EXPERIMENTAL EVALUATION OF HEAT FLOW FROM RECTANGULAR FINS ARRAY UNDER FORCED CONVECTION

SHAHRIZAL BIN IBRAHIM

Report submitted in partial fulfillment of the requirements
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Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

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UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Experimental Evaluation of Heat Flow from Rectangular Fins Array under Forced Convection*" is written by *Shahrizal bin Ibrahim*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

MR. ROSMAZI BIN ROSLI

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:
Name of Supervisor	: MR. IDRIS BIN MAT SAHAT
Position	: LECTURER
Date	: 21 JUNE 2012

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : MR. SHAHRIZAL BIN IBRAHIM

ID Number : MA 08066

Date : 21 JUNE 2012

DEDICATION

This work is dedicated to all those who have inspired me throughout my life, with special thanks to my family, Ibrahim, Juhrah, TJ, Ijan, Jira and Siti. And also to friends and fiends.

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ABSTRACT

The application of fins is to reduce heat from an object. The experiment is about utilizing the fins for heat dissipation. The method is by using an experimental set-up to observe temperature difference of 6 arrays of rectangular fins and calculate the Nusselt number to understand the convection force of the fins and validate the data with theoretical calculation from the experimental result. Second approaches are by wrapping each of the fins with aluminum coil and compare the result with experimental result without the wrap. Conclusion, it is observed that the highest value for the Nusselt number is 505.469 can be achieved by the wrapped fins array than without wrap on fins about 39.347 which is about 8.44% positive increment. Further research can be done through used of custom made fins in shape of aerofoil, which perhaps help in heat dissipation of the fins much better as the air flow is much smoother.

ABSTRAK

Aplikasi siripan dalam mengurangkan haba dari objek. Eksperimen ini adalah untuk mengekploitasi sirip-sirip untuk pembebasan haba. Metodologi yang digunakan untuk melihat keberkesanan adalah melalui memerhatikan perbezaan suhu pada 6 siripan berbentuk empat segi tepat dan perkiraan nombor Nusselt untuk meneliti keberkesanan kuasa pengaliran haba melalui udara dari sirip-sirip; Semua data yang diperolehi akan semak melalui perkiraan teori hasil dari keputusan eksperimen. Pendekatan kedua adalah melalui pembalutan sirip-sirip tersebut dengan pembalut aluminium dan data yang diperoleh akan dibandingkan dengan data sebelum ini. Secara kesimpulan, nilai tertinggi nombor Nusselt ialah 505.469 melalui cara pembalutan setiap sirip dan jumlah ini lebih tinggi dengan nilai 39.347 lebih dari tanpa pembalutan dengan peratusan 8.44 % kenaikan. Untuk menganalisa lebih lanjut, pengunaan sirip berbentuk *aerofoil* yang dibuat khusus, mungkin boleh mengurangkan haba dan memperbaiki pembebasan haba ke persekitaran dengan kelebihan mengaliran yang baik terhadap bentuknya.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
%	Percentage
±	Plus or minus
°C	Degree Celsius
h	Heat transfer coefficient
Q	Heat transfer rate
V	Velocity
W	Watt
ν	Kinematic viscosity

LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
ADI	Alternating Direction Implicit
CFD	Computer Fluids Dynamic
Gr	Grashof number
Nu	Nusselt number
Pr	Prandtl number
Ra	Rayleigh number
Re	Reynolds number
RMS	Root Mean Square

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Force convection is commonly used in electrical and electronic product to cool down electronic chips and electrical component. This is because the electronic chips and electrical component are prone to damage due to overheating; hence it causes a lot of money but with force convection the equipment able to be cooled at certain suitable temperature difference so it could avoid damage from overheating.

It is also important that optimize of heat flow from rectangular fin array must be observed and learnt so that it could be used in field of electronic or even the nuclear power plant for cooling. Though this studies is more on evaluation of force convection of the heat flow from rectangular fin array, but this application able to simulate the real performance of the fin array in an experimental basis.

1.2 PROBLEM STATEMENTS

In brief, this is a study on experimental evaluation of heat flow from rectangular fin array under forced convection. The evaluation would be done based on the heat flow of the rectangular fin array with the fin spacing. This evaluation would be in form of plotted graphs from the temperature difference of the heat flow. The heat flow would be driven by the force convection that is produce from the fans that cause the surrounding air to move. However the study is not only about force convection, the radiation is also considered because radiation does have some significant effect on the fin array heat flow although in this study. It may be small in values but the study would be viable for future research and other researcher. Lastly, all these data would be validating with the available literature for comparison. The comparison is conducted so that the data can be evaluated with consistency and accuracy.

1.3 OBJECTIVE

On the basis of evaluating the heat flow of the rectangular fin array through forced convection, it is important that all the parameters is identified and measured, through the experiment then only the evaluation of temperature can be done. From the result, tabulated data can be plotted into graph and presented. The data is then can be compare with the available literature in this study. Overall the objectives are to:

- Observed the temperature difference and validate with theoretical analysis;
- Novelty research using coil for better convection.

1.4 SCOPE

The experiment is confined with certain variable to perfectly guide the experiment into achieving the objectives. By doing so, the experiment can be done in brief and the result can be gained easily. Among the confined scopes are:

- Conduct experiments for different fin array geometry and orientation using the test bench available in Thermodynamics laboratory.
- Evaluate the heat transfer coefficients.
- Validate the results.

CHAPTER 2

LITERATURE REVIEW

2.1 RECTANGULAR FINS ARRAY

The study required some comparison with the literature to identify and make synthesis of the knowledge to whether the result is significantly align with the result from the literature or far off, this is important so that the experiment can be used for further study with accuracy and precision. There are many literatures that are made into technical paper that research on rectangular fin array and also anything related to heat transfer of material and fin. The main idea might not be the same with the study but by comparing with overall research, the intersection of knowledge can be synthesis to help with this research.

Sparrow et al. (1978) examined the laminar heat transfer characteristics to an array of longitudinal fins that is under an adiabatic shroud surrounded near adjacent to the fin tips. It is found that the heat loss is a minimum at the adjacent to the base and increases along the fin until the tip is reached. Whereas the occurrence of heat loss either at the tip or intermediate between the fin tips and the shroud is at maximum. Also it is found that the calculated heat transfer coefficients are varying along the length fin though some cases the values is negative. The overall heat loss from the fin is a basis of the unit area which is more efficient than the base. It is also demonstrate that the inapplicable of the shrouded fin arrays to the conventional uniform heat transfer coefficient model.

Tahat et al. (2000) examined the steady-state heat transfers from pin-fin arrays that were orthogonal to the mean air-flow for staggered and in-line arrangements of the pin fins. The aligned and staggered pin fins is optimal in design when the pin fins are used as arrays in heat exchangers.

Teerststra et al. (1999) examined the analytical model that is presented to predict the average heat transfer rate for forced convection, air cooled, plate fin heat sinks for use in the design and electronic applicable of heat sinks. The analysis conducted shown that average Nusselt number can be calculated as a function of the heat sink geometry and fluid velocity. The result confirm that the experimental results to be within 2.1% RMS and 6% maximum difference as performed through measurement of the air cooled, high aspect ratio heat sink prototype and the model. Though further are needed to include the effects of the baseplate and for shroud effect on if the channel spacing is equal to height of the fin and also the non-shrouded application if the flow bypass were to be examined.

Chen and Mucoglu (1976) analyzed the flow and heat transfer characteristics of laminar mixed forced and free convection about a sphere. The result found that the buoyancy force effects is about $Gr/Re^2 > 1.67$ for aiding flow and less than -1.33 for opposing flow in for force convection significantly. At $Re^2/Gr > 0.01$ is the significant value for the inertia force effects on free convection. Also overshoot has been exhibit by the buoyancy effected velocity profile by the local free stream velocity in order to aids the flow and for opposing the flow in S-shape.

Abramzon (1997) analyzed the simple method for estimating the radiate heat transfer from a rectangular array of plate fins to a nonreflecting ambient by using the method of closed-form evaluation. The closed-form analytical solution for this analysis is then compare with the literature and then summarized in graphical and tabular form. The result that heat transfer analysis can be analyzed by using closed-form analysis with little deviation, 3%.

Rong-Hua Yeh and Ming Chang (1995) analyzed the optimum design for longitudinal fin arrays in forced convection. The method is by taking the consideration rectangular, convex-parabolic-profile, triangular and concave-parabolic profile fins for parametric study and design analysis. From all this design, the aspect of ratio, separation between fins and heat transfer characteristics of optimized fin arrays are investigated. Thus a comparison in the total heat duties efficiencies of four different arrays is done to choose the most optimum. The result for optimized fin arrays is larger for smaller or larger Biot numbers. For single fins, it is optimum when the ratio for fin height and fin thickness is higher. The optimum arrays from large to small are rectangular-fin, convex-parabolic-fin, triangular-fin and concave-parabolic-fin arrays respectively but the four is insignificant than those of single optimized fin.

Dharma et al. (2007) analyzed the numerical analysis of combined convection and radiation heat transfer from a fin array with a vertical base and horizontal fins. The results from the numerical studies are then compared with the available literature. The problem is theoretical formulation of adjacent internal fins are treated as two fin enclosure. The numerical is solved using ADI method with relation between governing equations of mass, momentum and energy balance for the fluid in the two fin enclosure together to gained the heat conduction equation in the fins. Also the radiation is also included in the analysis. The results satisfied the comparison between experimental data existing in literature.

Kobus and Oshio (2005) had conducted theoretical and experimental study to investigate the influence of thermal radiation on the thermal performance of a pin fin array heat sink that is accurate on given situation and also determining the particular design parameters and environmental conditions for advantageous thermal performance of the thermal radiation. The experiment is conducted by corresponding physical parameter variations and emissivity of the heat sink, elevated ambient air temperature, visible hot surface temperature and radiation configuration factor. For the theoretical model, it is validated by the experimental data that included the influence of thermal radiation of thermal performance of a pin fin array heat sink, effective radiation of heat transfer coefficient and the convective heat transfer coefficient. From the results gained, it is thought that there is significant deterioration in the thermal performance when the thermal radiation is emitted from the hot surface and absorbed by the heat sink. Some problem occurs when it is hardly to suggest the radiation view factor and emissivity. On radiation view factor for the heat sink fins and hot surface is small, thus the thermal radiation emits from the hot surface to the fin array heat sink is less that the radiation emits from the fins to the environment. Overall it is important to take note that the fin diameter, length, spacing, and emissivity, base size, orientation, and temperature, air flow velocity and temperature, hot surface temperature, and emissivity, and radiation view factor between heat sink fins and the hot surface must take into consideration and account for accurate experimental data.

