APPROVAL

EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER OVER MACHNINING SURFACES USING INFRARED CAMERA

by

Sarvesh Nadaraj

A project dissertation submitted to the
Faculty of Science, Technology, Engineering & Mathematics
INTI INTERNATIONAL UNIVERSITY
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons) in
Mechanical Engineering

Approved:

Dr Abdulwehab A.Ibrahim
Project Supervisor

INTI INTERNATIONAL UNIVERSITY
NILAI, NEGERI SEMBILAN

APRIL 2015

DECLARATION

I, the undersigned, hereby declare that this report is my own independent work except as specified in the references and acknowledgements. I have not committed plagiarism in the accomplishment of this work, nor have I falsified and/or invented the data in my work. I am aware of the University regulations on Plagiarism. I accept the academic penalties that may be imposed for any violation.

Signature ....

Name ......SARVESH NADARAJ......

Matrix No. ......I 11007631......

Date ......01-06-2015......

ABSTRACT

Steam boiler is used mainly in palm oil mill to generate steam to produce electricity and for sterilization process. An important role of boiler tube heating system is played by forced and natural convection. The type of material and its surface roughness are important to determine the heat transfer rate. This research presents an experimental investigation by infrared thermography of heat transfer over machining surfaces. The overall objective would be to gather temperature gradient of machined surface by using infrared camera and analyses the rate of heat transfer of the machined surface. Three types of material was used for this experiment will be low alloy steel, carbon steel and stainless steel. The steel plates were milled to different surface roughness by varying the spindle speed of 1000 rpm and 1500 rpm. The roughness was measured before the heating process. Then, the material was heated up to 300°C and the natural and force convection experiment was conducted. For force convection, the wind speed was varied from 2.3m/s, 4.1 m/s and 5.2 m/s. As for the natural convection, stainless steel's final heat transfer rate for smooth surface is having variation of 7.24 Watt; manufacturing surface of stainless steel is having variation of 6.2 Watt while the rate of heat transfer for rough surface is having variation of 4.01 Watt. As for the force convection at 5.2 m/s, stainless steel's smooth surfaces final heat transfer rate for smooth surface is having variation of 26.3 Watt, while manufacturing surfaces final heat transfer rate is having variation of 22.81 Watt and the rough surfaces is having final heat transfer rate is having the variation of 21.51 Watt. As to conclude for both natural and force convection, smooth surfaces for all three types of material which consist of carbon steel, low alloy steel and stainless steel has the highest heat transfer rate. In this experiment it could be concluded that smooth surfaces of stainless steel have the highest transfer rate in both natural and force convection.

ACKNOWLEDGEMENTS

I take this opportunity to express my deep sense of gratitude and sincere thanks to all who have helped me to complete this work successfully. Special thanks to my parents for all support and creating an opportunity and support for me to pursue my educational goals. I also would like to thank my project supervisor, Dr. Abdulwehab A.Ibrahim for his guidance throughout these processes of research. I really appreciate his contribution in this project and for being there whenever I need his consultancy despite being in his busy schedule. My special thanks goes to my examiners Mr.Seyed Amirmostafa and Dr.Tezara Cionita for taking the effort to read through and marking my report.

Next I also would like to take this opportunity to thank Head of Mechanical Department Engr. Moey Lip Kean and my lecturer Mr.Jeya Gopi for assisting me in this precious project. Many thanks go to the Tan Sri Abdul Majid's librarians Ms Masilah Mansor and Ms Siti Khadijah for assisting in my project by searching of journals and articles. Other than that, I would like to thank the lab assistants, Mr Ravi, Mr Amir and Ms Mazlia who took their time and resources to assist me in the laboratory. Last but not least, special thanks go to my friends who had constantly supported and motivated me through this completion of the project.

DEDICATION

This thesis is dedicated to my family

TABLE OF CONTENTS

DECLARATION i
ABSTRACT ii
ACKNOWLEDGEMENTS iii
DEDICATION iv
LIST OF FIGURES viii
LIST OF TABLES xii
LIST OF ABBREVIATIONS xiii
NOMENCLATURE xiv
CHAPTER 1 1
INTRODUCTION 1
1.1. Background 1
1.2. Problem Statement 4
1.3. Objectives of the Report 4
1.4. Scope of the Research 5
1.5. Outline of The Report 6
CHAPTER 2 7
LITERATURE REVIEW 7
2.1. Introduction 7
2.2. History of Heat Transfer Convection Calculation 7
2.3. Relationship between Surface Roughness and Heat Transfer 8
2.4 Relationship between Milling Parameters and Surface Roughness 10
2.5 Heat Transfer Experimental Setup for Horizontal Plate 11
2.6 Heat Transfer Experimental Setup by Infrared Camera 14
2.7 Effect of Reynolds, Nusselt and Rayleigh Numbers 16
CHAPTER 3 19
METHODOLOGY 19

3.1. Introduction 19

3.2. Material Selection..19

3.3. Experimental Setup 20

3.4. Experimental Presentation..22

3.5. Mathematical Modeling..23

3.5.1 The natural convection relationships..23

3.5.2 Forced convection correlations 25

3.6 Flow Diagram 28

CHAPTER 4 29

RESULTS AND DISCUSSION..29

4.1 Introduction..29

4.2 Experimental Results of Surface Roughness..31

4.2.1 Relationship between Spindle Speed and Surface Roughness..36

4.3 Determination of Heat Transfer Rate for Natural Convection 37

4.4 Determination of Heat Transfer Rate for Forced Convection 39

4.5 Discussion of Natural Convection for Heated Plates 41

4.5.1 Experimental Results of Surface Temperature for Natural Convection 41

4.5.2 Relationship between Surface Roughness and Heat Transfer Rate 47

4.5.3 Effect of Nusselt Number and Rayleigh Number on Natural Convection..51

4.5.4 Effects of Rayleigh Number on Heat Transfer Rate for Natural Convection..54

4.6 Discussion of Forced Convection for Heated Plates 57

4.6.1 Experimental Results of Surface Temperature for the Forced Convection at the Wind Velocity of 2.3m/s..57

4.6.2 Experimental Results of Surface Temperature for Forced Convection at Wind Velocity of 4.1 m/s..63

4.6.4 Experimental Results of Surface Temperature for Forced Convection at Wind Velocity of 5.2 m/s..69

4.6.5 Relationship between Surface Roughness and Heat Transfer Rate for The Forced convection at the wind velocity of 2.3 m/s 75

