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Introduction of Anisotropic Heat Transfer Coefficient

Monday, 31 May 2021 16:40 (15 minutes)

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This presentation addresses heat transfer in porous media with the assumption of local thermal non equilibrium (LTNE). The macroscopic description makes use of a two-equation model featuring a heat transfer coefficient between the solid and fluid phases. This coefficient can be determined from direct pore-
scale numerical simulations by computing the ratio of the heat flux at the solid-fluid interface to the difference of the average temperatures [1]. When dealing with periodic materials, the resolution of the closure problems [2] obtained when using the volume averaging method can be considered for its evaluation. Both methods are widely used in the literature, but to our knowledge, no study has ever compared their predictions. For this reason, we have implemented both methods and applied them on basic periodic case where a creeping incompressible flow has been considered.

Results highlight two main facts. First, while the resolution of the closure problems provides a constant heat transfer coefficient, the method based on direct numerical simulations provides a time-varying coefficient that ends up to be equal to zero at steady-state. Special considerations are needed for a proper comparison of the two approaches. Second, as widely known, the heat transfer coefficient has shown to be a function of several parameters, mainly the Prandtl, Nusselt, and Biot numbers. The latter has been particularly investigated in this study by proposing a first analysis with homogeneous constant solid temperature and a second generic one with non-homogeneous and varying solid temperature.

Finally, the method based on direct numerical simulations is applied on a 3D CMT of Calcarb, a carbon fiber preform used as thermal protection in space vehicle heat shields. The results in terms of heat transfer coefficient are compared to experimental results obtained elsewhere [3].

The numerical framework developed during this study is made available in the Porous material Analysis

Toolbox based on OpenFoam (PATO) released Open Source by NASA [4] (www.pato.ac).

Time Block Preference

Time Block B (14:00-17:00 CET)

References

[1] F. Kuwahara, and M. Shirota, and A. Nakayama. A numerical study of interfacial convective heat transfer coefficient in two-energy equation model for convection in porous media. International journal of heat and mass transfer, 44(6):1153-1159, 2001.

[2] M. Quintard, and M. Kaviany, and S. Whitaker. Two-medium treatment of heat transfer in porous media: numerical results for effective properties. Advances in water resources, 20(2-3):77–94, 1997.

[3] L. Shaolin, and A. Ahmadi, and H. Scandelli, and C. Levet, and J. Lachaud. The Anisotropic Heat Transfer Coefficient in Carbon Fiber Felt. InterPore2021 Online Conference.

[4] J. Lachaud and N.N. Mansour. Porous-material Analysis Toolbox based on Openfoam and applications. Journal of Thermophysics and Heat Transfer, 28(2):191–202, 2014.

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