With the research from Sparrow et al. (1978) it is understood that fin have more effectiveness in heat transfer than the base. Also Tahat et al. (200) that aligned and staggered pin fins is an optimal design, hence if the experiment were to be design, this would be the optimal design. Furthermore, there is study by Chen and Mucoglu (1976) that said about the buoyancy affected the velocity profile, this should be carefully watched because in force convection velocity of wind on the duct is a controlled parameter. Though Abramzon (1997) research on simple method for estimating the radiate heat transfer only in closed-form analysis but this is something that can help to identify the experiment whether or not radiation is something to be carefully watched for it can be so significant. While Rong-Hua Yeh and Ming Chang (1995) studied confirm that rectangular fin is optimal design but single fin is much better in term of optimal design. And Rao et al. (2007) confirm that analysis can be done mathematically in numerical analysis for analyzing the heat transfer of the fin array and also it is important that radiation is included in the equation, hence radiation does have significant effect on heat transfer. Finally Kobus and Oshio (2005) identify all the parameters need to be taken into consideration for the experimental analysis.

Leung et al. (1985) had done the experiment on parallel fins with vary separation value at which is 12 ± 1 mm and 38 ± 1 mm. The experiment is conducted at uniform temperature about 40 °C and 80 °C with ambient environment at 20 °C upon the array of 3 mm thick, 250 mm long, horizontal rectangular duralumin fins extending 60 mm perpendicularly out of a 250 mm x 190 mm vertical rectangular duralumin base. The heat transfer performance is then check by comparing the vertical and horizontal rectangular fin arrays. The result found that vertical fin orientation has the more rapid steady-state heat losses. In practice the 38 mm gap configuration is great at having desired heat loss rate and also least use of materials for vertically rectangular base, but the horizontal oriented rectangular fin array may not be a good choice since it is relatively poor performance heat dissipations.

Ma et al. (1991) investigated the usage of Fourier series approach on two-dimensional rectangular fin with arbitrary variable heat transfer coefficient on the fin surface. The result obtained is the temperature distribution with three different boundary conditions at the fin tip and familiar expressions when the heat transfer coefficient is constant although in different form. It is also said that the different in one-dimensional computation and that two-dimensional analysis is about 8.7 %.

Culham and Muzychka (2001) analyzed the specification and design of heat sinks that are use electronic applications because it is not easily accomplished through the use of conventional thermal analysis tools because of "optimized" geometric and the boundary conditions was not known to be a priori. The method used is that allowing the simultaneous optimization of the heat sink design parameters based on a minimization of the generation of entropy associated with heat transfer and friction of the fluid. It is to be found that the optimization procedure had constrain any of the relevant design parameters this is due to manufacturing practicalities often take the precedent over the thermal considerations in the design and also the heat sink production. It is thought that by allowing the fin heights to a less than 25 mm are feasible if the entropy generation is minimized. Also heat sink may be a constrained due to the weight sensitive applications. To further this study a method such as Lagrange multipliers can be used so that it can increases the number of variables and nature of the imposed constraints.

Acharya and Patankar (1981) investigated the effect of buoyancy on laminar forced convection in a shrouded fin array. The method is by experimenting the fins and the base surface that is hotter or colder than the fluid. The result shown that hot fin and the base leads to secondary flow pattern which is single eddy and also that the buoyancy is significant that mean the Nusselt numbers and friction factors are higher than pure forced convection. Whereas the cold fin and base generates multiple eddy pattern as with the presence of a tips clearance. Also it is found that if the absence of tip clearance that the Nusselt number will be increased. Furthermore that the heat transfer coefficient distribute non-uniformly along the fin and the base.

Nag and Bhattacharya (1982) investigated experimentally the effect of vibration on natural convection of heat transfer from vertical rectangular fin arrays of different fin spacing and fin lengths. The used for this experiment have parameters with height at 250 mm, length 25 to 50 mm, spacing from 25 to 75 mm, thickness at 13 mm and width from 140 to 229 mm. By using the heating coils, the heat supplied is control by controlling the amount of power supplied to the coils. The vibration was excited by knocking a wooden piece where the base plate is located. The result of this experiment found that vibration did not have significant effect on heat transfer of fin array up to certain threshold value of amplitude and frequency (15 mm/s) but increase steadily with the increase in the intensity of vibration, with 250% maximum increment at vibrational energy input at 90 W.

Other than that, Leung et al. (1985) found the good orientation for more heat losses and that vertically rectangular base is the best for heat transfer. On mathematical analysis, Ma et al. (1991) found that there is different in one-dimensional and two-dimensional computation analysis, hence if analysis to be conducted, this must be taken into careful consideration. On dimensionless analysis of Nusselt number, Acharya and Patankar (1981) realized the effect on Nusselt number by the parameter and the condition of the fin. While the research done by Nag and Bhattacharya (1982) is a total opposite of all the research done, by researching the effect of vibration on natural convection, this must be watched as the research shown some effect on the heat transfer.

Mobedi and Yüncü (2003) investigated the natural convection heat transfer numerically on longitudinally short rectangular fin array on a horizontal base. The result is a comparison to the literature gathered to the experimental with variable from geometrical parameters, fin height and fin spacing. All these variables are solving into code based approach on vortices-vector that solve the governing equation in finite difference. The result found that with the increasing fin height it would decreasing the amount of air entering the middle part between fins this probably due to longitudinal boundary layer along the channel effecting the decreasing heat transfer coefficient with the fin length. While increasing the spaces between fins would retards the interference and thus increasing the heat transfer coefficient as it permits the flow of fresh air to enter the middle part between fins. Thus this explains the effect of height, spacing and length parameter, which are much interconnected to each other.

Mobedi and Anbar (1998) undergo experiment of free convection heat transfer from rectangular fin-array on a horizontal base. The experimental is to observe the effect of fin height about 6 mm to 26 mm, spacing about 6.2 mm to 83 mm, power supply 8 W to 50 W and fixed thickness at 100 mm and 3 mm. This is so that the experiment able to clearly delineate the separate roles of height, spacing and base-to-ambient temperature difference of the fins. The enhancement of the convection heat transfer rate of fin-arrays which is relatively to the base plate and also not dependent to the spacing and height ratio and number of fins. The increasing monotonous of the heat transfer with the temperature difference. Though the optimum spacing and height that varies below and above which reduce the natural convection. But the temperature difference has no significant effect on optimum spacing. Power supply is insignificant.

Jones and Smith (1970) are experimenting the various and wider range of spacing of arrays of isothermal fins on horizontal surfaces for average heat-transfer coefficients for free-convection cooling. The method is done by defining the optimum arrangement for maximum heat transfer, the design and the weight consideration on the heat transfer coefficient. The result suggests that the optimum spacing is about 10 inches; whereas if it is small optimum spacing, the height could be lower. Also the maximum heat transfer can occurs when the height and the gap between fins are about 0.56 sq. in., so meaning that there exists an optimum cross-sectional area for inflow of air. Furthermore the radiant heat transfer also has some significant effect of the fins array. Lastly the fins weight, light weight have wide space, short fins are incompatible with maximizing heat dissipation per unit base area, tall fins show a slight advantage on heat transfer and weight that are heavier in term of having longer spacing fins could have the higher heat transfer coefficient. The range of spacing between fins for optimum heat transfer is between 0.25 and 0.50 inches.

Sparrow and Acharya (1981) are trying to determine the non-monotonical varying heat transfer coefficient on vertical plate fin which exchange heat with its fluid environment through natural convection. The analysis is done through heat conduction equation for conventional fin model with simultaneously relating to conservation equation for mass, momentum and energy in the fluid boundary layer adjacent to the fin. The result of the analysis is said to be that the coefficient decreased at the beginning with minimum value then increased as with the increasing downstream distance. The result is directly affected by the behavior of the enhanced buoyancy that is the resultant of wall-to-fluid temperature difference along the stream wise direction.

Sobhan et al. (1990) had done experimental study on free convective heat transfer from fins and fin arrays attached to a heated horizontal base. The experiment is carried under steady state conditions, whereby the values for heat flux, temperature, heat transfer coefficients, local and overall Nusselt numbers are all been identified. The expected result would be the details discussion of flow and heat transfer mechanisms for the isothermal vertical flat plate, a single fin attached to a heated horizontal base and a fin array in the light. Whereby the correlation is done by comparing the overall Nusselt number with relevant non-dimensional parameters. Basically most experiment on fin are related to parameter such as fin spacing, length and orientation, temperature levels and thermo physical properties of the fluid. It is also found that horizontal orientation is suitable for short fins and vice versa and wider spacing increases the heat transfer coefficients. The chimney effect can be described that shorter fin could have higher convective coefficients so meaning that length must be considered. It is also found that aluminum fins are found to have higher temperature level, hence high Rayleigh number a given spacing, that smaller values for optimum fin spacing, thus this proves that optimum fin spacing decreases with increasing Rayleigh numbers. There is also finding on enhancement of local heat flux near the tip of fin array but this does not happen to single fin. The thermal conductivity ration is dependence to the fin and the surrounding air film. When the heat flux per unit length of the base is optimize, the fin efficiencies are at the highest values.

El-Sayed et al. (2002) experiment is about the effects of fin arrays geometries, longitudinal rectangular-fin arrays to pressure drop characteristics, fluid flow and heat transfer of fin tip-to-shroud clearance. Among investigated parameters are fin height (H), fin thickness (t), inter-fin space (W), number of fin and fin tip-to-shroud clearance (C). The result found that increasing axial pressure drop along tested model and thus the flow is deeply in stream-wise (X) direction, with increasing the fin height, the Reynolds number, and inter-fin space and the fin thickness decreasing. Also the increasing Reynolds number, the inter-fin space and the fin thickness would increase the tested model-mean Nusselt number. The fin tip-to-shroud goes off with clearance to fin height ratio (C/H) = 1.25. Where by when (C/H) = 1, the wire coil goes off.

Metzger et al. (1984) experimentally studied the internal cooling performance of two families of pin fin array geometries that have potential for aerofoil cooling. The method is applying the two families of utilize pin to circular cross section and oblong cross section with various orientation to flow direction. The result indicates that circular cross section can increase heat transfer while decreasing pressure loss. Though the use of oblong cross section increases heat transfer but increases the pressure loss. This concluded the pin surfaces relative to those of end wall surface and pin surface coefficients are approximately double the end wall values.

