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VIABLE COMBINED CYCLE DESIGN FOR AUTOMOTIVE APPLICATIONS

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ABSTRACT−A relatively new approach for improving fuel economy and automotive engine performance involves the use of automotive combined cycle generation technologies. The combined cycle generation, a process widely used in existing power plants, has become a viable option for automotive applications due to advances in materials science, nanotechnology, and MEMS (Mico-Electro Mechanical Systems) devices. The waste heat generated from automotive engine exhaust and coolant is a feasible heat source for a combined cycle generation system, which is basically a Rankine cycle in the context of this study. However, there are still numerous technical issues that need to be solved before the technology can be implemented in automobiles. A simulation was performed to examine the amount of waste energy that could be recovered through the use of a combined cycle system. A simulation model of the Rankine cycle was developed using Cycle-Tempo software. The simulation model was ultimately used to evaluate the rate of waste heat recovery and the consequential increase in the overall thermal efficiency of the engine with the combined cycle generation system under typical engine operating conditions. The most effective automotive combined cycle system recovered 68% of the waste heat from the exhaust and coolant, resulting in a 6% improvement in engine efficiency. The results are expected to be beneficial for evaluating the feasibility of combined cycle generation systems in automotive applications.

KEY WORDS : Combined cycle, Rankine cycle, Automotive engine, Heat recovery

1. INTRODUCTION

Skyrocketing fuel prices and stringent emission regulations have spurred auto manufacturers to develop automobiles with better fuel efficiencies and lower harmful engine-out emission levels. While remarkable progress has been achieved, such research has been somewhat biased toward an optimization of the combustion process or the injection system. It is generally known that the maximum thermal efficiency of an automotive engine is rarely above 40%. It has been assumed that further improvements in the thermal efficiency through optimization of the combustion process have reached a technical limit.

In recent research aimed at improving automotive energy efficiency, specific trends have emerged. One trend involves the development of electric hybrid cars. Research on hybrid automobiles is actively being cond-ucted by many automotive companies (Kim., 2000; Walters *et al*., 2001; Hirose *et al*., 2002; Liu *et al*., 2011; Shin *et al*., 2011; Suh *et al*., 2011; Wang and Luo, 2011; Kim *et al*., 2010). Another trend is the downsizing of the internal combustion engine, which is also considered to have great potential in improving the thermal efficiencies of engines (Hauet and Maroger, 2002; Zaccardi *et al*., 2009; Fraser *et al*., 2009; Lee *et al*., 2010; Park *et al*., 2010; Liu *et al*., 2010). A relatively new approach for improving the overall energy efficiency of vehicles is the implementation of the cogeneration concept (Ringler *et al*., 2009; Freymann *et al*., 2005; Endo *et al*., 2007; Kadota and Yamamoto, 2008). It has been noted that energy loss in modern engines may reach approximately 60%. Therefore, recovering heat waste through an exhaust and cooling circuit seems to be a very effective way to improve the overall thermal efficiency. While cogeneration systems have been successfully adopted in many power plants, there is a concern that such systems may be too large for use in automobiles. However, advances in materials science, nanotechnology, and MEMS devices have made cogeneration applicable in automobiles.

In a cogeneration system, waste energy may be recovered in three different ways: turbo compounding, thermo-electric conversion, or thermodynamic processing (e.g., the Rankine cycle) (Saqr *et al*., 2008). The Rankine steam cycle has exhibited better efficiency than both thermo-electric devices and turbo compounding, which utilizes the kinetic energy of the exhaust (Ringler *et al*., 2009). A cogeneration system may also be categorized in terms of whether the recovered energy is utilized as auxiliary power or as electricity. BMW proposed a system in which dual turbines in Rankine cycles are directly linked

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