Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-012-2359-0

Thermal Optimization of the Heat Exchanger in an Automotive Exhaust-Based Thermoelectric Generator

Y. D. DENG,[1] X. LIU,[1,2] S. CHEN,[1] and N. Q. TONG[1]

1.—Hubei Key Laboratory of Advanced Technology for Automotive Components, Automobile Engineering Institute, Wuhan University of Technology, 205 Luoshi Road, Hongshan District, Wuhan 430070, China. 2.—e-mail: csmy89@163.com

Recent advances in thermoelectric technologies have made exhaust-based thermoelectric generators (TEGs) promising to recover waste heat. The thermal performance of the heat exchanger in exhaust-based TEGs is studied in this work. In terms of interface temperature and thermal uniformity, the thermal characteristics of heat exchangers with different internal structures, lengths, and materials are discussed. Following computational fluid dynamics simulations, infrared experiments are carried out on a high-performance production engine with a dynamometer. Simulation and experimental results show that a plate-shaped heat exchanger made of brass with fishbone-shaped internal structure and length of 600 mm achieves a relatively ideal thermal performance, which is practically helpful to enhance the thermal performance of the TEG.

Key words: Automotive exhaust heat, thermoelectric generator, hot-side heat exchanger, CFD simulation, bench test

INTRODUCTION

In internal combustion engines, approximately 40% of the fuel energy is lost in exhaust gas.[1] As one way to recover waste heat, TEG technology has attracted considerable attention due to its few moving parts, low noise, zero emissions, zero fuel consumption, and clean energy production. Thermoelectric modules containing a large number of *n*-type and *p*-type semiconductors, arranged in couples, are clamped with sufficient compressive force between a heat exchanger connected to the exhaust pipe and cooling water tanks in an exhaust-based TEG. Exhaust gas flows into the heat exchanger through a bypass to provide a heat source. The cooling water is pumped into the water tanks to form the cold side. Then, electric power is generated due to the temperature difference between the two sides of the modules based on the Seebeck effect.[2–6] Schematic diagrams of two kinds of TEGs are shown in Fig. 1a, b.

Increase of the overall efficiency is the main target in any TEG design. This aim can be achieved by maintaining a sufficient temperature difference across the thermoelectric modules and reducing thermal losses through the system as a whole.[7] This paper presents analysis of the heat exchanger. Regardless of other conditions, such as exhaust condition, cooling condition, and clamping force, raising the interface temperature by improving the heat exchanger will significantly enhance the overall efficiency of the TEG.

A certain number of modules are sandwiched between the heat exchanger and water tanks with series–parallel connection with a constant force due to the limited area and performance available with a single module.[8] To take advantage of the electricity generation performance of each module, optimization of the thermal uniformity of the heat exchanger is also vital.

SIMULATION OF THE THERMAL FIELD OF THE HEAT EXCHANGER

Typical software for analyzing turbulent mechanics, i.e., computational fluid dynamics (CFD), was

(Received July 6, 2012; accepted November 8, 2012; published online December 11, 2012)