Chyu et al. (1999) finding the actual magnitudes of heat transfer coefficients on both pins and end walls. The experiment is conducted using analogy of naphthalene sublimation technique so that it is able to reveal the individual heat transfer contributions from pins and end walls with entire wetted surface thermally active. The result came out that the general trends of the row-resolved heat transfer coefficients of pins or the end walls are insensitive to the nature of thermal boundary conditions. Also the pints have consistently about 10 to 20 percent higher heat transfer coefficient than the end walls but this is insignificant influence on the overall array-averaged heat transfer since it is nearly four times less than the wetted area of the uncovered end walls.

Sparrow and Kadle (1986) experimented with the effect of clearance between the fin tips and an adjacent shroud to the longitudinal fin array heat transfer response. The method is by experimenting the varied clearance from no clearance; variation of fin height and fluid flow rate through the array by using the air as working fluid and turbulent condition. The result shown that with clearance about 10, 20 and 30 percent to the fin height, the heat transfer coefficients were about 85, 74 and 64 percent of those that had no-clearance case. This concluded that the clearance slowed the rate of thermal development in the entrance region.

Shuja (2002) analyzed the balance between the entropy generation due to heat transfer and pressure drop and with the consideration of unit cost of entropy generation. By analyzing the equations, the cost of operation for a pin-fin array is presented. Thus it is presented the result of optimum fin diameter and length that happen to be minimum operational cost for the fin array.

Levy (1971) had done an experiment on heat dissipation by natural convection to environment by the optimum spacing between parallel vertical isothermal flat plates. The experiment is conducted by attaching parallel vertical plates on a surface and the surface is measure in term of temperature. The result shown that the effect of spacing between parallel vertical on the maximum rate of heat transfer. Also that minimum plate spacing is required to minimize the temperature difference between the plates and the fluids. The minimum temperature difference occur when the wall boundary layer do not merge as those of plate spacing is larger.

Bar-Cohen (1979) had done an experiment to determine the fin thickness for optimum natural convection through rectangular fins. The experiment conducted by using a constant heat transfer coefficient fin material so that the heat transfer can be said to be uniformly dissipation. The experiment is governed by the geometric of the fin, thermal and air property variation. The fin thickness is relatively affected by fin spacing but in sense of heat transfer the number of fins that accommodated per unit width of primary area is also taken into consideration. The result confirms that the superior thermal heat flow is relatively effective by the fins thickness, thus this could increase the efficiency of a fin and the number of fins on primary area. The fin thickness thermal performance is related to the environment, geometric and material constraints.

Taufiq et al. (2007) is analyzing the entropy generation due to heat transfer and fluid friction. For that reason, an optimal geometry is found when the minimizing the entropy generation rate as well as the minimized thermal irreversibility. The method is by the basis of entropy generation minimization subjected to global constraint so that the optimum thickness for fin array can be determined. Because this, the influence of cost parameters on the optimum thickness of fin array can be plotted and present in graphical form. Also, to reduce the heat transfer irreversibility, the heat transfer rate must be enhanced and the cross flow fluid velocity must be increased.

Aytunc et al. (2007) studied numerically the influences of the changes in fin geometry on heat transfer and pressure drop of a plate fin and tube heat exchanger. The method of the studies is by using computational fluid dynamics (CFD) programme called Fluent to analysis the symmetrical condition of fin with consideration of heat transfer, static and total pressure drop values upon 10 different fins. The results are then tabulated and normalized values. The end analysis found that the distance between fins is affecting the pressure drop and the downstream region affects the heat transfer positively.

Dinler and Yucel (2007) had studied the numerical simulation to investigate flows and heat transfer rates of fins in a pipe. The simulations include four different types of fluids and different fin heights and location. Also it is considering Reynolds number varies as the effects of fin on Nusselt number and friction factors were also changing. This is because the changes in fin height could change the Nusselt number and friction factor, because the increase in fin height can increase the Nusselt number and friction factor. But for the effect of fin location to the Reynolds numbers, the heat transfer rate and friction factor was negligible. Low Prandtl number fluids ($Pr = 0.011$) conductively mean Nusselt number will be slightly affected the flow rates. The result of the analysis, when fin height increase, the temperature gradient around the fin is also increase; The friction factor will also increase with the increase of fin height; Fin height is also reducing the flow cross sectional area, and thus lead to flow separation and then increase the pressure loss and friction factor; With the increases of the Reynolds number, the temperature gradient near the fin and all over the flow field are also increase; The location and the presence of the fin is insignificantly affect the mean Nusselt number (for unpinned and finned pipes the Nusselt number is 3.66) but the increasing Reynolds number eventually causes the flow to go turbulent and the mean Nusselt number increase consistently, the reason for this is that the conduction of heat transfer; The presence of fin reduces the mean Nusselt number only slightly; Only when the Reynolds number flows become high (low Reynolds number is less than or equal 1000) that the heat transfer becoming convective mode. If the located near the inlet, the Nusselt number becomes slightly higher. But the fin location has no effect on the friction factor. For convective heat transfer to be more pronounced, it is better to have a higher Prandtl number.

Yazicioglu and Yuncu (2007) investigated through experiment on steady-state natural convection heat transfer from aluminum vertical rectangular fins extending perpendicularly from vertical rectangular base. Through the experiment, about thirty different fin configurations from lengths of 250 and 340 mm were tested. All the fins have thickness of fixed 3 mm and height was varied from 5 to 25 mm and 5.75 to 85.5 mm. There are five heat inputs ranging from 25 to 125 W, hence the temperature differences between base-to-ambient were measured to evaluate the heat transfer rates from the fin arrays. The experiments result on convective heat transfer rate from fin arrays rely solely on geometric parameters and base-to-ambient temperature difference. The experiment also investigated roles of each parameter such as fin height, fin spacing and base-to-ambient temperature difference. It is found that convective heat transfer rate from fin arrays takes on a maximum with the effecting parameters from fin height and optimum fin spacing, and the spacing actually optimize the convective heat transfer rate. The optimum fin spacing is between 6.1 and 11.9 mm for length range 100 to 340 mm, fin height from 5 to 25 mm and array of 3 to 34 fins, also base-to-ambient temperature difference from 30 to 150 K.

Harahap and Setio (2001) experimenting with five duralumin vertical rectangular fin-arrays with the base horizontally oriented to measure the heat dissipation from it. For the fin parameters, inter-fin separation distance is about 6.25 to 7.95 mm, the temperature difference of ambient-to-air from 19.0 ± 0.1 °C to 125.0 ± 0.1 °C, length of the fin range from 127 to 254 mm, the height from 6.35 to 38.10 mm, thickness from 1.02 to 3.10 mm, and fins per array from 10 to 33 fins. It is concluded that inter-fin separation distance and the fin length were both prime geometric parameter for generalizing the rate of heat dissipation and the rate of natural convection heat-transfer from horizontally-based vertically finned arrays.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The study will be conducted through experimentation and analytically. The experiment would be conducted to see the real world application and result of this study. Whereas the analytical is to have it confirms the result in manner of identifying the effecting parameters and instrument. Also the study also included the available literature to be compared with the experimental result and analysis.

By using the available lab apparatus and instrument at the thermodynamics laboratory, the experiment will focusing the heat flow phenomena on the rectangular fin array. This will be conducted under forced convection with steady state condition inside a rectangular duct. The rectangular fins array will be place inside the rectangular duct. Fins design is fixed at about 6 fins with horizontal orientation to the air way. The thermocouple would be used to measure the temperature. The heat source is an electrically supply to the fin base and heat would be conducted to the rectangular fins array on the surface of the base.

There would be at least 5 point of temperature difference to be collected. The first point is at the inlet of the duct and the last one is at the outlet of the rectangular duct. The rest 3 of the points are at the center and sides of the fin. On those 3 points, the points would examine each of the fins, about 6 of the fins. This is because the spacing cans also affecting the fins heat transfer coefficient. Also the length of each fin is accounted because it could effects the heat transfer coefficient at the start and at the end. Fin base is also taken into consideration for temperature measurement.

For the analytical study, there would be calculation with iteration of the experiment, the calculation is based on the analytically study from available literature. The reason for this so that the experiment can be compared relatively with the iteration calculating analysis. This is because the experimentation only involved with the forced convection and limited measuring point of the heat flow. The calculation would be able to show that there is something missing variable to be counted. For example of that missing variable is the heat transfer through the radiation and the heat absorbed by the rectangular duct. All these reason can be taken into consideration with the calculation as the experiment is limited in term of instrumentation and measurement.

The value and limit of this experiment is yet to be determined. This is because only planning has been conducted, whereas the experiment has not yet to be done. Overall the experiment and analysis were done by having 3 values and the rest is constant. For example, constant fluid flow rate and condition and with 3 distinct values on the electrical supply to the fin base. Though this is not limited with 3 values, the 3 values are only limitation to determine the minimum, maximum and middle values. Within the range of the minimum and maximum can there be values to determine optimum and graph plotting. But the measuring point is still the same, as are the points to determine the heat flow.

For start, there can be 3 ways experiment directions. These directions are meant that only variable that happens to be changed is from that parameter. The parameters is going to be tested is the electrical supply to the fin base, rectangular fins array orientation and the fan speed. But all these direct would only measure the effect on the related points. Also there is need for non-convective heat transfer but with different electrical supplied to the rectangular fins.

In logical sense, it is assume that the expected result would be that the heat transfer coefficient would increase with the increases of the fan speed. Also the horizontal orientation is better heat transfer coefficient than the vertical orientation of the fins array. Lastly, higher heat would be supply with the increases of the voltage supply to the fin base.

3.2 VALIDATION

After data gained from the experiment, the relative formulation is used for the generative data for heat transfer rate, Q, the Nusselt number, Nu, and the heat transfer coefficient. This data would be compared by par with its theoretical value. The result would determine the experiment validation and plausibility.

3.3 COMPARISON ON NOVELTY APPROACH

The idea of novelty is something new to the experiment, on this experiment the fins is wrapped with aluminum coil to see if the effect on the heat flow of the fins and heat dissipation of the fins. For the comparison, the experimental value of the Unwrapped fins would be compared with the wrapped fins, since the values for the internal energy can be determine almost accurately rather than the fins analysis through theoretical analysis.

