WASTED HEAT RECOVERY SYSTEM: HOW TO GAIN ENERGY

ABDUL MUHAIMIN BIN MOHD SHAFIE

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SUPERVISOR DECLARATION

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

Signature : ……………………………..

Supervisor :DR. MUSTHAFAH BIN MOHD TAHIR

Date : ……………………………..

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ABDUL MUHAIMIN BIN MOHD SHAFIE

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Faculty of Mechanical Engineeing
Universiti Teknikal Malaysia Melaka

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DECLARATION

“I hereby declare that the work in this report is my own except for the summaries and quotations which have been duly acknowledge.”

Signature :…………………..
Author :ABDUL MUHAIMIN B. MOHD SHAFIE
Date :..………………….

Special for

Father and mother

Family

Lecture and friends

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ABSTRACT

Waste heat is one of the sources that can produce energy. Furthermore, waste energy produces no emission to the environment. In this study, a waste heat recovery system is build up and an experiment is conducted to the system. An Organic Rankine cycle is selected among the other Rankine cycle due to its characteristics. This report also discussing about the component that is used in the waste heat recovery system and their specification. Furthermore, an experiment has been done in order to find the highest power gained and what is the different in temperature when the power at peak. The working fluid used in the waste heat recovery system is refrigerant R-134a as it is the most suitable to apply in the system. The heat is gained from the engine before it is cooled at the radiator. In order to transfer the heat from one working to other working fluid, heat exchanger is used. The graphs of power and different in temperature versus time are used to analyze the result. The maximum power gained from the experiment is 37.84 Watt. That value stated means that the power that should be transfer from the radiator coolant to the heat recovery system.

ABSTRAK

Haba buangan adalah salah satu sumber tenaga yang dapat menghasilkan tenaga.Selain itu, haba buangan juga tidak menghasilkan produk yang mencemarkan alam sekitar. Kajian ini, sistem pemulihan haba buangan akan dibina dan akan dilakukan eksperimen ke atasnya. Sistem kitaran Organik Rankine telah dipilih dari kitaran Rankine yang lain diatas faktor-faktor yang tertentu. Laporan ini juga membincangkan tentang komponen yang digunakan didalam sistem pemulihan haba buangan dan juga spesifikasinya.Tambahan pula, satu eksperimen telah dijalankan untuk mencari nilai kuasa yang tertinggi diperolehi dan aoa perbezaan di antara suhu apabila berada pada puncak. Bendalir kerja yang digunakan di dalam sistem pemulihan haba adalah penyejuk R-134a kerana ia paling sesuai untuk sistem tersebut. Haba yang diperolehi dari enjin sebelum ia disejukkan oleh radiator. Untuk memindahkan haba dari satu cacair kerja kepada cecair kerja lain, plat penukar haba digunakan.Graf kuasa dan perbezaan suhu berlawanan masa digunakan untuk dianalisis.Keputusan menunjukkan kuasa maksimum yang diperolehi dari eksperimen adalah 37.84 Watt.Nilai yang dinyatakan bermaksud kuasa yang sepatutnya dipindahkan dari cecair penyejuk kedalam sistem pemulihan haba.

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°C	Degree Celsius
W	Watt (Power)
°F	Degree Fahrenheit
q_{in}	heat in
q_{out}	heat out
$w_{\text{turb, out}}$	Work Turbine out
$w_{\text{pump, in}}$	Work pump in
h	enthalpy
KJ/Kg	Kilojoule per kilogram
MPa	Mega Pascal
Psi	Per square inch
$\dot{m}$	Flow rate
η_{R_th}	Thermal efficiency
rpm	Revolution per minute
kg/m^3	Density
K	Kelvin
W	Work

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Recently, the development of a country used a lot of energy consumption. Industrial development, increasing in number of the vehicles in the road, and domestic equipments used a large scale of energy to operate. There are many sources that can convert into electric energy such as, fuel, hydro, wind, and others. Over the time, crude oil and petroleum product will become limited, costly to find and produce. At the same time, the demand for these sources is high. Moreover, environmental problems also need to be considering in the development. Green house effect and pollution are an example of the environmental problem recently.

