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JUDUL: **DESIGN AND DEVELOPMENT OF EXHAUST GAS CALORIMETER FOR GASOLINE / COMPRESSED-NATURAL GAS (CNG) HYDRAULIC DYNANOMETER ENGINE (GACOHYDE) TEST-RIG**

SESI PENGAJIAN: 2007/2008

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DESIGN AND DEVELOPMENT OF EXHAUST GAS CALORIMETER FOR GASOLINE / COMPRESSED-NATURAL GAS (CNG) HYDRAULIC DYNANOMETER ENGINE (GACOHYDE) TEST-RIG

TENGKU MOHD HAIRIL AZWAN BIN TENGKU ABDULLAH

A report is submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

MAY 2008

SUPERVISOR DECLARATION

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT DECLARATION

I declare that this thesis entitled "Design and Development of Exhaust Gas Calorimeter for Gasoline / Compressed-Natural Gas (CNG) Hydraulic Dynamometer rngine (GACOHYDE) Test-Rig" is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : Tengku Mohd Hairil Azwan Bin Tengku Abdullah

Dedicated to my beloved

Mother,

Father,

Sisters,

Brothers,

Special friends

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Not forgetting my mother, my brothers, sisters and all my family members and special thanks to my special friends for giving me lots of supports in the aspects of moral, social and financial during my degree. This project definitely not exists without full encouragement from all of them.

ABSTRACT

This project is needed to design and develop the exhaust gas calorimeter system for test-rig hydraulic for 4-stroke gasoline engine and compress natural gas (CNG) engine with major consideration on the interchangeability portability heat transfer and workability of system. The objective of the exhaust gas calorimeter is to measure the percentage of the energy from fuel burn in combustion camber lost to exhaust gas. In *general case for the internal combustion engine 38% form the energy of fuel burn in* combustion camber lost in exhaust gas [4]. Major component of the exhaust gas calorimeter system include heat exchanger, radiator, water tank and water pump. There are two important problems in exhaust gas calorimeter analysis, they are rating existing heat exchangers and sizing heat exchangers for a particular application. The existing of the temperature for exhaust gas from the calorimeter $T_{e,out}$ does not fall below about 60°C because, if the temperature of existing of the temperature for exhaust gas from the calorimeter is lower, the system in the exhaust will start to condense giving up its latent heat [2]. *To avoid this problem happened determination of the rate of heat transfer and* the pressure drop across the heat exchanger and selection of a specific heat exchanger from those currently available and also the rate of flow of cooling water through the calorimeter should regulated [2].

ABSTRAK

Projek ini bertujuan untuk mereka bentuk dan menghasilkan ekzos gas kalorimeter untuk hidrolik test-rig bagi engin gasolin dan engin gas mampatan (CNG) dengan mengambilkira kadar pertukaran hada dan keupayaan system tersebut. Tujuan utama ekzos gas kalorimetr ni adalah untuk mengukat peratusan tenaga daripada pembaran bahan bakar didalam kebuk pembaran didalam engine yang hilang didalam gas ekzos. Kebiasaannya untuk engine pembakaran dalam 38% hasil tenaga daripada pembaran bahan bakar didalam kebuk pembaran engine akan hilang melalui ekzos gas[4]. Komponen asas untuk ekzos gas kalorimeter ialah penukar hada, radiator, tangki air dan pump air. Terdapat dua masalah penting dalam analisis ekzos gas kalorimeter iaitu hasil kadar pertukaran hada dan saiz penukar hada untuk aplikasi tertentu. Suhu ekzos gas $T_{e,out}$ yang keluar daripada kalorimeter hendaklah tidak kurang daripada 60°C kerana akan menyebabkan gas ekzos akan meruap bergantung kepada hada pendamnya [2]. Untuk mengatasi masalah ini penetapan kadar pertukar hada dan kadar pengurangan tekanan merentasi penukar hada dan pemilihan pertukaran hada khusus adalah penting dan juga kadar aliran air merentasi kalorimeter hendaklah dikawal [2].

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

C_{pg};	Specific heat of exhaust gas;
C_{pw};	Specific heat of water;
C_{L};	Lower caloric value of fuel
m_f;	Mass flow rate of fuel,
m_g;	Mass flow rate of exhaust gas;
m_w;	Mass flow rate of water;
P_s	Indicated horsepower
P_e;	Engine power
Q_{fuel}	Total heat from burning fuel
$Q_{exhaust}$;	Total heat loss to the exhaust gas
$Q_{coolant}$	Total heat loss to the coolant
Q_{oil}	Total heat loss to the lubricant oil
$Q_{ambient}$	Total heat loss to the ambient
T_a;	Air temperature
$T_{ex,in}$;	Exhaust gas inlet temperature
$T_{ex,out}$;	Exhaust gas outlet temperature
$T_{w,in}$;	Water inlet temperature
$T_{w,out}$;	Water outlet temperature
$W_{friction}$;	Fuel energy loss to the friction work
ρ_f	Density of fuel
ρ_a	Density of water

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Title:

Design and Development of Exhaust Gas Calorimeter For Gasoline / Compressed – Natural Gas (CNG) Hydraulic Dynamometer Engine (GACOHYDE) Test-rig

1.2 Project Objective

1. To design exhaust gas calorimeter system for hydraulic dynamometer engine test rig
2. To determine the suitable value for mass water flow rate for the system
3. To fabricate the exhaust gas calorimeter system

1.3 Project Scope

1. Design a portable stand for heat exchanger and the cooling system for the exhaust gas calorimeter system
2. Structure analysis of the portable stand and the cooling system
3. Thermal analysis of the exhaust gas calorimeter system
4. Fabricate and assemble all parts and component of the calorimeter including the heat exchanger and the cooling system

1.4 Project background

In internal combustion engine, heat generated from the burned fuel is not fully utilized to move the vehicle but there are only 30% is used and the balance is loss, whether into the exhaust gas, cooling system, friction and accessories [4]. The highest amount of the heat from the burning fuel is loss through the exhaust gas [4]. This will cause the heat waste; we acknowledged that the heat cannot be destroyed but this heat can be re-utilized for other useful purpose. Before the re-utilization, the wasted heats through the exhaust need to be quantified. To quantify the amount of the wasted heat in the exhaust gas, a device capable of measuring the amount of heat is required. The suitable device is exhaust gas calorimeter, which is actually a heat exchanger. Influential parameters of the calorimeter are identified. A suitable range of water mass flow rate is needed to be determined. Thus a study is carried out to estimate the appropriate range of water mass flow rate.

1.5 Problem statement

From the initial study of exhaust gas calorimeter, there are three utmost important parameters must be considered in its operation. They are (1) the amount of heat absorbed by the water in the calorimeter, characterized by $T_{w,out}$ (2) the amount of heat cannot be absorbed by the water in the calorimeter, characterized by $T_{ex,out}$ (3) the range of the mass flow rate through the into the calorimeter. The first two parameters are variable controlled to vary the suitable mass flow through into the calorimeter system.

1.6 Flow chart

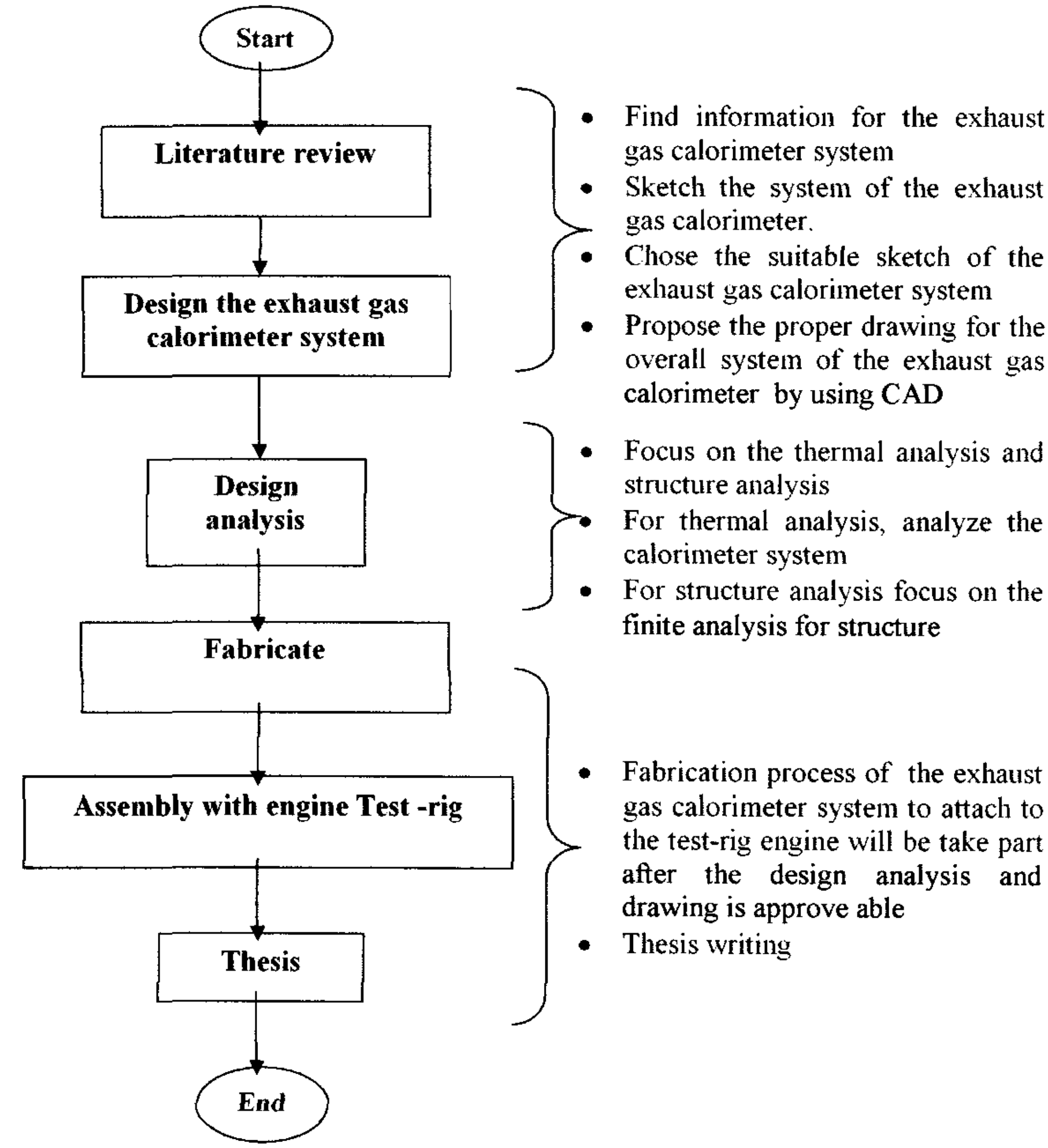


Figure 1.1 Project flow chart

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

The main purpose of this chapter is to give the overview information about the title "Design and Development of Exhaust Gas Calorimeter for Gasoline / Compressed – Natural Gas (CNG) Hydraulic Dynamometer Engine (GACOHYDE)". This chapter will give the details explanations about the energy of a gasoline engine, concept of exhaust gas calorimeter and how measurement the energy from the engine transfer to exhaust by measure the exhaust gas heat by using exhaust gas calorimeter also the new design of the exhaust of calorimeter.