3.4 INSTRUMENTATION AND MEASUREMENT

The instrument for the lab experiment is available at the lab, except for the aluminum coils. Thus is an experimental procedure not fabrication. Although the experiment result is somehow directly affected by the instrument, the only way to avoid significant data variation is through use of same instrument in short period of time before there would be changed on the instrument.

Figure 3.1: Experiment Set-up

From the Figure 3.1 is the main experiment set-up is a vertical rectangular duct with the fins located at the center. There is a fan allocated at the highest end, which would be the outlet. The inlet is covered with dotted holes. The instrument control power supply to the fins and the speed of the fan. There is no measurement instrument for temperature indicator.

On instrument control panel as in Figure 3.2 has the capability of controlling the power supply to the fins and also the power supply to the fan. The power supply is control by the coils thus there is some kind of inaccuracy and adjustable need to be done by time to time in the experiment. Nevertheless there is an indicator for the power supply to the fins which make thing easier to control still it needs labor work to maintain the value.

Figure 3.2: Instrument Control Panel

The experiment uses the fins that were provided along with the experiment apparatus, which mean it is calibrated experiment specimen for the experiment apparatus. The fins are rectangular fins array with 6 fins attached as seem in Figure 3.3. For the novelty the fins is wrapped with the aluminum coil.

The specific measurement for the fin is 114,04.8 mm in length, 88,00 mm in height and 6,35 in width. Overall the surface area is about 0.0121 m^2 for the 6 fins. Whereas for the wrapped aluminum coil there is no accurate surface but this would not affect the experimental result and analysis because the surface area is not used in experimental analysis and only experimental analysis is used for the wrapped fins as seem in Figure 3.4.

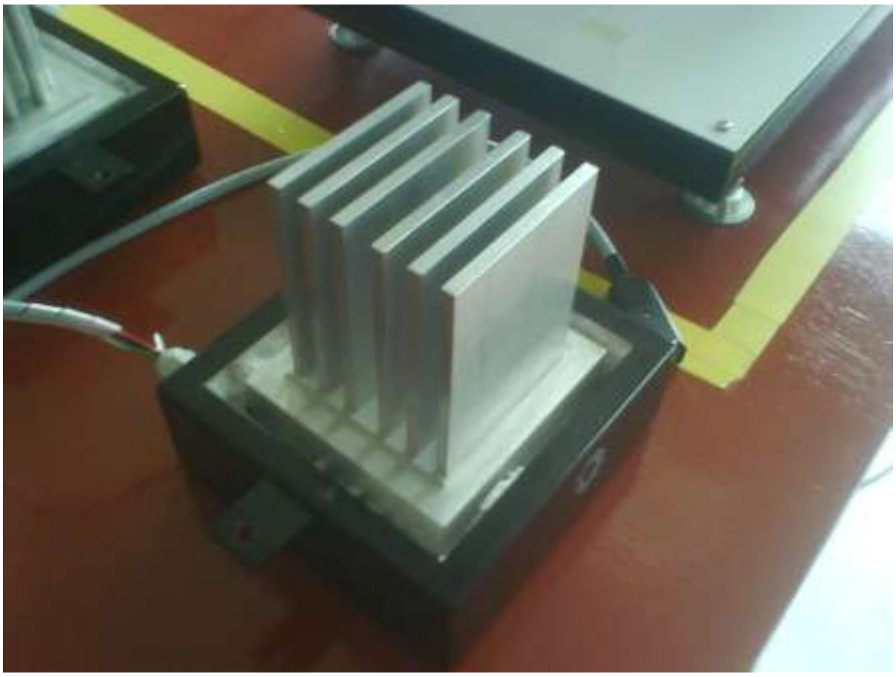

Figure 3.3: Unwrapped Rectangular Fins Array

Figure 3.4: Wrapped Rectangular Fins Array

For the measurement system, there is one instrument that is the electronic thermometer as in Figure 3.5, there is other tool, but the electronic thermometer with digital interface is much more accurate in displaying the value of the temperature different up to one decimal number. Also the probe it use is able to reach the inner environment of the rectangular duct and ergonomically easy for the reader to jot down the result.

Figure 3.5: Electronic Thermometer

The probe is used by applying it and touching its end to the surface of the base of the fins, put into idle on holes of outlet and inlet of the rectangular duct. It is effective in measuring the air temperature, although it is not capable of measuring the velocity.

3.4 CALCULATION

3.4.1 Definition

Table 3.1: Elements definition

Elements	Definition
Nu	Nusselt number
V	air velocity
Pr	Prantl Number
K	thermal conductivity
Tc	temperature at wall
T_D	outlet temperature
T_E	inlet temperature
h	heat transfer coefficient
ν	Kinematic viscosity

3.4.2 Sample of Calculation

Table 3.2: Sample of calculation and formula

Formula	Sample Calculation
$\mathrm{Nu_{Theoretical}} = 0.288\ (\frac{0.088\ \mathrm{V}}{\nu})^{0.731}.\mathrm{Pr}^{\frac{1}{3}}$	$\mathrm{Nu_{Theoretical}} = 0.288\ (\frac{0.088\ (0.8)}{1.6135})^{0.731}.\,0.7275 = 93.1229$
$\mathrm{h_{Theoretical}} = \frac{\mathrm{Nu_{Theoretical}}.\,\mathrm{k}}{0.105}$	$\mathrm{h_{Theoretical}} = \frac{93.1229(0.026065)}{0.105} = 23.1167\frac{W}{m}.\mathrm{°C}$
$\mathrm{Q_{Theoretical}} = 0.114048\mathrm{h_{Theoretical}}(\mathrm{T_C} - \mathrm{T_D})$	$\mathrm{Q_{Theoretical}} = 0.114048(23.1167)(31.5 - 32.65) =$ 72.105 watt
$\mathrm{Q_{Experiment}} = 0.0121\mathrm{C_p}\rho\mathrm{V}(\mathrm{T_D} - \mathrm{T_E})$	$\mathrm{Q_{Experiment}} = 0.0121(1007)(1.1545)(0.8)(32 - 27.5)$ = 50.642 watt
$\mathrm{h_{Experimental}} = \frac{\mathrm{Q_{Experiment}}}{0.114048(\mathrm{T_C} - \mathrm{T_D})}$	$\mathrm{h_{Experimental}} = \frac{50.642}{0.114048(31.5 - 32.65)} = 16.235\frac{W}{m}.\mathrm{°C}$
$\mathrm{Nu_{Experiment}} = \frac{0.105\mathrm{h_{Experiment}}}{\mathrm{k}}$	$\mathrm{Nu_{Experiment}} = \frac{0.105(16.235)}{0.026065} = 65.403$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter specialized in the results and discussion based on the experiment conducted in the thermodynamics laboratory. The experimental results will be presented in the table to facilitate the process of analyzing those results. Then the experimental results will be compared to each other. Recommendation will be given for future improvements. The experiment focusing the convective force for transferring heat from the rectangular fins array to the surrounding. The experiment is directly affected by the velocity and the heats supply the machine to the fin base. Thus there is two given manipulative variable which can directly affecting the experiment outcome.

4.2 EXPERIMENTAL RESULT, ANALYSIS AND DISCUSSION

All experiment result are consists on the temperature different between points and the specific air velocity. There 3 different heat supplies with 5 difference specific air velocity. Moreover there are also 2 types of fins, there are Wrapped and Unwrapped rectangular fins array.

4.2.1 Result of Rectangular Fins Array Experiment

To prove that the experiment is validated, the unwrapped rectangular fins are undergone an experiment which would validated with the current available data from literature. The validation would check the correlation between the two results and thus able to be confirmed with further experimentation.

Table 4.1: Result from Unwrapped Rectangular Fins Array

Heat Supply, W (W)	Air Velocity, V (m/s)	Surface Temperature, C (°C)	Outlet Temperature, D (°C)	Inlet Temperature, E (°C)
60	0.2	32.9	32.4	27.4
60	0.4	38.2	37.5	27.5
60	0.6	33.9	33.0	27.8
60	0.8	32.0	31.5	27.5
60	1.0	31.3	31.0	27.6
120	0.2	50.9	44.7	28.7
120	0.4	45.3	42.6	28.5
120	0.6	40.0	38.9	28.4
120	0.8	34.1	33.2	27.6
120	1.0	36.5	35.6	27.9
160	0.2	73.1	56.2	28.2
160	0.4	55.0	53.0	29.1
160	0.6	49.1	47.5	28.8
160	0.8	44.8	44.2	28.6
160	1.0	38.5	38.3	28.6

4.3.1 Analysis of Rectangular Fins Array

The experiment conducted with two manipulative interchangeable variables of the heat supply and since this is a convective experiment the air velocity is also taken into consideration. The other thing that could hinder the result is the surrounding condition. There are such as air surrounding velocity, humidity and temperature. Also the machine involved in this experiment that controls the heat supply and the air velocity in the duct.

Table 4.2: Data Manipulation from the Result of Unwrapped Rectangular Fins Array

Heat Supply, W (W)	Air Velocity, V (m/s)	Exp. Heat Transfer Rate, $Q_{exp.}$ (W)	Theo. Heat Transfer Rate, $Q_{theo.}$ (W)	Exp. Heat Transfer Coefficient, $h_{exp.}$ (W/m^2.°C)	Theo. Heat Transfer Coefficient, $h_{theo.}$ (W/m^2.°C)	Exp. Nuusselt number, $Nu_{exp.}$	Theo. Nuusselt number, $Nu_{theo.}$
60	0.2	14.067	60	24.669	105.219	99.376	423.863
60	0.4	54.929	60	48.163	52.609	191.303	208.965
60	0.6	43.529	60	73.398	101.172	293.480	404.534
60	0.8	45.015	60	98.676	131.524	397.505	529.828
60	1.0	47.829	60	123.345	154.734	496.881	623.327
120	0.2	43.241	120	23.697	65.762	93.224	258.711
120	0.4	77.449	120	48.163	74.623	189.973	294.344
120	0.6	87.203	120	72.821	100.208	289.246	398.029
120	0.8	63.021	120	98.676	187.891	397.505	756.898
120	1.0	106.582	120	98.676	187.891	391.941	746.304
160	0.2	70.145	160	21.966	50.104	80.056	182.608
160	0.4	121.553	160	44.594	58.700	164.613	216.679
160	0.6	144.778	160	67.885	75.022	253.844	280.532
160	0.8	153.546	160	81.924	89.931	338.259	340.708
160	1.0	131.074	160	118.484	144.631	466.122	568.986

The main focus of this experiment is to gain data for analysis. The analysis is done on two different methods by comparing theoretical result and experimental result and comparing wrapped fins array and rectangular fins array. The reason to compare theoretical result and experimental result is validate the data if the experimentally process is accurate or nearing to the accuracy. On the other hand, comparing Wrapped fins array and rectangular fins array is a novelty approach. The novelty approach must be support with validation in order to confirm the result is plausible.

