentuk baru yang akan dibangunkan.tesis iini lebih tertumpu kpd pengukuran corak prestasi pengubah haba. Dengan menggunakan intrumen yang sesuai, ujikaji dijalankan bagi mendapatkan data yang diperlukan. Data yang diperolehi di rekodkan dan dianalis.Bagi projek ini, radiator kerata diambil dan diaplikasikan sebagai salah satu contoh rekabentuk pengubah haba. Setiap model kereta mempunyai radiator yang berbeza-beza. Perbezaan ini dilihat daripada pelbagai aspek seperti bilangan ram,bilangan sirip,ketebalan sirip,keluasan permukaan dan luas ketumpatan. Di samping itu, dengan pembangunan rekabentuk yang baru,perbandingan terhadap corak prestasi boleh dilakukan.Bagi pembangunan rekabentuk radiator,elemen asas yang terkandung dalam rekabentuk pengubah haba perlu dipertimbangkan. Elemen asas ini merangkumi jenis bahan yang akan digunakan,bilangan barisan tiub,diameter dan panjang tiub. Pemerhatian terhadap kajian terdahulu dijadikan sebagai panduan bagi melaksanakan projek ini.

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LIST OF SYMBOL

SYMBOLS	DEFINITION
C_p	Specific heat of fluid
D	Diameter of tube
K_f	Thermal conductivity of the fluid
Q	Total heat transfer rate
ΔT	Temperature Drop
ΔP	Pressure Drop
Re	Reynolds number
Nu	Nusselt number
Pr	Prandtl number
m	Mass flow rate
ρ	Fluid density
v	Fluid velocity
μ	Fluid viscocity

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CHAPTER I

INTRODUCTION

1.1 Overview

Heat exchangers are common components in many everyday devices. Car engines, refrigerators, air conditioners, central heating boilers and radiators all contain heat exchangers. Their purpose is to transfer heat from a hot liquid or gas to a colder one.

Understanding the mechanisms that dominate heat transfer in a louvered fin heat exchanger provides the potential for reducing the heat exchanger's size and weight. This reduction in size can clearly benefit many industries, including transportation, heating, and air conditioning. Because more than 85% of the total thermal resistance in a typical air-cooled heat exchanger occurs on the air side, the performance of compact heat exchangers depends highly on the heat transfer occurring on the air side.

Louvered fins, rather than continuous fins, are commonly used in compact heat exchangers to break up boundary growth along the fins and increase the air side heat transfer surface area. The increase in surface area results because of the fin thickness that is exposed as a result of the louvers being stamped out of the fins. **Figure 1.1** illustrates a typical compact heat exchanger geometry comprised of louvered fins, where air passes along, and tubes, where water passes through. For this paper, heat transfer performance of car radiator will measure. Some aspect of different car radiator will consider such as number of louver, number of fins, fin thickness, surface area and area density.

Unlike continuous fins, louvered fins interrupt the boundary layer growth along the tube wall, which could be thought of as a flat plate. Generally, the aspect ratio of the tubes is such that the tube wall boundary layers do not intersect and the flow can be thought of as an external flow. The interruption of the louvers governs the thickness of the tube wall boundary layer and affects the tube wall heat transfer as well as fin performance near the junction.

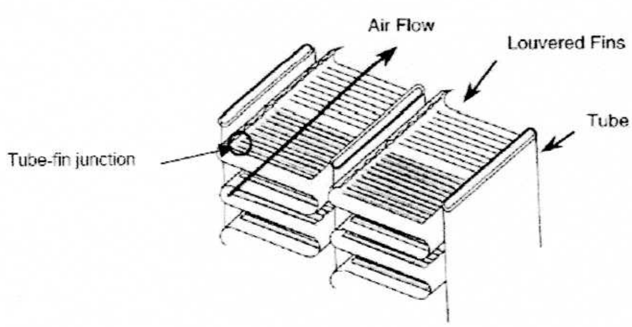

Figure 1.1: Typical louvered-fin compact heat exchanger (assembly)

