Numerical predictions of gauge rake thermal state in high-enthalpy flow

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It is required to have flat uniform profile of velocity, pressure, temperature and other parameters at the aerodynamic nozzle exit for correct altitude experiments on the on-ground testing rigs, imitating high Mach number flying conditions. Using special measure system with pressure and temperature gauge rake is one of the ways of controlling of flow parameters at the on-ground facility aerodynamic nozzle exit. It is well known that maximum allowable temperatures and heat fluxes depend on efficiency of water cooling of measuring rake heat-loaded parts. Thus, the main purpose of current investigation is rake parts thermal state analysis. One-dimensional calculations are not reliable enough due to complex 3D-geometry of the rake, so in current study the 3D steady-state numerical analysis is performed. At the first stage, the most heat-loaded part is analyzed and leading edge thermal state analysis is carried out, with imitation of thermal boundary conditions on coolant (water) side. Instead, convection boundary condition is applied: coolant temperature is fixed (300 K) and range of heat transfer coefficients are chosen for applied working conditions (10, 20 and 30 kW/(m²K)). At the second stage the calculation of hydraulic losses in water cooling duct of measuring rake was performed in simplified approach. The approach of 2-stage numerical simulation (gas-solid domain and solid-water domain) reduced simulation time without increase of error for the current task. Efficiency of water cooling scheme in measuring system with pressure and temperature gauge rake is verified at simulation. Thus, high reliability and operability of whole measuring system is confirmed.