Short-Term Behavior and Steady-State Value of BHE Thermal Resistance

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Topic: A transient parametrical study of the grout thermal resistance of the BHE, *i.e.*, the resistance between the tubes and the ground, is performed through COMSOL Multiphysics®.

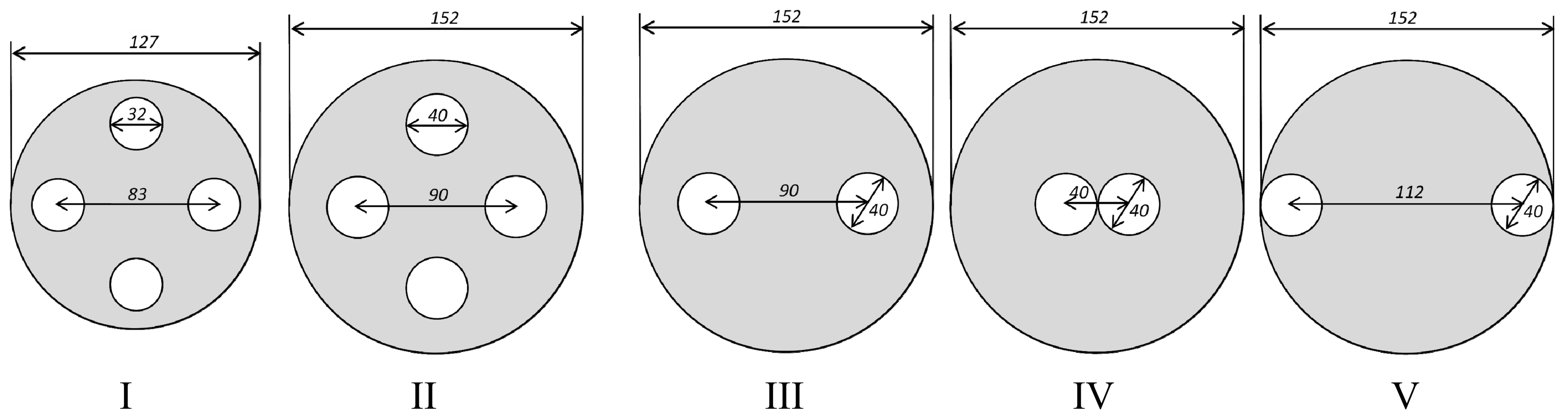

Figure 1. Double and single U-tube BHEs (lengths are in mm).

Numerical Model: Dimensionless transient heat transfer by conduction in BHE and surrounding ground.

Governing Eqs. Dimensionless quantities

$$\frac{\partial T^*}{\partial \tau^*} = \nabla^{*2} T^* \qquad T^* = k_g \frac{T - T_g}{Q_0}, \ \tau^* = Fo_D = \frac{k_g \tau}{(\rho c)_g D^2}$$

$$\frac{\partial T^*}{\partial \tau^*} = \frac{k^*}{(\rho c)^*} \nabla^{*2} T^* \qquad k^* = \frac{k_{gt}}{k_g}, \ (\rho c)^* = \frac{(\rho c)_{gt}}{(\rho c)_g}$$

B.C. and I.C.

$$-\left(\nabla^* T^* \cdot \mathbf{n}\right)\Big|_{S^*} = \frac{1}{4\pi k^* D_t^*} \qquad T^* = 0$$

Parameter values:
$k^* = 0.4, 0.7, 1.0$; $(\rho c)^* = 0.4, 0.7, 1.0$

The average dimensionless temperature at the interface tubes-grout (g-function g_{gt}) and that at the interface grout-ground (g-function g_b) are evaluated. Their difference $g_{Rgt} = g_{gt} - g_b$ is representative of the dimensionless grout thermal resistance per unit length.

Results: For a given value of k^*, in the short-term period as the value of $(\rho c)^*$ increases the value of g_{gt} decreases. On the contrary, as Fo_D increases, the curves approach and tend to a common value, which is a decreasing function of k^* (Fig.3, left).