An alternative ways to gain energy is required in order not only to reduce the energy consumption but also to reduce the environmental problem. A low-grade heat source is one of the sources that can be considered as a new energy sources. The study of an interest for a low grade heat recovery has grown dramatically in recently years. Usually, low-grade heat is a by-product of a system and these heats usually wasted through a cooler which act to cool down the system. There are many sources of low-grade heat that can be recovering such as biological waste heat, engine exhaust gases, domestic boilers, solar thermal, power plant, and heat from vehicle’s engine.

Low-grade heat can produce an electric which can be used for another system. In a cement power plant that is currently located in Switzerland, they use wasted heat from the suspension preheated gas and clinker cooler waste air and convert them into a clean electrical energy (Bornet, 2011). These processes not only make the efficiency of the power plant increase, but also reduce the production of the CO_2 emission. Twenty percent of the consumption of the cement power plant also can be save using low-grade wasted heat sources(Bornet, 2011). Recovering wasted heat can reduce the dependence on the crude oil, produce no additional risky emission such as carbon and reduce the operating cost.

1.2 PROBLEM STATEMENT

Since a few years ago, development of a world's economy leads to produce a by-product commonly carbon dioxide which a sources of the green house effect. Moreover, the usage of raw fuel seems to be increase over the time. People cannot depend only on a raw fuel that will decrease slowly. They need to find new sources that may reduce the usage of a raw fuel. Waste heat is one of the sources that can produce energy without adding the carbon emission to the environment. Plus, waste heat is one of the ways to reduce the dependence on the foreign oil.

Internal combustion engine (ICE) operates by converting chemical energy which is fuel into kinetic energy. This process occurs when the engine operate passing a spark into a compressed cylinder that contain a mixture of fuel and oxygen gas. During the combustion process, cylinder temperature often reaches quite high value. Overheating of the head cylinder may cause to overheated spark plug electrodes causing pre-ignition that leads to power lost of the engine. Temperature reach often affect the performance of the engine, and to reduce the engine's temperature to a desire temperature, radiator is used to remove the heat from the engine into a surrounding. The fuel efficiency of the ICE is around 25 to 35% (Ganesan, 2007). This means that only 25 to 35% of the fuel is used to drive the vehicle. Another 65 to 75% is lost in term of heat, dissipated through exhaust, and friction. 30 to 35% of the total heat supplied by the fuel is removed through cooling medium which is radiator by carried away the lubricating oil and heat to the radiator(Ganesan, 2007).

Waste heat from the radiator can be used as new sources of energy by converting the heat energy into an electrical energy. This can be done by building a heat recovery system for a vehicle that can be used in the future. The usage of the clean sources leads to produce a health environment.

1.3 OBJECTIVE

Main objective in this project is to build up a waste heat recovery system and obtain energy form the wasted heat in this system. This study also will prove that the theory that wasted heat can be recovered by heat recovery system. Moreover, the ancillary objective in this study is to analyse the different of heat in the radiator that will produce a high energy for the recovery system.

1.4 SCOPE

Heat from the vehicle's radiator (60°C- 80°C in this study) is use as a waste heat for the waste heat recovery system. In this study, the experimental equipment is build up and the equipment is setup from the beginning by repairing the engine. Air motor will use as the turbine in this experiment to shows that he energy is recover.

1.5 THESIS OVERVIEW

These reports consist of 5 main chapters which are:

CHAPTER 1 - INTRODUCTION

Introducing the readers to the general background of the case study, the objective of the project, scope of the project, and the problem statement that leads to this study.

CHAPTER 2 - LITERITURE REVIEW

In this chapter, it consists of a study about this project about their theory. This study are referred from the books, journals, thesis and internet.

CHAPTER 3 - METHODOLOGY

This chapter mainly about the progress of the project. This is shown using a flow chart. In this chapter also including the process of collecting the data and information from the previous study, collecting of data, drawing the system, process and analyse the data to obtain the final result.