4.6.6 Relationship between Surface Roughness and Heat Transfer Rate for The Forced convection at the wind velocity of 4.1 m/s 78

4.6.7 Relationship between Surface Roughness and Heat Transfer Rate for The Forced convection at the wind velocity of 5.2 m/s 81

4.6.8 Effects of the Nusselt Number and Reynolds Number at Wind Velocity of 2.3ms/ 4.1m/s and 5.2m/s. 84

4.6.9 Effects of the Reynolds Number on Heat Transfer Rate at Wind Velocity of 2.3ms/ 4.1m/s and 5.2m/s. 87

CHAPTER 5 90

5.1 Conclusion 90

5.2 Recommendation for Future Work 91

REFERENCES 92

APPENDIX A 94

LIST OF FIGURES

Figure 2-1 Forced and Natural Convection Image 8
Figure 2-2 Arithmetical Mean Deviation of Profile 10
Figure 2-3 Diagram of the geometrical parameters and discrete heaters (N=5) 12
Figure 2-4 Diagram in square room of the heated thin plate and dimensions 12
Figure 2-5 Flows through to corners, edges and a central region 13
Figure 2-6 Thermal image of thin plate on above surface 15
Figure 2-7 Experiment setup for IR Thermography analysis 15
Figure 2-8 Image result of infrared camera 16
Figure 2-9 Relationship between Nusselt Number and Rayleigh Number 18
Figure 3-1 Sample plate in horizontal position 20
Figure 3-2 Hand held roughness tester (Time Inc.) 21
Figure 3-3 FLIR infrared camera setup 21
Figure 3-4 Display of thermal image in laptop screen 22
Figure 3-5 Flow chart of the research 28
Figure 4-1 FLIR Infrared Image in CSV Format 29
Figure 4-2 Image contour of Surface Temperature in Matlab software. 30
Figure 4-3 (a) Manufacturing Surface (b) Rough Surface, 1000 rpm (c) Smooth Surface 1500pm of Low Alloy Steel 32
Figure 4-4 (a) Manufacturing Surface (b) Rough Surface, 1000 rpm (c) Smooth Surface 1500pm of Carbon Steel 33
Figure 4-5 (a) Manufacturing Surface (b) Rough Surface, 1000 rpm (c) Smooth Surface 1500pm of Stainless Steel 34
Figure 4-6 Surface Temperature of Low Alloy Steel with Manufacturing Surface at 0 and 300 seconds 41
Figure 4-7 Surface Temperature of Low Alloy Steel with Smooth Surface at 0 and 300 seconds 42
Figure 4-8 Surface Temperature of Low Alloy Steel with Rough Surface at 0 and 42
Figure 4-9 Surface Temperature of Carbon Steel with Manufacturing Surface at 0 and 43

Figure 4-10 Surface Temperature of Carbon Steel with Smooth Surface at 0 and 300 seconds 44
Figure 4-11 Surface Temperature of Carbon Steel with Rough Surface at 0 and 300 seconds 44
Figure 4-12 Surface Temperature of Stainless Steel with Manufacturing Surface at 0 and 300 seconds 45
Figure 4-13 Surface Temperature of Stainless Steel with Smooth Surface at 0 and 300 seconds 46
Figure 4-14 Surface Temperature of Stainless Steel with Rough Surface at 0 and 300 seconds 46
Figure 4-15 Time against Rate of Heat Transfer of Low Alloy Steel 47
Figure 4-16 Time against Rate of Heat Transfer of Carbon Steel 48
Figure 4-17 Time against Rate of Heat Transfer of Stainless Steel............................ 49
Figure 4-18 Time against Heat Transfer Rate for Smooth Surface of Three Materials 50
Figure 4-19 Rayleigh Number against Nusselt Number at Different Surface Roughness of Low Alloy Steel 51
Figure 4-20 Rayleigh Number against Nusselt Number at Different Surface Roughness of Carbon Steel 52
Figure 4-21 Rayleigh Number against Nusselt Number at Different Surface Roughness of Stainless Steel 53
Figure 4-22 Rayleigh Number against Rate of Heat Transfer Low Alloy Steel.......... 54
Figure 4-23 Rayleigh Number against Rate of Heat Transfer of Carbon Steel 55
Figure 4-24 Rayleigh Number against Rate of Heat Transfer of Stainless Steel......... 56
Figure 4-25 Surface Temperature of Low Alloy Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 2.3 m/s 57
Figure 4-26 Surface Temperature of Low Alloy Steel with Smooth Surface at 0 and 300 seconds for wind speed of 2.3 m/s 58
Figure 4-27 Surface Temperature of Low Alloy Steel with Rough Surface at 0 and 300 seconds for wind speed of 2.3 m/s 58
Figure 4-28 Surface Temperature of Carbon Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 2.3 m/s 59
Figure 4-29 Surface Temperature of Carbon Steel with Smooth Surface at 0 and 300 seconds for wind speed of 2.3 m/s 60

