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Thermoelectric Generators for Automotive Waste Heat Recovery Systems Part II: Parametric Evaluation and Topological Studies

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A comprehensive numerical model has been proposed to model thermoelectric generators (TEGs) for automotive waste heat recovery. Details of the model and results from the analysis of General Motors' prototype TEG were described in part I of the study. In part II of this study, parametric evaluations are considered to assess the influence of heat exchanger, geometry, and thermoelectric module configurations to achieve optimization of the baseline model. The computational tool is also adapted to model other topologies such as transverse and circular configurations (hexagonal and cylindrical) maintaining the same volume as the baseline TEG. Performance analysis of these different topologies and parameters is presented and compared with the baseline design.

Key words: Thermoelectric generators, waste heat recovery, automotive exhaust, skutterudites

INTRODUCTION

In part I of this study, we developed a comprehensive model to analyze the performance of thermoelectric generators (TEGs) based on automotive exhaust gas as the heat source.[1] The model was then employed to assess the electric power generation of General Motors' prototype.[2,3] In the second part of the study, presented here, parametric evaluation of the baseline model is performed with the goal of achieving optimized configurations. Several other topologies are also discussed in detail.

Morelli[4] emphasized that internal finning and diffuser arrangements in the TEG system are important for minimizing the temperature difference between the hot gas and the hot side of the thermoelectric device. Hence, design of an efficient heat exchanger is key to enhance the heat transfer from the poorly conducting exhaust gas to the thermoelectric modules (TEMs) for improved electrical power generation. It is a known fact that the power-generating capacity of TEMs depends on the temperature difference across the junctions. Temperatures across the TEMs are found to drop considerably due to the rapid drop in the exhaust gas temperature as it advances along the length of the TEG. Skutterudites have high ZT at temperatures $>300°C$, hence the TEMs near the rear end of the TEG have low power output as a result of the much smaller temperature gradient across them as compared with modules at the leading edge of the system. On the other hand, TEMs based on bismuth telluride perform much better than skutterudites at lower temperatures ($T < 250°C$). Hence, using a hybrid configuration could help to increase the system's electrical power output for the given thermal profile inside the TEG. In addition to this arrangement, TEMs would perform better if they face the hottest temperatures inside the TEG. This could only be achieved with modifications of the TEG geometry. Crane et al.[5] described the evolution from planar topography of a TEG to a cylindrically shaped TEG during phases 3 and 4 of the BSST-led

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