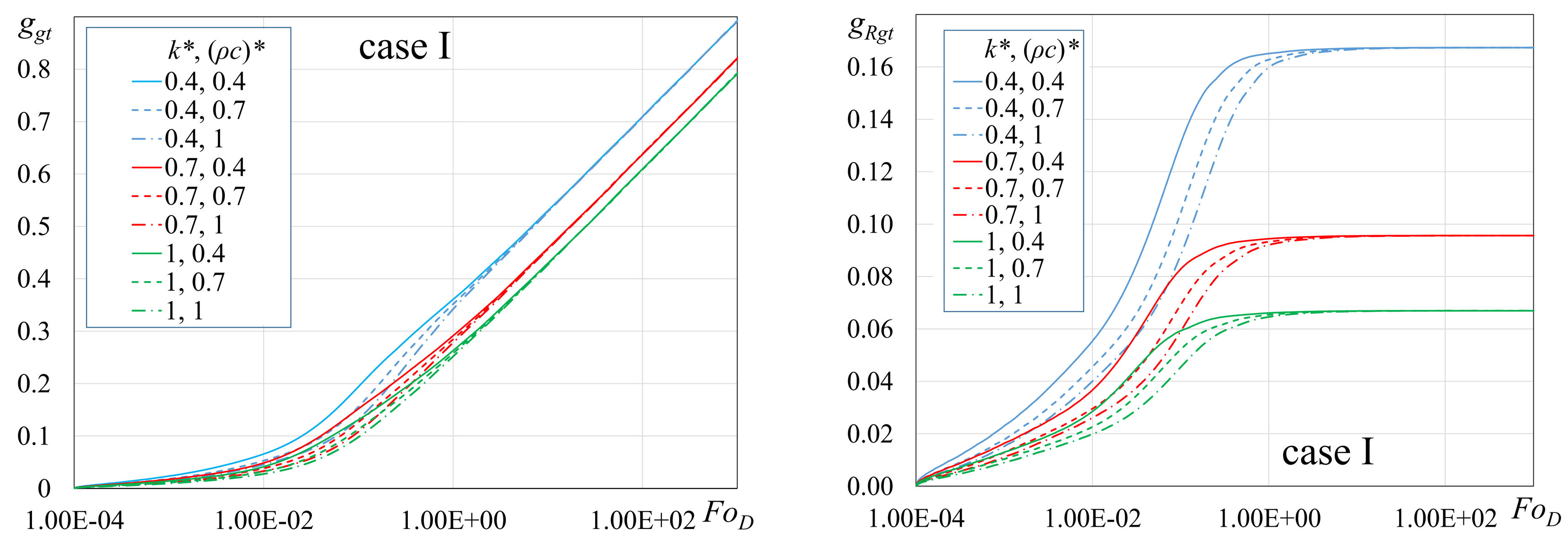

Figure 3. Plot of g_{Rgt} and g_{Rgt} as a function of Fo_D.

For given values of k^*, there exists a threshold value of Fo_D such that the curves become independent of both $(\rho c)^*$ and Fo_D: the corresponding value of g_{Rgt} represents the dimensionless steady-state grout thermal resistance per unit length (Fig.3, right).
The evaluation of all the contributions to the steady-state BHE thermal resistance shows that case I could perform better than case II.

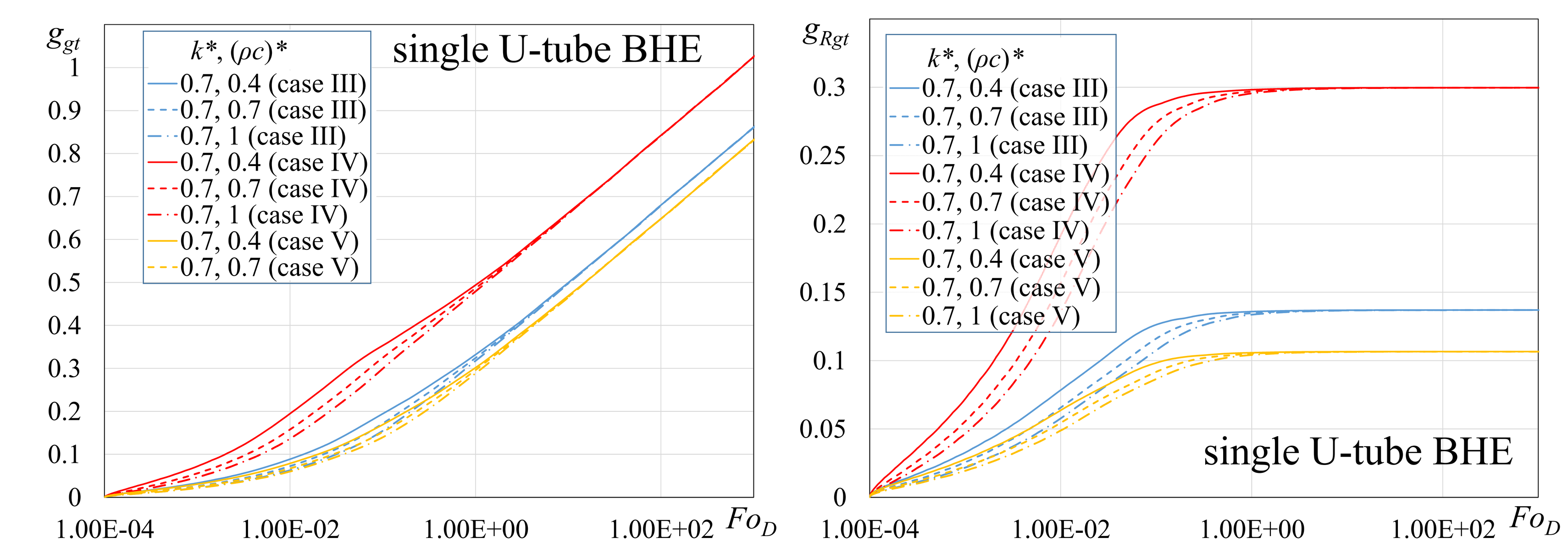

Figure 4. Plot of g_{Rgt} and g_{Rgt} as a function of Fo_D.

As the distance between the tubes increases, the dimensionless grout thermal resistance for unit length of a single U-tube BHE decreases (Fig.4).
A comparison with Paul's correlation

$$g_{Rgt} = R'_{gt} \cdot k_g = \frac{1}{k^* \cdot \beta_0 \left(1 / D_t^* \right)^{\beta_1}}$$

shows a sufficient agreement.

Conclusions: the pipe spacing and the heat capacity ratio play an important role in the transient behavior of the BHE internal resistance, whereas the pipe spacing and the conductivity ratio play an important role in the steady value of the BHE thermal resistance.