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PROCEEDINGS

A Systematic Analysis of Fatigue Life and Comprehensive Performance of Flexible Wearable Thermoelectric Devices Subjected to Thermo-Mechanical Coupling

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ABSTRACT

In recent years, wearable technology has burst onto the scene as a game-changer, completely transforming multiple facets of our daily lives—from keeping tabs on our health to facilitating communication for staying connected. It has found its way into diverse fields such as healthcare, education, the military, engineering, and sports. However, a major challenge hindering the popularization of wearable devices is the need for a reliable power source. Conventional batteries, though widely used, have limitations, including the need for frequent recharging or replacement, which hinder the seamless integration of wearable technology into everyday life [1]. To address this challenge, researchers and engineers have turned to alternative power generation technologies, with wearable flexible thermoelectric generators (WFTEGs) emerging as a promising solution [2]. WFTEGs harness the temperature gradient between the body and the surrounding environment to generate electricity, offering a sustainable and potentially infinite power source for wearable devices [3]. However, the longevity of these devices is compromised by fatigue propagation in brittle thermoelectric materials due to internal cracks.

We present a three-dimensional (3D) numerical model of WFTEGs with through-thickness cracks, accounting for body heat and thermal contact resistance. The effects of flexible substrate thickness, heat sink convection coefficient, and bending radius on the output power density, conversion efficiency, and fatigue life of WFTEGs are comprehensively examined. The results reveal that although increased body heat enhances thermoelectric performance, it simultaneously reduces fatigue life. Removing the cold-end flexible substrate and utilizing an efficient heat sink can improve both thermoelectric performance and fatigue life. Interestingly, the fatigue life initially decreases but then increases as the bending radius decreases, which is attributed to the crack closure effect on fatigue crack propagation. To prevent accelerated fatigue and optimize device durability, environments with a bending radius of approximately 14.33 mm should be avoided. These findings provide valuable insights into the structural optimization of WFTEGs, ensuring their long-term reliability and safety.

KEYWORDS

Thermomechanical load; thermoelectric performance; fatigue life; through-thickness cracks; wearable flexible thermoelectric generators

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