4.3.2 Validation

On first idea, the validation would compare the theoretical data and experimental data of Nusselt number, Nu and heat transfer coefficient, h. The Nu is a non-dimensional number which is the ratio of convective to conductive heat transfer across and normal to the boundary. The larger the number of Nu thus means the higher the convectively. Whereas, the heat transfer coefficient is the level of heat is transfer to the surrounding. The transfer could be in form of other form such as radiation, conduction or convection.

4.3.3 Terms of Validation

The idea of verify the rightful validation. The graphs are signifying the analysis of the experiment as a whole. First the graphs have to be compared, since there are many graph can be used to analyses the data and also there are too huge scope that can be covered on this experiment.

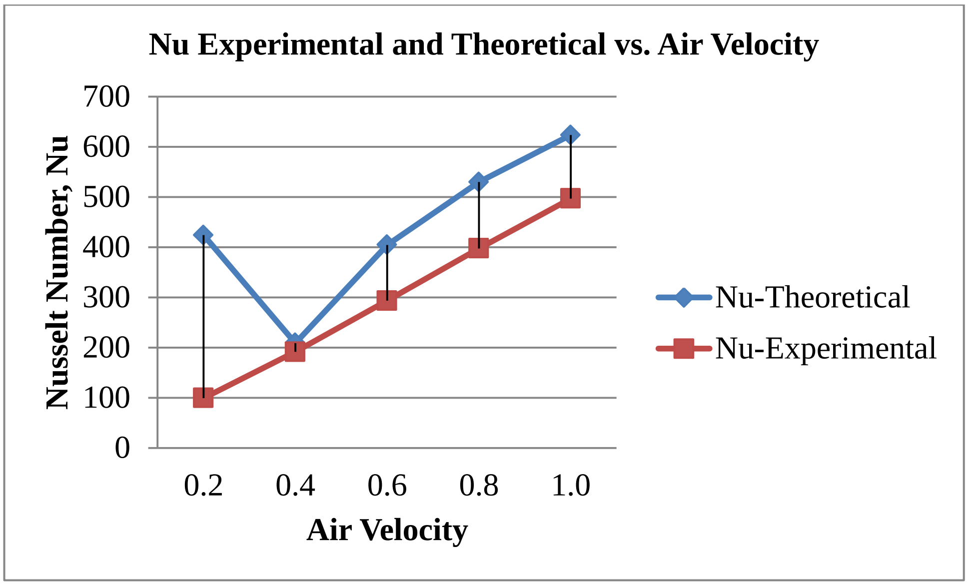

Figure 4.1: Graph of Theoretical and Experimental Nu vs. Air Velocity at heat supply 60 W

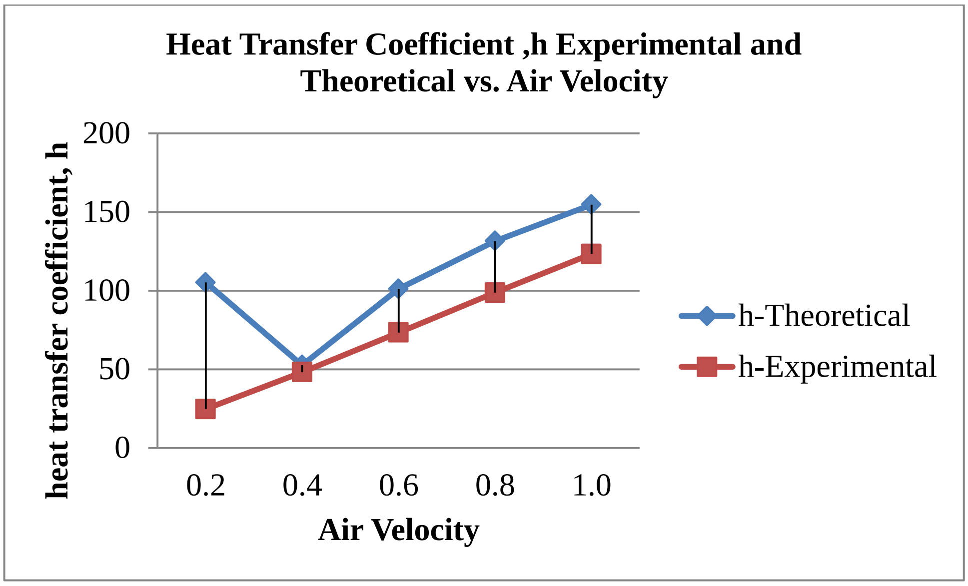

Figure 4.2: Graph of Theoretical and Experimental h vs. Air Velocity at heat supply of 60 W

From Figure 4.1 and Figure 4.2, it is shown that the graph does resemble to each other. The only different is the value, this is because the heat transfer coefficient is much to talk about the transfer rate and at the same time this is clearly shown that the other factor is also directly affected by each other. Meaning to say if the Nusselt number increase, the heat transfer coefficient will also increase.

Thus to make the scope smaller and the analysis effectively the, the only thing that would be analyses is the Nusselt number. This is also because of the direct link between Nusselt number and the convective force. Also to find out the heat transfer rate from the fins array, the comparison of the heat transfer rate, Q is also used to see the effectiveness of the method and the experiment.

The terms are also involved the comparison analysis of the Unwrapped fins array and the Wrapped fins array. But both are done in experimental comparison due to the nature of the fins instead of theoretical value which is differ from the experimental and much more closer to the both fins. Also because there were many variables are not yet verify through theoretical calculation, whereas the experimental is sufficient to learn the validated data analysis.

4.3.4 Validation of Unwrapped Fins Array

The validation would do by using the theoretical and experimental data. The analysis will be done through the examination of the graphs gained from the data manipulation to the formulation set by.

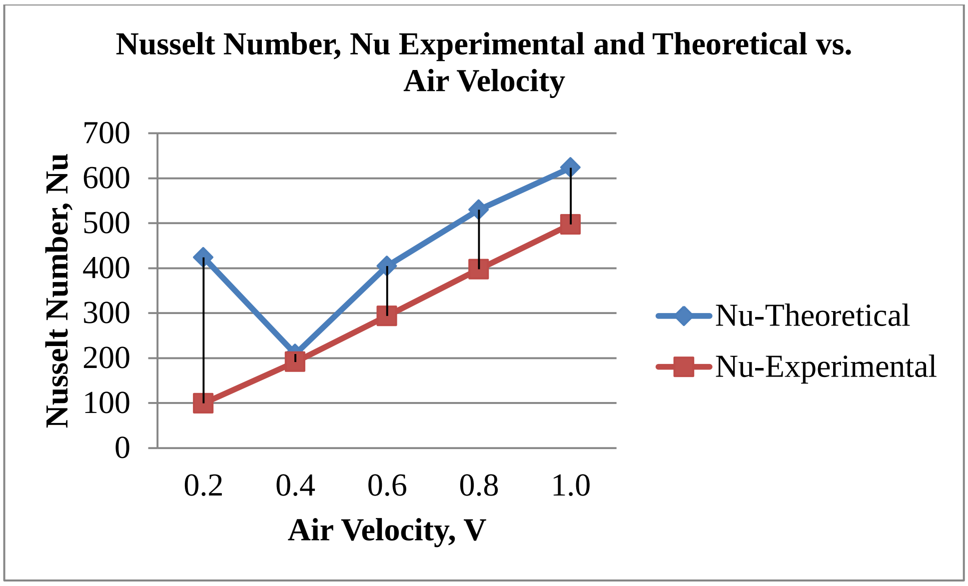

Figure 4.3: Graph of Theoretical and Experimental Nu vs. Air Velocity at heat supply 60 W

From the Figure 4.3, roughly there anomaly, especially at air velocity at 0.4 m/s. From the data gain, the temperature at the point seems to have increase and thus achieving almost the same result as the experimental value, meaning with very little error. But then again the value at the 0.2 m/s of air velocity seems to have gone wrong, higher than the rest of the experiments. Although this is not common, but the data seem legit and plausible.

The other explanation would be because of the material use as it is not a research material instead it is a lab instrument use for practical purpose of lab experiment. But this is seem sufficient for the experiment as the result seem to have gone better after 0.4 m/s of air velocity. Thus this anomaly would be ignored as part of experimentation error.

Also, the idea of using experimental is much to do with surrounding condition of the rectangular duct than with fins as does by the theoretical calculation. Due to this it is supported that the fins does at some point become dynamic and less stable for analysis then the surrounding air temperature of the duct, since the air is much more thoroughly distributed the energy of the heat whereas the fins form unequal distribution of heat energy over its body.

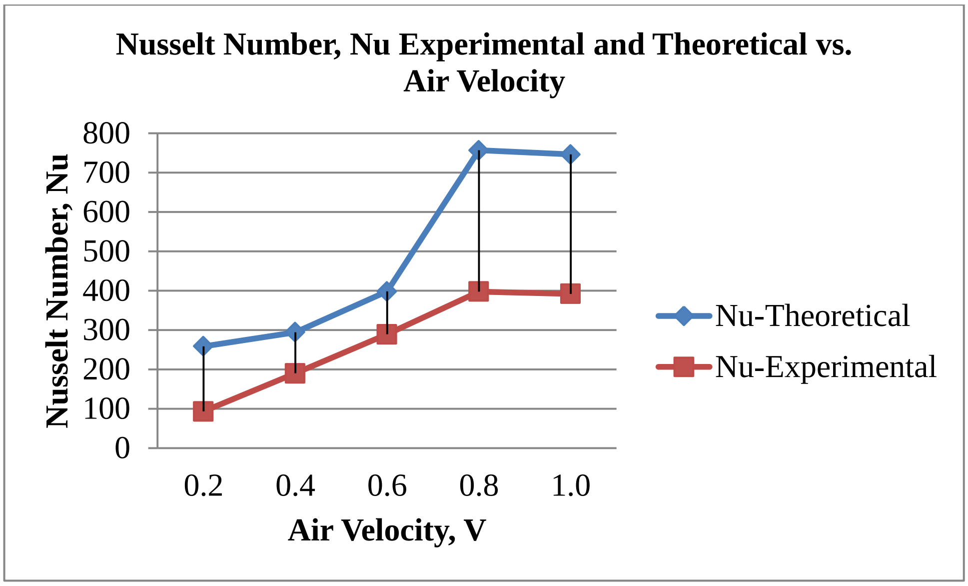

Figure 4.4: Graph of Theoretical and Experimental Nu vs. Air Velocity at heat supply 120 W

From the Figure 4.4, the graph showed much more similar in pattern of both comparisons. Even though the both have some difference is value but the pattern seems to have been plausible to say that the experiment had done its purpose. In this graph it could be said that higher power supply to the fins would make the result much more stable in term of pattern although the level of convectively is different.