Figure 4-30 Surface Temperature of Carbon Steel with Rough Surface at 0 and 300 seconds for wind speed of 2.3 m/s 60
Figure 4-31 Surface Temperature of Stainless Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 2.3 m/s 61
Figure 4-32 Surface Temperature of Stainless Steel with Smooth Surface at 0 and ... 62
Figure 4-33 Surface Temperature of Stainless Steel with Rough Surface at 0 and 62
Figure 4-34 Surface Temperature of Low Alloy Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 4.1 m/s 63
Figure 4-35 Surface Temperature of Low Alloy Steel with Smooth Surface at 0 and 64
Figure 4-36 Surface Temperature of Low Alloy Steel with Rough Surface at 0 and.. 64
Figure 4-0-37 Surface Temperature of Carbon Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 4.1 m/s 65
Figure 4-38 Surface Temperature of Carbon Steel with Smooth Surface at 0 and 300 seconds for wind speed of 4.1 m/s 66
Figure 4-39 Surface Temperature of Carbon Steel with Rough Surface at 0 and 300 seconds for wind speed of 4.1 m/s 66
Figure 4-40 Surface Temperature of Stainless Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 4.1m/s 67
Figure 4-41 Surface Temperature of Stainless Steel with Smooth Surface at 0 and ... 68
Figure 4-42 Surface Temperature of Stainless Steel with Rough Surface at 0 and 300 seconds for wind speed of 4.1 m/s 68
Figure 4-43 Surface Temperature of Low Alloy Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 5.2 m/s 69
Figure 4-44 Surface Temperature of Low Alloy Steel with Smooth Surface at 0 and 70
Figure 4-45 Surface Temperature of Low Alloy Steel with Rough Surface at 0 and 300 seconds for wind speed of 5.2 m/s 70
Figure 4-46 Surface Temperature of Carbon Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 5.2 m/s 71
Figure 4-47 Surface Temperature of Carbon Steel with Smooth Surface at 0 and 300 seconds for wind speed of 5.2 m/s 72
Figure 4-48 Surface Temperature of Carbon Steel with Rough Surface at 0 and 300 seconds for wind speed of 5.2 m/s 72
Figure 4-49 Surface Temperature of Stainless Steel with Manufacturing Surface at 0 and 300 seconds for wind speed of 5.2 m/s 73

Figure 4-50 Surface Temperature of Stainless Steel with Smooth Surface at 0 and 300 seconds for wind speed of 5.2 m/s 74
Figure 4-51 Surface Temperature of Stainless Steel with Rough Surface at 0 and 300 seconds for wind speed of 5.2 m/s 74
Figure 4--52 Time against Rate of Heat Transfer of Low Alloy Steel at Wind Speed of 2.3 m/s 75
Figure 4-53 Time against Rate of Heat Transfer of Carbon Steel at Wind Speed of 2.3 m/s 76
Figure 4-54 Time against Rate of Heat Transfer of Stainless Steel at wind speed of 2.3 m/s 77
Figure 4-55 Time against Rate of Heat Transfer of Low Alloy Steel at Wind Speed of 4.1 m/s 78
Figure 4-56: Time against Rate of Heat Transfer of Carbon Steel at Wind Speed of 4.1 m/s 79
Figure 4-57 Time against Rate of Heat Transfer of Stainless Steel at wind speed of 4.1 m/s 80
Figure 4-58 Time against Rate of Heat Transfer of Low Alloy Steel at Wind Speed of 5.2 m/s 81
Figure 4-59 Time against Rate of Heat Transfer of Carbon Steel at Wind Speed of 5.2 m/s 82
Figure 4-60 Time against Rate of Heat Transfer of Stainless Steel at wind speed of 5.2 m/s 83
Figure 4-61 Reynolds Number against Nusselt Number for Smooth Surface of Low Alloy Steel, Carbon Steel, and Stainless Steel at Wind Speed of 2.3 m/s 84
Figure 4-62 Reynolds Number against Nusselt Number for Smooth Surface of Low Alloy Steel, Carbon Steel, and Stainless Steel at Wind Speed of 4.1 m/s 85
Figure 4-63 Reynolds Number against Nusselt Number for Smooth Surface of Low Alloy Steel, Carbon Steel, and Stainless Steel at Wind Speed of 5.2 m/s 86
Figure 4-64 Reynolds Number against Rate of Heat Transfer for Smooth Surface of Low Alloy Steel, Carbon Steel and Stainless Steel at wind speed of 2.3 m/s 87
Figure 4-65 Reynolds Number against Rate of Heat Transfer for Smooth Surface of Low Alloy Steel, Carbon Steel and Stainless Steel at wind speed of 4.1 m/s 88
Figure 4-66 Reynolds Number against Rate of Heat Transfer for Smooth Surface of Low Alloy Steel, Carbon Steel and Stainless Steel at wind speed of 5.2 m/s 89

LIST OF TABLES

Table 3-1 Material Properties 19

Table 4-1Surface Roughness Data for Low Alloy Steel..35

Table 4- 2 Surface Roughness Data for Carbon Steel 35

Table 4- 3 Surface Roughness Data for Stainless Steel..36

LIST OF ABBREVIATIONS

Symbol	Description
Gr	Grashof number
Nu	Nusselt number
Pr	Prandtl number
Ra	Rayleigh number
Re	Reynolds number
CD	Drag coefficient
IR	Infrared
Ra	Surface roughness number

