ANN based estimation of heat generation from multiple protruding heat sources on a vertical plate under conjugate mixed convection

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ABSTRACT

Inverse Heat Transfer Problems (IHTP) are characterized by estimation of unknown quantities by utilizing any given information of the system. In this study, the inverse problem of estimation of heat generation in multiple two dimensional protruding heat sources on a vertical plate, a geometry frequently encountered in the cooling of electronic equipment, is carried out from the information available on the temperature distribution on the substrate on which these sources are mounted. A non-iterative method is applied utilizing Artificial Neural Networks (ANN) and covariance analysis to estimate the heat generation in the protruding heat sources on a vertical plate. The forward model involving laminar, two dimensional, steady, incompressible fluid flow and mixed convection heat transfer is numerically solved with FLUENT 6.3 for known values of heat generation in the protruding sources and the temperature distribution thus obtained on the PCB substrate is utilized to train the ANN for the inverse model. Parametric studies are conducted on the forward model to investigate the effect of Richardson number, Reynolds number, the chip and substrate conductivities on the heat dissipation to the fluid flowing over the heat sources. The trained networks are finally used to estimate the heat generation from the sources for a given temperature distribution on the substrate wall generated, for known values of the heat generation rates, which serve as the “measured” temperature distribution. Use is made of covariance analysis in order to identify the important temperature locations sufficient to carry out the inverse analysis. Finally, a systematic investigation on the effect of noise in the temperature “measurements” on the estimates also has been carried out.

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1. Introduction

Space programs in the late 50’s and early 60’s have played an important role in the advancement of theory and application of Inverse Heat Transfer problems (IHTP) where the goal is the estimation of heat flux on the surface of the space vehicle during its return to atmosphere. This technique of estimation of unknown quantities from the information available has now become diversified. In general, inverse estimation is carried out when direct estimation is not feasible. Such techniques are also widely applied in an estimation of unknown boundary conditions, the geometric characteristics, initial conditions or the thermo-physical properties of the material or medium, from the available experimental data. Similarly, the thermo-physical properties of anisotropic materials vary with temperature and space and thus measurement of such properties under operating conditions becomes complicated and in some cases highly unsatisfactory if conventional methods are used. Inverse techniques greatly simplify such problems and yield satisfactory results.

Convection continues to occupy an important place in contemporary research in the thermal sciences. Heat treatment, electronic cooling, turbo-machinery and heat exchangers are a few applications where both natural and forced convection are important. Often due to complexity involved in the computations, it becomes increasingly difficult to analyze convection for complex geometries especially when an inverse solution is sought. Inverse convection problems generally involve estimation of inlet temperature profile in laminar flows, transient inlet temperature in laminar flows, axial variation of the wall heat flux and simultaneous estimation of space wise and time wise variations of the wall heat flux. Unlike conduction problems, the convection problems involve the highly non-linear and formidable Navier Stokes equations and the energy equation. Additionally, in natural convection problems the momentum and energy equations are coupled and invariably the Boussinesq approximation is invoked to model density.

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