2.2 Energy balance in an Internal Combustion Engine

When an engine burns fuel it will convert the energy stored in the fuel chemical bonds into useful mechanical work and into heat. Different types of fuel have different amounts of energy. The conservation of energy principle defined by the first law of thermodynamics says that when all of the fuel energy is released by burning in the engine cylinders it doesn't disappear. In a generic internal combustion engine, only 30% of the total energy available may be converted to useful energy. Of the remaining 80% of the total energy, approximately 38% may be lost through exhaust heat, 30% through water heating in the cooling system,6% lost to surrounding and 6% through motor friction [3],[4]. The total quantity of energy stays the same and must be accounted for. In the case of the gasoline engine shown below it either becomes thermal energy (heat) or mechanical energy (work). The ratio of the energy destruction or irreversibility decreases with an increase in the mass of air to the mass of fuel ratio (AF) for a combustion process. Other sources of irreversibility, such as friction and heat transfer across a temperature difference, are also expected to increase with an increase in engine speed. The observation of a minimum in energy destruction is due to the fact that the energy content of the exhaust heat also increases with engine speed.

The burning fuel energy can define by

$$\dot{E}_{in} = \dot{E}_{out} \tag{2.1}$$

$$Q_{fuel} = \text{Heat} + \text{Work} \tag{2.2}$$

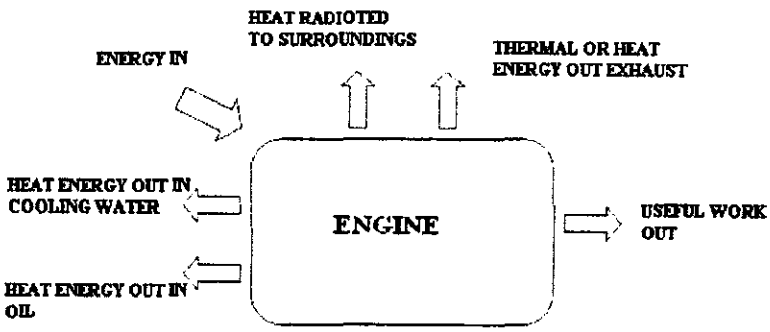


Figure 2.1 Energy Balance in Engine in steady state operating

For many engines, the heat loses can be subdivided:

$$\dot{Q}_{loss} = \dot{Q}_{coolant} + \dot{Q}_{oil} + \dot{Q}_{ambient} + \dot{Q}_{exhaust} \tag{2.3}$$

With CI engines on the high end, heat flow to the coolant is about

$$\dot{Q}_{coolant} \approx 10\text{–}30\% \tag{2.4}$$

At high load, energy lost to the coolant can amount to about half of the brake power output, increasing to about twice the brake power output at low load depending on the type of oil and engine speed.

$$\dot{Q}_{oil} \approx 5\text{–}15\% \tag{2.5}$$

Losses directly to the surrounding are

$$\dot{Q}_{ambient} \approx 2\text{–}10\% \tag{2.6}$$

Friction losses are on the order of

$$\dot{W}_{friction} \approx 6\% \tag{2.7}$$

Losses through the exhaust gas

$$\dot{Q}_{exhaust} \approx 35\text{-}38\% \tag{2.8}$$

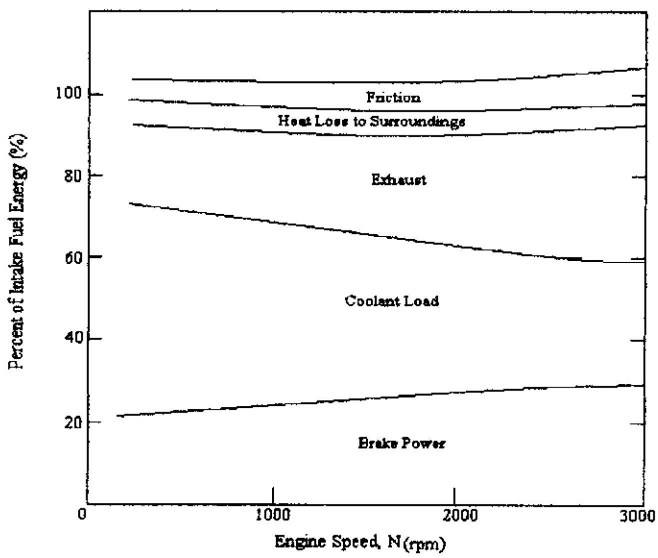


Figure 2.2 Distribution of energy in a typical SI engine

2.3 Method of measurement the exhaust heat

In internal combustion engine the exhaust process occurs in two steps, first exhaust blowdown followed by the exhaust stroke the result flow out the exhaust pipe is a non-steady-state plusing flow which is often modeled as pseudo-steady-state. Exhaust blowdown occur when exhaust valve starts to open toward the end of the power stroke, at this time the pressure in the cylinder is still at about 4-5 atmosphere and temperature upward of 1000 K. After exhaust blowndown the piston passed BDC and start toward TDC in the exhaust stroke, at this time the pressure in the cylinder resisting the piston in this potion is slightly above the atmospheric pressure of the exhaust system. The difference between cylinder pressure and exhaust pressure causes by the flow through the exhaust valve as piston pushes the gases out the cylinder [1]. Exhaust gas flow rate we can define as summation of the fuel consumption rate and air consumption rate. For an accurate measurement of the exhaust heat, use is made of an exhaust gas calorimeter which the exhaust gas is cooled to a moderate temperature and he heat content measured from observation of cooling water flow rate and temperature.[2]

The exhaust gas flow rate define by

$$m_g = m_f + m_a \qquad (2.9)$$

$$m_f = \frac{Pe\ x\ C_{pf}}{\rho_f} \qquad (2.10)$$

$$m_f = \frac{Pe\ x\ C_{pf}\ x\ 14}{\rho_a} \qquad (2.11)$$

assume that air fuel ratio 1:14

The heat content of the exhaust gas in the system can be expressed as the sum of three constituent parts:

1. Heat loss between the exhaust manifold and the exhaust gas calorimeter
2. Heat extracted in the exhaust gas calorimeter
3. Residual heat in the gases leaving the exhaust gas calorimeter

However in the exhaust gas calorimeter system, the heat loss between the exhaust manifold and the exhaust gas calorimeter considered is zero that means we assume that there are no heat losses during exhaust gas flow through the exhaust manifold to the calorimeter. The overall heat in the exhaust gases expressed as a rate of energy flow is given by:

$$\text{Total heat from exhaust gas} = \text{Heat from existing exhaust gas from calorimeter} + \text{Heat absorb by water} \tag{2.12}$$

$$Q_{exhaus} = (m_f + m_a)\, C_p\, T_{ex,out} + m_w C_w\, (T_{w,out} - T_{w,in}) \tag{2.13}$$

The temperature of the gas leaving the calorimeter $T_{ex,out,}$ does not fall below about 60°C (333K). This is approximately the dew point temperature for exhaust gas at lower temperatures the system in the exhaust will start to condense giving up its latent heat. So for the solution the rate of flow of cooling water through the calorimeter should regulated so that the

2.4 New design of exhaust gas calorimeter

Exhaust gas calorimeter is a device used for calorimetric, the science of measuring the heat of chemical reactions or physical changes as well as heat capacity. The word calorimeter is derived from the Latin word caller, meaning heat. This device use thermodynamics first law concept which is the energy is cannot be destroyed but it will be convert into another condition which is heat energy or mechanical energy. Exhaust gas calorimeter use concept of heat exchanger to measure the heat energy contents from exhaust gases and enables to determine the energy lost to exhaust in the energy balance in internal combustion engines. The main components of the Exhaust Gas Calorimeter are gas to-water shell and multi-tube heat exchanger, control valve, instrumentation units. Exhaust gases from the test engine mounted on the flow through the tubes, jacket of constantly flowing cooling water surrounds the tubes, and the heat content of the gases is assessed by measuring the cooling water flow rate and the inlet and outlet temperatures.

Concept of the new design of the exhaust gas calorimeter should be portable stand-alone which is can be place to any place without use another method to move it, the system of the new design of exhaust gas calorimeter which is use closed loop cooling system which is use the same cooling water for the overall cycle without waste the cooling water, in this system must include the cooling system to cool the cooling water to use for the another cycle while the system in running. The important component in the close loop cooling system for exhaust gas calorimeter system is radiator, radiator fan, water tank water pump and connecting hoses.

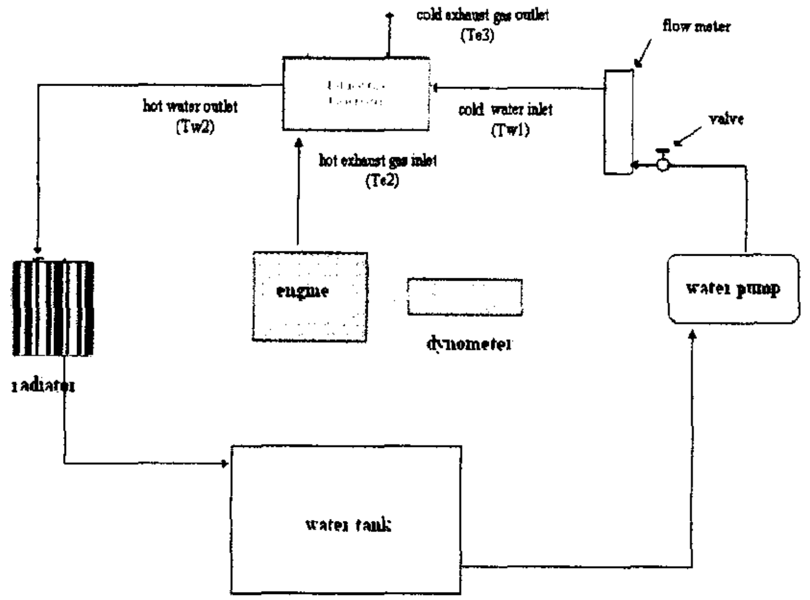


Figure 2.3 Diagram of exhaust gas calorimeter with close loop cooling system

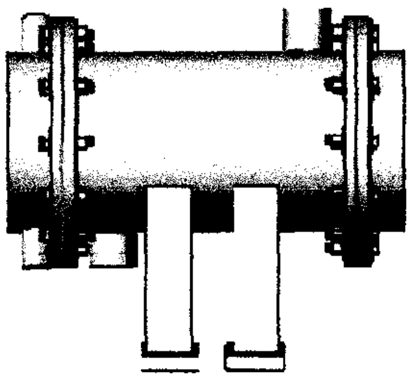
2.4.1 Heat Exchanger

A heat exchanger is a device to define energy transferred from one fluid to another across a solid surface. Whether the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted. One common example of a heat exchanger is the radiator in a car, in which a hot engine-cooling fluid, like antifreeze, transfers heat to air flowing through the radiator. There are thus three heat transfer operations that need to be described: [9]

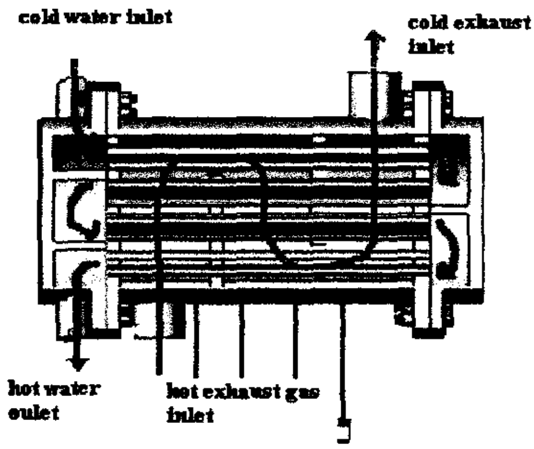
1. Convective heat transfer from fluid to the inner wall of the tube,
2. Conductive heat transfer through the tube wall, and
3. Convective heat transfer from the outer tube wall to the outside fluid

Exchanger analysis and design therefore involve both convection and conduction. Radiation transfer between the exchanger and the environment can usually be neglected unless the exchanger is uninsulated and its external surfaces are very hot. Heat exchangers may be classified according to their flow arrangement which is parallel-flow, counter-flow or cross-flow. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. [5] In actual, most large heat exchangers are not purely parallel flow, counter flow, or cross flow, they are usually a combination of the two or all three types of heat exchanger. This is due to fact that actual heat exchangers are more complex than the simple components shown in the idealized figures used to depict each type of heat exchanger. The reason for the combination of the various types is to maximize the efficiency of the heat exchanger within the restrictions placed on the design. That is size, cost, weight, require efficiency, type of fluids, operating pressure, and temperatures, all help determine the complexity of a specific heat exchanger.