Also, if the graph above to be compared with Figure 4.5, there is no anomaly. This due heat supplied to the fins and then has the heat energy uniformly distributed over the fins and the surrounding condition of the rectangular duct. Due to this, it is believe that the fins have some sort of rate which heat release and supply, but only at higher heat supply then the fins able to uniformly release and absorb heat with its optimum heat capacity. This would add another factor of determining the heat that supposed to be used for stable and accurate experimentation and also for the industry guideline.

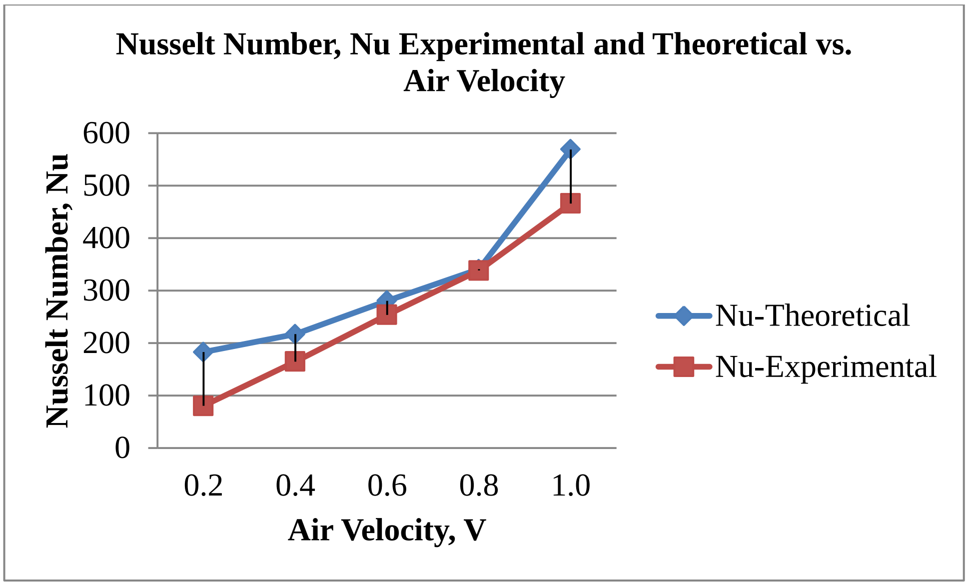

Figure 4.5: Graph of Theoretical and Experimental Nu vs. Air Velocity at heat supply 160 W

If Figure 4.4 is about legitimacy of heat supply and the plausible pattern for much stable convectively data. The graph from Figure 4.5 is about the increase of heat supply about 160 W would bring close the result with much more closely to the theoretical values. Thus this mean that the higher the heat supply to fins, the much more accurate.

This also means that the experiment would be much accurate at higher temperature with the higher heat supply to the fins. This is probably due to the condition of the fins and the rate of which the heat is supply out from the fins. At higher heat energy meaning, the dynamic condition of constant changing of energy can be stabled with more uniformly distributed heat energy to the fins and the surrounding condition of the rectangular duct where the fins is experimented.

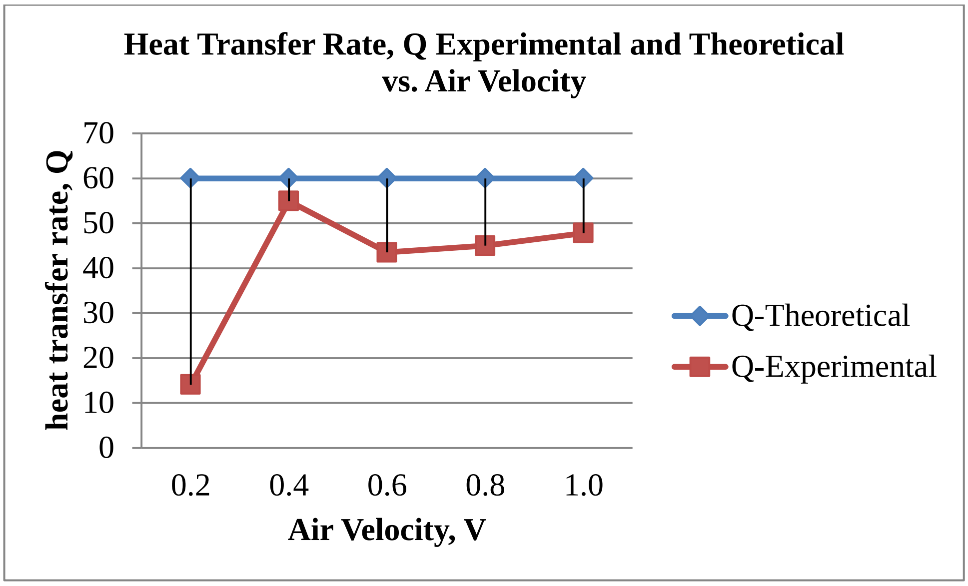

Figure 4.6: Graph of Theoretical and Experimental Heat Transfer Rate vs. Air Velocity at heat supply 60 W

From the Figure 4.6, the graph shown is the result of the affected Nusselt number and heat transfer rate on the fins. Even though the constant heat was supplied to the fins at about 60 W, but the result shown that it would never be able to reach 100 % efficiency, especially at about 0.2 m/s of air velocity. The reason is the same as Figure 4.3. It is presume that Nusselt number is affecting the overall heat transfer rate of the fins.

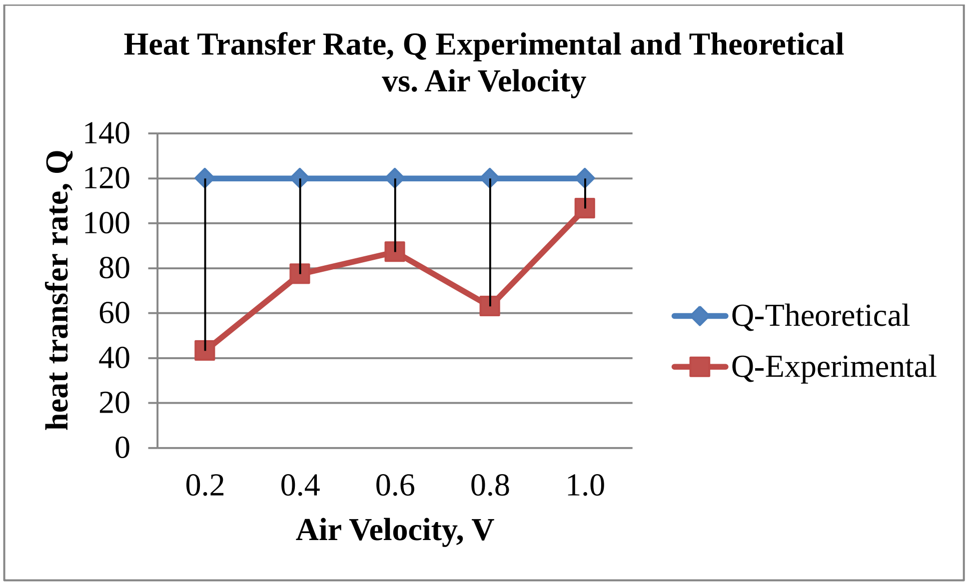

Figure 4.7: Graph of Theoretical and Experimental Heat Transfer Rate vs. Air Velocity at heat supply 120 W

If the graph of Figure 4.7 and Figure 4.4 are to be compared, it is to be thought that the higher the slope at Figure 4.4, the less efficient it would, thus the less heat transfer rates it would be, just like from Figure 4.7. From Figure 4.4, it is shown that the pattern is almost the same, at the graph is almost perfect match for the experiment but, the higher slope between 0.6 and 0.8 m/s of air velocity does somehow affecting the heat transfer rate at the 0.8 air velocity. But then the heat transfer rate increase back at 1.0 m/s of air velocity.

Thus mean that, even if the Nusselt number is about the same like having it constantly increase over the air velocity, it is still not enough, the precise and good heat transfer rate would be when the Nusselt number is closer between the theoretical and the experimental result.

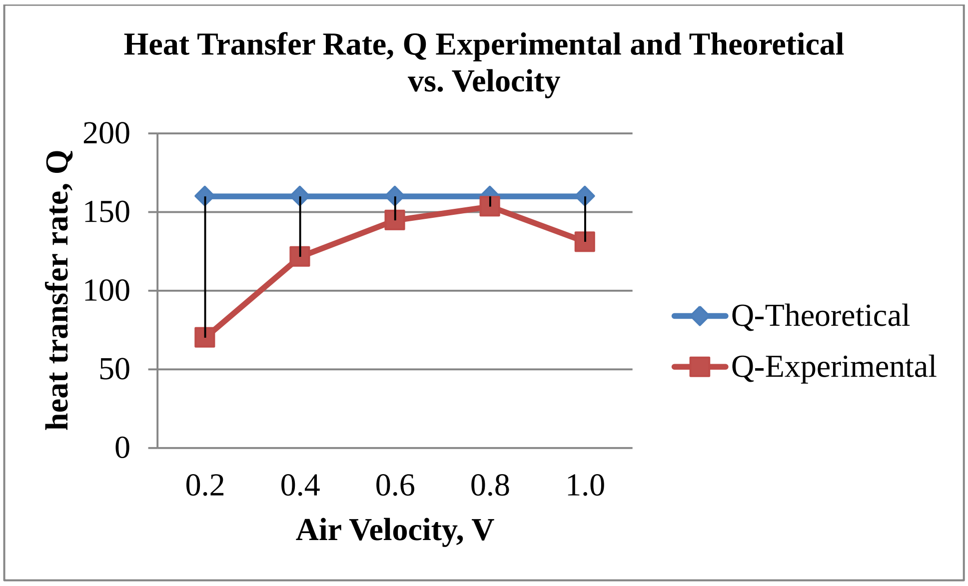

Figure 4.8: Graph of Theoretical and Experimental Heat Transfer Rate vs. Air Velocity at heat supply 160 W

The Figure 4.8 shown only the efficiency of heat transfer rate at 0.8 m/s of air velocity is the best and efficient, although from 0.2 until 0.8 of air velocity are increasing but at 1.0 m/s, the result seem to have decrease, this is connected to the Figure 4.5 whereby the theoretical and experimental value seem to have the gap widen thus result the heat transfer rate.

