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Experimental Study of Exhaust Gases Recirculation for Cooling Purposes

**A Research Submitted to the
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Higher Diploma in Engineering / Mechanical Engineering /
Fuel and Power**

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

((يُؤْتِي الْحِكْمَةَ مَنْ يَشَاءُ))

وَمَنْ يُؤْتَ الْحِكْمَةَ فَقَدْ أُوْتِيَ خَيْرًا كَثِيرًا

وَمَا يَذْكُرُ إِلَّا أَهْلَ الْأَنْبَاءِ))

صَدَقَ اللَّهُ الْعَلِيُّ الْعَظِيمُ

سورة البقرة - الآية (٢٦٩)

Certification

I certify that this research entitled " **Experimental Study of Exhaust Gases Recirculation for Cooling Purposes**" has been prepared by "*Dergham Ali Karim*" under my supervision at the department of Mechanical Engineering, College of Engineering, University of Babylon as a partial fulfillment of the requirements for the Degree of Higher Diploma of Science in Mechanical Engineering / Fuel and Power.

I recommend that this research be forwarded for examination in accordance with the regulation of the University of Babylon.

Signature

Assist. Prof. Dr. Qusay Rasheed Abd Al-Amir

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Data: / / 2022

Dedication

To

My dear father

My mother

My dear brother and the flowers of my life, my sisters

I dedicate my modest effort.

Dergham.

Acknowledgments

Praise be to God, Lord of the Worlds, and prayers and peace be upon our master Muhammad. At first,

I would like sincerely to express my deepest thanks and appreciation to my supervisor, Assist. Prof. Dr. Qusay Rasheed Abd Al-Amir for his guidance, consistent encouragement, support and enthusiasm throughout the duration of this research. Without his involvement and commitment this work wouldn't have materialized.

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Dergam Ali Karim

/ / 2022

Abstract

almost all automobile air conditioning systems are powered by a conventional vapor compression system which adds more load on the engine, consumes more fuel and reduces engine efficiency. Kia car air conditioning system was designed equipped with an electric compressor with a capacity of 2 kilowatts that works by recovering waste heat from exhaust gases. In other words have converted the kinetic energy of the exhaust gases into electrical energy by linking the engine exhaust with the gas turbine to generate torque that is transmitted to the dynamo and thus generates a continuous electric current. This process needs a power inverter to change the phase of the direct current generated by the dynamo to the alternating current to operate the electric compressor for the refrigeration system. Through this design, the energy generated by the expansion of the exhaust gas to rotate the blades of the turbine that drives the dynamo to generate electric power. Experimental work was carried out using a four-cylinder Kia carnival diesel engine, The diesel engine was chosen for a number of reasons, including the fact that diesel fuel has a higher density than gasoline, giving it around 15% more power. Furthermore, the temperature of a diesel engine exhaust gases is higher than that of a gasoline engine the results showed that the engine efficiency improved through a decrease factor in several variables such as the rate of fuel consumption, the temperature of the exhaust gases, and the amount of heat released from the engine about 4.4%, 10.1% and 18%, respectively. On the other hand, the results also showed that the performance coefficient of the proposed cooling system increases about 3.7% if compared to the traditional cooling system. Based on these results, we were able to find a solution to the energy wastage problems of the air conditioning system in a vehicle that works on the vapor compression cycle.

Nomenclature

Symbol	Description	Units
COP	Coefficient of performance of the cooling system	-
$c_{p_{ex}}$	The heat capacity of the exhaust gases	kJ/kg.k
h	The enthalpy	kJ/kg
I	The current	Amp.
LcV	Low calorific value of diesel fuel	MJ/kg
m_{ex}	The flow mass of the of the exhaust gases	kg/s
m_{fuel}	The mass flow rate of the diesel fuel	kg/s
m_{ref}	The flow mass of the refrigerating fluid	kg/s
Q_{cond}	Heat released by the condenser	W
Q_{evap}	Heat absorbed by the evaporator	W
Q_{rej}	The wasted heat from the engine	W
T	The temperature	C
V	Voltage	Volt
W_{comp}	The work done by the compressor	W
W_{dynmo}	The energy generated by the dynamo	W
W_t	the input power to the Turbine	W

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Chapter One

Introduction

Chapter One: Introduction

1.1 Introduction:

more emphasis is placed on energy conservation. Refrigeration and air conditioning is one of the growing engineering fields, and the current system is hampering the environment because they suffer from various environmental problems such as depletion of the ozone layer and global warming due to the emission of harmful gases such as hydrofluorocarbon, chlorofluorocarbon and carbon dioxide. To satisfy the increasing global demand for energy, the rate of depletion of nonrenewable energy sources must be reduced while alternative renewable sources are developed. This can be accomplished by enhancing traditional power plants' overall thermal efficiency. Exhaust heat recycling is the most widely used approach. The majority of today's systems recover waste heat as thermal energy, which is then transformed into electricity in a traditional steam power plant. Another option that has gotten little attention thus far is the direct conversion of the energy contained in the exhaust fumes produced by fuel combustion into electricity.

A problem of a traditional automotive internal combustion engine is that only around one-third of the energy spent is transformed into useful mechanical energy. The remaining two-thirds of total energy in water-cooled engines is squandered in engine cooling systems and exhaust gases, resulting in increased entropy and substantial environmental pollution [1]. As a result, there is a desire to convert the vehicle's waste heat into productive job output.

The internal combustion engines of diesel-powered autos contain 45 MJ/kg of poor heating value (LHV). The energy waste from burning diesel oil in compression engines is around 27 MJ/kg of energy in the exhaust gas, as seen in Figure 1.1.

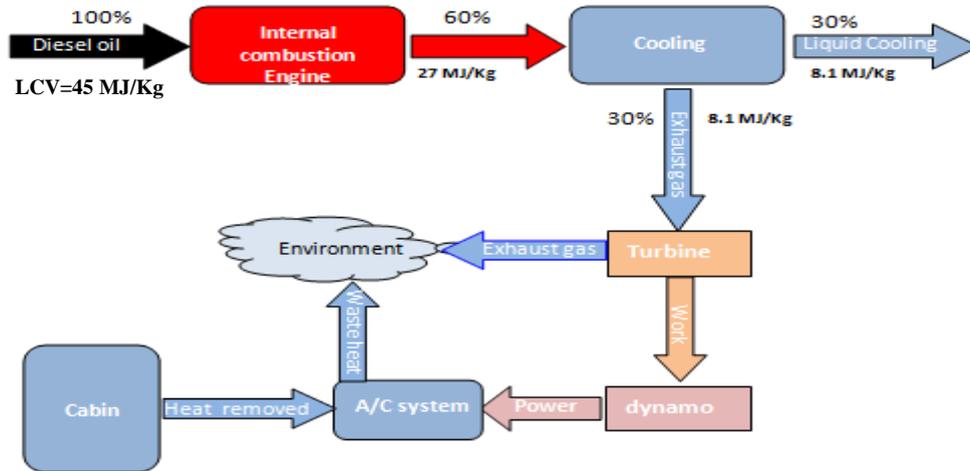


Figure (1-1) The average amount of useful and wasted energy produced by an internal combustion engine in this study

The performance of an automobile's internal combustion engine is impacted by the presence of auxiliary systems that are powered by the engine's mechanical output. As with traditional air conditioning systems that use vapor pressure to cool the cabin or carry products [2,3]. Therefore, In the past three decades, heat recovery from automotive exhaust emissions has become an important demand.

1-2 Applications:

1. The application can be used in air conditioning in aircraft.
2. It can be used in the conditioning of commercial buildings and airports near power plants.
3. Can be used in air conditioning for industrial purposes.
4. The application can be used for the purposes of heating the cabin of cars and aircraft.

1-3 The scope of present study

The main purpose of this project is to utilize the energy of exhaust gases come from the engine to generated the electricity and cooling. As a result of this project design has been advantages:

1- Reducing fuel consumption and thus reducing the emissions of exhaust gas in the ambient.

3- Improving the efficiency of the engine by removing the load resulting from the cooling system.

4- Increasing the coefficient of performance of the cooling system

1-4 Outline of research

Chapter One: Introduces the growing global need for energy, as well as the rate of depletion of nonrenewable energy sources, and ways to turn waste energy into useful energy.

Chapter Two: Deals with previous related literature, which presents the contributions and work of the experimental and theoretical on the recovery of waste heat from exhaust gases and its use as a heat source in various air conditioning systems.