NOMENCLATURE

Symbol	Description, Unit
T_s	Surface temperature, [K]
T_∞	Temperature of the fluid sufficiently far from the surface, [K]
L_c	Characteristic length of the geometry, [m]
h	Heat transfer coefficient, [W/m^2 °C]
k	Thermal Conductivity, [W/m °C]
A_s	Heat Transfer surface Area, [m^2]
T_{surr}	Surrounding Temperature, [K]
U	Fluid Velocity, [m/s]
$\dot{Q}$	Rate of heat transfer, [W]
$\dot{Q}_{rad}$	Rate of radiation heat transfer, [W]
T_f	Film Temperature, [°C]
τ_s	Shear stress, [N/m^2]
F_f	Friction Force, [N]
ρ	Density, [kg/m^3]
μ	Dynamic viscosity, [kg/m s]
V	Kinematic viscosity, [m^2/s]
β	Thermal expansion coefficient, [1/K]
σ	Stefan-Boltzman Constant, [5.67×10^{-8} W/m^{2}K^4]
ρ	Density, [kg/m^3]

CHAPTER 1

INTRODUCTION

1.1. Background

Recently researches on reducing carbon dioxide emissions that have drastic effect on global warming have become an important issue in the power generation field. In the year of 2008, Ministry of Energy, Green Technology and Water Malaysia (KeTTHA) along with Department of Occupational Safety and Health (DOSH) had enforced an issue of challenges of sustainability (KeTTHA, 2009). According to the studies of industry development, the number of factories has increases significantly in Malaysia for the past five years (Jasin, 2010). The trend shows that great percentage of energy consumption used by the increase of the industry. Researches on improving energy saving efficiency of buildings are still ongoing.

Now a days, most of the food industry are self-sufficient where generates electric for their industry use. For an example, palm oil mills using the steam boilers to generate energy. According to the studies by Malaysian Palm Oil Board (MPOB), there are 426 palm oil mills and 56 palm oil refineries plants operating in Malaysia (MPOB, 2013). Each of these plants usually equipped with at least a boiler with varying steam generation capacity of between 15 MT/hr to 40 MT/hr. The two main types of boilers usually found in the mills are the water-tube (WT) and fire-tube (FT) boilers. Generally, the WT has a higher steam generation capacity than the FT type boiler.

Basically, the steam boiler used in food industries are used to generate steam to produce electricity and for sterilization process. Solid fuel such as of palm fibre, plywood chip, sugar mill bagasse and rice mill husk are fed into these boilers to generate steam required by the plant (Boilermech, 2013). Boiler manufacturers conduct continuous research on proving solution that enable industry to meet today's steam, energy and environmental requirements (Boilermech, 2013).

Referring to water tube boiler, water flows in tubes that are heated from outside by the help of fire. The fuel was burned in the chamber called a furnace, creates the hottest gas which heating the water in the boiler tubes. In smaller boilers, extra producing tubes are separate in the furnace, while larger utility boilers rely on the water-filled tubes that make up the walls of the furnace to generate steam. The heated water then rises into the steam drum. Here, saturated steam is drained off the top of the drum. The steam will re-enter the furnace through a super heater to become superheated. Treated water at the bottom of the water drum will proceed to the feed water drum thru large-bore 'down comer tubes', where it pre-heats the feed water supply. To reduce the usage of fuel, exhaust gases are also used to pre-heat the air blown into the furnace several time. The natural convection and forced convection are occurs in a common boiler system (Rashid et al., 1998). Figure 1.1 shows the water tube boilers conceptual diagram.

An important role of boiler tube heating system is played by forced and natural convection. By proper alteration of fluid convection in the boiler system, it will deliver an almost perfect heat flow and changes in properties of the fluids. Figure 1.2 shows the boiler roles where induced draft fan used to blow the air into the furnace. The normal burning condition in boiler can be specified as natural convection and the usage of forced draft fan can be specified as the forced convection.

The efficiency of steam generation in boiler is more depends on the boiler tubes (Mimura and Ishitsuka, 1998). In contrast, not every boiler using same alloys tube in boiler. Material such as carbon steel, low alloy steel and stainless steel are commonly used for boiler tubes. The type of material and its surface roughness are important to determine the heat transfer rate.

Roughness defined as the amount of the small scale difference in the altitude of a surface in contrast to large scale differences which may be part of the geometry of the surface or unwanted curliness. Researches shows that surface roughness is an undesirable property as it may cause friction, wear, drag, fatigue, and heat loss. The rough surface of a plate faces a lot of heat losses (Maisuria, 2013). According to researchers from MIT, simple, micro scale roughening of a surface can dramatically affect its transfer of heat (Ryan Enright, 2012).

Caused by this, the alloy tube of the inner part of boiler is a crucial of how efficiency the convection of heat happens at the furnace. Hence, the study about the material and its surface roughness shall be considered. This reflection can be magnify and confirm by design an experiment of convection of heat. By assuming the boiler tubes as sample plates, a heat transfer experiment over the plates for forced and natural convection is studied and specified clearly in this research.

