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EXPERIMENTAL-THEORETICAL ANALYSIS OF CONJUGATED HEAT TRANSFER IN AERONAUTICAL SENSORS AND STRUCTURES WITH ANTI-ICING SYSTEMS

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Abstract

The present lecture reviews theoretical-experimental studies undertaken at COPPE/UFRJ on conjugated heat transfer problems associated with the transient thermal behavior of heated aeronautical Pitot tubes and wing sections with anti-icing systems. The experimental analysis includes flight tests validation with the military aircraft A4 Skyhawk (Brazilian Navy) and wind tunnel runs (INMETRO and NIDF, COPPE/UFRJ), including the measurement of spatial and temporal variations of surface temperatures through infrared thermography. The aim is to demonstrate the importance of accounting for the conduction-convection conjugation in more complex models that attempt to predict the thermal behavior of the anti-icing system of such sensors and structures under adverse atmospheric conditions. The theoretical analysis first involves the proposition of an improved lumped-differential model for heat conduction along the probe, approximating the transversal temperature gradients within the metallic and ceramic (electrical insulator) walls. The convective heat transfer problem in the external fluid is solved using the boundary layer equations for compressible flow, applying the Illingsworth variables transformation considering a locally similar flow. The nonlinear partial differential equations are solved using the Generalized Integral Transform Technique in the *Mathematica* v7.0 platform. In addition, a fully local differential conjugated problem model was more recently proposed, including both the dynamic and thermal boundary layer equations for laminar, transitional and turbulent flow, coupled to the heat conduction equation at the sensor or wing solid wall. With the aid of a single domain reformulation of the problem, which is rewritten as one set of equations for the whole spatial domain, via space variable physical properties and coefficients, the GITT is again invoked to provide hybrid numerical-analytical solutions to the velocity and temperature fields within both the fluid and solid regions. Then, a modified Messinger model is adopted to predict ice formation on either wing sections or Pitot tubes, which allows for critical comparisons between the simulation and the actual thermal response of the sensor or structure.