Chapter Three: Explains the detailed description of the experimental test rig and manufacturing method and also practical steps for tests and working conditions.

Chapter Four: Uses simulation **computer program which called Diesel-RK** to find the positional capacity of the engine after adding the characteristics of the engine used in the project.

Chapter Five: Presents results and discussion of experimental work.

Chapter Six: Compiles the final conclusions and research recommendations for future studies.

Chapter Two

Literature Review

Chapter Two: Literature Reviews

2-1 Introduction

Large quantities of waste heat from industrial facilities and operations are released into the environment, resulting in thermal pollution and wasted energy. Therefore, the utilization and recovery of waste heat are crucial from an energy conservation and environmental protection standpoint. In numerous technical applications, the utilization of waste heat techniques is well acknowledged. In addition to being an alternative to conventional ozone-depleting liquid-free compressor vapor refrigeration units, a conventional (vapor-compression cycle) refrigeration system can be powered by a variety of relatively low-temperature heat sources (such as heat recovered from industrial processes or a heat engine), making it an ideal choice for heat recovery applications. This chapter presents numerous theoretical and experimental studies on the recovery of waste heat from exhaust gases and its usage as a heat source in a variety of air conditioning systems, as well as in relation to thermoelectric generation.

2-2 Review of theoretical and empirical research:

Automobile engines emit a substantial amount of heat into the atmosphere. In the average operating range of a 3-liter gasoline engine with a maximum output power of 115 kW, the total waste heat dissipation can range from 20 kW to 400 kW, according to Johnson [4]. It is estimated that, for a normal and representative drive cycle, the average heating power available from waste heat is around 23 kW, compared to the cooling capacity of 0.8-3.9 kW given by ordinary passenger car systems. Another disadvantage of the automobile vapor-compression refrigerant system is that the compressor consumes an excessive amount of engine power, hence decreasing the vehicle's overall efficiency. As the release of Chlorofluorocarbon from these air conditioners has a negative impact on the environment, the absorption cycle has been identified as the

optimal solution. Patented in 1954, scientist Keating devised the absorption refrigeration system for mobile applications. This technology can be used on huge vehicles, boats, and trains [5]. The absorption cooling system utilizes ecologically benign refrigerant fluids, with ammonia and water or lithium bromide and water being among the most frequent. In 1972, McNamara[6] invented and patented a turbine- or steam-powered absorption machine. This system utilized a blend of two liquid ammonia and helium systems.

In previous years, numerous studies and researches were conducted on the construction of the vapor absorption refrigeration cycle in automobiles as an alternative to the vapor compression refrigeration cycle, because the vapor-compression refrigerant cycle uses environmentally unfriendly compounds and an expensive system. Economically, it creates noise, wastes heat energy, and increases fuel use, causing environmental damage. Since the sixties of the previous century. Several research have been conducted on the exploitation of the thermal energy produced by an engine's exhaust gases, which is now lost to the environment. A third of the fuel combustion energy in an automobile engine is transformed to usable work, a third is lost in the radiator, and a third is lost as heat in the exhaust system, according to studies (Greene and Lucas, [1]). 15 kW of thermal energy may be extracted from the exhaust stream of even a relatively modest automobile engine, such as the Nissan1400 (Wang, [7]). This heat is adequate for an absorption cooling system to function. Sohail and Tiwari [8] have examined an automobile's intake air conditioning system that uses the exhaust gases of a four-cylinder diesel engine to heat the solution within the generator. Both lithium bromide, water and ammonia were employed as the system's operating materials. It observed that the lithium bromide and water-based cooling system has a crystallization issue, while the ammonia and water-based system requires an additional heat source in addition to the exhaust energy source. [9] Ghassemi introduced the automotive ammonia water

absorption cooling system. The results indicated that the system performance coefficient decreased by approximately 0.29 (COP = 0.29). Salim [10] hypothetically simulated a lithium bromide single-stage water absorption cooling system for autos that uses heat from the exhaust fumes of the internal combustion engine. This system is applicable for both water-cooled and air-cooled applications and employs modular simulation of advanced absorption system. Shah Alam [11] presented three liquid vapor absorption cooling systems powered by a four-cylinder, four-stroke passenger vehicle. One ton is the capacity of the car's air conditioner. It demonstrates that the heat needed for the air conditioner is more than double the amount supplied from the engine exhaust. Ramanathan et al [12] simulated a car air conditioning system using the absorption refrigeration cycle. A simulation model in steady state was used and, the performance of the vapor absorption cooling system was investigated. The aqueous pair of lithium bromide was also used as a working mixture due to its superior thermodynamic and transport qualities in comparison to typical refrigerants used in applications involving vapor pressure refrigeration.

The recovery of waste heat from small sources, such as automobile engines, and its application in particular to sorption fluids is uncommon, according to previous research on the design and selection of sorption cycle systems. The most important reasons include: its large and complex size, its need for constant maintenance, its low efficiency (COP =0.5) [13], and the deposition of lithium bromide in the absorber basin, which reduces the performance of the cycle.shon in figure (2,1)

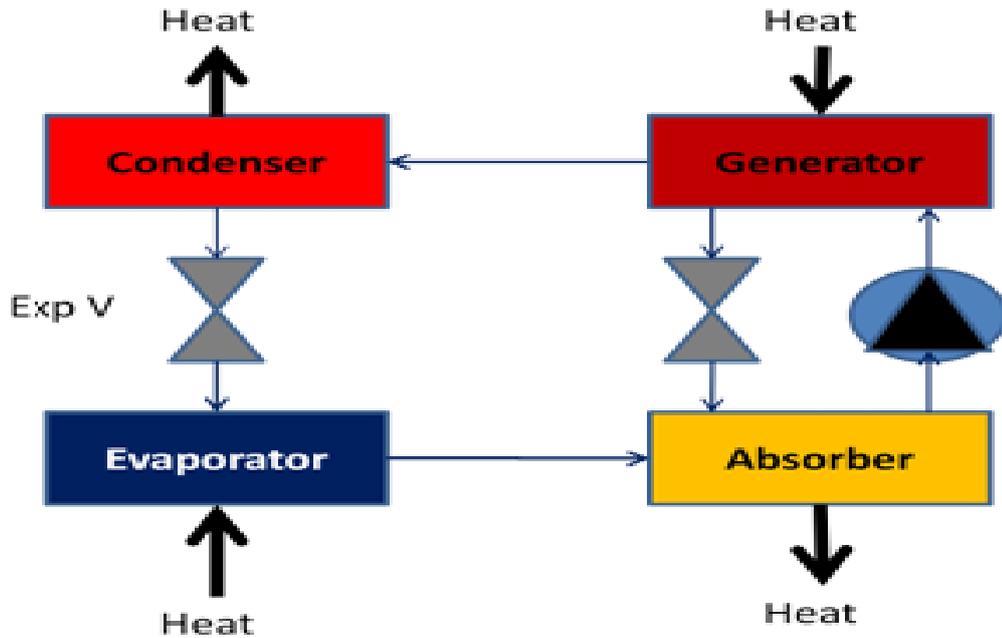


Figure (2-1) Shows the main components of the absorption cycle

Organic Rankine cycle is a well-known process for transforming low-temperature heat into electricity. The Organic Rankine cycle uses organic working fluids that can be evaporated at very low temperatures and produce work through expansion processes [15]. The Organic Rankine cycle system has been lauded for its superior efficacy in recovering low-grade heat compared to traditional steam or gas cycles [16]. Several studies investigating the use of Organic Rankine cycle in ICEs estimated that the use of Organic Rankine cycle in heavy-duty vehicles might reduce fuel consumption by 3 to 10 percent [17]. A flexibility, affordability, adaptability, and low maintenance requirements are all advantages of the Organic Rankine cycle. The thermodynamic and experimental performance of Organic Rankine cycle combined with heavy-duty engines has been investigated in a variety of research initiatives. Zhang et al. [18] designed a prototype Organic Rankine cycle system with a screw expander and compact heat exchangers to recover waste heat from diesel engines. Zhang et al. [19] investigated the control method for Organic Rankine cycle in automobiles and developed a more

effective proportional-integral closed-loop control system to manage the operation. The proposed control system decreased response time and improved output power by 3.23 percent, according to their findings. The process of thermodynamic optimization involves the selection of a suitable Organic Rankine cycle working fluid and operating parameters.