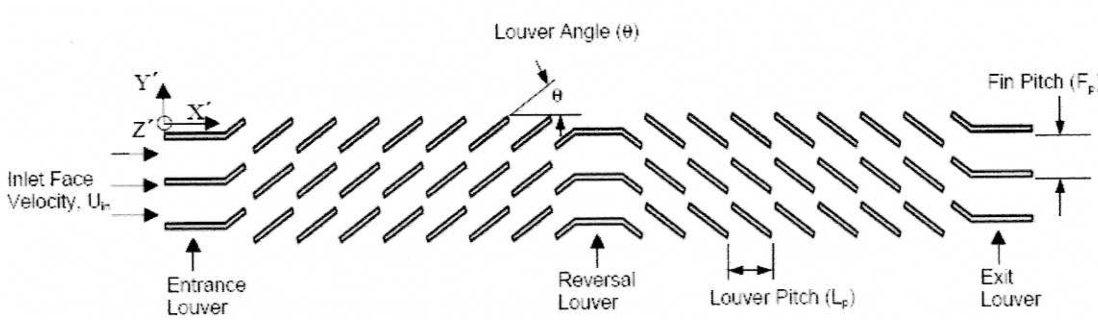

Figure 1.2: Side view of louvered fins.

1.2 Project Title

"Performance of Different Types of Heat Exchanger Designs"

1.3 Objectives of the Project

The main objectives of this project are:

- To collect the data information about the thesis.
- To gather the literature review for comparison with the thesis
- To preparing a data for a new design
- To design a test rig:
- To measure heat transfer performance of different types of heat exchangers based on existing designs.
- To measure and predict heat transfer performance for micro tube heat exchanger design based on new innovation designs.

1.4 Scopes of the project

The scopes of this project are included:

- Acquire different types of heat exchanger units.
- Literature review specially on performance of heat exchanger
- Set up instruments on heat exchangers test rig.
- Collect experimental data and analyze.
- Design and fabricate macro and micro tubes heat exchangers unit.
- Test heat transfers performance.

1.5 Project Outlines

There are 9 chapters in this thesis report. Chapter 1 gives some introductions and the objectives about this project. Chapter 2 provides literature review for this project. this chapter reviews the related work that has been done by other people. The theory of this project is shown in chapter 3, Chapter 4 contains the main part of this project and review about designing and fabricating..

Chapter 5 shows experimental set up. Chapter 6 presents about data and analysis of this project. Chapter 7 was contains the discussion of this project. Chapter 8 and 9 contains the recommendation and the conclusion of this report.

CHAPTER 2

LITERATURE REVIEW

Fewer studies have addressed three-dimensional effects in louvered fins relevant to compact heat exchangers. Flow visualization studies by Namai, et al. (1998) were completed in which three-dimensional fin models were used. These three-dimensional models included several different geometries at the tube-wall junction. Their overall conclusions were that there are strong three dimensional characteristics in louvered fin flows.

McLaughlin and Webb (2000) investigated the performance of automotive heat exchangers under dry and wet conditions. They reported that the heat transfer coefficient is not influenced by flow depth or louver pitch, but the friction factor increases for a smaller louver pitch and a larger tube thickness. In contrast, Kaiser and Jacobi (2000) observed both heat transfer and pressure drop increases for smaller louver pitch and explained that the number of louvers along a streamline increases for a smaller louver pitch and a higher louver angle. However since the conclusions from both reports are based on limited experiments, their observations should be generalized after further investigations over a wider range of parameters. Suga and Aoki (1995) studied thermal wake effects in a multi-louver bank by 2-D numerical analysis, and they suggested a simple formula for fin pitch, louver pitch and louver angle that minimizes heat transfer degradation by thermal wakes.

Atkinson, et al. (1998) performed computational simulations of both two and three-dimensional models whereby the three-dimensional model included the effects of the tube. Their results indicated that the three-dimensional models gave predictions that were in better agreement with experimental observations of both pressure losses and heat transfer reported by Achachia and Cowell as compared with their two-dimensional predictions.

