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The Influence of Sensor Position on the Measurement of Recovery Temperature in Compressible Flow

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Extended Abstract

The measurement of temperature in high-speed, compressible flows is complicated by the fact that both the static and dynamic components of temperature can be significant and may be difficult to discern from one another based on the sensor temperature alone. In most cases, the sensor measures neither the static or total temperature, but rather an intermediate “recovery temperature”, which comprises the static temperature and a portion of the dynamic temperature [1]. Since it is normally the static (thermodynamic) temperature that is needed, a means must be available to convert the sensor (recovery) temperature into static temperature. A study conducted by Parker et al. [2] included both experiments and computational fluid dynamics simulations, and investigated the meaning of the temperature value measured by a simple cylindrical probe (thermistor sensor) inserted into a high-speed airflow in a small pipe. The study compared the sensor temperature to a temperature measured by a highly-accurate instrument and then presented an analytical approach for converting the sensor temperature to the local static temperature based on other easily attainable measurements. The article also showed that the measured temperature was dependent upon the sensor position in the airflow. The results show that the recovery factor is dependent on whether the sensor tip is aligned with the tube inner wall or protruding into the airflow.

Details of conjugate simulations of a cylindrical sensor placed in a compressible flow of air in a tube show how probe protrusion leads to a modified flow field and a different sensor temperature. Specifically, for a given flow rate, static temperature in the vicinity of the sensor nose is shown to drop with increasing protrusion length due to the increased local velocity. Since static temperature of air just upstream of the sensor is shown to be identical, changes at the sensor are entirely due to its position L relative to the tube wall. The static temperature, T_s, in the vicinity of the sensor tip drops substantially when the sensor protrudes towards the centreline of the tube, however, this is offset by the local warming that occurs in the sensor wake. The net effect is a different sensor temperature, which is different from both the local static and dynamic temperatures. The temperature results at the sensor are then converted to local static temperature, which is the quantity desired to be measured at that location.

References

[1] M. J. Parker, B. T. Jentz, N. J. Dyck, A. G. Straatman, On the measurement of temperature and recovery factor in high-speed subsonic duct flow, Flow Measurement and Inst., 83, 102090, 2022.
[2] E. R. G. Eckert and R. M. J. Drake, Analysis of Heat and Mass Transfer, 1st ed. McGraw-Hill, 1972.