complete title

subtitle

name
Supervised by Prof. XXX

Your Institution

March 21, 2025

What's & Why STEG?

- Thermoelectric materials often perform suboptimally in wide temperature range applications;
- STEG can enhance overall performance.

Figure 1: (a) STEG structure; (b) Dependence of thermoelectric figure of merit on temperature for different materials.

What's Machine Learning (ML)?

- ML is essentially a mathematical model that reflects the mapping relationship between inputs and outputs;
- The mapping relationship needs to be determined through training on large datasets.

Figure 2: Common basic machine learning models. (a) Decision tree model; (b) Artificial neural network model.

What's Evolutionary Computation (EC)?

- EC solves optimization problems by mimicking natural behaviors;
- EC + ML, using pre-trained surrogate models for evolution.

Figure 3: Applications of evolutionary computation. (a) Particle swarm optimization for drone trajectory optimization (Int. J. Aerosp. Eng. 2020.1 (2020): 8820284.); (b) Genetic algorithm for constructing multi-objective optimization Pareto front. (`https://github.com/Bin-Cao/Bgolearn`)

Optimization Analysis of Segmented Thermoelectric Generator Based on Genetic Algorithm

Innovations

1. Developed an optimization method based on genetic algorithms for STEG.
2. Selected thermoelectric materials based on compatibility factors.
3. The integral optimization of the P-segment TEG is performed by GA.
4. The conversion efficiency and power output of STEG are significantly improved.

Numerical Model & Solution Method

Figure 4: Numerical Model

- **Discrete Control Equation:**

$$K_j^i\left(T_j^{i-1}-T_j^i\right)-K_j^{i+1}\left(T_j^i-T_j^{i+1}\right)$$
$$+IT_j^i\left(\alpha_j^i-\alpha_j^{i+1}\right)+\frac{1}{2}I^2\left(R_j^i+R_j^{i+1}\right) \quad (1)$$
$$=0$$

- **Thermoelectric Characteristics:**

$$K_j^i=\frac{A_j}{L_j^i}\cdot\frac{\lambda_j\left(T_j^{i-1}\right)+\lambda_j\left(T_j^i\right)}{2} \quad (2)$$

$$\alpha_j^i=\frac{\alpha_j\left(T_j^{i-1}\right)+\alpha_j\left(T_j^i\right)}{2} \quad (3)$$

$$R_j^i=\frac{L_j^i}{2A_j}\cdot\left[\rho_j\left(T_j^{i-1}\right)+\rho\left(T_j^i\right)\right] \quad (4)$$

1. Background
2. Renew. Energy, 2020, 156: 710-718.
3. **Energy, 2018, 147: 1060-1069.**
4. Appl. Energy, 2024, 355: 122216.
5. Discussion

STEG Optimization Design Based on 3D Numerical Simulation and Multi-objective Genetic Algorithm

Innovations

1. item 1
2. item 2

Plate-shaped STEG Structure and Parameters

Table 1: Model Parameters and Dimensions.

Parameter	Value	Unit
Total number of thermoelectric arms	N^2	1
Total number of thermoelectric pairs N_{par}	$\frac{N^2}{2}$	1
Arm-to-pair area ratio Y	Y	1
Substrate length $I_{substrate}$	40	mm
Thermoelectric arm length h_{eg}	3	mm
Cold end p-type dimensionless length $L_{p,c}$	$I_{p,c}/l_{leg}$	1
Cold end n-type dimensionless length $L_{n,c}$	$I_{n,c}/l_{leg}$	1
Hot end p-type dimensionless length $L_{p,h}$	$1 - L_{p,c}$	1
Hot end n-type dimensionless length $L_{n,h}$	$1 - L_{n,c}$	1
Thermoelectric arm width W_{TE}	$\frac{y \times I_{substrate}}{N}$	mm
Thermoelectric arm cross-sectional area A_{TE}	$W_{TE} \times W_{TE}$	mm^2
Semiconductor volume V	$N^2 \times A_{TE} \times h_{eg}$	mm^3

Figure 5: STEG Plate Module

Problem Description

Governing Equations: Theoretical Basis

1. Energy conservation:
$$\nabla \cdot \vec{q} = Q$$
2. Current continuity:
$$\nabla \cdot \vec{j} = 0$$
3. Thermoelectric constitutive equations:
$$\begin{cases} \vec{q} = -\lambda \nabla T + \alpha T \cdot \vec{j} \\ Q = -\nabla V \cdot \vec{j} \\ \vec{j} = -\sigma(\nabla V + \alpha \nabla T) \end{cases}$$

In the above equations, $\vec{q}$ is the heat flux vector, Q is the Joule heating source, $\vec{j}$ is the current density vector, λ is the thermal conductivity, α is the Seebeck coefficient, and σ is the electrical conductivity.

Objective Function: Algorithm Optimization

- The objective is to minimize the semiconductor volume and maximize the output power:

$$\begin{cases} J_1 = V' \\ J_2 = -P = -IV_{\text{module}} = -N_{\text{pair}} IV_{\text{pair}} \end{cases}$$

- Constraints:

$$\begin{cases} 0.1 \leq I \leq 5 \\ 20 \leq N \leq 50 \\ 0.3 \leq \gamma \leq 0.9 \\ 0.3 \leq L_{p,c} \leq 0.6 \\ 0.2 \leq L_{n,c} \leq 0.5 \\ P \geq 0 \\ T_{p,interface} \leq 550 \\ T_{n,interface} \leq 500 \end{cases}$$

Optimization Results

Figure 6: Using TOPSIS to determine the most feasible TEG design from the candidate options. This TEG surpasses traditional TEGs in terms of (b) thermoelectric performance, (c) output voltage and current, and (d) output power and conversion efficiency.

Currently the GOAT

Innovations

1. item 1
2. item 2

COMSOL-Multiphysics Simulation Data Generation

Table 2: Input Parameter Ranges and Other Geometric Values

Parameter	Symbol	Value	Unit
Total length of TE legs	L	10	mm
Length of each p-type segment	L_i^P	$0.1 - 9.7$	mm
Length of each n-type segment	L_k^N	$0.1 - 9.7$	mm
Height of alumina	$l_{Al_2O_3}$	1	mm
Height of copper electrode	l_{Cu}	1	mm
Radius of external load resistance	r	1.5	mm
Length of horizontal rods	l	8	mm
External load resistivity	ρ	$10^{-7} - 10^{-2}$	Ωm
Area of TE legs	A	3×3	mm^2

Summary

1. item 1
2. item 2

Insights

1. item 1
2. item 2
3. item 3

Thanks!