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The Virtual Continuous TEG Model: Efficient Optimization of Thermogenerators

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Dimensioning a thermoelectric generator for vehicle applications poses major challenges. Besides the fundamental process of determining the layout, an optimization procedure is necessary to harness the maximum potential from a thermoelectric system under given boundary conditions. The thermal boundary conditions encountered in this application are not constant. In this context, a multichannel thermogenerator shows benefits by distributing individual mass flows in relation to the operating point maximizing power output across the entire range of operating points. The innovative approach underlying the continuous thermogenerator model supports the process of global optimization. The parameters to be optimized are configured as dimensionless variables. The model not only guarantees very short computation times but also maintains high quality. The optimization method is presented in detail using an example of searching for an optimum material layout, variable fin geometry, and variable leg height across and along the direction of gas flow. The materials or material combinations to be analyzed are lead and bismuth telluride. The heat exchanger has a reference geometry. The article describes the combination of dimensionless optimization parameters that provides the greatest increase in thermoelectric power output compared with the basic concept. The discussion concludes with a cost–benefit analysis of the measures chosen.

Key words: Continuous model, multichannel thermogenerator, optimization, thermoelectric material segmentation

Nomenclature

Ar	Ratio of cross-sectional area between n- and p-type legs
H'_x	Enthalpy flow in gas channel
I	Electrical current
l_s	Sum of length of TE-leg and the gap between the two legs
n_y	Number of pairs of TE-legs across the direction of gas flow
R_x	Total electrical resistance
dR_x	Differential electrical resistance
dQ'_{wallx}	Differential thermal flow into heat exchanger wall
dQ'_F	Differential Fourier flow
dQ'_J	Differential Joule flow
dQ'_P	Differential Peltier flow
P_{el}	Electrical power
dP_{el}	Differential electrical power
ΔP_{el}	Difference electrical power
qn, qp	Ratio of material segmentation of n- and p-legs
$R_{th,tot}$	Total thermal resistance
$R_{th,TE}$	Thermal resistance of thermoelectric material
r_{min}	Minimum value of optimization function
r_{max}	Maximum value of optimization function
r_0	Boundary value of optimization
s	Fin density
$T_{\mathrm{source}\ x}$	Temperature of heat source at inlet of heat exchanger
$T_{\mathrm{sink}\ x}$	Temperature of heat sink
T_{hx}	Temperature of hot surface of thermoelectric material along gas flow
T_{cx}	Temperature of cold surface of thermoelectric material along gas flow

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