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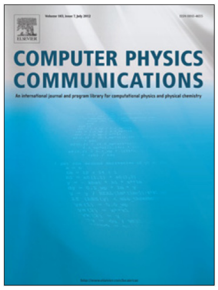

Time-dependent perfusion coefficient estimation in a bioheat transfer problem

Mansur I. Ismailov, Fermín S.V. Bazán, Luciano Bedin

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Time-dependent perfusion coefficient estimation in a bioheat transfer problem

Mansur I. Ismailov [*], Fermín S. V. Bazán [†] and Luciano Bedin[‡]

Abstract

We consider the estimation of the time-dependent blood perfusion coefficient in the Pennes bioheat equation with Ionkin-type nonlocal boundary and integral energy overdetermination conditions. In contrast to several methods that transform the original problem into an inverse source problem and then estimate the perfusion coefficient through numerical differentiation, we propose an alternative method in which the coefficient is estimated directly through a nonlinear minimization technique. In the method, the bioheat equation is solved by the method of lines based on an highly accurate pseudospectral approach, and perfusion coefficient values are estimated by the Levenberg-Marquard method with the discrepancy principle as stopping rule. Numerical examples are presented to verify the accuracy and stability of the solution.

Keywords: Pennes equation; Chebyshev pseudospectral methods; non linear least squares problems; Levenberg-Marquardt method.

1 Introduction

A bioheat transfer model of living tissues that take into account the blood perfusion along the vascular system and the metabolic heat generation was first introduced by Pennes [30]. Since then, there have been a renewed interest in the study of thermal tissues properties and various bioheat transfer equations with applications in distinct scenarios have been proposed. These include the Cattaneo-Vernotte equations [7, 10, 43], the dual-phase lag model of bioheat transfer [31, 36] and the Generalized dual-phase lag bioheat equation [48]. Additional bioheat transfer equations can be found in [5, 14, 18, 26, 32, 35, 45]. In this work, based on a parabolic heat conduction model, we concentrate on the determination of the blood perfusion coefficient (the coefficient of lowest term) under Ionkin-type nonlocal boundary and integral energy overdetermination conditions. Theoretical results regarding existence and uniqueness of solutions for this inverse problem for different boundary conditions and measurements are available in several works. For example, based on a series expansion method in terms of eigenfunctions of an appropriate Sturm-Liouville problem along with Gelfand-Levitan theory, the uniqueness of the space-dependent perfusion coefficient of a bioheat equation subjected to some classical boundary conditions and overdetermination conditions are derived in [39, 40]. However, extending these results to problems with nonclassical boundary conditions or overdetermination

*Department of Mathematics, Gebze Technical University, 41400 Gebze-Kocaeli, Turkey

†Department of Mathematics, Federal University of Santa Catarina, 88040-900, Florianópolis SC, Brazil, fermin@mtm.ufsc.br. The work of this author was supported by CNPq, Brazil, grant 477093/2011-6.

‡Department of Mathematics, Federal University of Santa Catarina, 88040-900, Florianópolis SC, Brazil, luciano.bedin@ufsc.br. The work of this author was supported by CNPq, Brazil, grant 477093/2011-6.