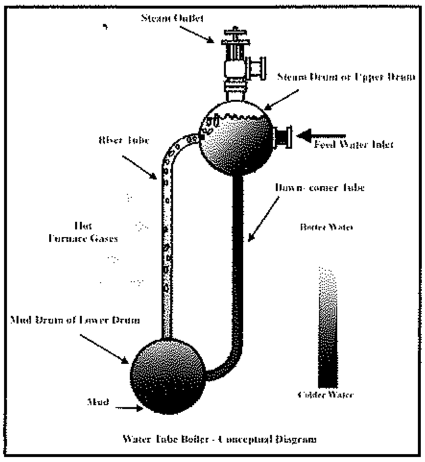

Figure 1-1 Boiler Conceptual Diagram

(Boilermech, 2013)

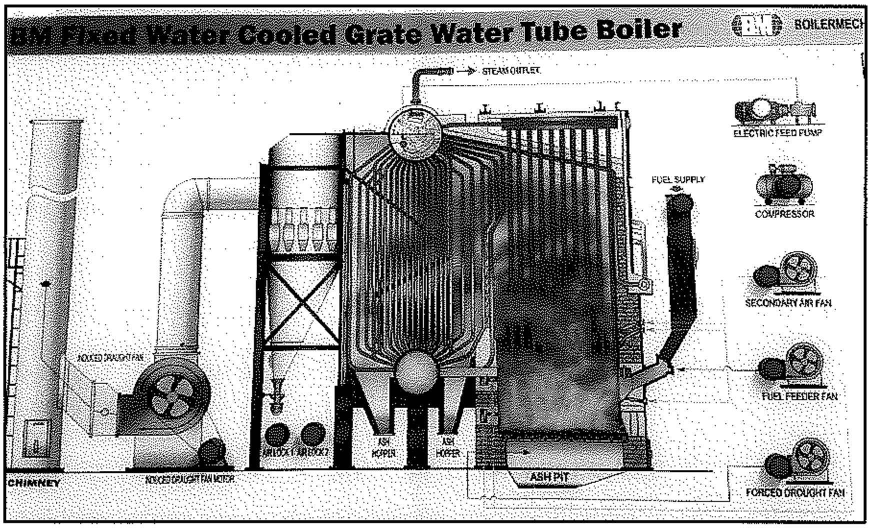

Figure 1-2 Water Tube Boiler System

(Boilermech, 2013)

1.2. Problem Statement

Nowadays, some of the steam boiler system is providing uneven steam generation for the usage (Mimura and Ishitsuka, 1998). The cause of uneven steam generation is because of slow heat transfer convection is happening inside the furnace of the steam boiler. In particular, the main problem that can be identified for the uneven heat is the type of material and its surface roughness used in steam boiler tube is not same due to multiple manufacturers (Boilermech, 2013). Different materials with different surface finishing have special properties. The properties of material are important to determine the fluid flow type. In detail, the Reynolds number needs the properties of a geometrical in order to determine the type of fluid flow. Either it by forced or natural convection, the transferred heat coefficient will be providing a dissimilar effectiveness rate conferring to the type of flow of fluid (laminar or turbulent flow). The steam boiler tubes are subjected to operate either in forced or natural convection. For forced convection, the heat transfer rate must be faster compared to natural convection. If the induced draft fan is off, the convection will occurs naturally in furnace to supply the heat to the boiler tubes. Forced and natural convections need to be determined so that the heat can be transferred more evenly in tubes.

1.3. Objectives of the Report

The overall objectives of the report are listed as follows:

- To conduct experiment on selected materials, non-thin plate to determine the roughness of the machined surface by using conventional milling.
- To study temperature gradient of the machined surface by using infrared camera
- To analyse the rate of heat transfers of the machined surface.

1.4. Scope of the Research

This report focuses on the convection of heat transfer on machined steel plates conferring to stable state room condition. It doesn't includes the losses of heat to the environment, inlet temperature and the outlet temperature. Only forced convection and natural convection is considered in this report.

Surface roughness of selected material will be varied by milling process. During the milling process, the spindle speed will be varied in order to obtain different surface roughness. The temperature distribution for different level of surface roughness that b determined with using IR camera was just for temperature on top surfaces of steel plates that positioned at horizontally and doesn't includes any temperature of bottom surfaces of the plates. Heat transfer theory says that the top surface temperature is required for convection calculations.

The effect of surfaces roughness is included in this thesis in order to define the heat transfer rate over machined surfaces. For natural convection, the effect of buoyancy forces is included in thesis in order to determine the movement of air. The scale of the buoyancy force was said to be equal to the mass of the fluid moved by the surfaces.

Convection on the horizontally placed steel plates depends on air properties and the surface roughness, at 1 atmosphere pressure. It includes velocity of fluid, thermal conductivity of the air, specific heat, density and thermal. In the way to calculate the heat transfer coefficient for both convection, just the surface roughness, Reynolds number, Grashof number, Rayleigh number, Nusselt number, Prandtl number and the will be considered in this thesis.

1.5. Outline of The Report

In the chapter 1 the introduction of the report stated. In this part, report background will be defined in a way to give the momentary idea and detail of this whole report. Besides that, difficulties that are in this experiment will be more clarified and the objectives of this report are clearly stated in this section. Moreover, the constraint and restrictions of the report are also being stated in this chapter for reference resolves.

Chapter 2 states the literature review of this report. In this chapter, the history of heat transfer convection, milling process theories, surface roughness theories, methodology of conventional milling, methodology of horizontal plate, methodology setup of infrared camera, mathematical modelling will described additionally in specifics. This is to ensure a dense contextual of the occurring steam boiler problem can be linked rapidly to this report. These literatures are revised all from available thesis and journal from different writer which relevant to this thesis.

Chapter 3 describes about methodology of this report. In this section, the sequence of the report will be clarified in point. The process and methodology of the experiment will be presented for direct representation. This chapter includes, selection of material, design of experiment, and mathematical modelling is itemized concisely. The experiment designing, parameters and added margin conditions which are stated previous will be applied systematically in this chapter.

Chapter 4 states the result and discussions of this thesis. In this chapter, the investigation that gathered from test be discussed and testimonial of the result being verified by stating to books, journals, and articles. Data tables and results graph from experiment will be comprised in this section.