CHAPTER 4 - DISCUSSION

In this chapter, it consist of the discussion from the result obtain in the previous chapter. It also has the result, graph and dimension of the system.

CHAPTER 5 - CONCLUSION

This chapter will show the conclusion about the study and the recommendation for the future improvements.

CHAPTER 6 - REFERENCE

All of the reference used in this report will be located in this chapter. This chapter will include the references from the book, journals, internet, and others

CHAPTER 2

LITERATURE REVIEW

2.1 THEORY OF AN ORGANIC RANKINE CYCLE

In this chapter, Organic Rankine cycle (ORC), Wasted heat recovery system, the component involved in the ORC will be introduced. All of the information stated in this chapter is through a study that has been done for this project.

2.1.1 RANKINE CYCLE SYSTEM

There are three types of Rankine power cycle, which is Stream Rankine Cycle (SRC), Organic Rankine cycle (ORC), and Kalina cycle (KC). Table 2.1 shows the waste heat stream that is classified by temperature. In this table, the cycle that needs to use as a reference for a system can be determine. For the Internal Combustion Engine, the radiators usually produce the heat at range 60 to 80°C. This type of ICE will use temperature that is classified as low temperature.

For a low temperature classification, there are two type of waste heat to power the technologies, which is Organic Rankine Cycle and Kalina cycle. For this study, Organic Rankine cycle is used to refer to the actual cycle. Kalina is not suitable for this project because Kalina use a mixture of water and ammonias the working fluid (Neeharika, 2012). Although Kalina cycle is more efficient energy extraction from the heat source and have an efficiency 15 to 25 percent more efficient thanORC, Kalina is dangerous if the system installed in the vehicle when an accident occurs.

Table 2.1 : Wasted heat streams classified by temperature (Neeharika, 2012).

Temperature Classification	Waste Heat Source	Characteristics	Commercial Waste Heat to Power Technologies
High (>927 °C)	• Furnaces - steel electric arc -steel heating -basic oxygen - glass melting • Coke ovens • Fume incinerators • Hydrogen plants	• High quality heat • High heat transfer • High power-generation efficiencies • Chemical and mechanical contaminants	• Wasted heat boilers and steam turbines
Medium (227-927 °C)	• Prime mover exhaust streams - gas turbine - reciprocating engine • Heat-treating furnace • Ovens - Cement kilns	• Medium power-generation efficiencies • Chemical and mechanical contaminants (some streams such as cement kilns)	• Waste heat boilers and stream turbine (> 227°C) • Organic Rankine cycle (< 527°C) • Kalian cycle (< 727°C)
Low (<227 °C)	• Boilers • Ethylene furnace • Steam condensate • Cooling water - furnace doors - annealing furnace - air compressors - IC engines	• Energy contained in numerous small source • Low power-generation efficiencies • Recovery of combustion streams limited due to acid concentration if temperature reduce	• Organic Rankine cycle (> 27°C gaseous streams, > -98°C liquid streams) • Kalian cycle (> -73 °C)

	• Low-temperature ovens	below -23 °C	

Many of impracticalities associated with the carnot cycle can be eliminated bysuperheating the steam in the boiler and condensing it completely in the condenser, as shown in Figure 2.1, a schematically on a T-s diagram (Cengal and Boles, 2011, p.551)˙Rankine cycle is the result of this case, which is the ideal cycle for the vapor power plants. Heat is converted into a work or energy by Rankine cycle (RC). The working fluid in the Rankine cycle is usually water or steam. The heat is supplied into a Rankine cycle which is in close loop in order to operate. 90% of the electric power generated in this world are comes from Rankine cycle(Wiser Wendell H.,2000). Commonly, biomass, coal, solar thermal, and nuclear power plants used Rankine cycle to regenerate the heat lost. For an ideal Rankine cycle, internal irreversibility does not involve and consists of the following process:-

1 – 2 Isentropic compression in pump
2 – 3 Constant pressure heat addition in boiler
3 – 4 Isentropic expansion in turbine
4 – 1 Constant pressure heat rejection in a condenser