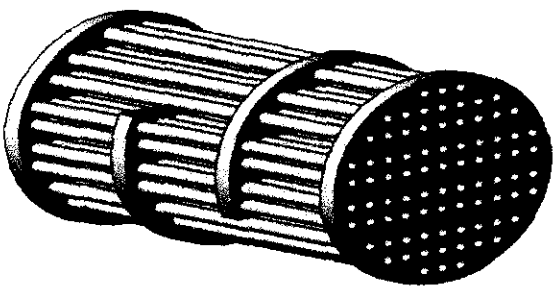
One method that combines the characteristics of two or more heat exchangers and improves the performance of a heat exchanger is to have the two fluids pass each other several times within a single heat exchanger. If the fluids pass each other only one, the heat exchanger is called a single-pass heat exchanger. If the fluids pass each other more than once, the heat exchanger is called a multi-pass heat exchanger. [9]



(a) Front view



(b) cross-section view



(c) Piping system in exhaust gas calorimeter

Figure 2.4 Exhaust gas calorimeter multi-pass cross-flow heat exchanger design

2.4.2 Close loop cooling system

This is what is called a closed cooling system. In heat exchanger process the cooling system is needed to remove that excess heat to make sure the system is not overheated and also to help the heat exchanger process in the calorimeter happened.

The closed cooling system is used in exhaust gas calorimeter. In closed cooling system there must have water pump, radiator, interconnect hoses, radiator cap, fan and water tank. The basic cooling system consists of liquid coolant being pumped by a mechanical water pump to circulate the coolant and also as the job of keeping the fluid moving through the calorimeter, then out to the radiator to cool the coolant by the air which is develop by fan. The heat in calorimeter is transferred from the hot exhaust gas to the coolant, which is flows to the radiator where the heat gets transferred to the air that is flowing through the fins which is develop by fan. Then the coolant flows back into the calorimeter where it picks up more heat and so on.

Controlling the temperature and heat exchange process in exhaust gas calorimeter system is the job of the cooling system.[7] In cooling system the radiator cap is used to control the pressure in the system, and some plumbing consisting of interconnecting hoses to transfer the coolant from the exhaust gas calorimeter to radiator. A cooling system works by sending a liquid coolant through passages in the piping in the exhaust gas calorimeter as the coolant flows through these passages to picks up heat from the calorimeter and also to help the heat exchange process happened.

Figure 2.5 Customize close loop cooling system for calorimeter

2.4.2.1 Radiator

The radiator core is usually made of flattened aluminum tubes with aluminum strips that zigzag between the tubes. These fins transfer the heat in the tubes into the air stream to be carried away from the radiator. On each end of the radiator core is a tank, usually made of plastic that covers the ends of the radiator. On most modern radiators, the tubes run horizontally with the plastic tank on either side. On other radiator, the tubes run vertically with the tank on the top and bottom. On older radiator, the core was made of copper and the tanks were brass. The new aluminum-plastic system is much more efficient, not to mention cheaper to produce. On radiators with plastic end caps, there are gaskets between the aluminum core and the plastic tanks to seal the system and keep the fluid from leaking out. On older copper and brass radiators, the tanks were brazed (a form of welding) in order to seal the radiator. The tanks, whether plastic or brass, each have a large hose connection, one mounted towards the top of the radiator to let the coolant in, the other mounted at the bottom of the radiator on the other tank to let the coolant back out. On the top of the radiator is an additional opening that is capped off by the radiator cap.

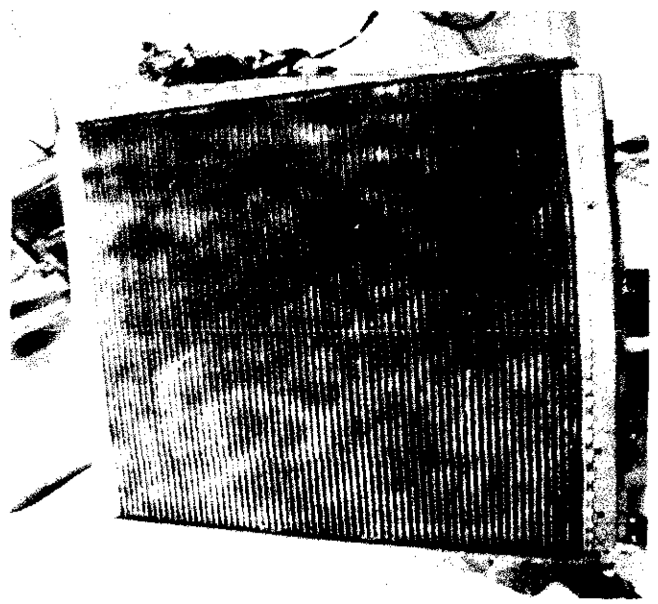


Figure 2.6 Radiator

2.4.2.2 Radiator Fans

Usually the cooling system in vehicle the radiator fans is function as to keep the air flow going through the radiator while the vehicle is going slow or is stopped with the engine running which is monitor by temperature sensor monitor engine temperature and sends this information to the computer to determines if the fan should be turned on and actuates the fan relay if additional air flow through the radiator is necessary but for this case the only air supplies is come from the fan cause this system is static it not moving. As long as the system is running, the fan will keep running to supply the air through the radiator to cool the coolant through in the radiator.

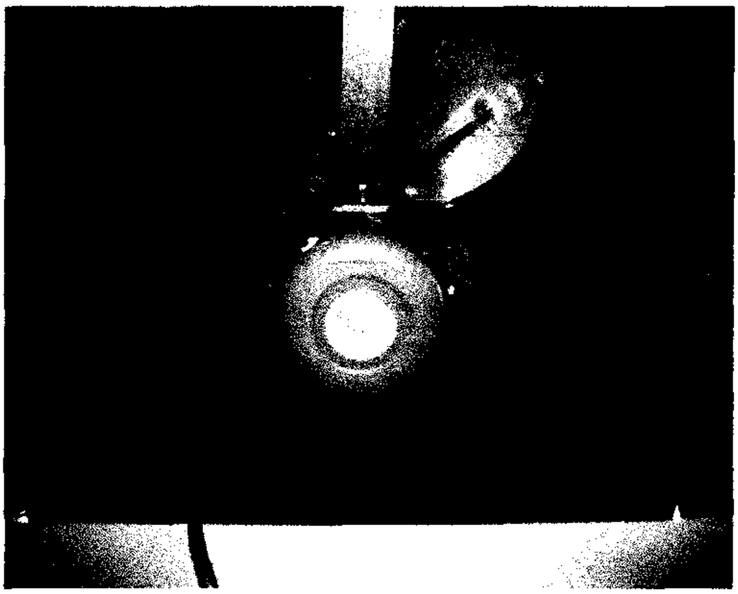


Figure 2.7 Radiator fan

2.4.2.3 Water tank

In usual cooling system in vehicle the water jacket surrounding the engine block is most important part to keep enough water in the cooling system also as a tank to collect the water for the system. In this case the water jacket is replaced by the water tank to running as water jacket function. The sizing of capacity of water tank is most important to make sure the cooling system can be operating in long operation time before the water is boiling..

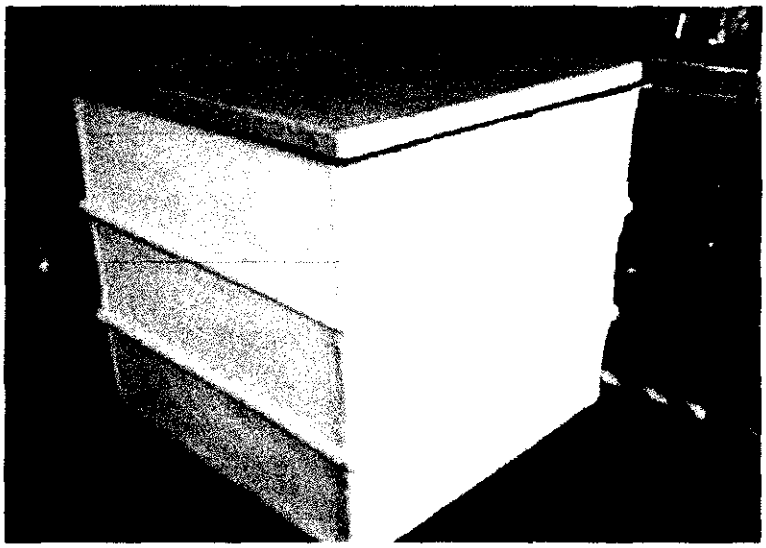


Figure 2.8 water tank

2.4.2.4 Water Pump

In usual close loop cooling system, a device is needed to push the coolant flow as long as the system is running. This job is done by water pump. In this project is used the electric single impeller close coupled centrifugal pumps which is fitted with the overhang impeller directly splined keyway on the motor shaft. The coolant pumped is conveyed into the spiral shaped volute of the pump body, to transforming the kinetic energy into dynamic pressure energy. Pressure and flow is achieved with minimum loss by means of the hydrodynamic closed impeller design. Pump body and motor support in cast iron. This pump can supply capacities of water up to 120m3/hr and the pressure heads can up be to 24 meters. This capacity of coolant supply is too high for this cooling system so we must use a device such as valve to control the capacities of coolant supply to the system.

Figure 2.9 Water pump

2.5 Design analysis

2.5.1 Structure analysis

Portable stand is the device to make the exhaust gas calorimeter can stand by itself. Portable means a designed to be light and easily to carry or move. Stand here is referring to the frame or piece for supporting or putting thing on. For the portable stand for calorimeter it just a frame which the colorimeter easy to move it is because the exhaust gas calorimeter weight is more than 100 kg, so before the portable stand is assemble to the calorimeter analysis of the design is the important part to avoid it from failure during the assembly process. Same case for the cooling system structure which analysis should be done on the drawing before the fabrication process take part, this is important because to make sure that the structure of the cooling system in useable to support the load of the water tank for capacity $1m^3$ or 1000kg and also can support the load of the radiator. In the structure analysis, we use the software ALGOR to analyses the concrete element and material model for easier and more realistic simulation of concrete structures. Using this software we use it to analyze the finite analysis of the structure of portable stand for calorimeter and the cooling system. In this analysis we focus on the maximum stress, maximum displacement and maximum load on the structure.