Chapter 5 consist the conclusions from this thesis. In this chapter, the final assumption of the thesis being recognized. For the support of the results obtained and discussions, certain explanations on the whole results of the experiment will be confirmed in this chapter. Furthermore, future suggestion and recommendation is contained within the end of the report.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

These part consists, a wide philosophy behind the experiment and discoveries will be clarified in fact. Each component will parted by heading in an ordered form. There are six subtitle that been recaps which are heat convections calculation history, relationship between surface roughness and heat transfer, relationship between milling parameters and surface roughness, heat transfer experimental setup for horizontal plates, the experiment of heat transfer using IR camera and effect of Reynolds number, Nusselt number, Rayleigh number. A sequential explanation of the theories in this section is needed for extra considerate and exploration.

2.2. History of Heat Transfer Convection Calculation

The cooling law of Newton partaken been used since 1701 to improve the theory of heat convection (Frank P.Incropera, 2013). In 1915, German scientist, Nusselt improves the boundary condition of convective by applying coefficient of heat transfer to elementary law of heat transfer (Frank P.Incropera, 2013).The physical properties which continuous with forced convection valid only conferring to law of Newton's.

This review mainly focuses which are correlated to the studies of appliances of transferred heat whom are convection, conduction and the radiation. Conduction and convection are similar appliances in which its required the existence of a material medium where else the convection process requires the existence of a motion of fluid (Pigeonneau and Flesselles, 2012).

Convection can be separated into two parts, natural and forced convection. Free flow of motion of fluid deprived of any outside force or the motion of fluid occur by naturally which as buoyancy is known as natural convection. In natural convection, the heat transfer coefficient is low. This is affected by a velocity of fluid is fairly less. (Frank P.Incropera, 2013). For forced convection, an external force like fan is used for force the fluid or air to flow above in the duct or a surface (Frank P.Incropera, 2013). Figure 2.1 is illustrations about diagram of forced and natural convection coordination.

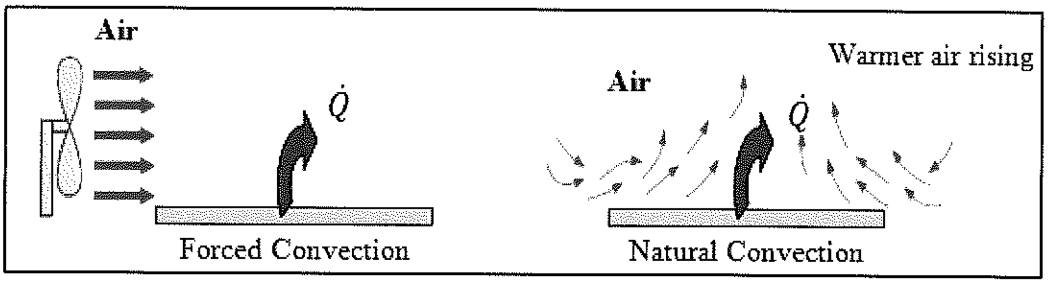

Figure 2-1 Forced and natural convection image
(Frank P.Incropera, 2013)

2.3. Relationship between Surface Roughness and Heat Transfer

Surface roughness are one of the most important characteristics of quality of work piece. Surface roughness might be effect on final function, production cost of pieces and also mechanical properties such as fatigues life, corrosion resistance and other features like friction, lubrication and so on. The surface roughness has been studied by many researchers since many years ago, because of it high importance in the efficiency in final product.

The first experimental exploration of the effect of surface roughness on flow of the fluid was that of Nikuradse, who is scale pressure drop and velocity profile for water flowing in duct roughened by sand grains. The observation was categorized in relations of roughness Reynolds number: hydro dynamically smoother, transitionally rougher, and fully rougher.

The heat transfer rate depends on its material surface. The higher the surface roughness of a material, lower the heat transfer between materials. Ferromagnetic steel that belongs to group of stainless steels resistant against heat and creep which are commonly used in pressure pipes, boilers, airspace equipment, manufacturing reactors components of turbines and also in screws and nuts which work in high temperatures has high surface roughness. Because of high surface roughness, low heat transfer takes place (Maisuria, 2013).

Hot rolled steels having an typical roughness height of about 12.5-25 μm, (DeGarmo, 2007). The wall roughness in the form of a less microns in the height such as mentioned above, can pointedly affect the heat transfer rate by disorderly the tinny thermal boundary layer.

Sometimes roughness is undesirable property as it may causes frictions, wear, drag, fatigue and heat loss, but it is some time beneficial, as it (texture) allows surfaces to trap lubricants and prevent them from welding together (Mohamed et al., 2011). It can be one of the main factors in the industry where heat transfer takes place. For examples, manufacturing industries that dealing with heat exchangers faces lot of losses and damage due to it. When two smooth surface materials are in contact with each other, heat transfer easily through conduction but materials with rough surface cannot contact properly and thus conduction does not take place completely.

The first quantitative surface finish measurement system was the light section microscope developed by Gustav Schmaltz in Germany during the 1930s. This microscope projected a back lighted slit at an angle to the vertical on the surface being measured. Distortions in the reflection magnified the surface irregularities. Peak and valley heights could be read from the microscope eyepiece. Components of specific size and geometry necessitated the removal of sections in order to utilize this device. Various roughness parameters have been used to determine the surface roughness. The parameters are such as, root-mean square deviation of profile, arithmetical mean deviation profile, point of ten heights of irregularities and profile bearing length ratio. The most common parameter is arithmetical mean deviation profile. Figure 2.2 shows the picture of arithmetical mean deviation of profile.

