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Refrigeration Effect using Waste Heat Recovery from Vehicles

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Abstract*— The internal combustion engine was a dominant prime mover in the current world with a disadvantage of lower efficiency and higher emissions. Major developments are going to increase the efficiency of the engine and reduce emissions. This project is conducted to improve the efficiency indirectly by recovering the waste heat from the exhaust of the vehicles. Nearly 80 percent of the heat is lost from the exhaust. The exhaust gases are expanded through the gas turbine and this is utilized to run the dynamo and to produce the electrical power to run the VCR cycle. This waste heat is recovered to produce the refrigeration effect in the vehicle. This waste heat recovering system is equipped with the gas turbine in the dynamo set up to produce the electrical power by expanding the exhaust gas through the turbine and utilizing the electrical power to run the VCR system.

Index Terms*— Waste heat, Energy consumption, Refrigeration, VCR cycle

I. INTRODUCTION

The increasing demand for energy leads to the search for new sources or new methods to save it. Internal combustion engines are mostly based on fossil fuels and are widespread thermal engines with disadvantages of greater emissions and limited efficiency. Generally refrigerating systems within the vehicles work by utilizing the engine power this increases the fuel consumption and reduces the mileage of the vehicle. Similarly releasing heat into the atmosphere increases the temperature of the surroundings.

The utilization of waste heat from the vehicles overcomes both the problems i.e., fuel consumption and the temperature rise of the surroundings. Operating the auxiliary appliances of the vehicle by using the waste heat does not affect the engine's efficiency. Since the waste heat is utilized to operate the appliances less heat is released into the surroundings. In this project exhaust heat of the vehicle is used to run a vapor compression system to produce the refrigeration effect.

II. LITERATURE REVIEW

The potential of waste heat energy which is available in IC engines, in different industries like cement, lime, glass, etc. which can be utilized through the waste heat recovery system has been mentioned in earlier studies from the different heat rejection systems and different methods to utilize the waste heat has been clearly mentioned. A recent review on 2022 [6] has reviewed the heat recovery in both residential and industrial sectors and also reviewed the different alternative methodologies to recover the heat from the heat rejection appliances. The heat recovery from the organic Rankine cycle using various methods like thermoelectric generation, turbo compounding, etc. is reviewed. the multigrade waste heat of the IC engine could be efficiently recovered by a cascade organic Rankine cycle. (C-ORC) is mentioned in earlier studies [5]. However, the waste heat recovery using ORC has its own limitation due to selection in organic fluids, space constraints, etc. This is clearly discussed in other review papers in earlier studies [7]. But it has future scope since it can operate with even low, high, or medium temperatures heat sources which are discussed in the same paper [7].

The waste heat recovery for residential appliances has been conducted by Receiving the waste heat from condensers of the refrigerator and utilizing the heat for increasing the temperature of the chamber i.e., Heat oven [3]. The heat recovery techniques have been improved by utilizing new techniques like heat pipes [2]. Waste heat recovery from the vehicles has already been proposed and this method is used to produce the electrical power into mechanical power using the Rankine cycle. It is to recover the heat from the exhaust through the heat exchanger which acts as a boiler and expands the water to produce the power [1]. Similarly, at the same time exhaust waste heat is used to run vapor absorption refrigeration is also proposed in the earlier studies [1]. However, there were many problems in the conversion of waste heat to high-grade energy for utilization purposes which have been clearly studied [4]

III. EXPERIMENTAL SETUP

The experimental setup is used to recover the waste heat from the exhaust of vehicles and run the refrigerator. the setup consists of a turbocharger which works as expanding device and is used to produce mechanical power as shown

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below in fig 1&2. the hot gases at high temperature and pressure are allowed to pass through the turbocharger then these gases expand and produce the shaft power. the power is transmitted to the alternator through a belt and pulley transmission system. The alternator converts the mechanical power into electrical power with a constant output of 12v and some rated current. then this power is provided to the invertor which steps up the 12v alternator supply to 230v and converts the dc supply to ac supply. this ac supplies refrigerator to produce the refrigerating effect

This experimental setup is done to utilize the heat of the exhaust gases to run the vehicle refrigeration system without affecting the engine power. it is a feasible setup that will reduce the fuel consumption of vehicles and increase the vehicle's efficiency and alternatively reduce the global warming effect by emitting the low-temperature gases into the atmosphere.

FIG 1. Experimental setup of waste heat recovery

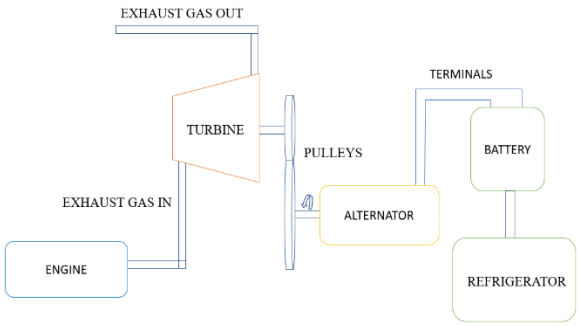

FIG 2. Schematic layout of the experimental setup

IV. DETAILS OF EXPERIMENTAL SETUP

1. Engine

The engine is the heat rejecting system. In this whole experimental setup, the engine converts the chemical energy to mechanical energy by producing an efficiency of 30% The remaining 60% of heat is being rejected into the atmosphere in various forms, and the majority of heat is rejected in the form of exhaust gases, i.e., around 30% of heat. The specifications of the engine being used in this experimental setup are given below in fig 3.

