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New Perspectives in Thermoelectric Energy Recovery System Design Optimization

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It is highly desirable to develop technologies that recover the large amounts of waste heat generated worldwide in industrial processes, automotive transportation, diesel engine exhaust, military generators, and incinerators to increase fuel efficiency and reduce CO_2 production and the environmental footprint of these applications. Recent work has investigated new thermoelectric (TE) materials and systems that can operate at higher performance levels and show a viable pathway to lightweight, small-form-factor, advanced thermoelectric generator (TEG) systems to recover waste heat in many of these applications. New TE materials include nanocomposite materials such as lead-antimony-silver-telluride (LAST) and lead-antimony-silver-tin-telluride (LASTT) compounds. These new materials have created opportunities for high-performance, segmented-element TE devices. New higher-performance TE devices segmenting LAST/LASTT materials with bismuth telluride have been designed and fabricated. Sectioned TEG systems using these new TE devices and materials have been designed. Integrated heat exchanger/TE device system analyses of sectioned TE system designs have been performed, creating unique efficiency–power maps that provide better understanding and comparisons of design tradeoffs and nominal and off-nominal system performance conditions. New design perspectives and mathematical foundations in optimization of sectioned TE design approaches are discussed that provide insight on how to optimize such sectioned TE systems. System performance analyses using ANSYS® TE modeling capabilities have integrated heat exchanger performance models with ANSYS® TE models to extend its analysis capabilities beyond simple constant hot-side and cold-side temperature conditions. Analysis results portray external resistance effects, matched load conditions, and maximum power versus maximum efficiency points simultaneously, and show that maximum TE power occurs at external resistances slightly greater than the TE module internal resistances in these systems. Mathematical relationships are given providing the foundation for this phenomenon.

Key words: Battery recharging, portable power, LAST/LASTT thermoelectric materials, thermoelectric system analysis

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Abbreviations

Variables

N	Number of TE couples
P_T	Total system power (W)
P_i	Power in section i of sectioned design (W)
$Q_{h,i}$	Hot-side heat transfer in section i