4.4.1 Result of Wrapped Fins Array Experiment

To do the novelty approach, the experiment is test with different in fins design, but since design and fabrication is pain staking problem and expensive, the idea is done through manipulation of fins with the cheap way such as wrap it with aluminum coil and shape it into aerofoil but not accurately aerofoil but the main idea is to create something different and to check whether that would make any different on the result of the experiment.

Table 4.3: Result from Wrapped Fins Array

Heat Supply, W (W)	Air Velocity, V (m/s)	Surface Temperature, C (°C)	Outlet Temperature, (°C)	Inlet Temperature, E (°C)
60	0.2	38.4	31.4	29.3
60	0.4	36.6	31.1	29.6
60	0.6	34.2	31.3	29.3
60	0.8	33.7	31.8	29.3
60	1.0	33.6	30.5	29.3
120	0.2	42.8	32.3	28.3
120	0.4	39.5	32.0	28.2
120	0.6	36.4	31.8	28.2
120	0.8	35.3	31.2	28.1
120	1.0	34.3	30.8	28.1
160	0.2	43.9	29.1	27.7
160	0.4	40.1	28.5	27.5
160	0.6	36.5	28.7	27.5
160	0.8	36.2	28.8	27.4
160	1.0	36.5	28.8	27.4

4.5.1 Analysis of Wrapped Fins Array

Similar to the unwrapped rectangular fins array experiment, the experiment conducted with two manipulative interchangeable variables of the heat supply and since this is a convective experiment the air velocity is also taken into consideration. The data is not validating but compare with the existing data from the validation of the previous experiment of unwrapped rectangular fins array. This is because the accurate data for the fins is not documented and design is as novelty as the result itself.

Table 4.4: Comparison between Wrapped Fins and Unwrapped Fins

Heat Supply, W (W)	**Air Velocity, V (m/s)**	**Unwrapped Rectangular Fins Array**			**Wrapped Rectangular Fins Array**		
		Exp. Heat Transfer Rate, $Q_{exp.}$ (W)	**Exp. Heat Transfer Coefficient, $h_{exp.}$ (W/m^2.°C)**	**Exp. Nuusselt number, $Nu_{exp.}$**	**Exp. Heat Transfer Rate, $Q_{exp.}$ (W)**	**Exp. Heat Transfer Coefficient, $h_{exp.}$ (W/m^2.°C)**	**Exp. Nuusselt number, $Nu_{exp.}$**
60	0.2	14.067	24.669	99.376	25.595	24.661	99.346
60	0.4	54.929	48.163	191.303	39.284	49.208	198.227
60	0.6	43.529	73.398	293.480	41.605	74.449	302.054
60	0.8	45.015	98.676	397.505	49.898	99.437	403.433
60	1.0	47.829	123.345	496.881	60.903	124.189	503.858
120	0.2	43.241	23.697	93.224	40.466	24.470	97.844
120	0.4	77.449	48.163	189.973	63.562	49.321	198.684
120	0.6	87.203	72.821	289.246	69.151	73.943	297.871
120	0.8	63.021	98.676	397.505	81.834	99.659	404.334
120	1.0	106.582	98.676	391.941	87.935	124.360	504.551
160	0.2	70.145	21.966	80.056	45.065	24.391	97.528
160	0.4	121.553	44.594	164.613	70.874	49.321	198.684
160	0.6	144.778	67.885	253.844	75.940	73.984	298.038
160	0.8	153.546	81.924	338.259	99.858	99.497	414.901
160	1.0	131.074	118.484	466.122	129.090	124.383	505.467

The focus of this novelty approach is to get an idea of how to increase the heat transfer rate as well as the convective heat transfer rate from the Wrapped fins array and compare that to the rectangular fins array result and see whether it is worthy to wrap the fins with an aluminum coil or not.

The idea is of this comparison is to see whether it is worthy to have a Wrapped fins or not, but according to early estimation based on the graph the base temperature is increasing at higher than the rectangular fins array. But the temperature of pattern is kind of the same only at lower level since the rate of which it is transferring is lowering.

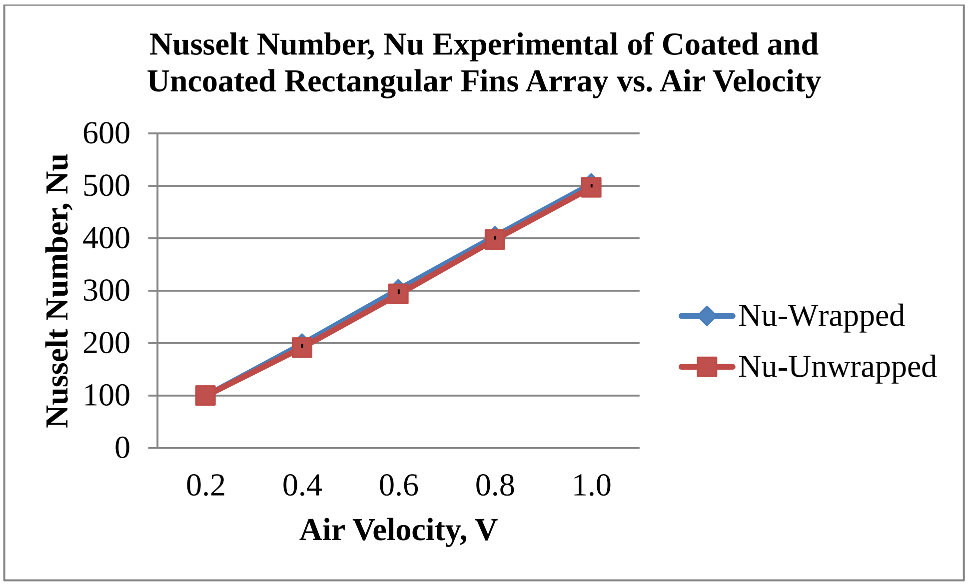

Figure 4.9: Graph of Wrapped and Unwrapped Rectangular Fins Array Nu vs. Air Velocity at heat supply 60 W

The graph of Figure 4.9 shown that the Wrapped and Unwrapped rectangular fins array does somehow resemble and in line with each other. This also proves that the validation was correct and the comparison is plausible at this point. Since the result of both fins are not far fetch from each other. Furthermore, the pattern of both line is the same.

The only problem is that the level of convective force is not sufficient and worth for the industry and for transferring heat off and cooling the fins. This must be improved so that the wrapping is valid for further research and application.

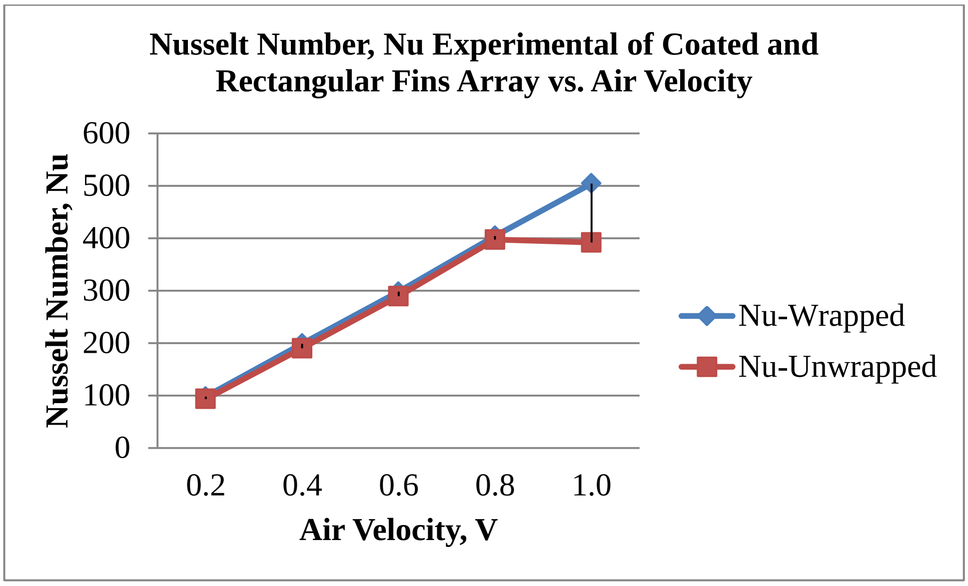

Figure 4.10: Graph of Wrapped and Unwrapped Rectangular Fins Array Nu vs. Air Velocity at heat supply 120 W

The graph of Figure 4.10 is still resemble similar pattern with the graph of Figure 4.9 but on one anomaly that was occur on 1.0 m/s of air velocity from Unwrapped fins array. This is not new in this experiment. Anomaly can occur due to material or reading error. Thus this is ignore and assume that the suppose result would be directly proportional and parallel to each other.

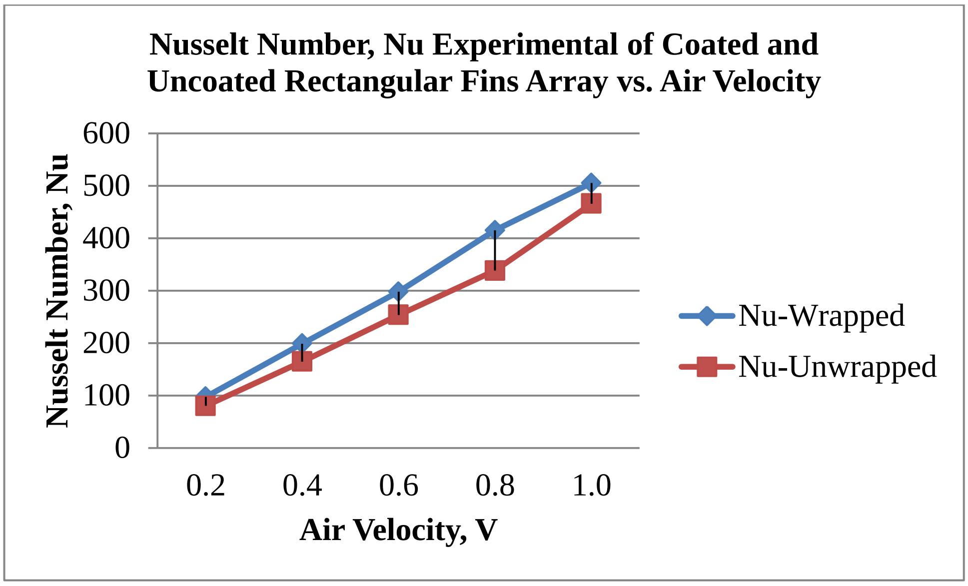

Figure 4.11: Graph of Wrapped and Unwrapped Rectangular Fins Array Nu vs. Air Velocity at heat supply 160 W

Other than the Figure 4.10, the Figure 4.11 and the Figure 4.9 seem to have come along with perfect match in term of pattern and slope it made. This is further prove that the anomaly in Figure 4.10 can be ignored and though to be normal error during experimentation.