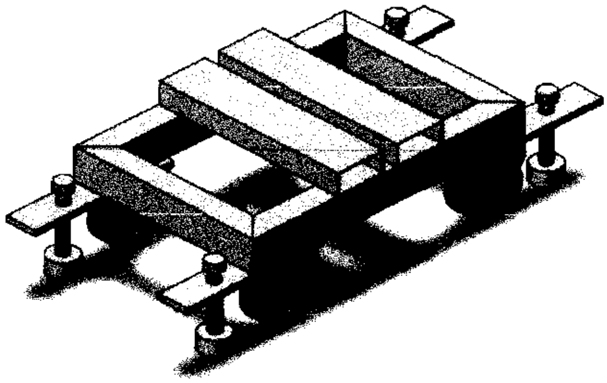


Figure 2.10 Portable stand structure

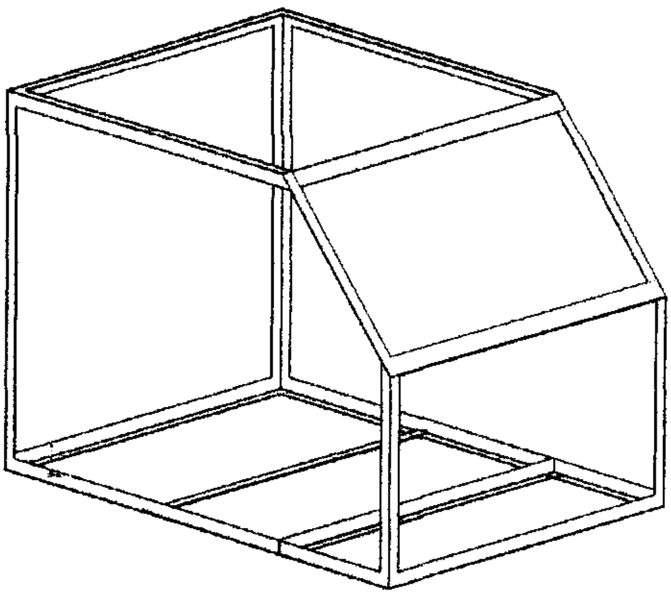


Figure 2.11 Cooling system structure

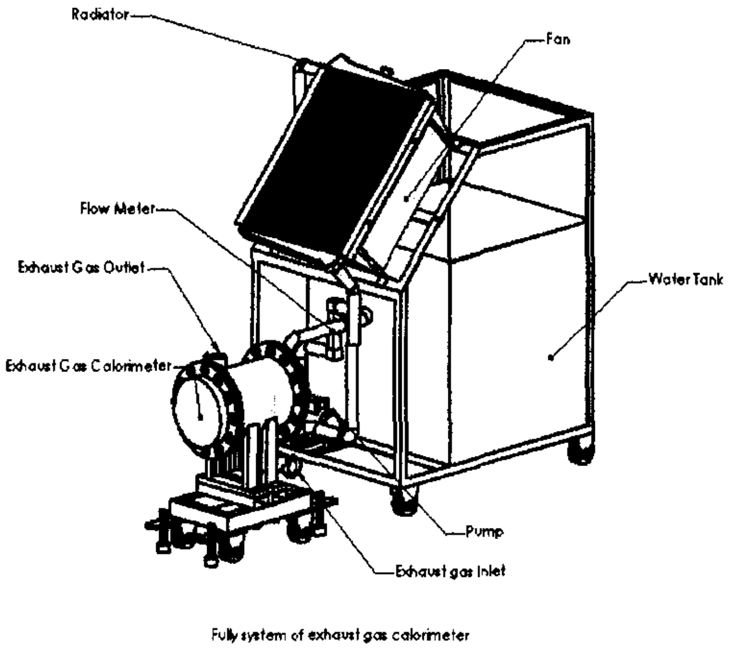


Figure 2.12 Drawing exhaust gas calorimeter system

2.5.2 Thermal analysis

The thermal analysis will do on the exhaust gas calorimeter system, to identify the problem in the system. Such as we known, in reality experimental of exhaust gas calorimeter the main problem in the calorimeter analysis is the rating existing heat exchange, the rating involves determination of the rate of heat transfer, the change in temperature of the two fluids, and the pressure drop across the heat exchanger.[9] All of this is unknown, and cannot be define before done the experimental of the calorimeter it self. However the rating of heat exchange in the calorimeter can be determine by controlling the mass flow rate of the water flows through into the calorimeter which is by controlling the mass flow rate, it will give effect to calorimeter efficiency according to the capability of the heat exchanger to absorb the amount of the exhaust heat flow through into the calorimeter, the water outlet temperature, the sizing of the calorimeter system and main component to the system such as heat exchanger, radiator, water tank and water pump.

CHAPTER 3

PROJECT METHODOLOGY

3.1 Introduction

Chapter 3 will guide the overall process that will use to achieve the goals and the objectives of this study. The methodology is a well planned system of method that has been designed and illustrated clearly to make the study smooth and achieved the goals. Figure 3.1 will shown the methodology flow to achieve the objective of the project which have been divide into two parts, first part is for semester 1 and second part is for semester 2. Following is the summary methodology flow chart.

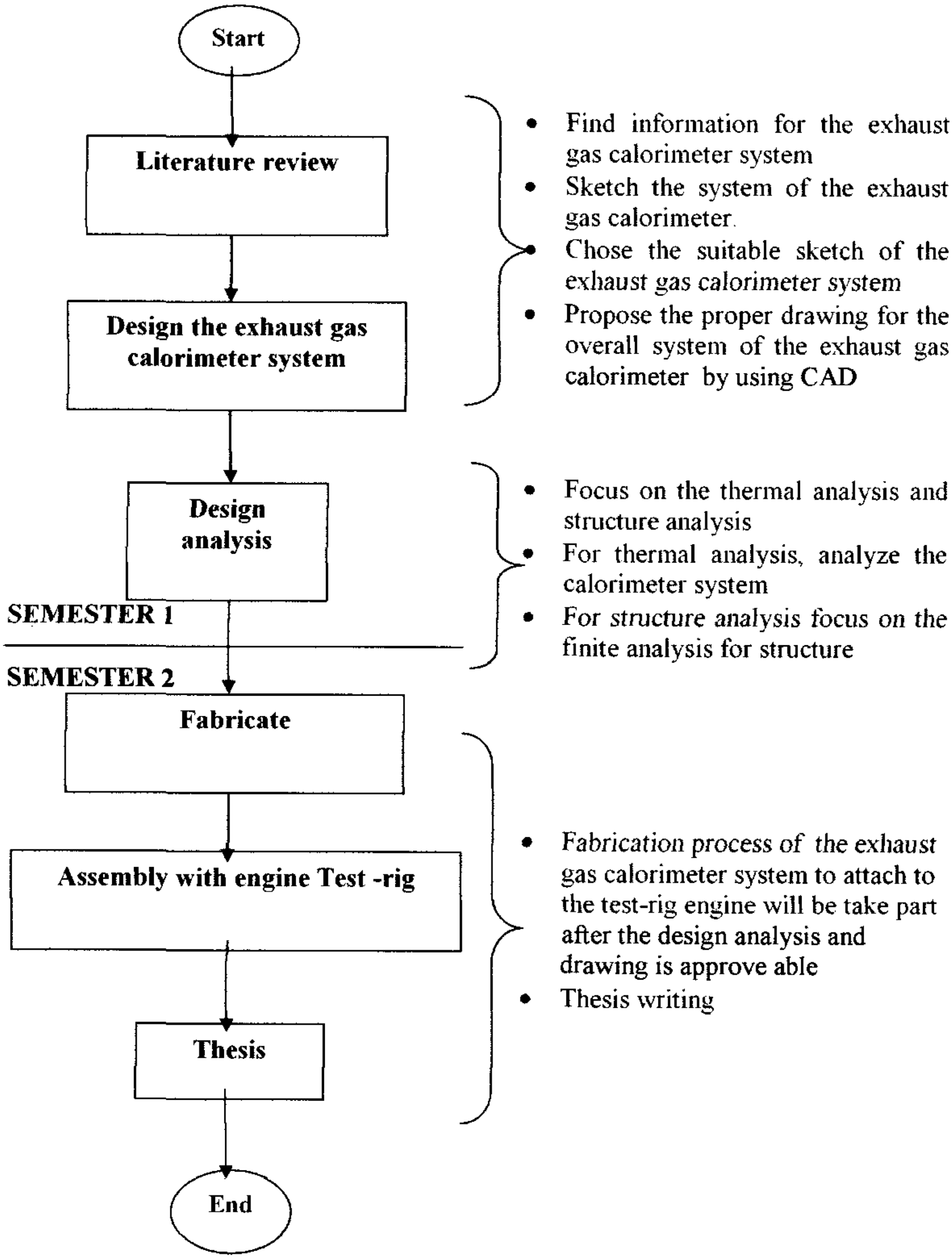


Figure 3.1 Flow chart of project

3.2 Literature review

The main purpose of this process is to study and get overview information about the title "Design and Development of Exhaust Gas Calorimeter for Gasoline / Compressed – Natural Gas (CNG) Hydraulic Dynamometer Engine (GACOHYDE)". This part will focus on the concept and the process of heat exchanger in the calorimeter and also about the energy of a gasoline engine, and how measurement the energy from the engine transfer to exhaust by measure the exhaust gas heat by using exhaust gas calorimeter.

3.3 Design the exhaust gas calorimeter system

This is important process to develop product. In this process we must consideration of cost, concept, and the main focus is function of the design. The step must start from sketch flow of the overall system with consideration of the function fro each component of the exhaust gas calorimeter system such as water tank, water pump radiator and heat exchanger. Then continue with chose suitable sketch then propose the sketch in proper drawing with dimension.

3.3.1 Design method

In this project the software that will be used to design the model is Solid Work. The Solid Work software is mechanical design automation as a computer added software. This is choose as it is possible for designers to sketch ideas of the design, experiment with features and dimension and produced model and detailed drawing. Solid Works enable us to design the models much more quick and precise. Solid Works designs are defined by 3D design and were based on component. To make the design of the whole part of the exhaust gas calorimeter it must have some steps must be followed. It includes:

1 Sketches : Create the sketches, know where to put the dimension, where to apply relation and so on

2 Feature : Select the appropriate features, determine the best features to apply, and so on.

3 Assemblies : Select what components to mates, what types of mate to apply and so on

3.4 Design analysis

In design analysis process the analysis will focus on the thermal analysis for heat exchanger and the structure analysis for the structure of the portable stand for calorimeter and the cooling

3.4.1 Thermal analysis method

. In the thermal analysis some calculation will be take part to determine the suitable value for mass water flow rate to the system. The thermal analysis will done into 3 case, first study the effect of the temperature outlet at 100% calorimeter efficiency, then continue with study the effect of the efficiency of the calorimeter and lastly study the effect of the mass flow rate at the variable water outlet temperature and variable efficiency. For the overall system the equation is use table in this analysis is

Total heat from exhaust gas = Heat from existing exhaust gas from calorimeter + Heat absorb by water (3.1)

$$Q_{ex} = (m_f + m_a)\, C_p\, T_{ex,out} + m_w C_w (T_{w,out} - T_{w,in} \quad (3.2)$$

From evaluate the equation above we can fine the effect of the water outlet temperature at 100% efficiency for case one by assume the total heat from exhaust 100% absorbed by the water in the calorimeter, from the equation we also can study the effect of the calorimeter efficiency of the calorimeter to the exhaust outlet temperature from calorimeter and effect to the mass water flow rate by fix the amount of the heat of water as in case 2.from that equation also we can find the effect of the mass flow rate at variable value of water outlet temperature and the variable value of the calorimeter efficiency to find the suitable range of mass flow rate for the exhaust gas calorimeter system by compare the case 1 and case 2. At the and of the thermal analysis we will can get the proper range of the mass flow rate to the system, this range of the mass flow rate is important to determine the calorimeter efficiency, the water outlet temperature, the sizing of the calorimeter system and main component to the system such as heat exchanger, radiator, water tank and water pump.

3.4.2 Structure analysis method

In the structure analysis we will focus on the finite analysis on the structure of portable stand for the calorimeter and for the cooling system by using the software ALGOR to analyze the model.

3.4.2.1 ALGOR

ALGOR is the software analyses; using software wizard for design studies and size optimization, which provide automated tools for achieving optimal designs based on user-supplied criteria; improved meshing capabilities; a new k-epsilon turbulence model for fluid flow analysis, which provides more accurate results and allows specification of wall roughness; and a new reinforced (rebar) concrete element and material model for easier and more realistic simulation of concrete structures.

ALGOR's wide range of simulation capabilities includes static stress and Mechanical Event Simulation (MES) with linear and nonlinear material models, linear dynamics, fatigue, steady-state and transient heat transfer, steady and unsteady fluid flow, electrostatics, full multiphysics and piping.

