Identification of material characteristics in heat and mass transfer

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Computational analysis of direct problems of heat and mass transfer comes from the classical thermodynamics, namely from the principles of conservation of mass, (linear and angular) momentum and energy (or enthalpy), applied to one- or more-phase continua. The resulting system of partial differential equations of evolution, supplied by appropriate boundary and initial conditions, needs a set of material characteristics. The development of new materials, structures and technologies leads to functionally graded materials, controlled phase changes, etc., thus all identification problems for such characteristics are much more delicate as those assumed by the linearized Fourier, Fick, Hooke, etc. constitutive laws, not covered by the analysis of model problems by [2].

For certain class of problems of heat transfer at high temperature, occurring in the production of fire-clay bricks, as well as in the design of fiber-optic-based systems of heat production and storage, the analysis of direct problems can be done using [3], whereas the inverse analysis, including uncertainty considerations, brings non-trivial difficulties, as discussed in [5]. In this presentation we shall study a (formally similar) inverse problem of capillary liquid transfer through in porous building materials with some a priori knowledge of micro-structure.

The basic scalar quantity in this case is the mass fraction of the liquid phase. The crucial problem is the reliable identification of the capillary transfer coefficient in the generalized Fick law, a function of mass fraction again. The simplified approaches rely on very special geometrical configurations, as that (still used) by Matano (1933), applying the Boltzmann transform (1894). The development of non-destructive (but indirect) experimental techniques, e. g. the of microwave ones, has motivated the development of integral and variational approaches, as those based i) on Green functions and some facts from the theory of distribution ii) on special integration to derive an additional problem iii) on attempts to implement the method of Matano without Boltzmann transform, completed by some least squares (linear regression) considerations, by [4], or on double integration using parametric equations of iso-lines and iso-(hyper-) surfaces by [1]. This presentation aims to demonstrate a general variational source of all such approaches and introduce a new MATLAB-supported approach, validated with experimental data.

References

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