Bernard Thonon has done a review of correlations for single-phase flow heat transfer and pressure drop of plate heat exchanger. His paper deals with single phase heat transfer and pressure drop in plate heat exchangers and reviews published data on single-phase flow heat transfer and pressure drop. After an introduction giving the main geometric characteristics of plate heat exchangers, information on the flow structure is given. Afterward, correlations for heat transfer and pressure drop are presented and compared. These correlations have been obtained either on corrugated channels representative of plate heat exchangers or on full scale industrial plate heat exchangers.

Olsson and Sunden (1995) have done the investigation of thermal and hydraulic performance of ten radiator tubes. The tubes tested are one smooth tube, two rib roughness tubes, five dimpled tubes and two offset strip fin tubes. The tubes are representative of flat tube geometries applied in automotive heat exchangers, for example radiators. Isothermal pressure drop data were taken for Reynolds numbers in the range of 500-6000. These data are presented as Fanning friction factors and inlet loss coefficients. Heat transfer data were taken in the same Reynolds number range and the results are presented as Colburn j factors, as well as Nusselt numbers. The tubes are compared by considering the flow area goodness factor and the volume goodness factor. From their experiment, all the enhanced tubes provide increased heat transfer coefficients as compared to the smooth tube, but the related pressure drops were increased comparatively more than heat transfer. The rib roughness tubes showed the best performance as the volume goodness factor was considered.

Kim and Bullard (2000) have done the experiment study on the air-side heat transfer and pressure drop characteristics for multi-louvered fin and flat tube heat exchangers has been performed. For 45 heat exchangers with different louver angles (15–29), fin pitches (1.0,1.2, 1.4 mm) and flow depths (16, 20, 24 mm), a series of tests were conducted for the air-side Reynolds numbers of 100–600, at a constant tube-side water flow rate of 0.32 m^3/h. The inlet temperatures of the air and water for heat exchangers were 21 and 45°C, respectively. The air-side thermal performance data were analyzed using effectiveness-NTU method for 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 functions of Reynolds number based on louver pitch. The general correlations for j and f factors are developed and compared to other correlations. The f correlation indicates that the flow depth is one of the important parameters for the pressure drop.

Nuntaphan et al. (2004) examines the air-side performance of total of 10 cross flow heat exchangers having crimped spiral configurations under the dehumidification. The effect of tube diameter, fin spacing, fin weight, transverse tube pitch and tube arrangements are examined. From their studied, the results indicate that the heat transfer coefficient of wet surface is slightly lower than that of dry surface. The report also included the effect of tube diameter on the air side performance is significant. Larger tube diameter not only gives rise to lower heat transfer coefficient but also contributes significantly to the increase of the pressure drops. This phenomenon is applicable in both dry and wet condition. For wet surface, the influence of fin height is negligible and the effect of fin spacing on the heat transfer performance is rather small. However, increasing of the fin spacing tends to have a lower heat transfer coefficient. The tube arrangement plays an importance role on the heat transfer coefficient; narrower transverse pitch gives higher heat transfer coefficient.

Tafti, et al. (2000) solved three-dimensional computational models of multi louvered fins for a fully-developed flow and predicted a number of interesting flow features at the tube-wall junction. Their study incorporated a geometric transition zone between the louver and the tube wall that served to produce vortices such that the heat transfer was increased along the louver.

DeJong and Jacobi (1998) investigated the flow, heat transfer and pressure drop for louvered fin. Louver-by-louver mass transfer data are acquired for Reynolds numbers from 130 to 1400. Pressure-drop data are obtained using a low-speed wind tunnel and local flow structures are visualized using dye injection in a water tunnel. Particular attention is placed on the role of vortex shedding in heat transfer enhancement. In contrast to recent studies for similar offset-strip arrays, vortex shedding is found to have less impact in louvered-fin arrays.

