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Numerical Modeling of Combined Transient Radiation and Conduction Heat Transfer in Mineral Wool Insulations

S. Veisheh; A. Hakkaki-Fard

ABSTRACT

This article deals with numerical modeling of coupled heat conduction and radiation in glass wool and rock wool insulations in transient condition using semi-empirical parameters obtained from experimental results. In this research needed thermophysical and physical parameters for numerical model, such as: heat capacity, effective thermal conductivity, fiber's diameter, and apparent and solid density of these mineral wools are determined by experiments. Radiation heat transfer is modeled by direct simulation and applying Monte Carlo ray trace method; and the thermal conductivity due to air/solid conduction is determined by semi-empirical relation obtained by inverse parameter estimation method as well as experimental results. Radiation is coupled with conduction via heat source term in heat conduction equation. Code results are in a good agreement with experimental results.

KEYWORDS : Thermal insulation, mineral wool, numerical modeling, combined radiation and conduction.

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Cp-T

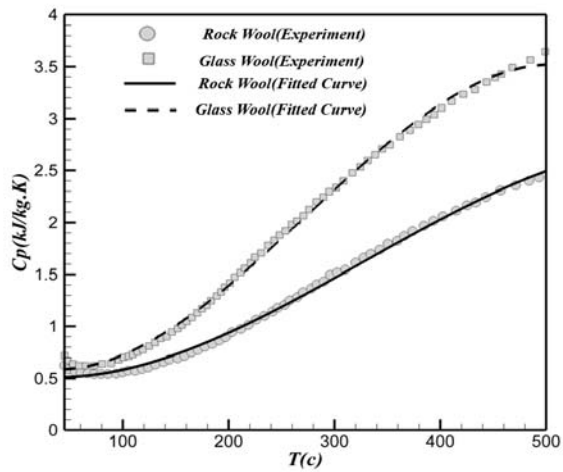
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$$C_p = 3.89 \times 10^{-5} T^3 + 3.34 \times 10^{-2} T^2 + 0.613 T + 501 \quad ()$$

$$C_p = 2.27 \times 10^{-5} T^3 + 2.23 \times 10^{-2} T^2 + 1.56 T + 540 \quad ()$$



$$k(T)$$

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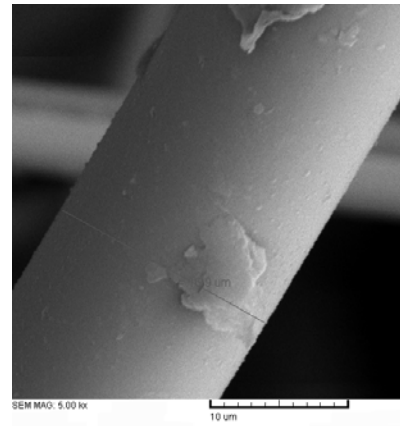
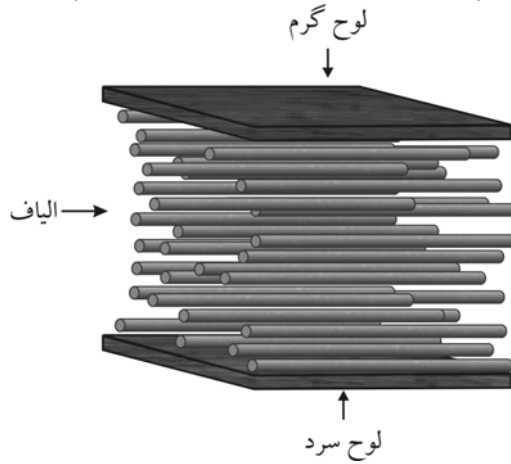
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$$k(T) = 10^{-3} (0.2274 T^{0.82} + 0.0523 \rho^{0.91} (1 + 0.0013 T)) \quad () \quad /$$

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$$k(T) = 10^{-3} (0.0620 T^{1.014} + 0.0572 \rho^{0.91} (1 + 0.0081 T) + 0.7171) \quad () \quad \pm$$