3.5 Fabricate

In this process, the exhaust gas calorimeter will be complete to be attach to the dynometer engine test-rig, with fabricate all the part of calorimeter start from the portable-stand for calorimeter, following by fabrication for the cooling system including the water tank, radiator, water pump and water hoses to complete the cooling system for the exhaust gas calorimeter system. The basic construction tool such as arc welding, metal cutter measurement tools and hand tools will be using in the process. There are two considerations to take part. in this process, they are:

- Dimensioning and design
- Material choosing

3.5.1 Dimensioning and design

In the dimensioning the insulation of exhaust gas calorimeter and portable stand for calorimeter and the sizing of water tank, water pump and radiator has been classified in the design process.

3.5.2 Material choosing

Materials choose is one of the important elements to have a better accuracy of insulation, portable stand for calorimeter and the structure for the cooling system.

For the insulation for the exhaust gas calorimeter we use double layer insulation which is the first layer is glass fiber and second layer which is the outer layer is aluminum. These materials choose because the fiber glass has the lower value of thermal conductivity so we can reduce the heat transfer from the body to the surrounding and for the aluminum as the outer layer because o prevent the radiation from the body to the surrounding and also to prevent the adsorb the temperature from surrounding, so with this criteria so we can get the accuracy result

For the portable stand and the structure for cooling system the criteria of the material choosing must consider the strange to hold out the load more than 100 kg, easy to fabricate, and Corrissonless.

3.6 Assembly with engine test-rig

In this process the calorimeter which has been fabricated will be assemble with engine test-rig. In this process the main objective is how to link the exhaust manifold to the exhaust gas calorimeter. In this process also need to setup all the instrument to complete the exhaust gas calorimeter system by arrange the piping for the water which include the radiator, water tank and water pump connect to the exhaust gas calorimeter. At a later stage this project will complete the temperature instrumentation on the system.

3.7 Thesis

Write the full report of project start from beginning until last.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter will focus on two analysis part, for the thermal analysis and for the structure analysis. For the thermal analysis, we will focus on the exhaust gas calorimeter and the water tank. This all analyze had been done by the calculation to get the particular application for this project. For the structure analysis we will focus on the finite analysis for portable stand structure for the cooling system and for the calorimeter

4.2 Structure analysis

Structure analysis only focus on the finite element analysis for design of the portable stand of the calorimeter and cooling system. In this analysis process, we use the software ALGOR to analyze the failure part of the portable stand in steady state or in static condition when we applied the load on the structure. Material which has been chose for the both structure is Steel ASTM A36 which is usually use for structure and the maximum modulus of elasticity for the material is 1.9995×10^{11} N/m^2.

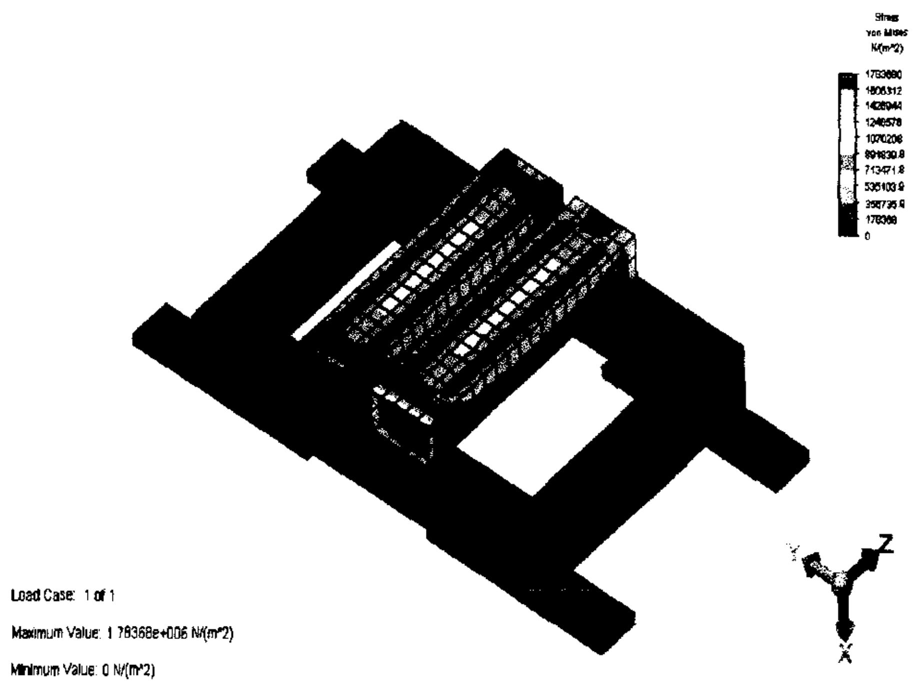


Figure 4.1 Finite analysis of load on the portable stand structure

Figure 4.1 show the result fore the finite analysis of load for the boundary condition for the portable stand when provide 1500N of load in static stress with linear material model on the surface of the top of the structure where is the calorimeter place on and at the bottom surface have been fixed at all vector and every edge of the structure where the roller places on , from that figure we can see only the upper surface have some effect from the load given, the value of the stress von misses from the result is too small to compare the value of modulus of elasticity of the material , so from this result this structure is safe to use for the portable stand for calorimeter.

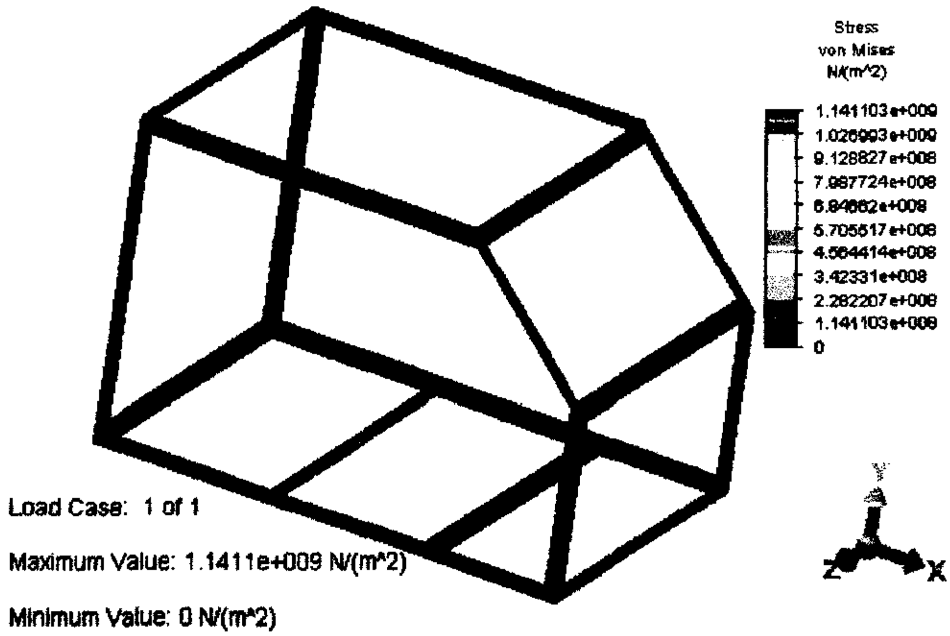


Figure 4.2 Finite analysis of load on the cooling system structure

Figure 4.2 shown the result of the finite analysis of load on the cooling system structure in static stress with linear material model condition the result show there are maximum value of stress on the plate surface at the middle of the structure where the water tank place on. On that surface 10000N have been provide that may be can same with the value of water tank load when fulfill with water, from the result shown the maximum value of the stress von mises is equal to $1.1411\text{x } 10^9$ this value is low to compare the value of modulus of elasticity of the material, to reduce the maximum stress on that surface, a piece of plywood will be fix on that surface to support the load and reduce the load which only on that surface to contribute to all surface.

4.3 Thermal Analysis result

The result for thermal analysis had done by collect the data from the experimental for the dynamometer test-rig engine for Wide Open Throttle (WOT). In this project, the analysis will focus on the critical engine speed for 4G13 which is at 4000rpm because from the experimental of the hydraulic dynamometer test-rig engine the maximum brake power can achieved is only at 4000 rpm instead of 5500 rpm .As the indicated power increase, the brake power will increase to a maximum and then decreases at higher speeds. This because of friction losses increase with speed and become the dominant factor at very high speeds [1].

4.3.1 Exhaust gas analysis result

Exhaust gas analysis is important because we must known the properties of exhaust gas like exhaust gas temperature, exhaust gas volume and flow rate of exhaust gas outlet from combustion camber through the calorimeter to get suitable sizing of exhaust gas calorimeter system. All the thermal analysis results are shown in graph below. From data provide, the calculation is made to get analysis result as shown below

Example calculation

Table 4.1 Physical contants

Density of Fuel	$\rho_f = 0.0075$ kg/m^3
Density of Air	$\rho_a = 1.18076515213313$kg/m^3
Specific Heat of air at constant pressure	$C_p = 1.00$ kJ/kg.K
Specific Heat of water	$C_w = 4.18$ kJ/kg.C
Lower calorific value of fuel	$C_L = 41.78 \times 10^6$ J/kg

*assumes that the specific heat of exhaust gas, C_{pg}, is equal to the specific heat of air, C_p. Temperature of air, T_a is equal to ambient 27°C.

Heat content of the exhaust was measure by equation below;

$$Q_{ex} = Q_{ex,out} - Q_{in} = (m_f + m_a)\, C_{pg}\, T_{ex} - m_a\, C_{pg}\, T_a$$

Table 4.3 Data result for experimental of hydraulic dynamometer engine test-rig

Engine speed (rpm)	T_{ex} (K)	m_f (kg/sec)	m_a (kg/sec)
1500	1279.315	0.001523	0.01916
2000	1203.763	0.002303	0.028047
2500	1228.08	0.002696	0.032386
3000	1298.856	0.002561	0.036208
3500	1212.853	0.003989	0.0458
4000	1261.337	0.004207	0.051206

At engine speed 1500 rpm

$$Q_{ex} = [(0.001523 + 0.01916) \times (1) \times (1279.315)] - [0.01916 \times 1 \times 300]$$

$$Q_{ex} = 20.71177 \text{ kW}$$

At engine speed 2000 rpm

$$Q_{ex} = (0.002303 + 0.028047) \times (1) \times (1203.763) - [0.028047 \times 1 \times 300]$$

$$Q_{ex} = 28.119855 \text{ kW}$$

This calculation was repeated for 2500rpm, 3000rpm, 3500rpm and 4000rpm, as result in figure 4.3 below

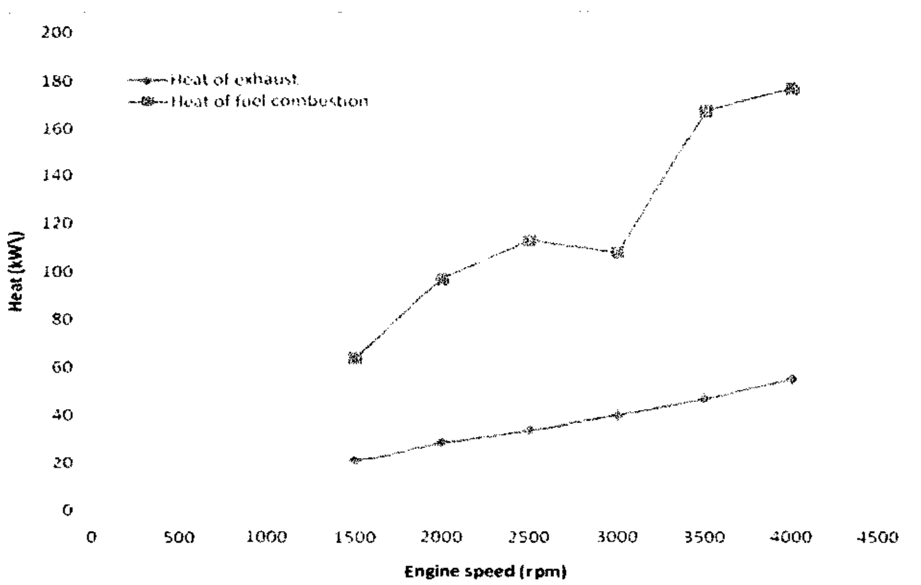


Figure 4.3 Comparism of the fuel burn heat with exhaust heat by calcution from actual experiment for dyno test-rig engine

However the for the accurate measurement of the exhaust heat, use is made of and exhaust gas calorimeter because it is not possible to show the indicated power directly in this energy balance since the different between it and the power output representing friction and losses, appears elsewhere as part of the heat to the cooling water and other losses.