In year 1996, Wang, Chi and Chang presented an experimental study of heat transfer and friction characteristics of typical louver fin and tube heat exchange. Extensive experiments on the heat transfer and pressure drop characteristics of louver fin and tube were analyzed. In particular, the experiment data indicate that the number of tube row does not effect the frictions factors, the effect of the number of the tube row is negligible for Re>2000, and a significant reduction of the heat transfer performance is found for Reynolds number less than 2000 for six row coil. Besides that, fin pitch has negligible effect on the heat transfer characteristics for Re>1000, and the heat transfer performance decrease of fin pitch for Re<1000. The cross over phenomena of the friction factors are much less pronounced as compared to the plain fin configuration. Their report also shown for the present louver fin configuration, the heat transfer characteristics for multi rows coils may be benefit from using smaller heat transfer tube especially for $V<1.5ms^{-1}$. However, for the one configuration, there is no improvement of the heat transfer coefficients compare to the 10% reduction of pressure drop due to the tube size reduction was report in the present study.

Joen et al. (2005) was determined the heat transfer correlation and friction characteristics for an adaptation of the standard inclined louvered fin type. An experiment study of a fin and tube exchanger was performed. A test rig was constructed to measure the heat transfer rate on the air and waterside of the heat exchanger. In their paper, a fin type of a commercially available heat exchanger has been tested. A wide range of Reynolds number on the airside was investigated. The effectiveness –NTU method is used to measure the value of heat transfer coefficient. From their studied, for low Reynolds number the predicted convective heat transfer coefficient lies within the error margin of the measurements, but it consistently higher. For high Reynolds numbers (greater than 1000), the predicted value are 10% greater. This indicates that for low Reynolds numbers the impact of certain changes to the fin pattern is small and that therefore correlations determined for similar fin patterns can be used. For high Reynolds numbers the changes have a more pronounced impact, obligating the use of an accurate correlation.

Ebeling, 2003 has done the measurements and predictions of the heat transfer at the tube-fin Junction for louvered fin heat exchangers. The tube wall heat transfer results presented in this paper were obtained both experimentally and computationally for a typical compact heat exchanger design. Both isothermal and constant heat flux tube walls were studied. For the experimental investigation, a scaled-up model of the louvered fin-tube wall was tested in a flow facility. Although computational results for the isothermal tube wall are shown, control of the experimental isothermal tube wall proved to be unrealistic and only heat transfer measurements along the constant heat flux tube wall were made. For the constant heat flux tube wall, reasonable agreement has been achieved between the measurements and the steady, three-dimensional computational predictions. The results of the study showed that high heat transfer coefficients existed at the entrance to the louver array as well as in the louver reversal region. Vortices created at the leading edge of the louvers augmented heat transfer by thinning the tube wall boundary layer. Results indicate that an augmentation ratio of up to 3 times can occur for a tube wall of a louvered fin compact heat exchanger as compared to a flat plate.

Wang and Chi (1998) studied the airside performance of fin and tube heat exchangers with plain fin configurations. The effect of the number of tube rows, fin pitch and tube diameter on the thermal hydraulic characteristics was examined. Depending on the number of tube rows, it was found that the heat transfer characteristics were strongly related to the fin pitch. From their experiment, the effect of tube row on the heat transfer performance is especially pronounced at low Reynolds number where the number of tube rows is large and the fin pitch is small. The effect of the number of tube rows on friction performance is comparatively small. From their experiment showed that the effect of tube diameter on heat transfer performance is related to fin pitch as well.

Yan and Sheen (1999) investigated the heat transfer and pressure drop characteristics of fin and tube exchangers with plate, wavy and louvered fin surfaces. Thirty six samples of plate, wavy and louver fin and tube heat exchangers with different fin pitch and tube row number were tested. Various comparison methods have been adopted to evaluate the performance or the heat exchanger among various surfaces. Results are presented as plots of friction factor f and Coldburn j factor against Reynolds number in the range 300-2000. For their experiment results, shown that at the same Re, a louver fin geometry shows larger value of f and j factors, compared with the plate fin surface. Besides that, at the same frontal velocity, the pressure drop ΔP increases with the increasing tube row numbers. Finally, for comparison using VG-1 criteria, about 40% surface area reduction was found for a louver fin heat exchanger, relative to the plate fin heat exchangers, and the area reduction increases with the fin pitch.