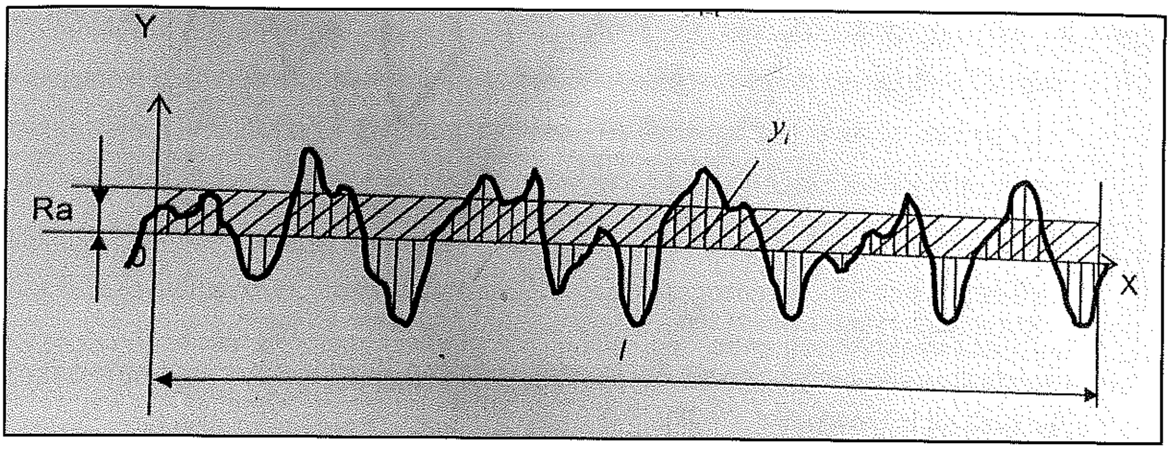

Figure 2-2 Arithmetical mean deviation of profile

(Cheng, 2009)

2.4 Relationship between Milling Parameters and Surface Roughness

Many researchers published their study on finding the connection between milling limitations and surface roughness. They carried out a lot of researches about milling parameters and heat transfer. Between some manufacturing machining procedures, milling is a vital machining procedure. End milling process is the utmost mutual metal removal operation encountered. It is widely used in a variety of manufacturing industries. The surface roughness amplified linearly as the spindle speed and tool diameter increases and feed rate is the most significant parameter when other parameters are kept fixed. By increasing the structure, tool toughness and decreasing the spindle chatter or vibration it might be improve work piece surface quality (Jasni and Lajis, 2012).

Another research was conduct to identify the consequence of varying cutting parameters such as spindle speed, depth of cut per pass, depth, feed per tooth and coolant applicant to surface roughness on aluminum and copper. The research mainly said that the surface roughness is influenced by feed per tooth and coolant application (Kiswanto et al., 2014).

Machining process sources production of huge quantities of energy of thermal within a moderately slender area of the cutting area. The generated thermal energy and the problems of its evacuation from the cutting zone account for high temperatures in machining. The amount thermal energy made in the machining process is corresponding to mechanical work. The alteration of mechanical energy into thermal energy took place during machining process. In the edge and outside surface of a tool, mechanical work is changed into heat due to intensive friction between the tools, machined surface. Further transformation of mechanical work into heat takes place thru chip founding, over plastic distortion of work piece material. The thermal energy consequently produced is expatriates by the conduction, convection and radiation.

Surface roughness of stainless steels 304 and 316 using two carbide tools coated by Titanium Nitride and Aluminum Oxide has been studied (Pittalà and Monno, 2011). Based on his report, can identified that both cases by increasing cutting speed the surface roughness and machining force reach to a minimum measure and then by more increment of this speed they increase. The cause of decrement of surface roughness is that the built-up edge did not form, and the cause of decreasing the force is decrement of contact area and shear strain in the Flowing area as a result of raising temperature. Increasing in both roughness and force are caused by tool wearing. The speeds of cutting, Feed rate of the cut, axial and radial depths of cut have been considered as input limitations, and surface roughness as production one.

2.5 Heat Transfer Experimental Setup for Horizontal Plate

In this experiment, a heated carbon steel plate with the dimensions of width of 100mmm, length of 100mm and thickness of 3mm was positioned in horizontal location (Jamalabadi, 2014). The delivery of temperature along the steel plate for natural convection and forced convection was being measured by the use an IR camera. Besides that, the even temperature area on a steel plate was sightseen. The position setup of steel plate is presented in Figure 2.3.

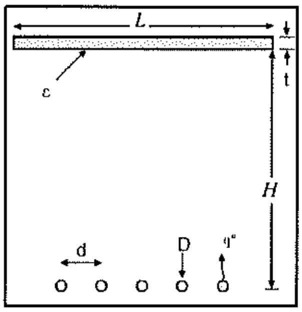

Figure 2-3 Diagram of the geometrical limitations and detached heaters

(Jamalabadi, 2014)

(Boukhattem et al., 2013), proposed the two dimensional studies of transferred heat in the heated steel plate by natural convection in the existence of fluid or air in the room in closed room condition. A thin steel plate was positioned with horizontally with an feature percentage of 50 over hundred with objectives of examine the fluid flow with obtained outcomes was discussed in the situation of vertically adiabatic steel walls and isothermal horizontally steel partitions. The schematic diagram of the heated steel plates set up is shown in Figure 2.4.