The Stirling cycle is one of the most promising choices for the vapor compression cycle as a result of its use of non-chlorofluorocarbon materials, its simplicity, and its high thermal efficiency. Kim [19] and others have investigated the Stirling cycle system, which is powered by a linear actuator devoid of a piston. The entire machine is hermetically sealed, continuously adjustable, and capable of maintaining high efficiency at low loads. The lack of certain features renders the Stirling cooling system impracticable for use in a variety of applications, such as automobiles.

The Desiccant cycle is another technology for air conditioning and refrigeration within a vehicle. This cycle absorbs vast quantities of liquid water and water vapor. minaal sahot and saffa B.Riffat [20,21]. A blower removes the air to be cooled from the conditioned environment and passes it through drying layers. This continual enthalpy action takes the moisture from the air, heating and drying it. The heat exchanger subsequently reduces the temperature of the air to near ambient levels. Finally, water is poured into the airway again. This continual enthalpy process humidifies and cools the air before it enters the passenger compartment. The future of the dryer cycle in automobile air conditioning hinges on the development of new dryers and dryer/air exchangers that can minimize the size of the entire system. As with present technology, the drying mechanism is impractical for use in a vehicle.

Wang et al. [22] submitted a concept for an adsorption-powered air conditioner for the locomotive driver's cabin that is powered by exhaust gases (450) °C and whose cooling power and coefficient of performance, respectively, are 5 kW and 0.25. The cycle time is 1060 seconds when the exhaust temperature is 450 °C, the cooling air temperature is 40 °C, and the coolant water temperature begins at 10 °C. The cooling capacity was increased from 164 W/kg to 200 W/kg.

There is a new method for cooling the truck air compartment using Harish and Parishwad [23], which is the method of chemical absorption (adsorption). A number of portable experimental results suggest that adsorption devices are feasible. Activated carbon and NH₃ have been proposed as a refrigerant-adsorbent duo shown in figure (2,3).

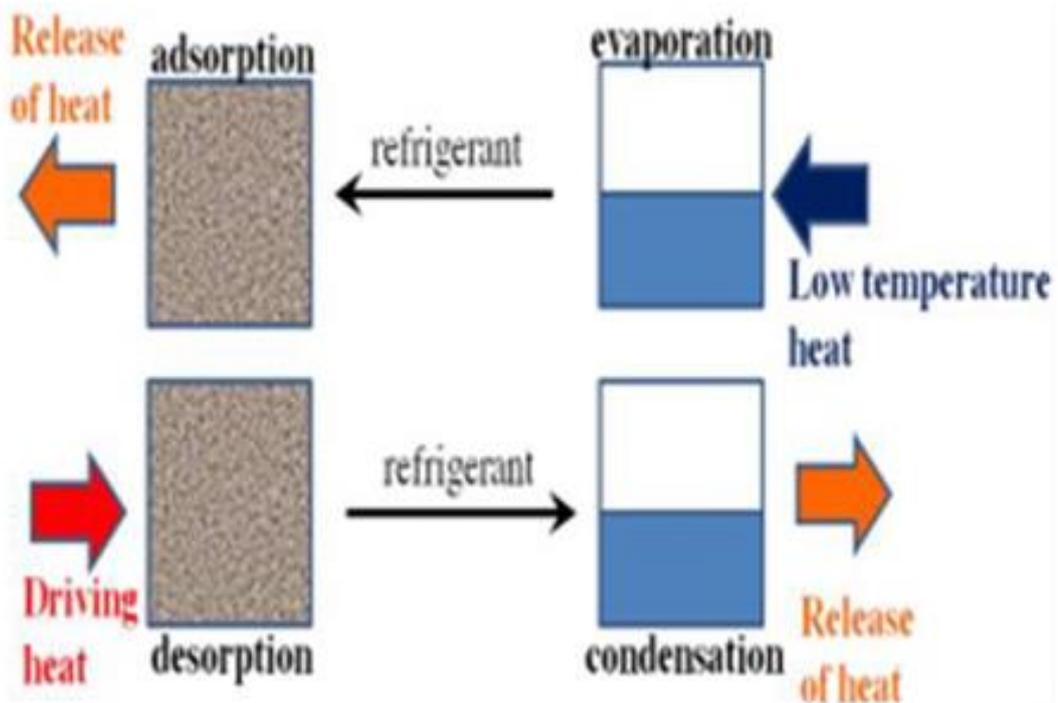


Figure (2-3) A chemical absorption cooling system

Wang et al.[24] (2009) compared the performance of several applicable systems and concluded that the adsorption system is superior for car cooling. Zhong and Wert [25] have presented an air conditioning system for heavy duty vehicles that reduces fuel consumption and engine emissions, hence increasing engine efficiency. The tabulated data indicates that the COP. of the system increases significantly as the cycle time increases, but the total cooling capacity continues to decrease over the same time period.

Previous studies estimated that if the amount of driving energy necessary for the creation of electricity (about 6 percent) could be recovered, this would result in a 10 percent reduction in overall fuel consumption [26]. It makes logical that recycling and reusing waste exhaust gas can improve fuel energy efficiency and minimize air pollution. Thermal power technologies, such as the Thermoelectric Generator , consequently attracts considerable global interest. Thermoelectric Generator is a technology that converts thermal energy to electricity immediately. It is tiny, silent, very reliable, and environmentally friendly, with no moving parts. Due to these benefits, it is currently gaining prominence as a research direction [27]. HI-Z in the United States, Nissan in Japan, and BMW in Germany had successfully created a thermoelectric engine to recycle vehicle exhaust gas several years ago. However, the amount of heat that is recycled is generally less than 5 percent. This is partially constrained by thermoelectric substances. Despite obstacles, it may be able to recover significant volumes of exhaust waste heat with thermoelectric devices, especially as materials research and heat transfer technologies continue to enhance the performance of these elements. As China's present national aim and the U.S. Department of Energy's commitment to decrease America's dependence on foreign oil get increasing attention, continued research in this area is encouraged [28].

Through previous studies. It is clear to us that the vapor compression cycle is the most successful air conditioning and refrigeration cycle, despite the problems of energy waste and environmental pollution. Through this design, the problem of energy wastage was solved and environmental pollution was reduced to some extent by reducing fuel consumption.

Chapter Three

Experimental Work

Chapter Three: Experimental Work

3-1 Detailed description of the design:

The design section consists of three basic components, namely the car cabin, the cooling system, and the engine and its accessories. These components come together to form the proposed system. The real picture of the experimental device with associated hardware and main components is shown in Figure (3.1).

