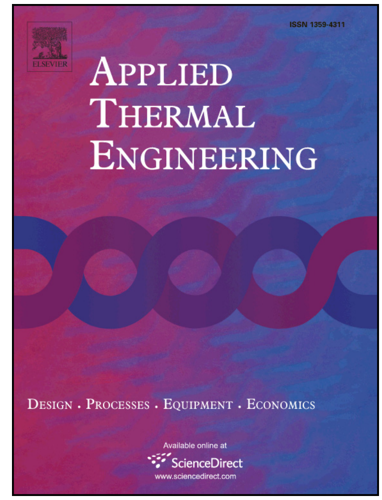

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J.L. Pérez-Aparicio, R. Palma, P. Moreno-Navarro

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J.L. Pérez-Aparicio*[a], R. Palma[b], P. Moreno-Navarro[a]

[a]*Department of Continuum Mechanics & Theory of Structures, Universitat Politècnica de València, Spain*
[b]*Department of Mechanical Engineering & Construction, Universitat Jaume I, Castellón de la Plana, Spain*

Abstract

This paper presents a numerical study on the influence of pulsed electric signals applied to the overcooling of thermoelectric devices. To this end, an experimental setup taken from the literature and a commercial cell are simulated using a complete, specially developed research finite element code. The electro-thermal coupling is extended to include the elastic field, demonstrating that the increment of cooling can produce mechanical failure. Numerical results are developed and the variation of overcooling versus pulse gain and versus duration is validated towards a new analytical expression and the experimental data. The issue of optimal intensity at steady-state is also newly developed. Thermal and mechanical trends are presented using constant and variable (with temperature) material properties for a single thermoelement. While some of the first trends are similar to those of published works, others are different or directly new, all closer to those of the experiments. The mechanical results have not been thoroughly studied until recently. The three-dimensional finite element mesh includes non-thermoelectric materials that are fundamental for the current study. Distribution of stresses during steady and transient states are shown inside the thermoelement, for five components and for the combined Tresca stress. Concentrations at corners of the lower side appear close to the cold face. Due to these concentrations, 27-node isoparametric, quadratic brick elements are used. It is shown that the mechanical field is an important factor in the design of pulsed thermoelectrics, since for practical applications the stress levels are close or slightly above the admissible limits.

Keywords: Pulsed thermoelectric materials, Joule, Peltier, Thomson, Thermal stresses, Dynamic analytical solution, Optimal intensity, Stress distributions

1. Nomenclature

l	Length	m
ρ	Mass density	kg/m^3
c_p	Specific heat	J/kg K
α_T	Thermal expansion coefficient	1/K
λ	Lamé's first parameter	Pa
μ	Lamé's second parameter	Pa
κ	Thermal conductivity	W/K m
γ	Electric conductivity	A/V m
α	Seebeck coefficient	V/K
$\mathcal{T}$	Entry of tensor $\boldsymbol{T}$	Pa
x	Spatial coordinates	m
T	Temperature	°C
j	Entry of vector $\boldsymbol{j}$	A/m^2
V	Electric potential	V
I	Electric current	A
A	Cross-sectional area	m^2
P	Pulse gain	–
t	Time	s
Δ	Increment operator	–
$\boldsymbol{j}$	Electric flux	A/m^2
∇	Gradient operator	1/m
$\nabla\cdot$	Divergence operator	1/m
$\boldsymbol{q}$	Thermal flux	W/m^2
$\boldsymbol{T}$	Stress tensor	Pa
$\boldsymbol{C}$	Elasticity tensor	Pa
$\boldsymbol{S}$	Strain tensor	m/m
$\boldsymbol{\beta}$	Thermal stress tensor	Pa/K
$\boldsymbol{u}$	Mechanical displacements	m
$\boldsymbol{\mathcal{K}}$	Stiffness matrix	
$\boldsymbol{C}$	Damping matrix	
$\boldsymbol{\mathcal{M}}$	Mass matrix	
c	Integration constant	
$\boldsymbol{0}$	Null vector	
Q	Thermal power	W
Z	Figure of merit	1/K
s	Laplace frequency	1/s