SEM

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T_C T_H

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$$(q_r)_i = \sigma(\varepsilon_H D_{H_i} T_H^4 - \varepsilon_i D_{H_i} T_i^4) + \sigma(\varepsilon_i D_{iC} T_i^4 - \varepsilon_C D_C T_C^4) + \sigma \sum_{j=1}^i (\varepsilon_j D_{ji} T_j^4 - \varepsilon_i D_{ij} T_i^4) + \sigma \sum_{j=i+1}^n (\varepsilon_i D_{ij} T_i^4 - \varepsilon_j D_{ji} T_j^4) \quad ()$$

D_{nm}

n

)

m

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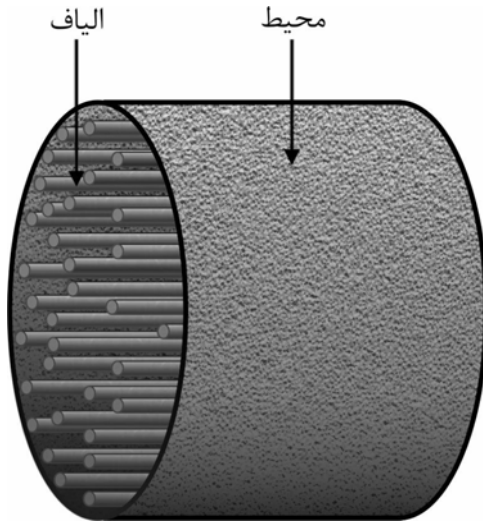
$$q_i = q_c + q_r \quad ()$$

$$\frac{\partial}{\partial x} \left(k(T) \frac{\partial T}{\partial x} \right) + \frac{dq_r}{dx} = \rho c_p(T) \frac{\partial T}{\partial t} \quad ()$$



(kg/m³)

(cm)



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$$\varepsilon_m A_m D_{mn} = \varepsilon_n A_n D_{nm} \quad ()$$

