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Fluid Selection of Organic Rankine Cycle for Waste Heat Recovery from Engine Test Cell

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Abstract

In manufacturing an engine, it is needed to evaluate the engine performance. This is performed in test cell. During the test, a significant portion of fuel energy is wasted. In this work, an Organic Rankine Cycle (ORC) is used to produce electrical power from the waste heat of the engine test cell. To achieve the best results, different working fluids are examined in ORC and performance of the system is determined for each case from the energy and exergy viewpoints. Finally a parametric study is done to reveal the effects of some decision variables on the performance of the system. The results show that selection of different working fluids in ORC has considerable effect on energy and exergy performance of the system. It is concluded that, the system with R123 as a working fluid for the organic rankine cycle, has the highest work produced, among considered working fluids, whereas R11 results the highest energy and exergy efficiency for heat recovery process. Also, the results of parametric study reveal that, increasing evaporator temperature increases produced work and exergy efficiency while increasing condenser temperature, pinch point temperature difference in the evaporator and degree of superheat at ORC turbine inlet decreases produced work and exergy efficiency.

Keywords: energy, exergy, engine test cell, heat recovery, working fluid

Introduction

Reciprocating engines are frequently employed in low and medium power generation units. The lower and upper limits are often a function of the fuel in use; these can range from 50 kW to 10 MW for natural gas, from 50 kW to 50 MW for diesel, and 2.5 MW to 50 MW for heavy fuel oil. Compression ignition diesel engines are among the most efficient simple-cycle power generation options on the market. Efficiency levels increase with engine size and range from about 30% for small high speed diesels up to 42–48% for the large bore, slow speed engines. It is expected that efficiencies can improve to a 52% in the near future [1]. According to the studies presented, diesel engines are more efficient than the equivalent ones with gas turbines, since they have a higher electrical performance that is the most important parameter in the electricity production [2].

In manufacturing an engine, it is needed to test its performance. Test duration time is dependent to the engine power and application, as well as the kind of test. In an internal combustion engine, the output is not a big portion of fuel heat energy and the rest is wasted. Heat lost is due to exhaust coolant system, convection and radiation from engine and exhaust line. To improve the thermal efficiency and recover the heat energy of combustion products, an Organic Rankine Cycle (ORC) can be used.

In converting low and medium temperature thermal energy sources into electricity the Organic Rankine Cycle (ORC), among the bottoming cycles, shows some promising features. The interesting characteristics of working fluids used in the ORC (compared with water in Rankine cycle) such as having a relatively low enthalpy drop through the expander (higher mass flow rates) have made investigators to pay more attention on these cycles. Higher mass flow rate across the turbine, causes a reduced value of gap losses which in turn brings about a higher value of turbine adiabatic efficiency. The state of working fluids at the ORC turbine exit is mostly superheated vapor. This point avoids the drop erosion and allows a reliable operation and a fast start-up of the ORC cycle [3,4].

Many studies have investigated the ORC performances. Some works have been done to couple ORC to gasoline engines [5,6]. To couple ORC to diesel engines there was effort by Hountalas et al [7]. Also Zhang et al used a finned-tube evaporator to recover engine exhaust heat [8].

The second law of thermodynamics improves an energy assessment as it considers the true thermodynamic value of an energy carrier and the real thermodynamic inefficiencies in processes or systems. Exergy describes the thermodynamic quality of a given quantity of energy. Exergetic efficiency compares the actual performance of a system to the ideal one and exergy destruction measures the losses that hinder the performance [9].

In the present work, an Organic Rankine Cycle (ORC) is used to recover the waste heat from engine test cell. Work produced by ORC as well as exergy efficiencies and destructions are calculated for ORC components and entire cycle. To achieve the best results, different working fluids are examined in ORC and the results are compared. Finally a parametric study is performed to study effects of some important parameters of the heat recovery process such as evaporator temperature, condenser temperature, pinch point temperature difference in the evaporator and degree of the superheat at ORC turbine inlet on the work produced and exergy efficiency of the cycle.