4.3.2 Exhaust gas calorimeter analysis

For accurate measurement of exhaust heat, use is made of an exhaust gas calorimeter. In the exhaust gas calorimeter the exhaust gas is cooled to a moderate temperature and heat content measure form the observation of cooling water flow rate and temperature rise. In this analysis we assume that the heat from the exhaust gas exit from the combustion chamber is constant means that's there are no heat loss during the exhaust flow along the exhaust pipe to the inlet of calorimeter. However not 100% of the exhaust heat is absorb by water in the calorimeter, the heat still loss in existing exhaust gas from the calorimeter. The heat absorb by the water from temperature exhaust is depend on the efficiency of the heat exchanger itself.

The expression for exhaust gas heat becomes;

Total heat from exhaust gas	=	Heat from existing exhaust gas from calorimeter	+	Heat absorb by water

$$Q_{exhaus} = (m_f + m_a)\, C_p\, T_{ex,out} + m_w C_w\, (T_{w,out} - T_{w,in})$$

In this analysis we will done into 3 cases, first study the effect of the water outlet temperature at 100% calorimeter efficiency, second study the effect of calorimeter efficiency and third is comparison the effect of the water outlet temperature and the effect of the efficiency of the calorimeter. At the last of this analysis, we can define the maximum and minimum of the mass flow rate of the system at speed engine at 4000rpm.

4.3.2.1 Study the effect of the temperature outlet at 100% calorimeter efficiency

This is only the ideal cases, which is we assume that 100% of the exhaust heat is absorbed by water in the calorimeter without loss the heat to the environment in the exhaust gas existing from the calorimeter. However this concept is not accurate because, in natural case of the calorimeter system, there are still have heat loss into the environment through the exhaust gas existing from the calorimeter, but this result can be as the reference for the maximum value for the exhaust gas calorimeter system.

The expression for exhaust gas heat becomes;

Total heat from exhaust gas	=	~~Heat from existing exhaust gas from calorimeter~~ $\rightarrow 0$	+	Heat absorb by water

$Q_{exhaus} = m_w C_w (T_{w,out} - T_{w,in})$

According to the equation above, the heat from exhaust heat inlet to the calorimeter is 100% absorb by water in the calorimeter, using the equation above we can define the value for mass water flow rate by given variable value of $T_{w,out}$ which is we known the value of $T_{w,out}$ cannot be lower or same to ambient temperature and cannot above from boiling water stage temperature, so we make assumption that the range of the $T_{w,out}$ is in 40°C to 90°C. The value for Q_{ex} is collect from the actual experimental for the hydraulic dynamometer test-rig engine.

Example calculation analysis

At engine speed 4000 rpm, $Q_{ex,}$= 54.533785kW , $T_{w,in}$ = 27 °C at ambient temperature

1) $T_{w,out}$=40 °C

   $54.533785 = m_w \times (4.18) \times (40 - 27)$

   m_w=1.0036 kg/sec

2) $T_{w,out}$=50 °C

   $54.533785 = m_w \times (4.18) \times (50 - 27)$

   m_w = 0.5672 kg/sec

This calculation is repeated for the $T_{w,ou}$= 70 °C , 80 °C and 90 °C, the result from the calculation as shown as in figure 4.4 in page 34.

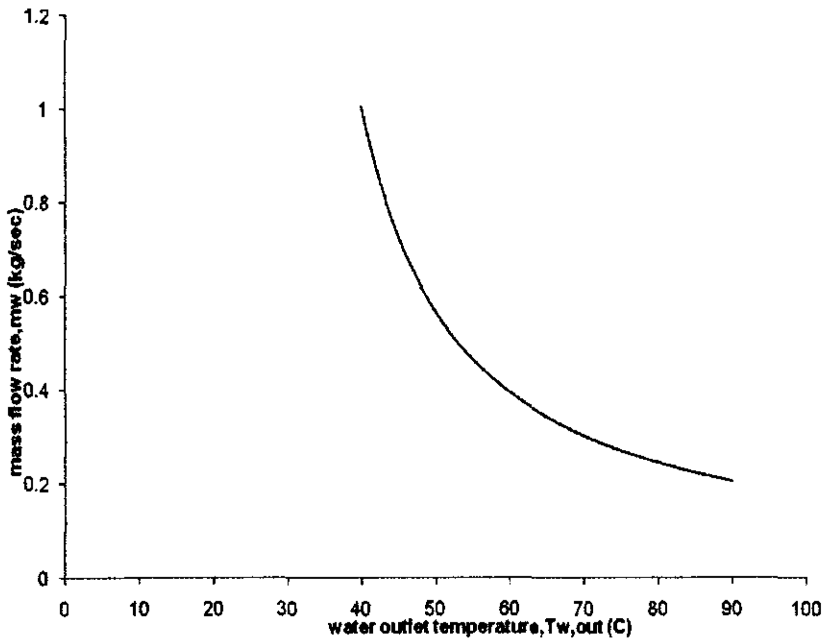


Figure 4.4 The effect of the water outlet temperature onto the mass water flow rate at 100% calorimeter efficiency

From the result above we can said that, when the value of the water outlet temperature is small, the value of the mass flow rate must be bigger, so on in the opposite term. That means the water flow rate outlet from the calorimeter can give the effect to the value of the mass flow rate, in the actual case, the value of the water outlet temperature we can cannot control it, but the value of the water outlet temperature can determine by controlling the value of the mass flow rate. According to this result the range of the mass flow rate at the 100% calorimeter efficiency at variable value of water out temperature are in 1kg/sec to 0.2 kg/sec.

4.3.2.2 Study the effect of the efficiency of the calorimeter

In this case the heat from the exhaust gas flow into the calorimeter is not 100% absorb by the water in the calorimeter, there are still have the heat loss through to the existing exhaust gas from the calorimeter, this concept more to the actual concept of the exhaust gas calorimeter. In this case the analysis is done by fix the amount of the heat absorb by the water varying the calorimeter efficient to study the effect of the mass water flow rate and exhaust gas outlet temperature from the calorimeter at the variable of the efficiency of the calorimeter.

The expression for exhaust gas heat becomes;

Total heat from exhaust gas	=	Heat from existing exhaust gas from calorimeter	+	Heat absorb by water

$$Q_{exhaus} = (m_f + m_a)\, C_p\, T_{ex,out} + m_w C_w\, (T_{w,out} - T_{w,in})$$

According the equation above the total of the exhaust heat flow into the calorimeter is equal to the sum of the heat from the existing exhaust gas from calorimeter and the amount of the heat absorb by water in the calorimeter, the efficiency of the calorimeter is depend to the amount of the heat absorbed by the water from the exhaust heat flow into the calorimeter means, if the efficiency of the calorimeter is 90%, the amount of exhaust heat flow into calorimeter was absorbed by water only 90% from the total of exhaust heat, the balance of the exhaust heat is loss through the existing of the exhaust gas from the calorimeter

Example calculation

Total Exhaust heat = 54.533785 kW, the calorimeter efficiency is 90 % ,
water outlet temperature= 90 °C, water inlet temperature= 27 °C

Heat absorbed by water = 54.533785 x 90%

= 49.0804065 kW

Heat loss through the exhaust gas = 54.533785- 49.0804065

= 5.4533785 kW

Heat absorbed by water = m_w x C_w x $(T_{w,out} - T_{w,in})$

$$49.0804065\text{kW} = m_w \times 4.18 \times (90 - 27)$$

$$m_w = 0.18638\text{kg/sec}$$

Heat loss through the exhaust gas = m_g x C_{pg} x $T_{ex,out}$

$$5.4533785\ \text{kW} = 0.055417 \times 1 \times T_{ex,out}$$

$$T_{ex,out} = 98.0462\ \text{K}$$

This calculation is repeated to the calorimeter efficiency at 80%, 70%, 60%, and 50%, result from the calculation is show in figure 4.5 below.

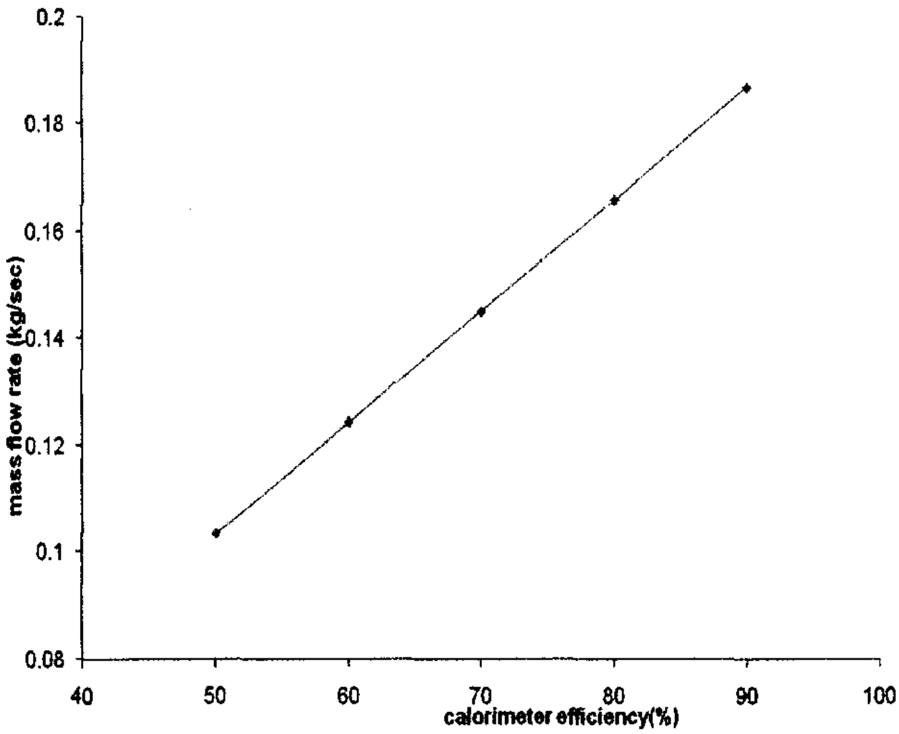


Figure 4.5 The effect of the mass flow rate at the variable calorimeter efficiency

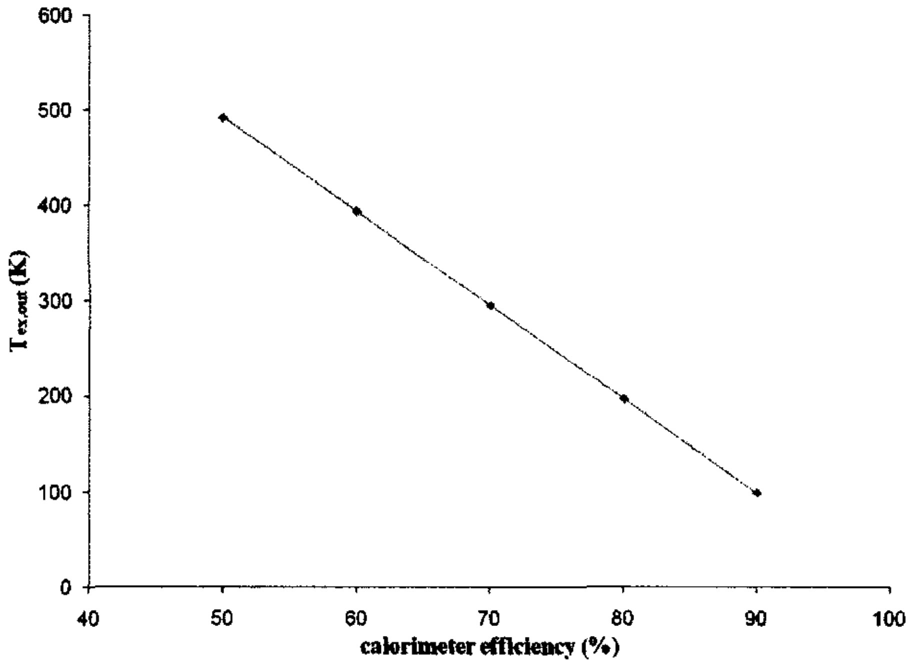


Figure 4.6 The effect of the exhaust outlet temperarature from the calorimeter at the variable of calorimeter effieciency