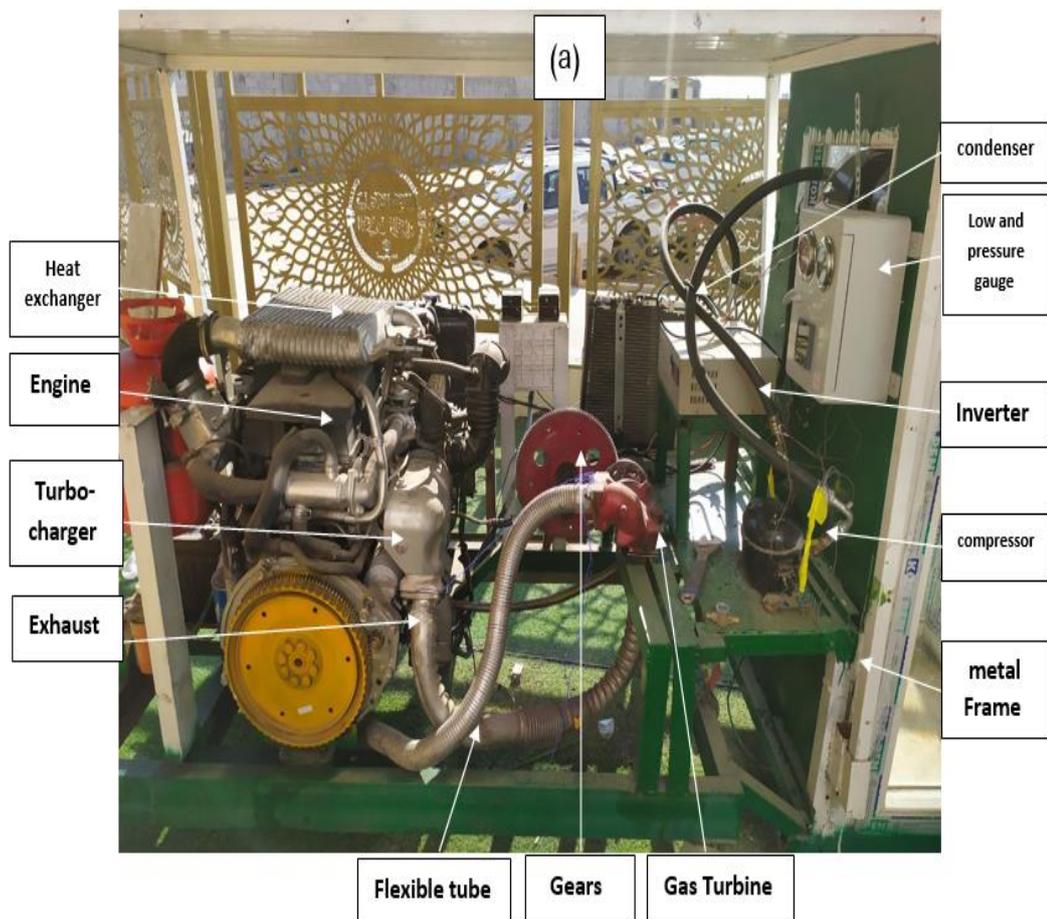




Figure (3-1) A photograph of the proposed system with the associated measuring devices and equipment in the laboratory building at the Al-Mustaqbal University Collage (a) a back view and (b) a front view.

3-2 Description of the experimental section and components:

A Kia Carnival internal combustion engine with attachments, running on four-stroke turbocharged diesel fuel, was employed as the experimental model in this investigation. A heat exchanger (intercooler) is also installed in the engine to reduce the temperature of the air exiting the compressor and entering the engine. The diesel engine was chosen for a number of reasons, including the fact that diesel fuel has a higher density than gasoline, giving it around 15% more power. Furthermore, the temperature of a diesel engine's exhaust gases is higher than that of a gasoline engine. The remaining specifications are listed in Table No. (3-1)

Table (3-1): Engine Specifications

Type of engine	Diesel engine with turbocharger
Max. speed	2800 rpm
Max. power	63.8 kW
Fuel	Diesel
Compression ratio	17:1
Engine cooling	Water
Max. Torque	235 N.m at 2800 rpm
Capacity	4.399 L
No. of cylinder	4 cylinder
No. of valves	4 per cylinder
Diameter cylinder	97 mm
Stroke length	128 mm
Displacement	3782 cm ²
Mean effective pressure	6.8 bar
Turbocharger	Radial type
Compressor of turbocharger	Centrifugal type

Other components that can be added to the engine include:

1. Frame Metal: The angle iron frame is designed to install the engine and its accessories.

2. Gas turbine: To produce work, the exhaust gas expands from a high pressure to a low pressure. The gas turbine is designed to move the dynamo.

3. Dynamo: is an electric generator. It converts mechanical rotation into a direct electric current by using rotating wire coils and magnetic fields. A dynamo machine is made up of a stator, which creates a continuous magnetic field, and an armature, which rotates within that field. Dynamo have descriptions as following: Current: 40A, Voltage 12V.



Figure (3-2) A photograph of the Dynamo for Uaz 469 car

4. Gears: - Gears were selected through theoretical experiments and by using trial and error to reach the appropriate choice.

5. Flexible tube: - It is used to take exhaust gas at a desired temperature and pressure without causing temperature drop during the turbine expansion process.

6. Inverter: An inverter that converts direct current into alternating current, as well as converts voltages from 12 volts to 220 volts.

7. Control board: contains the fuel and oil sensors, as well as the engine temperature gauge, and is used to turn all the switches on and off. Figure (3-3) depicts the engine's basic components and accessories.



Figure (3-3) A photograph of the main parts of the engine and its accessories

On the other hand, The cooling system in the car, as shown in Figur (3-4), is charged with refrigerating fluid of the type (R143a), and the system consists of the following dimention (0.5 * 0.5 * 1.5):



Figure (3-4) A photograph of the parts and components of the car's cooling system and its accessories.

1. Electric compressor: It have descriptions as following: Model: QD28G, Power Supply: 220-240V/ 50Hz, Displacement: 2.8 cm³, Rated Power : 75W, and Rated Current: 0.65A.



Figure (3-5) compressor

2. Condenser and fan unit: A fin and tube type condenser is easy to build and run since it uses the natural velocity of air when the vehicle is moving. To cool the condenser, a fan is utilized to force air out. Figure 3.6 illustrates a condenser

and fan unit with the following dimensions: 32 cm width, 32 cm height, and 2 rows.



Figure (3-6) Condenser and Fan unit

3. The evaporator and blower unit are of the cover and coil type, with the refrigerant fluid passing through it and turning into steam as it exits the evaporator, and this process is accompanied by the absorption of heat from the space. Figure (3,7) illustrates an evaporator and blower unit with dimensions of 28 cm in width, 8 cm in height, and 5 rows. The air from the evaporator is pushed into the cabin by a blower.



Figure (3,7) Evaporator and blower unit

4. Automobile cabin: a glass compartment with proportions of (0.5 * 0.5 * 1.5) for a vehicle.

3-3 Proposed system manufacturing method

The manufacturing method can be described through the following stages:

The first stage: Using a Kia diesel engine with its accessories represented by the heat exchanger (radiator) with gaskets, fuel tank and battery.

The second stage: building the external structure (frame) to install the engine and its accessories.

The third stage: designing a control panel (the board) to connect the engine assembly (the predecessor and the dynamo). The board also consists of an engine start and stop switch with a set of engine and oil temperature sensors.

Fourth stage: conducting theoretical and practical calculations in choosing a gas turbine and a flexible tube made of aluminum that connects the engine to the gas turbine.

The fifth stage: represents the stage of connecting the gas turbine with the dynamo to generate continuous electric current using a set of gears to transmit torque from the gas turbine to the dynamo. It was accomplished by rotating the dynamo and generating electricity by the speed of exhaust gases.

The sixth stage: represents the connection of the inverter between the dynamo on the one hand and the reciprocating compressor of the cooling system on the other.

Sixth stage: Connecting the engine and its accessories with the cooling system.

The last stage: linking the proposed system with the measuring equipment.

Note: All mentioned stages are illustrated and are found in paragraph (3,8)

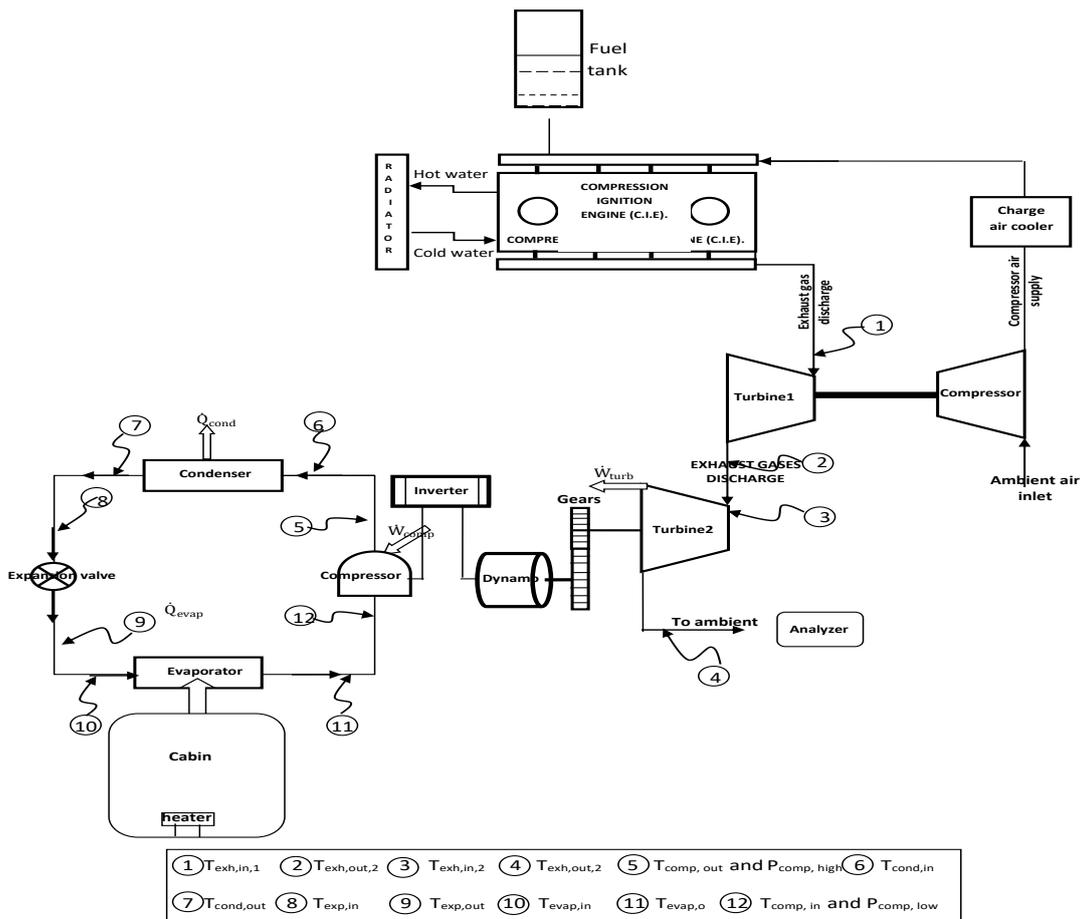


Figure (3-8) A schematic diagram of the proposed system

3-4 Practical steps for tests and working conditions:

The tests were carried out after connecting the engine and its accessories with the cooling system and its accessories, and placing measuring devices and equipment at specific points. The refrigeration system was charged with Freon

gas (R134A) by using system charging (see figure 3.9), after which two types of tests were conducted:



Figure (3-9) System charging

A. The first test is performed on the engine:

The fuel consumption rate and the input power of the engine at a variable speed is calculated using the following measuring equipment:

- 1- Type K (Ni-Cr)/(Ni-AL) thermocouples are used to measure the temperature of the exhaust gases before and after they leave the gas turbine.
- 2- The Vane type anemometer is used to measure the flow velocity of the exhaust gases.
- 3- The mass of fuel is measured per unit time using a scale and a stopwatch.
- 4- Digital Tachometers (DT-6235B) are used to measure the rotational speed of an engine.
- 5- The Analyzer scale is used to calculate the carbon dioxide emitted from the exhaust, which causes global warming.

B. The second test is conducted on the refrigeration system:

The cooling load at the evaporator, the heat released from the condenser, and the performance coefficient of the refrigeration system at a variable speed are calculated through the measurement equipment, as follows

1. The Turbine Flow meter is used to measure the flow mass of Freon (R134A) fluid
2. The Bourdon pressure gauge is used to measure the high and low pressures of the refrigerating fluid
3. Thermocouples are used to measure the temperature of the refrigerating fluid at the entry and exit of each component of the refrigeration cycle.

3-5 Standard Terms and Conditions:

Vehicle cooling and air conditioning systems must meet two main requirements:

- (a) Provide a cooling power of 2 kW at design conditions.
- (b) To allow the vehicle to pass a standard test which is a reference for manufacturers. Standard testing consists of the following steps:
 - 1- The cabin temperature should drop to about 25°C within 10 minutes with the cooling system running when the air is fully recirculated (400m³/h) without external feed.
 - 2- The cooling power required during the standard test is about 6 kW which is 4 kW higher than the design conditions.

3-6 Basic equations in practical calculations:

The work done by the compressor (W_{comp}) is calculated from the following equation:

$$W_{comp} = m_{ref} (h_5 - h_{12}) \quad \dots\dots(1)$$

where h_{12} , h_5 represent the enthalpy at the inlet and outlet of the compressor and are calculated from the pressure and temperature of the icing fluid at points 5 and 12, respectively, and m_{ref} represents the flow mass of the refrigerating fluid.

The heat absorbed by the evaporator (Q_{evap}) is calculated from the following equation:

$$Q_{evap} = m_{ref} (h_{11} - h_{10}) \quad \dots\dots(2)$$

where h_{11} , h_{10} represent the enthalpy at the inlet and outlet of the evaporator and are calculated from the pressure and temperature of the icing fluid at points 11 and 10, respectively.

The heat released by the condenser (Q_{cond}) is calculated from the following equation:

$$Q_{cond} = m_{ref} (h_7 - h_6) \quad \dots\dots(3)$$

where h_7 , h_6 represent the enthalpy at the inlet and outlet of the condenser and are calculated from the pressure and temperature of the icing fluid at points 6 and 7, respectively.

The internal work of the gas turbine (W_{τ}) is calculated by applying the first law of thermodynamics to flow processes as follows:

Energy Input - Energy Output = Increased Energy in the System

$$\dots(4) \quad Q_{rej} - W_T = m_{ex} c_{p_{ex}} (T_4 - T_3)$$

where T_4, T_3 represent the temperatures of the exhaust gases at the inlet and outlet of the gas turbine, respectively. And $c_{p_{ex}}$, m_{ex} represent the flow mass and the adiabatic heat capacity of the exhaust gases, respectively.

We calculate wasted heat from the engine, assuming that 30% of the engine's power is removed from the outside, as follows:

$$\dots(5) \quad Q_{rej} = 0.3 m_{fuel} \cdot LCV$$

Where m_{fuel} represents the average running mass of the diesel fuel and L.C.V is the low calorific value of diesel fuel which is equal to 45MJ/kg. Substituting equation No. (5) into Equation No. (4), we get the power of the gas turbine:

$$\dots(6) \quad W_T = 0.3 m_{fuel} \cdot LCV - m_{ex} c_{p_{ex}} (T_4 - T_3)$$

The energy required to operate the dynamo can also be calculated from the law of energy conservation., where the electrical power of the compressor is equal to the energy generated by the dynamo:

$$W_{dynmo} = W_{comp} = V \cdot I \cdot \cos \theta \quad \dots(7)$$

Coefficient of performance (COP) of the cooling system can be calculated from the ratio of the amount of heat absorbed in the evaporator to the capacity of the compressor, as follows:

$$COP_R = \frac{Q_{evap}}{w_{comp}} = \frac{m_{ref}(h_{11}-h_{10})}{V \cdot I \cdot \cos \theta} \quad \dots(8)$$

The heat rejection ratio (H.R.R) of cooling system is the ratio of amount of heat rejection at the condenser to the amount of heat absorbed at the evaporator.

$$H. R. R = \frac{Q_{cond}}{Q_{evap}} = \frac{h_7 - h_6}{h_{11} - h_{10}} \quad \dots(9)$$

Chapter Four

Results And Discussin

Chapter Four: Results and Discussion

Exhaust gases from a 4-cylinder diesel internal combustion engine equipped with a turbocharger were used to generate enough electricity to drive a 2kW air-conditioning system of the vapor-compression cycle."This is done by expanding the exhaust gases inside turbine to generate torque that drives the dynamo. As for the diesel engine, increased engine speed increases consumption of fuel, the quantity of heat released from the engine, and the temperature of exhaust gases coming out of the engine, as is known in advance. Experiments on the proposed system indicated an improvement in the rate of fuel consumption, as indicated in Figure(4.1) with compared to the usual system (direct coupling of the cooling system and the engine). When the engine speed is increased, the temperature of the exhaust gases and the amount of heat generated from the engine both rise, as illustrated in Figures (4.2) and (4.3), respectively. In the same figures, we also note that the temperature of the exhaust gases and the amount of heat released from the engine are lower for the proposed system, and this shows a reduction in waste energy if compared with the usual system. The influence of diesel engine speed on CO₂ emissions is depicted in Figure (4.4)."

On the other hand, the results obtained from practical experiments showed that the cooling load increases gradually with time (see figure (4.5)) and also an increase in the coefficient of performance with increment of the engine speed (see figure (4.6)). "From the results, it was found that the coefficient of performance improved for the proposed system more than the usual system. The heat rejection ratio with operation time for proposed and usual systems is depicted in figure (4.7). Figure (4.8) shows the P-H diagram of new cooling system.

Based on these findings, solutions have been found to the problem of energy loss resulting from burning diesel fuel in internal combustion engines and using it

to operate the air conditioning system in the automobile that works with the vapor compression cycle."