Engine specifications

TYPE	2-Stroke petrol engine (Air-cooled)
MAKE	Bajaj
RATED POWER OUTPUT	1.5 HP, 9000 RPM
BORE DIAMETER “D”	57
STROKE LENGTH “L”	57
COMPRESSION RATIO	7.4:1
STARTING	By kick/self-start
DIA OF ORIFICE	mm

FIG 3. Engine

2. Turbocharger

A turbocharger is connected to the exit of the engine as shown in fig 4. The hot gases with high temperature and pressure of nearly i.e., 4.2 bar passes through the turbine axially and leaves radially by producing mechanical power. After expansion, both the pressure and temperature of the gases are reduced and then left in the atmosphere. This mechanical power is then provided to the alternator through a belt and pulley transmission system.

FIG 4. Turbocharger

3. Alternator

The main function of an alternator is to convert mechanical energy into electrical energy. The high-speed turbine shaft is connected to the alternator shaft as shown below in fig 5, due to the high rpm it recharges the battery. It is provided with the voltage regulator and rectifier which helps in maintaining the voltage to 12v even if there is a variation in rpm of the turbine

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shaft. The setup uses Maruti 800 alternator with a 12v and 35amp to produce electric power.

FIG 5. Alternator

4. Battery

The battery is connected to the alternator output. It is used to store the power produced by the alternator and supply it to the invertor, As shown in fig 6. Here the battery stabilizes the voltage that keeps your engine running. The specification of the battery is a 12v and 60 amperes battery. It regulates the voltage supply.

FIG 6. 12v Battery

5. Refrigerator

A refrigerator is a final device where the power produced from the exhaust is utilized to produce the refrigeration effect. It consists of a compressor to which the electrical power is provided to perform the required function. A compressor is the main part of the refrigerator to produce a cooling effect. The cooling effect is produced in the evaporator part of the refrigerator. The specifications of the refrigerator used in the setup are 50 liters capacity and 100 watts.

V. REFRIGERANTS R134A

The refrigerant R134A is also named tetra fluoro ethane composed of 2 atoms of carbon, 2 atoms of hydrogen, and 4 atoms of fluorine. its molecular weight is 133.4 and its boiling weight is 15.1 deg F. chemical formula of R134A is CF3 CH2 F. R 134A does not have any ozone depletion potential and has few greenhouse effects. It is non-flammable and non-corrosive. It is an inert gas used primarily used as a high temp refrigerant for domestic refrigerants and automobile air conditioners. The temp raises between -22 to 202 deg F.

VI. RESULTS AND DISCUSSIONS

S. No	LOAD (kg)	AIR FLOW RATE	EXHAUST TEMPERATURE	SPEED OF TURBINE (rpm)	TIME TAKEN FOR 10ml FUEL CONSUMPTION IN sec	MASS FLOW RATE OF EXHAUST IN g/s
1	2.5	11.5	151	15333	42.98	3.539
2	5	11.5	197	23146	40.38	3.549
3	7.5	11.5	248	25048	38.30	3.559
4	10	11.1	311	27584	3.79	3.587

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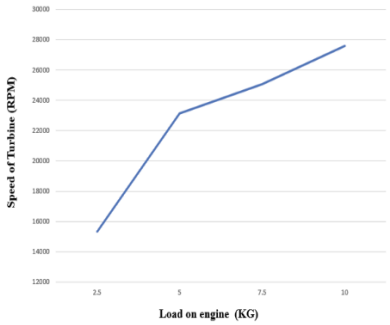

FIG 7. RPM vs LOAD

Fig 7 shows the variation of the speed of the turbine at the exhaust of the engine, with the change in the load, applied to the engine, as the load on the engine increases the speed of the turbine has increased.

Fig 8 shows the variation of the exhaust temperature of the gases with a change in the load of the engine. As the load is increased the temperature of exhaust gases are increasing. this exhaust temperature helps in increasing the rpm of the turbine

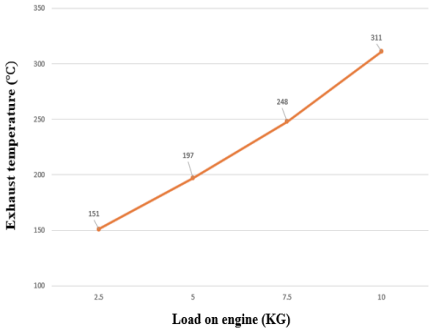

FIG 8. TEMP vs LOAD

VII. CONCLUSION

In this paper, the study and working of the refrigeration effect using waste heat recovery from vehicles mechanism led to the following conclusions.

- It has been seen that after research the efficiency of the vehicle has been increased by the heat recovery system.
- It reduces the fuel consumption of the vehicle by providing the power required to run the appliances of the vehicle from exhaust gases heat.
- This experiment shows that recovery of waste heat from the exhaust of a vehicle is used to run the refrigerator of 50 Watts capacity.

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