From the both figure above, we can see that the effect of the calorimeter efficiency to the mass flow rate and the effect of the calorimeter efficiency to the exhaust gas outlet temperature from the calorimeter as shown on the Figure 4.5 and Figure 4.6. From that figure we can said that the efficiency of the calorimeter give the influent to the amount of the mass flow rate and the exhaust gas outlet temperature from the calorimeter, where the mass flow rate will be higher when the calorimeter efficiency is higher, but different situation to the exhaust gas outlet temperature from the calorimeter, where the exhaust gas outlet temperature from calorimeter is lower when the calorimeter efficiency is higher. The value of the exhaust gas outlet from the calorimeter must not below to the 60°C (333K) because at this point, it is approximately the dew point temperature for the exhaust gas which is at the lower temperature the steam in the exhaust will start to condense, giving up its latent heat. So according to the result above the efficiency of the calorimeter could not be higher then 66.25%,that means the exhaust heat absorbed by the water in the calorimeter cannot be achieve higher than 66.25% from the total amount of exhaust heat flow into the calorimeter.

4.3.2.3 Study the effect of the mass flow rate at the variable water outlet *temperature and variable efficiency*

In this case, we are combine the situation for first case and second case with study the effect for the mass flow rate when applied the variable value of calorimeter efficiency and the value of the water outlet temperature from the calorimeter, from this case it is more to the reality concept of the exhaust gas calorimeter. We state the value for the water outlet temperature, $T_{w,out}$ is in range 40°C to 90°C because the $T_{w,out}$ cannot be lower or same to ambient temperature and cannot above from boiling water stage temperature and the efficiency of calorimeter in range 60% to 10%.

Example calculation

1) Total Exhaust heat = 54.533785 kW, the calorimeter efficiency is 60% ,
water outlet temperature= 90 °C, water inlet temperature= 27 °C

$$\text{Heat absorbed by water} = 54.533785 \text{ x } 60\%$$
$$= 32.720271 \text{ kW}$$

$$\text{Heat loss through the exhaust gas} = 54.533785 - 32.720271$$
$$= 21.813514 \text{ kW}$$

$$\text{Heat absorbed by water} = m_w \text{ x } C_w \text{ x } (T_{w,out} - T_{w,in})$$
$$32.720271 \text{ kW} = m_w \text{ x } 4.18 \text{x } (90 - 27)$$
$$m_w = 0.12425 \text{ kg/sec}$$

$$\text{Heat loss through the exhaust gas} = m_g \text{ x } C_{pg} \text{ x } T_{ex,out}$$
$$21.813514 \text{ kW} = 0.055417 \text{ x } 1\text{x } T_{ex,out}$$
$$T_{ex,out} = 393.625 \text{ K}$$

2) Total Exhaust heat = 54.533785 kW, the calorimeter efficiency is 60 % , water outlet temperature= 80 °C, water inlet temperature= 27 °C

Heat absorbed by water = 54.533785 x 60%

= 32.720271 kW

Heat loss through the exhaust gas = 54.533785- 32.720271

= 21.813514 kW

Heat absorbed by water = m_w x C_w x $(T_{w,out} - T_{w,in})$

32.720271 kW = m_w x 4.18x (80 – 27)

m_w = 0.14769 kg/sec

Heat loss through the exhaust gas = m_g x C_{pg} x $T_{ex,out}$

21.813514 kW = 0.055417 x 1x $T_{ex,out}$

$T_{ex,out}$ = 393.625K

3) Total Exhaust heat = 54.533785 kW, the calorimeter efficiency is 60 % , water outlet temperature= 70 °C, water inlet temperature= 27 °C

Heat absorbed by water = 54.533785 x 60%

= 32.720271 kW

Heat loss through the exhaust gas = 54.533785- 32.720271

= 21.813514 kW

Heat absorbed by water = m_w x C_w x $(T_{w,out} - T_{w,in})$

32.720271 kW = m_w x 4.18x (70 – 27)

m_w = 0.182042 kg/sec

Heat loss through the exhaust gas = m_g x C_{pg} x $T_{ex,out}$

21.813514 kW = 0.055417 x 1x $T_{ex,out}$

$T_{ex,out}$ = 393.625K

This calculation is repeated to the calorimeter efficiency at 60%, 50%, 40%, 30% and 20% at $T_{w,out}$ in range 90°C to 40°C result from the calculation is show in figure 4.7 below

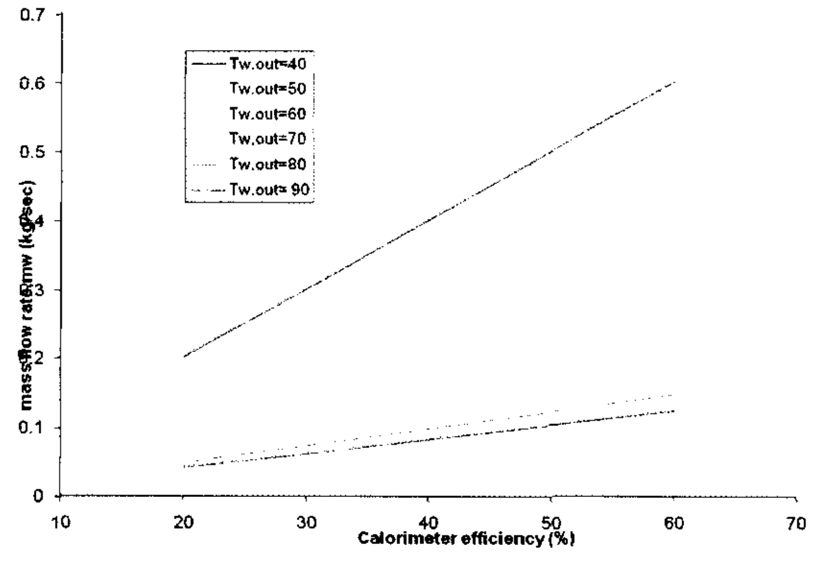


Figure 4.7 The effect of the calorimeter efficiency to the mass flow rate according to the water outlet temperature, $T_{w,out}$

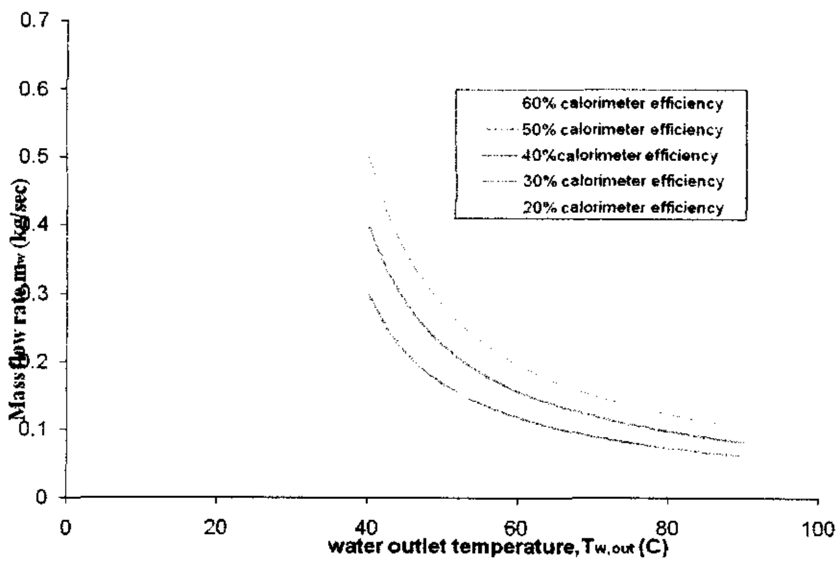


Figure 4.8 The effect of the water outlet temperature, $T_{w,out}$ to the mass flow rate according to the calorimeter efficiency.

From the both figure above, show the effect of the mass flow rate when applied the variable value of calorimeter efficiency and the value of the water outlet temperature from the calorimeter. From both figure above we can said that the efficiency of the calorimeter can give the influent to the amount of the mass flow rate, where the mass flow rate will be higher when the calorimeter efficiency is higher, at each value for the water outlet temperature from the calorimeter as shown on Figure 4.7 and for Figure 4.8 show the value of mass flow rate are lower at the higher value of the water outlet temperature from the calorimeter for each calorimeter efficiency but, the value of mass flow rate at the same amount of water outlet temperature is higher when the calorimeter efficiency is higher. So from the result the range of the mass flow rate for this system at speed engine 4000 rpm is in 0.60214 kg/sec to 0.041417 kg/sec

4.3.3 Important finding and modification needed from the analysis

From the thermal analysis which has been done, the important finding in the result is the range of the mass flow rate for each assumption water outlet temperature and the calorimeter efficiency. Such as we known, in reality experimental the value of the temperature outlet we can define by controlling the amount of the mass water flow rate through into the system and also the calorimeter efficiency, we can define it from the capability of the heat exchanger to absorb the amount of the exhaust heat flow through into the calorimeter. All of this is unknown, and cannot be define before done the experimental of the calorimeter it self. So the only one of unknown which we can control only the mass flow rate of the water flows through into the calorimeter which is by controlling the mass flow rate, it we give the effect to the calorimeter efficiency, the water outlet temperature, the sizing of the calorimeter system and main component to the system such as heat exchanger, radiator, water tank and water pump.

According to the result of range of mass flow rate some modification should be done to make sure the system is work properly by put a valve in to the system to control the amount of the flow rate, this is because the flow rate of the water pump which is use in this system is very high to compare the range of the mass flow rate amount needed to the system. This system also needs the flow meter to measure the amount of the water flow through the calorimeter. The suggestion of the location of the valve and flow meter is locate before the water flow into the calorimeter because the temperature outlet water may be higher, that can give damage to the valve and flow meter. The modification of the system has been done as in the Figure 4.9, Exhaust gas calorimeter the test-rig system schematic diagram which is shown the location of the flow rate meter and flow into the exhaust gas calorimeter system.

