Modeling and optimization of thermoelectric generator for waste heat recovery

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Abstract:

Tremendous energy is dissipated as waste heat during industrial process. Many waste heat recovery technologies have been proposed to recover those waste heat to energy. Among those waste heat recovery technology, thermoelectric generator (TEG) has its distinct advantage of directly converting heat into electricity and reliability, long lifetime, no moving parts and no gas emissions. The thermoelectric material has been investigated extensively in recent decades and the figure of merit *ZT* has been continuously enhanced. However, the thermoelectric module (TEM) and system development is rather stagnant and the overall efficiency is quite low for practical applications. This has raised urgent need for development of simulation and design tools of TEG.

Design and optimization relies on effective simulation tool development. However, the simulation of TEG (consists of TEM and HEX) is a complex problem as it involves thermo-electric coupling effect, solid state heat transfer and convective heat transfer as heat exchangers are usually adopted. To address this issue, the first part of this thesis proposes a numerical model to simulate the TEM and its heat transfer system. 3-D CFD model and 1-D numerical model are both developed and validated against experiments and the models prove to be accurate enough. After the numerical model is developed and validated by experiments, the optimization and design work is conducted on TEM and TEG.

Many previous optimization works assume fixed temperature boundary condition, but this assumption is only applicable to limited practical circumstance. The effect of different boundary condition is rarely investigated. This thesis investigated the effect of different type of boundary condition on the optimization of TEM and TEG, and it is found that the optimized geometry parameter, thermoelectric (TE) elements height, cross-section area vary significant significantly under different boundary condition assumption. With this finding, the TEM and HEX are optimized simultaneously by Taguchi method to take into consider the interactive effect in the last

part of this thesis. And the contribution of each factor to the power output variance are quantified.

This thesis provides a set of numerical models for TEG simulation, and optimization method by Taguchi method for preliminary design of TEG for waste heat recovery from exhaust gas. As low computation cost is required and the ability of consider different boundary conditions, the proposed model and optimization method can be generalized to a broad range of waste heat recovery applications.