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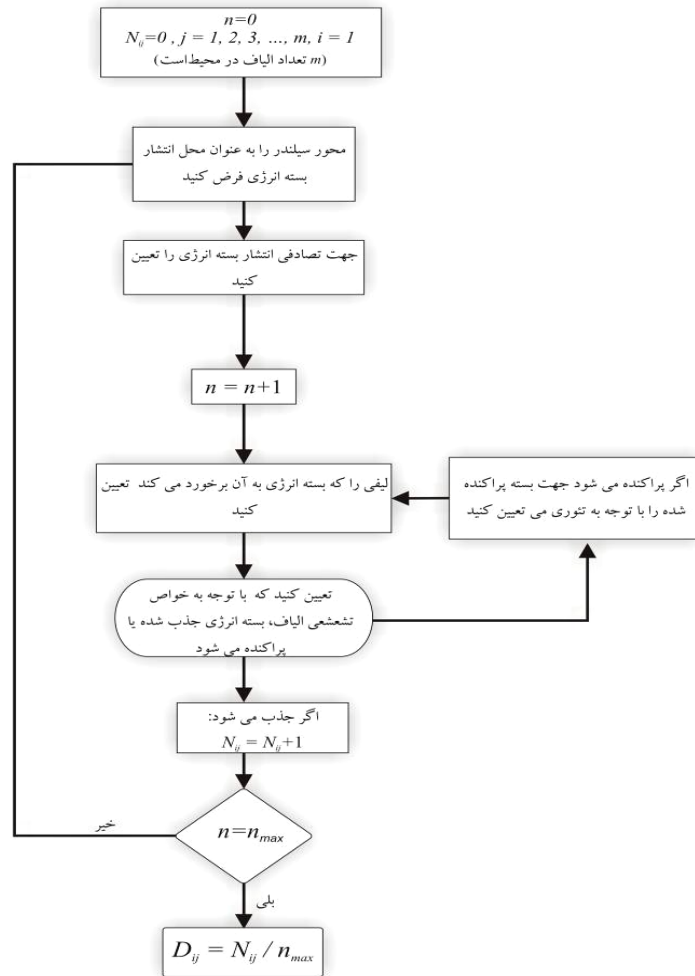
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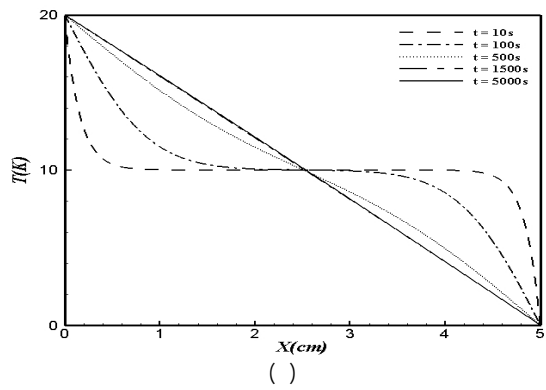
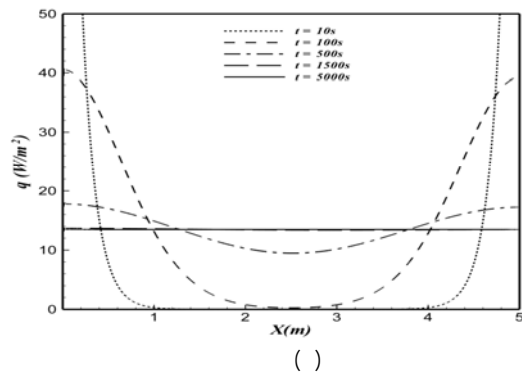
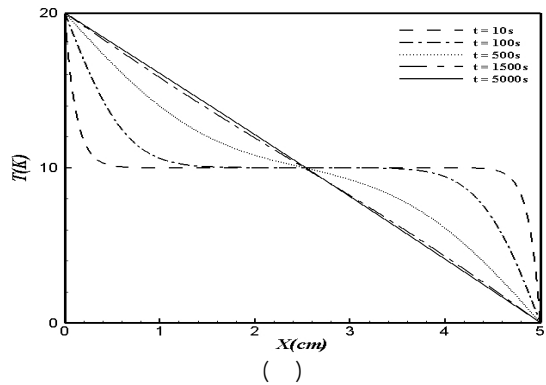
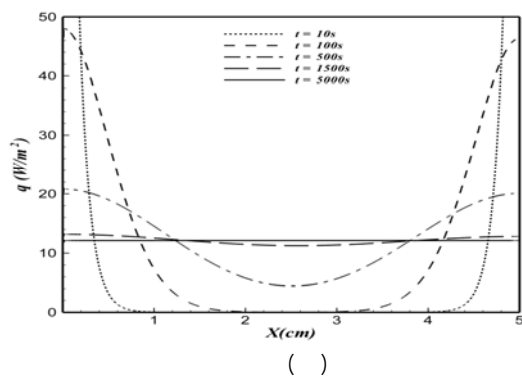
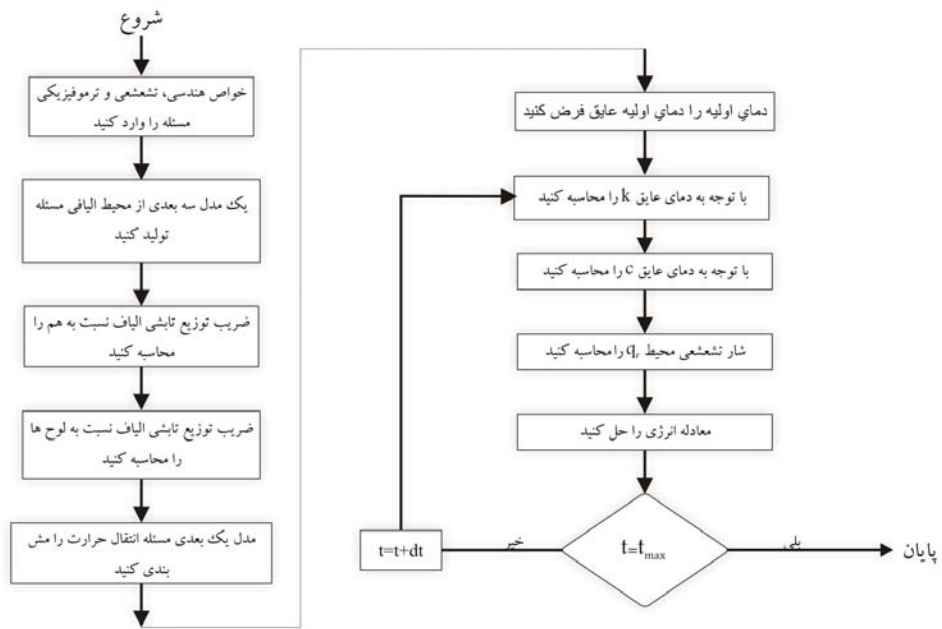
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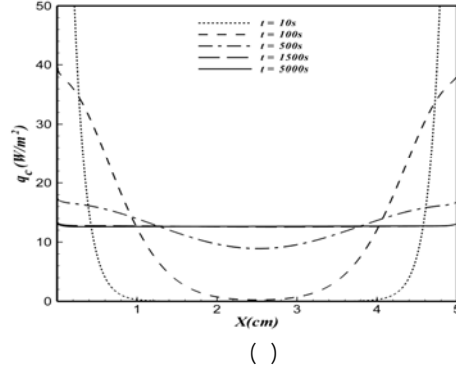