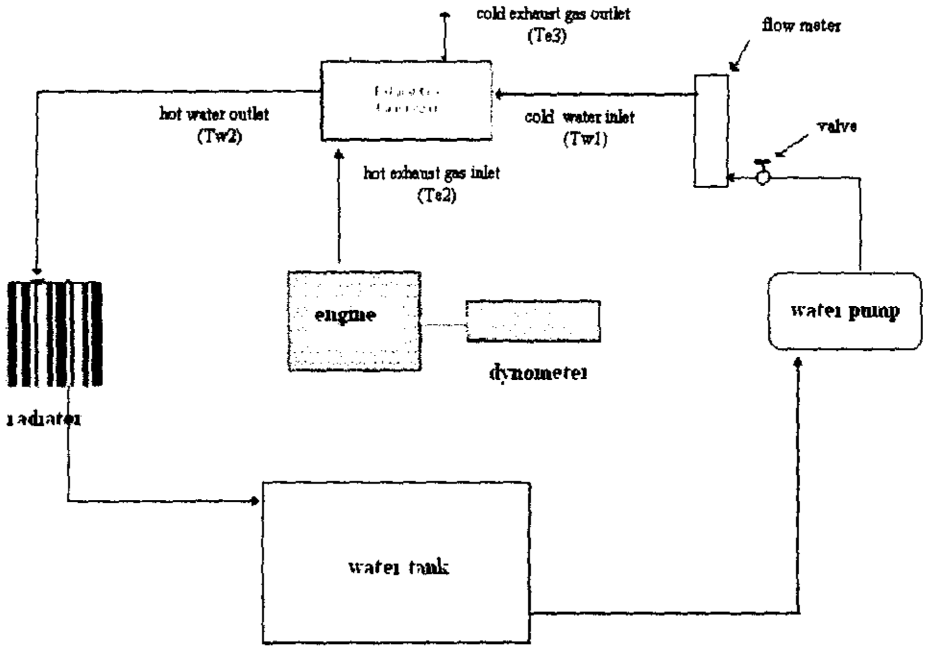


Figure 4.9 Exhaust gas calorimeter the test-rig system schematic diagram

CHAPTER 5

CONCLUSION

This project has attempted to measure the heat transfer form engine to exhaust gas to measure the energy transfer by designing and develop the exhaust gas calorimeter for gasoline / compressed – Natural Gas (CNG) hydraulic dynamometer engine test-rig Three types of methods have been used for this project; first with computer added software to design the exhaust gas calorimeter, follow by analysis thermal analysis and structure analysis for the design,

With all the analysis results obtained, the water flow rate is the main controller which is independence value, by change the value of the mass flow rate we can get the different value of result but with condition of the $T_{ex,out}$,$T_{w,in}$, and the calorimeter efficiency. The available range value for mass flow rate for this system at speed engine 4000 rpm is in 0.60214 kg/sec to 0.041417 kg/sec. However to get more accurate result, the experimental should the done for the exhaust gas calorimeter to the engine testing.

REFERENCES

1 Engineering Fundamentals of the internal combustion engine, Willard w. pulkrabek, university of Wisconsin-platteville

2 Engine testing, Theory and practical, 2nd edition, Micheal Plaint and Anthony Martyr

3 http://www.wipo.int/pctdb/en/wo.jsp?wo=2007056252&IA=WO2007056252 &DISPLAY=DESC access on January04, 2008

4 www.chemeng.ed.ac.uk/~mbiggs/mjbc_teaching/engineering1/2003 04/ohs/lecturehandouts3.pdf access on January04, 2008

5 http://en.wikipedia.org/wiki/heat_exchange access on January04, 2008

6 http://en.wikipedia.org/wiki/Internal_combustion_engine acess on March05, 2008

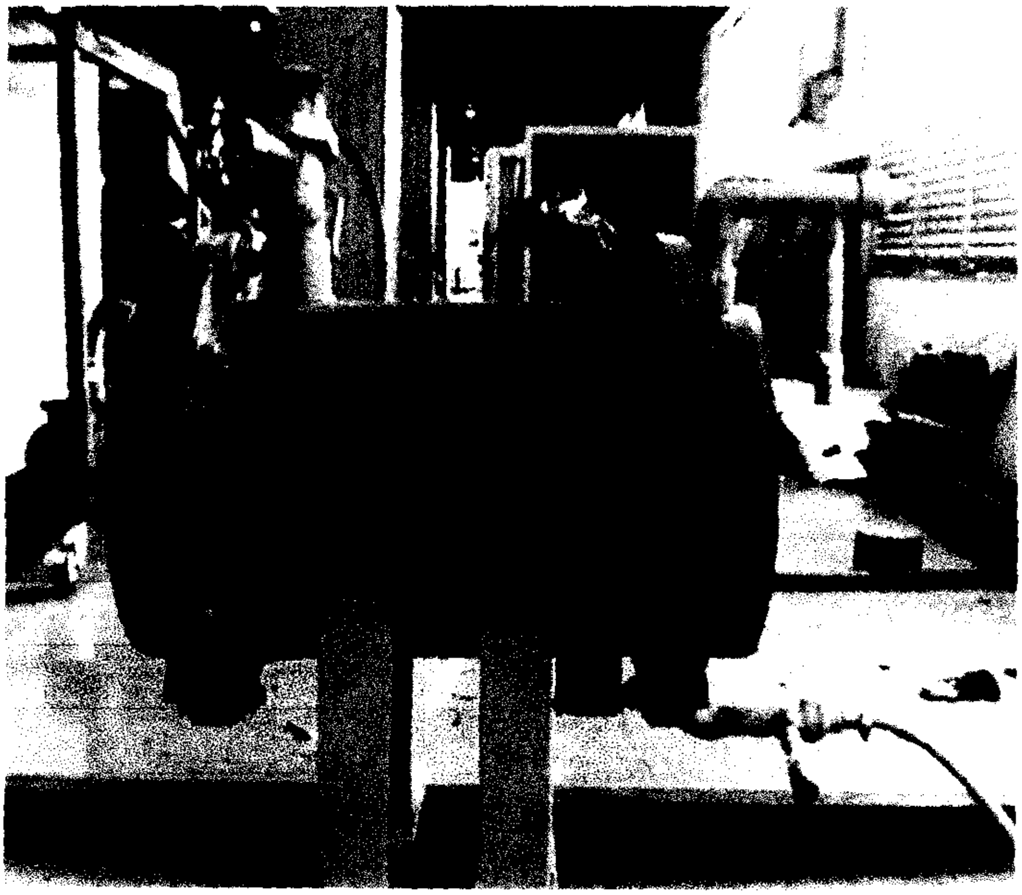
7 http://mypage.direct.ca/k/kdomries/cooling.html access on Feb03, 2007.

8 http://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node131.h ml access on Feb03, 2007

9 http://www.engineersedge.com/heat_exchanger/heat_exchanger_menu.shtml access on January04, 2008

APPENDIX A

Body of heat exchanger

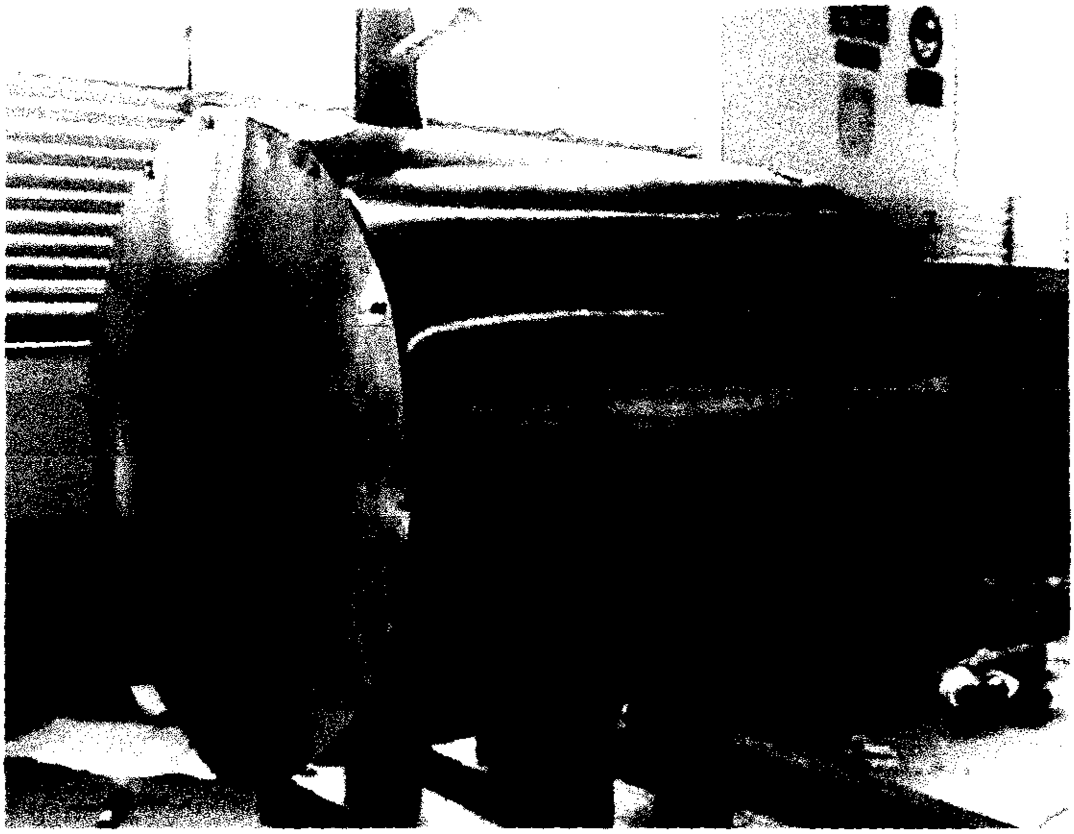


APPENDIX B

First layer insulation of heat exchanger using glass fiber

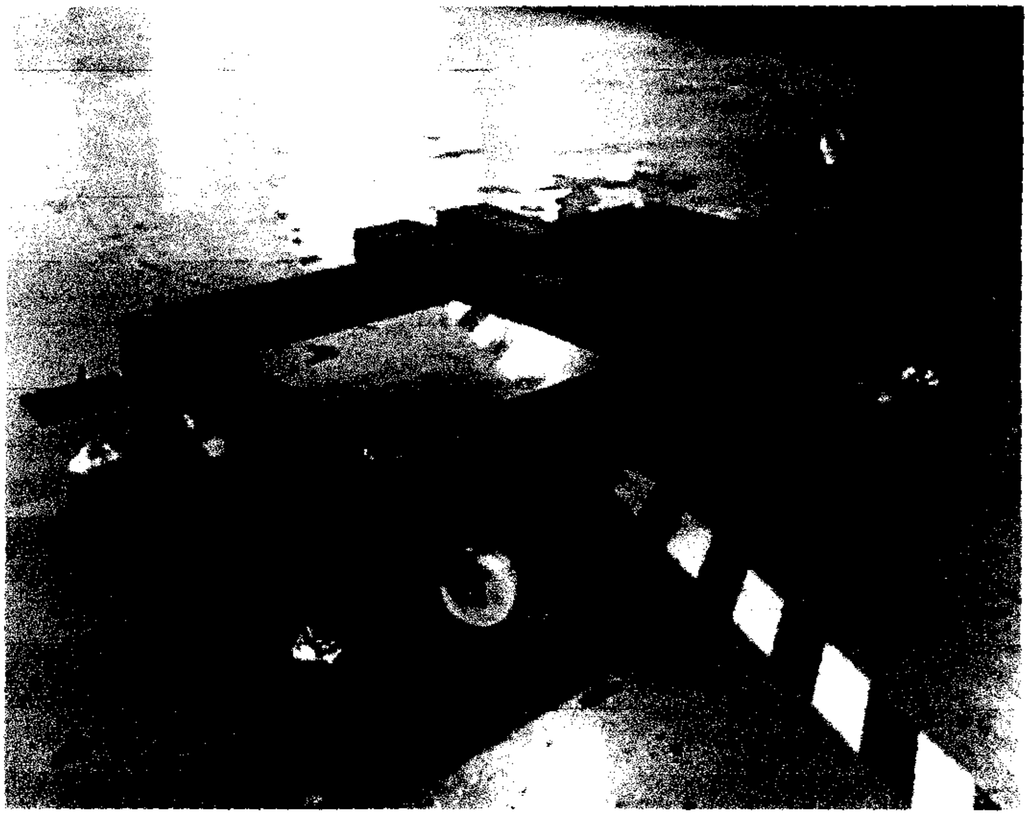
APPENDIX C

Second layer insulation of heat exchanger using aluminum plate



APPENDIX D

Portable stand for calorimeter



APPENDIX E

Exhaust gas calorimeter with cooling system