Aerospace Engineering Thesis Defense

Towards Affordable Personal Weather Stations: Impact of Geometry and Flow Characteristics on Heat Transfer Coefficient from Heated Cylindrical Sensors

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Abstract

The measurement of the radiation and convection that the human body experiences is important for ensuring safety in extreme heat conditions. The radiation from the surroundings on the human body is most often measured using globe or cylindrical radiometers. The large errors stemming from differences in internal and exterior temperatures and indirect estimation of convection can be resolved by simultaneously using three cylindrical radiometers (1 cm diameter, 9 cm height) with varying surface properties and internal heating. With three surface balances, the three unknowns (heat transfer coefficient, shortwave, and longwave radiation) can be solved for directly. As compared to integral radiation measurement technique, however, the bottom mounting using a wooden-dowel of the three-cylinder radiometers resulted in underestimated the total absorbed radiation.

This first part of this thesis focuses on reducing the size of the three-cylinder radiometers and an alternative mounting that resolves the prior issues. In particular, the heat transfer coefficient in laminar wind tunnel with wind speed of 0.25 to 5 m/s is measured for six polished, heated cylinders with diameter of 1 cm and height of 1.5 to 9 cm mounted using a wooden dowel. For cylinders with height of 6 cm and above, the heat transfer coefficients are independent of the height and agree with the Hilpert correlation for infinitely long cylinder. Subsequently, a side-mounting for heated 6 cm tall cylinder with top and bottom metallic caps is developed and tested within the wind tunnel. The heat transfer coefficient is shown to be independent of the flow-side mounting and in agreement with the Hilpert correlation.

The second part of this thesis explores feasibility of employing the three-cylinder concept to measuring all air-flow parameters relevant to human convection including mean wind speed, turbulence intensity and length scale. Heated cylinders with same surface properties but varying diameters are fabricated. Uniformity of their exterior temperature, which is fundamental to the three-cylinder anemometer concept, is tested during operation using infrared camera. To provide a lab-based method to measure convection from the cylinders in turbulent flow, several designs of turbulence-generating fractal grids are laser-cut and introduced into the wind tunnel.

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