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Computational model for refrigerators based on Peltier effect application

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Abstract

A computational model, which simulates thermal and electric performance of thermoelectric refrigerators, has been developed. This model solves the non-linear system that is made up of the thermoelectric equations and the heat conduction equations providing values for temperature, electric consumption, heat flow and coefficient of performance of the refrigerator. Finite differences method is used in order to solve the system and also semi empirical expressions for convection coefficients.

Subsequently a thermoelectric refrigerator with an inner volume of 55×10^{-3} m^3 has been designed and tested, whose cold system is composed of a Peltier pellet (50 W of maximum power) and a fan of 2 W. An experimental analysis of its performance in different conditions has been carried out with this prototype, which, in his turn, has been useful for assessing the accuracy of the developed model. The built thermoelectric refrigerator prototype, offers advantages with respect to vapour compression classical technology such as: a more ecological system, more silent and robust and more precise in the control of temperatures which make it suitable for camping vehicles, buses, special transports for electro medicine, etc.

Keywords: Thermoelectricity; Simulation; Refrigeration; Peltier

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Nomenclature

A_{taco}	heat extender transversal area (m^2)
$A_{ais\,inter}$	insulation area that separates both cold and hot sides (m^2)
C	calorific capacity (W/s K)
COP	coefficient of performance
c_p	specific heat at constant pressure (J/kg K)
E	voltage difference (V)
e	insulation thickness (m)
E_{AB}	Seebeck electromotive force (V)
h_{int}	convective heat transfer coefficient for the inside (W/m^2 K)
h_{ext}	convective heat transfer coefficient for the outside (W/m^2 K)
I	electric current (A)
J	current density (A)
k	thermal conductivity (W/mK)
k_{Al}	aluminium thermal conductivity (W/mK)
k_{ais}	insulator thermal conductivity (W/mK)
L	length (m)
L	length of heat extender (m)
Nu	Nusselt number
Pr	Prandtl number
$\dot{Q}$	heat flow per unit time, heating power (W)
$\dot{Q}_P$	Peltier heating power (W)
$\dot{Q}_H$	Peltier pellet hot side heat flow (W)
$\dot{Q}_C$	Peltier pellet cold side heat flow (W)
$\dot{q}_\sigma$	Thomson heat flow per unit volume (W/m^3)
$\dot{q}_J$	Joule heat generation per unit volume per unit time (W/m^3)
q^*	heat generation per unit volume per unit time (W/m^3)
R	thermal resistance (K/W)
R_{ais}	thermal resistance of the refrigerator insulation (K/W)
R_{taco}	thermal resistance of the heat extender (K/W)
R_p	thermal resistance of the Peltier pellet (K/W)
$R_{ais\,inter}$	thermal resistance of the insulator that separates both hot and cold dissipaters (K/W)
R_e	electric resistance (Ω)
Re	Reynolds number
S	surface (m^2)
T	absolute temperature (K)
t	temperature (°C)
T_{amb}	ambient temperature (K)
T_{dh}	hot side dissipater temperature (K)
T_{hp}	Peltier hot side temperature (K)