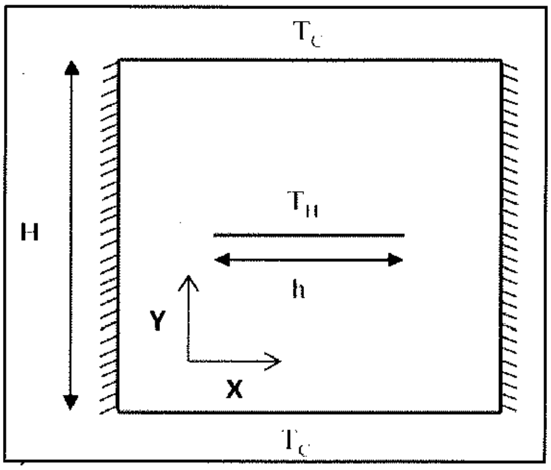

Figure 2-4 Diagram and dimensions of the heated thin steel plate in square room

(Boukhattem et al., 2013)

The next study is about an experiment flow of natural convection measurement from horizontally placed steel plates which cooled in the air by moderate Rayleigh number (Martorell et al., 2003). Two experimental plates which are steel plate and copper plate were heated by using an electric power. The difference of the surface temperature is detected thru the diagonal direction for the heated steel plates. As the higher thermal conductivity of the copper experimental plate, the surface of the copper plate is defined as almost isothermal.

By referring to diagram in Figure 2.5, a rectangular shape and a squared shape of the adequate cross length could be dividing to edges, central region and the corners with the air flow to be in normal on the edges part. In instantaneous, a heat transfer affects throughout the edges, central region and corners can be established as a three dissimilar average coefficient. The both three different averages coefficient is only not happen if there is the instance of circular shape of the plate with a adequate radius.

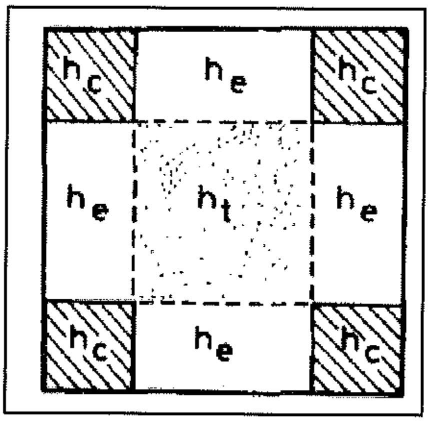

Figure 2-5 Air flows over to corners, central region and the edges

(Husar and Sparrow, 1968)

By means of the natural convection, an research of a horizontal position of fluid layer below was heated isothermally. The time was set from zero and the preliminary temperature at zero seconds. (Pigeonneau and Flesselles, 2012). At the precarious Rayleigh number have been fixed the slow heating method reasons the temperature profiles of conduction variations to linear as the time permits or else can be quantified as the steady convection by buoyancy-driven condition. During a heating time some thermally noise identified in the experimental atmosphere which leads to the thermal convection.

Claaseen (1963) investigate a laminar boundary layer condition flow on heated horizontal steel plate. The upper part of plate surface which was been heated. The steel plates were attached and placed in the location that guides interventions. The driving force of air and driving buoyancy of fluid were flows directly above the heated steel plate vertically or inclined was perpendicular to the highest borderline layer. There are no additional protection was took and the separate possible convection of free flow current been settled up inside the laboratory.

The investigational studies of transfer of heat and characteristics of flow of normal convection with horizontally placed heated steel plates in the an inclusion part (Horibe et al., 2012). The main purposes were to examine characteristics of flow of heat transfer occur about the horizontally placed heated steel plates that completed in the inclusion zone. The experiment setup was tracked by dual heated steel plates were fixed to vertical position of velocity flow in the enclosure zone. After the other part was content thermal isolation boundary condition by single when the ceiling temperature was retained at a constant lower temperature.

2.6 Heat Transfer Experimental Setup by Infrared Camera

Infrared thermography is the measurement of temperature through the detection of infrared radiation. It is a non-contact and non-invasive temperature measurement technique.

In an experiment conducted by (Jamalabadi, 2014), the preheated carbon steel plates with the dimensions of the width 1000mm, the length of 1000mm and the thickness of 3mm was located in horizontally point. The distribution of temperature on the plate was measured by using an infrared camera. The experiment carried out under one dimensional heat transfer condition. Figure 2.6 shows the IR image of the heated plate on the upper surface with using infared camera.

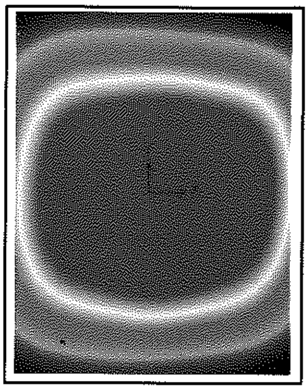

Figure 2-6 Thermal image of a thin steel plate on upper surface

A heat mass transfer experimental was conducted with the condition of one dimensional heat transfer conduction by using the resin and alumina Nano composite experiment plate. The result of the experiment is measured by an infrared camera. Figure 2.7 shows experimental setup.

Each component in the experiment are labelled. Figure labeled (a) was represents IR Camera, label (b) is the camera which is stationary on vertical of experimental arrangement. The label (c) was the isolation of steel plate with the Nano composite plate thermal heater and label (d) is the frame case. Both labels (e & f) are the data procurement system and data acquirement of system microcomputer.

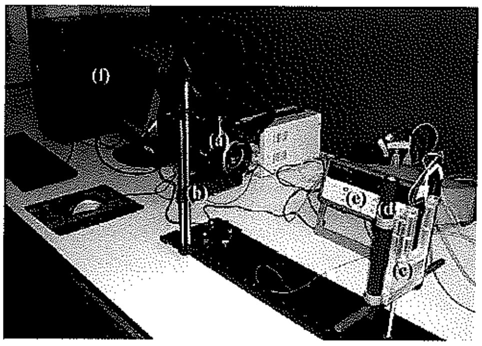

Figure 2-7 Experimental setup for analysis of IR Thermography

(Carlomagno and Cardone, 2010)

The result of temperature gradient and surface characteristic of the heated steel plate was obtained in the time of 200 seconds of heating duration with the dimensions of