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Two-Dimensional Thermal Resistance Analysis of a Waste Heat Recovery System with Thermoelectric Generators

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In this study, it is shown that two-dimensional (2D) thermal resistance analysis is a rapid and simple method to predict the power generated from a waste heat recovery system with thermoelectric generators (TEGs). Performance prediction is an important part of system design, generally being simulated by numerical methods with high accuracy but long computational duration. Use of the presented analysis saves much time relative to such numerical methods. The simple 2D model of the waste heat recovery system comprises three parts: a recovery chamber, the TEGs, and a cooling system. A fin-structured duct serves as a heat recovery chamber, to which were attached the hot sides of two TEGs; the cold sides were attached to a cooling system. The TEG module and duct had the same width. In the 2D analysis, unknown temperatures are located at the centroid of each cell into which the system is divided. The relations among the unknown temperatures of the cells are based on the principle of energy conservation and the definition of thermal resistance. The temperatures of the waste hot gas at the inlet and of the ambient fluid are known. With these boundary conditions, the unknown temperatures in the system become solvable, and the power generated by the TEGs can be predicted. Meanwhile, a three-dimensional (3D) model of the system was simulated in FloTHERM 9.2. The 3D numerical solution matched the solution of the 2D analysis within 10%.

Key words: Thermal resistance, waste heat recovery system, thermoelectric generator, modeling

INTRODUCTION

Thermoelectric generators (TEGs) have been studied for more than a century. In many applications, the TEG converts heat into electricity.[1–5] In the reported work on models of waste heat recovery systems, harvesting of energy from exhaust heat is emphasized. Computational methods and models of thermal resistance assist in analysis and improve performance.[6–9]

In the present work, a model of a waste heat recovery system was developed using two-dimensional thermal resistance analysis. This method helps to solve the temperature gradient of the TEG modules. The solutions enable performance estimates of waste heat recovery systems. The same systems were modeled using FloTHERM 9.2 software. The solutions of the thermal resistance model are compared with the results of simulations.

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TWO-DIMENSIONAL THERMAL RESISTANCE

The concept of 2D thermal resistance is based on one-dimensional (1D) thermal resistance. The thermal resistance circuit is an electrical analogy with heat transfer. The heat rate (Q) is analogous to the current flow in an electric circuit. The analog of the temperature difference (ΔT) is the voltage difference. In 1D thermal resistance analysis, the thermal resistance is defined as