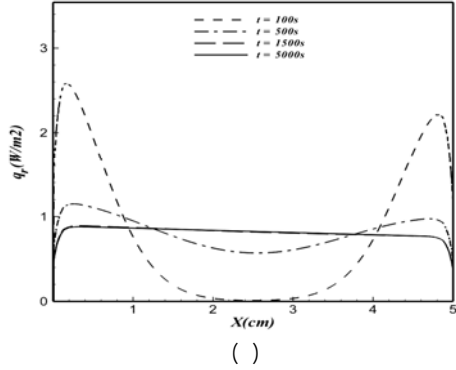
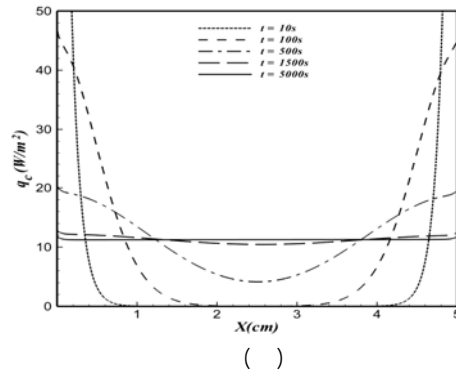
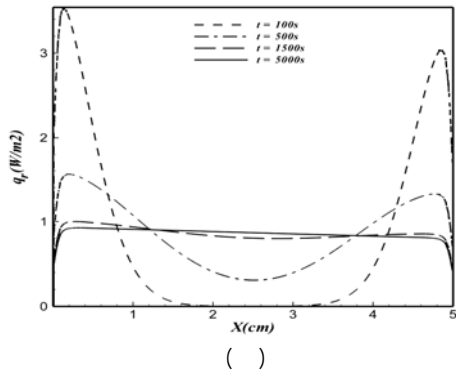
$$O[\Delta t, (\Delta x)^2]$$



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D_{mn}	
ϵ_H	
ϵ_C	
ϵ_i	
ρ	(kg/m^3)
σ	$(5.668 \times 10^{-8} W/m^2.K^4)$
C	
H	

C_p	(J/kgK)
d	(m)
k	$(W/m.K)$
q_t	(W/m^2)
q_c	(W/m^2)
q_r	(W/m^2)
T	(K)
t	s
x	(m)

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¹ HFM

² NETZSCH

³ Oxford Camscan MV 2300

