RoBuT Wind Tunnel Description

This unique facility was built specifically for the task of providing flow and thermal validation data for Computation Fluid Dynamics (CFD) for transient and steady mixed convection. Mixed convection refers to the domain between forced convection, where the fluid motion is provided by an external source (e.g. a blower) and natural convection, where the motion is due to density gradients in a gravitational field, or buoyancy. For mixed convection, natural convection remains important even though an external source of motion is used.

The design philosophy of the tunnel is in keeping with current CFD validation methodology, which requires that the experiment be easily modeled. Doing so ensures that differences between the validation data and the simulation are attributable to the numerical model and cannot be attributed to differences between the model and the experiment.

Operation of the Facility

The wind tunnel is positioned in either the buoyancy aided or buoyancy opposed orientation and locked into place. The PIV equipment is positioned at the desired measurement location (either the inlet, or one of the three heat flux sensor positions). The power supplies for the heaters are powered on along with the control circuit power supply. The plate is then heated to the desired temperature using the LabVIEW software. Once the desired temperature is reached, the blower is set to the desired speed. After reaching the experimental conditions (steady-state or the start of the transient), the PIV data are acquired and the boundary conditions recorded. Meanwhile, the room temperature is controlled and the room lighting turned off.

Equipment Features

The test section is a 1-ft square cross section that is 2 meters long. No assumptions are made about 2-dimensionalilty or uniformity of inflow or surface temperatures. Instead, all boundary and inflow conditions are measured. One wall of the test section is heated while the other three are transparent, allowing for non-intrusive, high fidelity, laser-based velocity measurements.

Perhaps the most unique feature of the facility is the capability to rotate the entire facility 180º. Doing so changes the influence of buoyancy from aiding the flow motion to opposing it.

The inflow profile is measured using planar PIV and will be stored along with the validation data. Therefore, the CFD model can use actual inflow data (including the mean velocity, TKE, turbulence length scales, or Reynolds Stresses, as necessary).

The heated wall is instrumented with 160 thermocouples (to provide surface temperature boundary conditions) and three heat flux sensors (to provide system response data). The thermocouples are placed such that, based on finite element simulations of the plate, the surface temperature field can easily be interpolated. The plate is heated by six separate heaters, allowing the heat flux to be adjusted to maintain a constant surface temperature or heat flux, if desired. The heaters are powered by DC power supplies and controlled through LabView software. The maximum surface temperature is 190ºC, which, over the 2-meter length of the plate, gives a maximum Grashof number in excess of 10^{10}.

Validation system response quantity data include the heat flux at the sensor locations in addition to velocity data in the laminar and turbulent parts of the plate. Two-component PIV data can be acquired with a single-camera PIV system. The tunnel is an open circuit facility and thus operates with room air as a working fluid. The room in which the tunnel is installed is dedicated to this experimental facility and has its own HVAC capability, ensuring that the room temperature can be carefully controlled. Furthermore, the temperature of the inflowing air is fixed by a heat exchanger and thermal controller on the tunnel inlet.

Calibration and Characterization:

The measured pressure drop through the contraction is compared with the expected pressure drop computed using Bernoulli's equation and the measured velocity. The expected frictional losses are also compared to the pressure drop through the test section.

Maintenance and Repair Procedures:

The maintenance required for the wind tunnel includes regular lubing of the blower and cleaning of the test section.

Some repair procedures are included, such as repairing a failed heater and broken thermocouple or heat flux sensor wire. When a heat flux sensor wire breaks, insulating shrink tube is placed over the unbroken section of wire. Then the break is soldered together and the shrink tube is fixed over the solder joint. Broken thermocouples in the polycarbonate walls are replaced with newly calibrated ones, and plate thermocouples are repaired similarly to the heat flux sensor.

When a heater required replacement, the entire test section is removed from the wind tunnel and placed on the test section service stand. The clamps holding the clear walls and the heated plate are removed (along with the National Instruments chassis). The clamps/instrumentation are lowered onto the service stand. Then the still assembled three clear walls are lifted from the plate and set aside, with care taken to keep the Teflon sides from falling off. The Teflon sides are set next to the sides of the heated plate. The heated plate is now ready for inspection or service.

To replace a heater, one end of the heated plate (either leading edge or trailing) is lifted just enough to get to the heater to be replaced. The service stand has attaching pieces that are used to hold the top nickel-plated plate up off of the heaters. Fishing line is attached to the thermocouples that are threaded through the heater on available end of the thermocouple. The heater is removed and the thermocouples threaded through the insulation and heaters. Once a new heater is ready, the process is repeated in reverse.