2014

Effect of Leg Geometries, Configurations, and Dimensions on Thermo-mechanical and Power-generation Performance of Thermoelectric Devices

Ugur Erturun
Virginia Commonwealth University

Effect of Leg Geometries, Configurations, and Dimensions on Thermo-mechanical and Power-generation Performance of Thermoelectric Devices

See Additional Files for entire dissertation

Author: Erturun, Ugur

Abstract:

Environmental challenges, such as global warming, growing demand on energy, and diminishing oil sources have accelerated research on alternative energy conversion methods. Thermoelectric power generation is a promising method to convert wasted heat energy into useful electrical energy form. A temperature gradient imposed on a thermoelectric device produces a Seebeck potential. However, this temperature gradient causes thermal stresses due to differential thermal expansions and mismatching of the bonded components of the device. Thermal stresses are critical for thermoelectric devices since they can generate failures, including dislocations, cracks, fatigue fractures, and even breakdown of the entire device. Decreases in power-generation performance and operation lifetime are major consequences of these failures. In order to minimize thermal stresses in the legs without affecting power-generation capabilities, this study concentrates on structural solutions. Thermoelectric devices with non-segmented and segmented legs were modeled. Specifically, the possible effect of various leg geometries, configurations, and dimensions were evaluated using finite-element and statistical methods. Significant changes in the magnitudes and distributions of thermal stresses occurred. Specifically, the maximum equivalent stresses in the rectangular-prism and cylindrical legs were 49.9 MPa and 43.3 MPa, respectively for the temperature gradient of 100ºC. By using cylindrical legs with modified dimensions, decreases in the maximum stresses in legs reached 21.2% without affecting power-generation performance. Moreover, the effect of leg dimensions and coaxial-leg configurations on power generation was significant; in contrast, various leg geometries and rotated-leg configurations had very limited affect. In particular, it was possible to increase power output from 20 mW to 65 mW by simply modifying leg widths and heights within the defined range. It should be noted, however, this modification also increased stress levels. It is concluded that leg geometries, configurations, and dimensions can be redesigned for improved durability and overall performance of thermoelectric devices.