THERMAL TILE DESIGN FOR LOW-UNCERTAINTY CONVECTIVE HEAT TRANSFER MEASUREMENTS

Jorge Pérez Bárcena,
Cedric Babin,
Fabrizio Fontaneto,
Turbomachinery & Propulsion Department
von Karman Institute for Fluid Dynamics

ABSTRACT

A novel experimental approach for convective heat-transfer measurements under controlled wall-temperature conditions is presented. Unlike conventional thin-foil techniques, the proposed configuration does not require Joule-heating elements, enabling a more direct relationship between the measured heat flux and the wall convective heat flux when radiative contributions are minimized or appropriately corrected. The device is based on a custom thermoelectric assembly developed in collaboration with ELiNTER AG and Meerstetter Engineering GmbH. It comprises two spanwise arrays of four Peltier cells, each equipped with a heat-flux sensor positioned 10 mm beneath the exposed surface. The sensors provide the feedback signal for closed-loop control.

The device was installed 0.9 m downstream of the leading-edge nose of a flat plate. The assembly measures 0.44 m in width and 0.60 m in the streamwise direction, covering a span approximately 10% larger than the estimated two-dimensional turbulent flow region. Its streamwise extent was selected to allow the thermal boundary layer to adjust to the imposed thermal step while fully capturing a downstream pressure-gradient region. The exposed plate is also interchangeable for surface roughness studies. For bulk-flow total temperatures close to ambient conditions, the system was designed to achieve wall temperatures of 280 K in cooling mode, and 328 K in heating mode, with an expected spanwise temperature standard deviation of 0.2 K. Conductive and radiative losses are maintained below 0.5% and 4%, respectively, by means of a polyisocyanurate-foam enclosure and a nickel-based infrared-reflective surface treatment. The resulting platform provides accurately controlled and spatially uniform thermal boundary conditions for investigating turbulent convective heat transfer under turbomachinery-relevant flow conditions.