By comparing all three graphs from Figure 4.9, Figure 4.10 and Figure 4.11, the graphs show some improvement of convection force with increasing heat supply and also with more air velocity. Thus is approving that the wrapping is plausible for reducing heat from the rectangular fins array and improving convection force.

It is observed that the highest value for the Nusselt number is 505.469 can be achieved by the wrapped fins array than without wrap on fins about 39.347 which is about 8.44% positive increment.

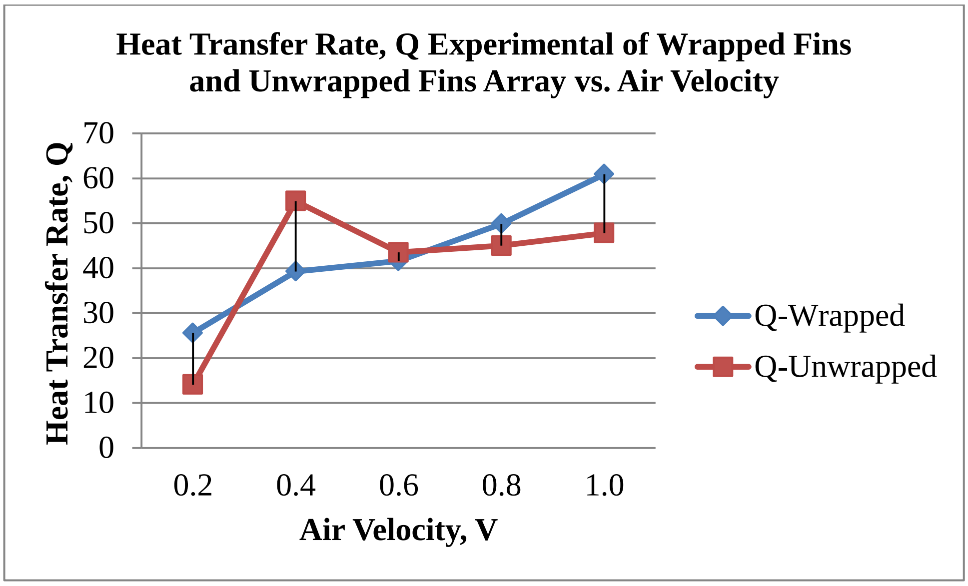

Figure 4.12: Graph of Wrapped and Unwrapped Rectangular Fins Array Q vs. Air Velocity at heat supply 60 W

Even though heat transfer coefficient seems related and affecting the Nusselt number, but it is not. It is in fact the other way around. The heat transfer rate would be used to determine the heat transfer coefficient and then to find the Nusselt number. Thus the thing that affecting the heat transfer rate is the temperature difference in the rectangular where the fins are been experimented.

By analyzing the key effecting variables of the formulation, it is thought that the Wrapped seem to have caused the heat flow to be more uniformly distributing the heat energy and also the heat is much more proportion with air velocity. While this could be thought as due to turbulent, but the length of the fins and also the speed of the air velocity would never cause the air inside the rectangular duct into turbulent condition.

There are two reasons for this, the shape and the material. The aluminum wrapping of the fins is rough and handmade, though the difference might be small but the result confirm some difference due to the rough surface. The material, because it is thick and aluminum with enlighten silver surface is much more prone to emits heat rather than storing it, thus it can be said that the aluminum coil that Wrapped the fins actually work as an amplifier of the fins to transfer heat.

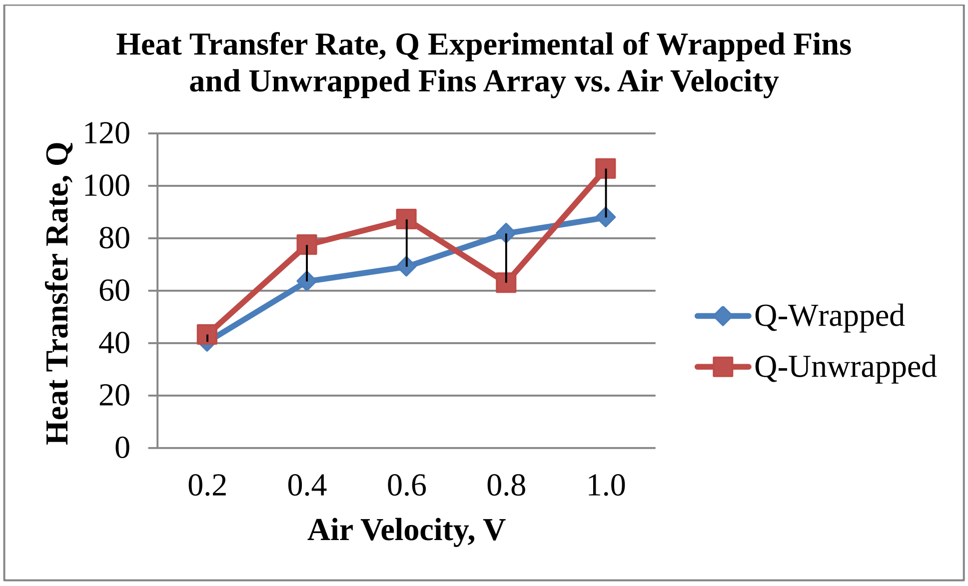

Figure 4.13: Graph of Wrapped and Unwrapped Rectangular Fins Array Q vs. Air Velocity at heat supply 120 W

From the graph of Figure 4.13, there is only one anomaly, and this is ignored, due to experimentation error. The Wrapped rectangular fins array seems to have increase with its heat transfer rate with due to the air velocity. This also means that Wrapped is better in term of heat dissipation, with less error occurrence. The error is when the unwrapped rectangular fins array is below the Wrapped fins array; this is because the pattern is inconsistent. But the pattern seems to have improved with higher heat supply to the fins than from the result of Figure 4.11.

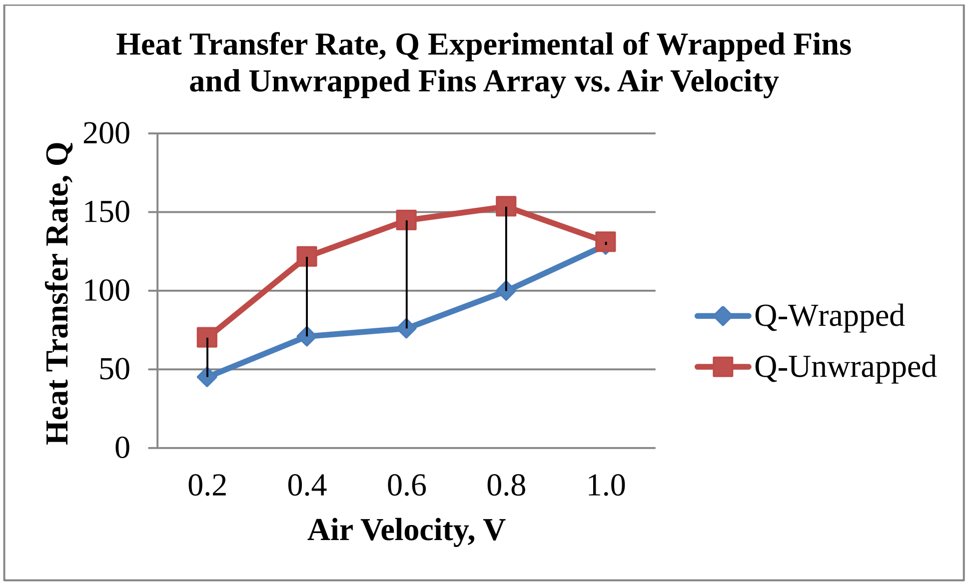

Figure 4.14: Graph of Wrapped and Unwrapped Rectangular Fins Array Q vs. Air Velocity at heat supply 160 W

From the Figure 4.14, the result is much more clean and smooth, although it is not entirely parallel but the proportion of its going up with steady slope is plausible result the whole experiment. Again, with higher heat supply the result would be much more predictable. This is due that the heat dissipation is evenly distributed throughout the rectangular duct faster and thus changes the condition of the air temperature. At 1.0 m/s of air velocity, the heat is able to by par achieve almost no different of heat transfer rate but this is no good since the expected result should be bettered and the wrapping actually work to reduce heat from the fins. This is would be another research, but then again, the overall changes are plausible to say that the wrapping does worked to reduce heat and with an anomaly.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The project was able to accomplish its objectives that are to observe the temperatures difference on the rectangular duct and the fins, and also to compare the data with theoretical calculation and also the experiment also conducted on novelty approach of observing the performance of wrapped coil on the fins for convection analysis. With that it is observed that the highest value for the Nusselt number is 505.469 can be achieved by the wrapped fins array than without wrap on fins about 39.347 which is about 8.44% positive increment.

5.2 RECOMMENDATION

Regarding the experimental result, it is also believed that the design of the fins and the material can directly affecting the convection force of the fins. If there are more for the research a custom made fins would be useful for more effective convection and also the determination of fins material. On that it is suggested that an aerofoil shape of fins to be used for the experiment since aerofoil is better for air flow thus meaning to have better heat dissipation and distribution. Moreover material such as aluminum can be very useful for heat dissipation with its lower heat capacity and cheaper cost.

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APPENDIX A

GANTT CHART FOR FINAL YEAR PROJECT 1

Table 6.1: Gantt Chart for Final Year Project 1

Week / **Tasks**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Introduction														
Literature														
Methodology														

APPENDIX B

GANTT CHART FOR FINAL YEAR PROJECT 2

Table 6.2: Gantt Chart for Final Year Project 2

Week / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Experiment														
Result														
Analysis														
Conclusion														