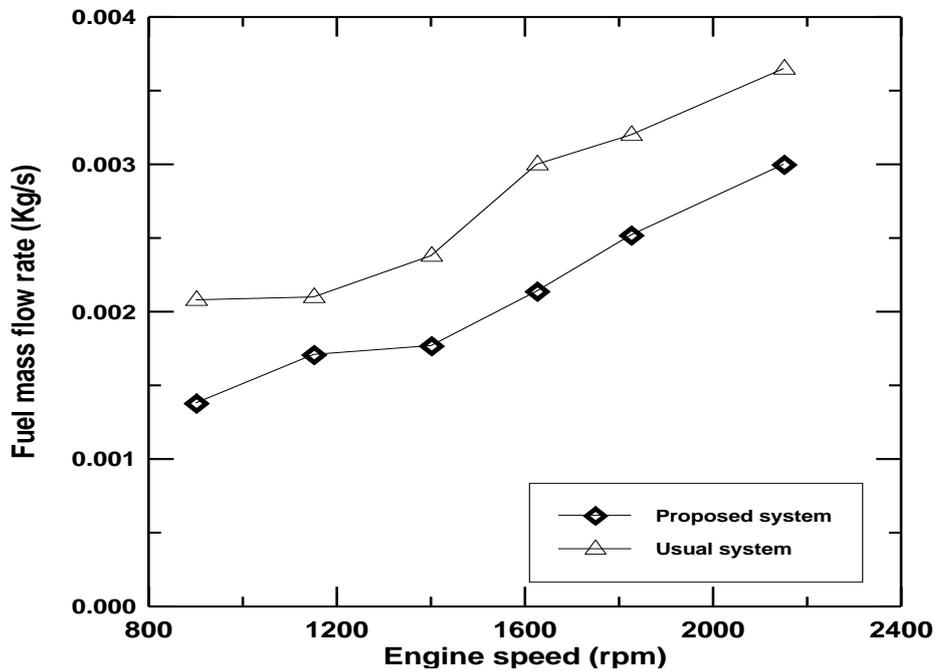


Figure (4.1): Diesel engine speed versus the fuel mass flow rate

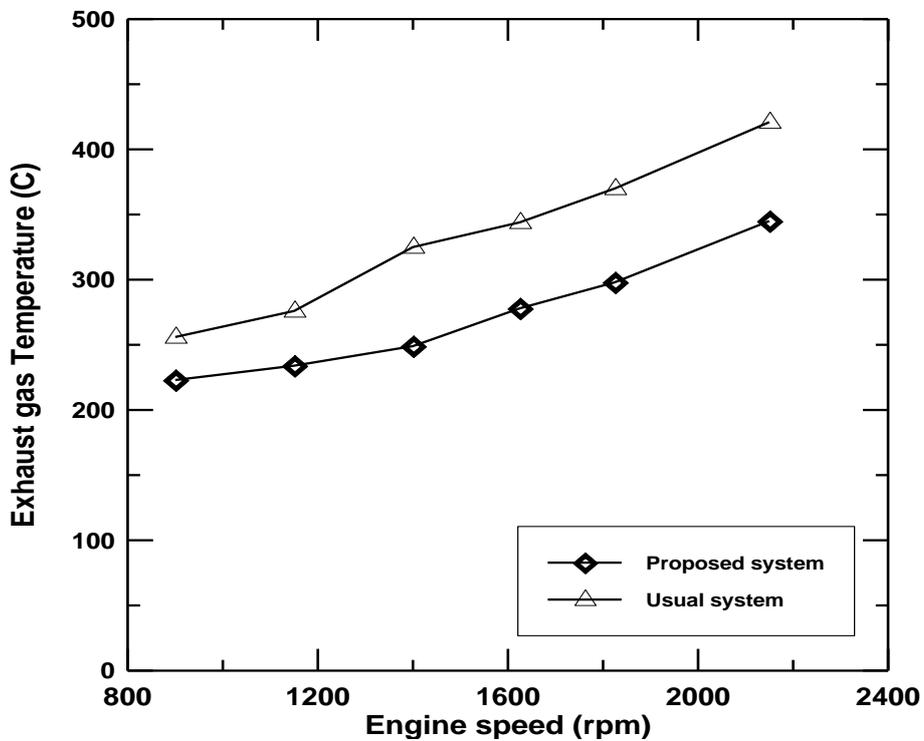


Figure (4.2): Diesel engine speed versus the exhaust gas temperature

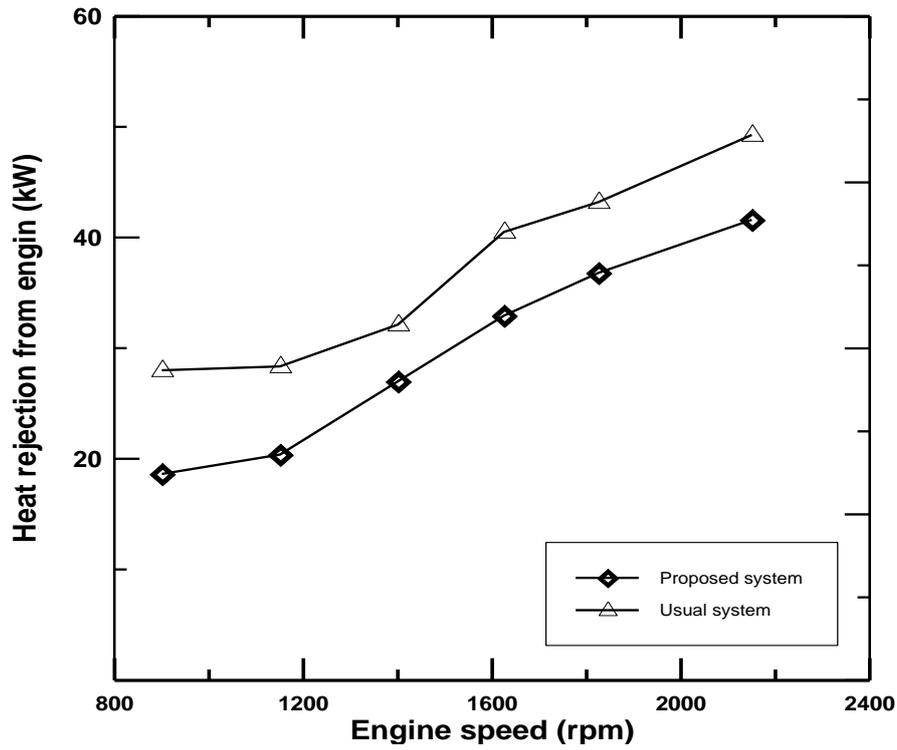


Figure (4.3): Diesel engine speed versus the heat rejection from engine.

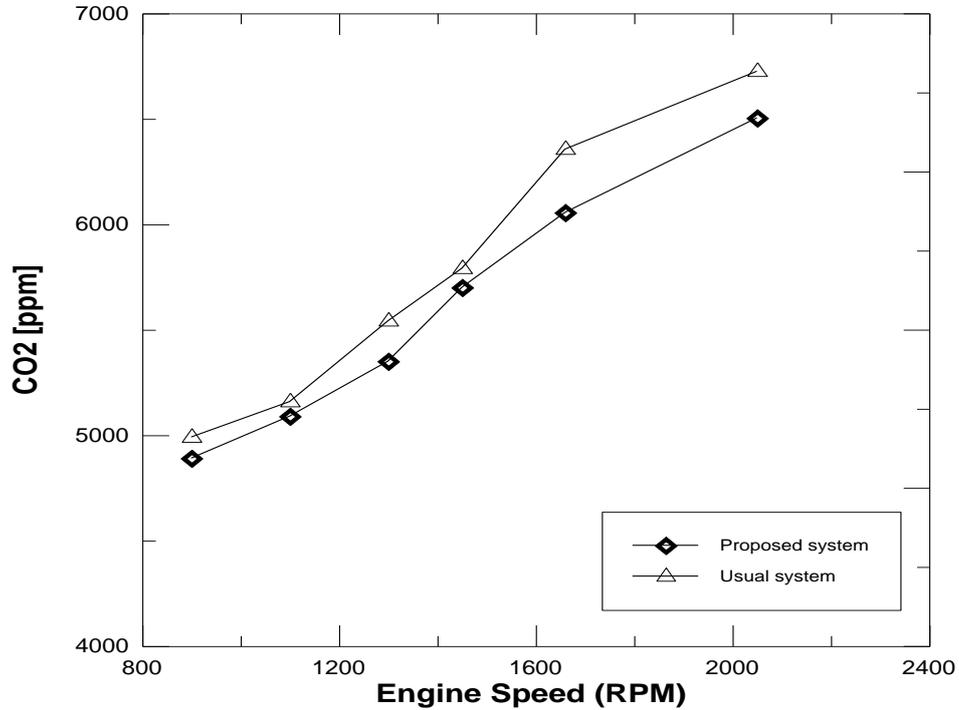


Figure (4.4): Diesel engine speed versus the CO2 emission.

