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Thermodynamic Analysis and Feasibility Study of Internal Combustion Engine Waste Heat Recovery to Run its Refrigeration System

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ABSTRACT: Automobiles refrigeration systems are mainly vapor compression refrigeration systems, and they use high power which is taken directly from the engine. The use of these systems will increase fuel consumption, and this fuel consumption will increase up to 15%. By considering the importance of fuel saving, optimum use of fuel will be necessary. One of the effective ways, is the waste heat recovery from the engine exhaust gas. The purpose of this study is the thermodynamic analysis of a new cogeneration system based on internal combustion engine. In fact, the system will generate power using heat recovery from exhaust the engine, and then the power will be used to run the refrigeration system. The system is used in the actual operating modes of gasoline and diesel engines. Different refrigerants are used in the system. Results show that the system can generate required refrigeration capacities of both automobiles and buses. Furthermore, additional refrigeration capacities will also be available. R245fa and R600 refrigerants have better performances in the system. Maximum refrigeration capacity generated by the system is 20 kW when using gasoline engine exhaust gases waste heat recovery, and 130 kW when using diesel engine exhaust gases waste heat recovery.

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1- Introduction

In internal combustion engines, a large portion of the fuel energy is wasted by the exhaust gases. Energy balance of fuel combustion in an automobile engine indicates that the portion of the fuel energy which is converted to the useful work is about on third, while the fuel remaining portion is wasted mainly through the radiator as well as the exhaust system [1]. Air condition systems in automobiles and buses are necessary for comfort of driver and passengers. Appropriate air condition system increases thermal comfort and improves drivers' performance as well as safety at high ambient temperatures [2].

Application of absorption refrigeration systems may not be appropriate in automobiles because they operate in two phases .The working conditions of these systems increase the need for maintenance and therefore, these systems will not be suitable for cars [3], or they may have low Coefficient of Performance (COP) [1].

Other refrigeration systems are organic Rankine vapor compression refrigeration systems and ejector refrigeration systems. To achieve higher coefficient of performances in these systems, high temperature heat sources are needed. Selecting appropriate refrigerants in these systems are important [3].

Automobiles air conditioning systems are mainly vapor compression refrigeration systems and they consume high axial power which is directly taken from engine. The use of these systems will increase fuel consumption. For both economic and environmental purposes, optimal use of fuel is necessary. One of the effective ways that can be suggested, is the engine exhaust gases waste heat recovery.

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Little and garimella [4] investigated the various ways of generating refrigeration capacity by using engine exhaust gases waste heat recovery. Wang et al. [5] examined a vapor compression refrigeration system with R245fa refrigerant, in which refrigeration and power cycles work independently. Wang et al. [6] studied the effects of different parameters on the coefficient performance of a refrigeration system with R245fa refrigerant. Jeong and Kang [7] studied an organic Rankine vapor compression refrigeration system, in which the needed power of the compressor is supplied by the Rankine cycle turbine. The results indicated that R245fa refrigerant had the best performance in system. Li et al. [8] investigated the effects of different refrigerants on the organic Rankine vapor compression refrigeration system and determined coefficient of performances on the basis of temperature changes in the heat exchangers. Wang et al. [9] reviewed application of the Rankine cycles to utilizing the engine exhaust gas. Yu et al. [10] utilized organic Rankine cycle for recovering the waste heat from diesel engine exhaust gas, and stated that by changing evaporating pressure, thermal efficiency of system can be increased up to 5.8%. Salek et al. [11] investigated on diesel engine exhaust gases waste heat recovery. They analyzed Rankine cycle and ammonia absorption refrigeration cycle which were coupled to the diesel engine. The results show the recovery of 10% of the engine power. Velez et al. [12] studied utilizing the organic Rankine cycle for producing power from the low temperature heat sources examining various working fluids. Tchanche et al. [13] reviewed various applications of organic Rankine cycles and assumed heat sources with temperatures lower than 230 ºC as low temperature heat sources. Shu et al. [14] stated that decomposition temperature of organic fluids in low temperature heat sources are about 200 - 300 ºC. Daviran