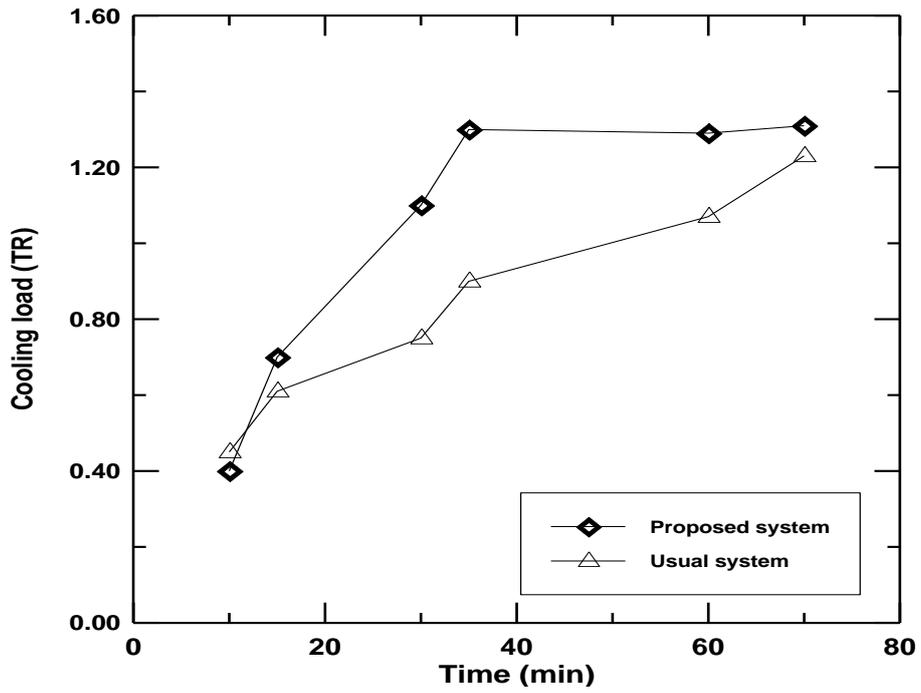


Figure (4.5): Cooling effect with time

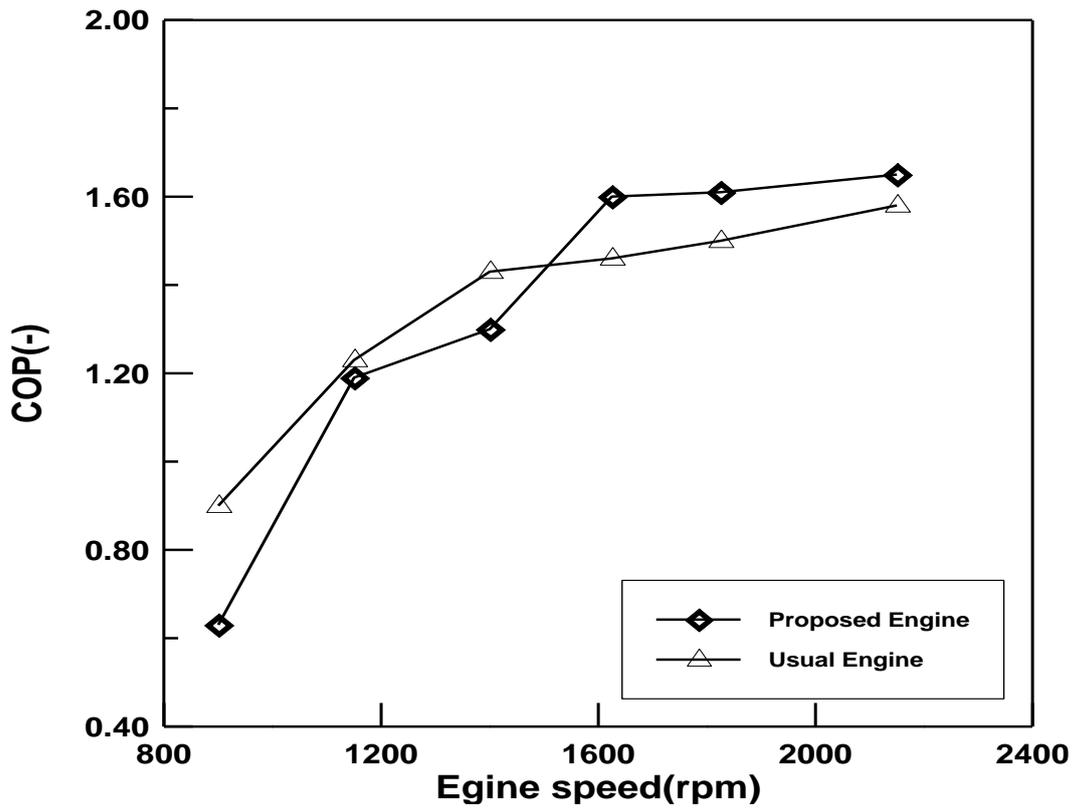


Figure (4.6): Diesel engine speed as function for COP

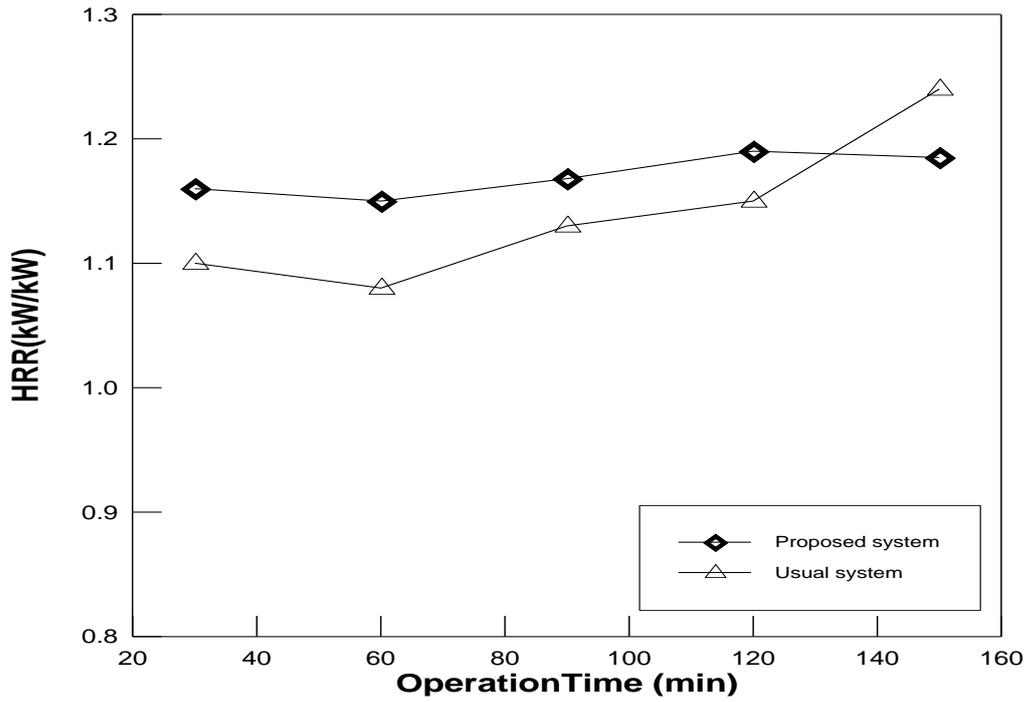


Figure (4.7): HRR with operation time

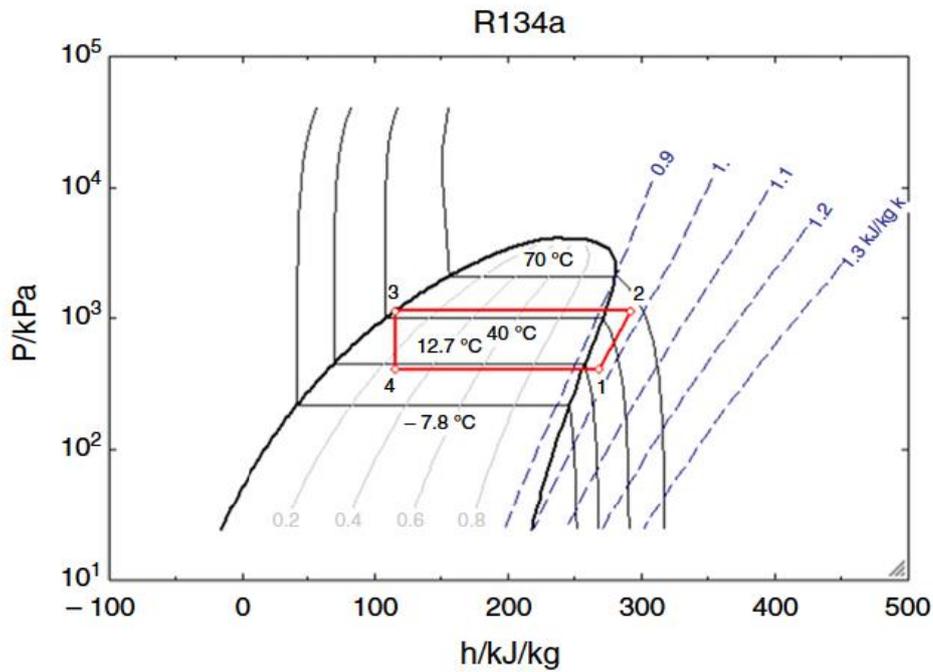


Figure (4.8): The P-H diagram of new cooling system

Chapter Five

Conclusions And

Recommendations

Chapter Five: Conclusions and Recommendations

5-1 Conclusions:

In this study, we exploit the energy of the exhaust gas that was previously wasted to generate enough electrical work to operate the cooling system of a car by converting the kinetic energy of the exhaust gas into electrical energy. This was done by connecting the exhaust of the Kia Carnival engine with the gas turbine on the one hand and connecting the gas turbine with the dynamo on the other side, meaning we converted the kinetic energy into electrical work. The traditional air cooling system has also been operated through the electrical work produced by the dynamo after it is connected to an electric compressor. An inverter is used to change the phase of the current from DC to AC. The exhaust gas recycling process has been utilized as follows:

- 1- Generating electrical energy and using it for different purposes
- 2- Improving the thermal efficiency of the engine by reducing the load on the engine
- 3- A decrease in the fuel economy of a diesel engine to about 17%, and thus leads to the possibility of reducing emissions of harmful gases to the environment such as carbon monoxide, carbon dioxide, nitrogen oxides and others.
- 4- Improving the performance coefficient of the refrigeration cycle

5-2 Future Recommendations:

- 1- Using the scale of the exhaust gas analyzer (analyzer) to find out the concentrations of the various exhaust gases
- 2- Using a dynamometer scale to calculate the positional capacity of the engine and thus calculate the thermal efficiency of the engine.
- 3- Using exhaust gases for heating purposes.

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2 Appendix (A) Measurement and calibration equipment



Figure 1 Calibration Certificate of all instruments from **Lutron company** such as Thermometer and thermocouples.

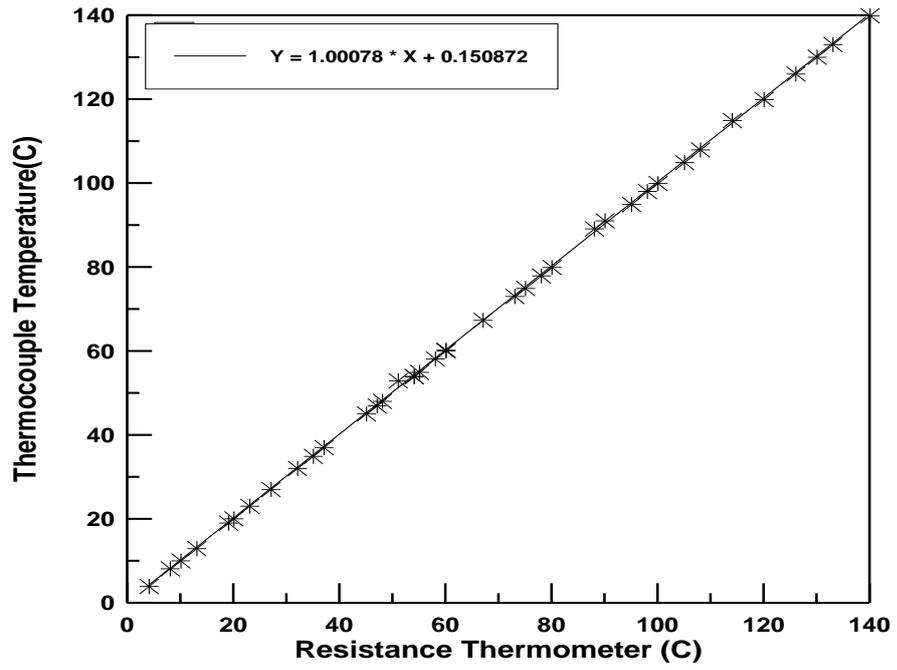


Figure 2 Thermocouple Calibration Results

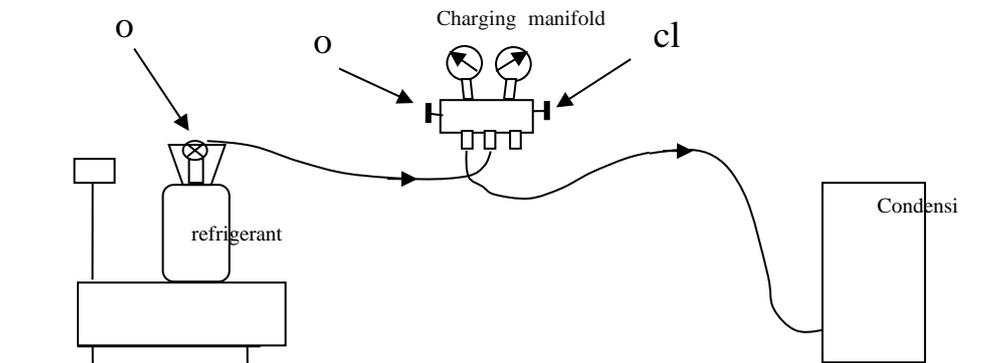


Figure 3. System charging

الخلاصة

في أيامنا هذه ، يتم تشغيل جميع أنظمة تكييف هواء السيارات تقريبًا بواسطة نظام ضغط البخار التقليدي (VCR) الذي يضيف المزيد من الحمل على المحرك ، ويستهلك المزيد من الوقود ويقلل من كفاءة المحرك. ان الهدف الاساسي لهذا المشروع هو تصميم منظومة تكييف هواء سيارة نوع كيا مزودة بضغط كهربائي بسعة 2 كيلو وات تعمل من خلال استعادة الحرارة المهدرة من غازات عادم. وبمعنى اخر, اننا قمنا بتحويل الطاقة الحركية لغازات العادم الى طاقة كهربائية عن طريق ربط عادم المحرك مع التوربين الغازي لتوليد عزم دوران ينقل الى الدينامو وبالتالي يتولد تيار كهربائي مستمر. وهذه العملية تحتاج عاكسة قدرة لتغيير طور من التيار المستمر المتولد من الدينامو الى التيار متناوب لتشغيل الضاغط الكهربائي لمنظومة التبريد. ومن خلال هذا التصميم تم استثمار طاقة المتولدة بسبب تمدد غاز العادم لتدوير ريش التوربين الذي يقود الدينامو لتوليد الطاقة الكهربائية. تم تنفيذ الأعمال التجريبية باستخدام محرك الديزل رباعي الأسطوانات Kia carnival و المحاكاة المحرك تمت باستخدام Diesel-RK بسرعة محرك متغيرة. أظهرت النتائج تحسن كفاءة المحرك من خلال عامل انخفاض في عدة متغيرات مثل معدل استهلاك الوقود ، ودرجة حرارة غازات العادم ، وكمية الحرارة المنبعثة من المحرك بنحو 4.4% ، 10.1% و 18% على التوالي عند سرعة المحرك 1600 دورة في الدقيقة. من ناحية أخرى . كما أظهرت النتائج أيضًا أن معامل الأداء لنظام التبريد المقترح يزيد بنحو 3.7% إذا ما قورن بنظام التبريد التقليدي. وبناء على هذه النتائج فأنا استطعنا إيجاد حل لمشاكل هدر الطاقة لنظام تكييف الهواء في سيارة يعمل بدورة انضغاط البخار.



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دراسة تجريبية لإعادة تدوير غازات العادم لأغراض التبريد

بحث

مقدمة إلى كلية الهندسة – جامعة بابل وهي جزء من متطلبات نيل درجة الدبلوم
العالي في الهندسة / الهندسة الميكانيكية/ وقود وطاقة

أعدت بواسطة

درغام علي كريم

المشرف من قبل

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