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Continued development of the Irwin sensor for use in pedestrian wind studies

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SUMMARY:
The Irwin sensor is widely used measuring surface wind speeds within boundary layer wind tunnels for predicting pedestrian-level wind conditions. The simple design of the sensor allows the simultaneous measurement of wind speeds at a potentially large number of locations, as is a common requirement in regulatory pedestrian-level wind studies. Measurements of the directional response of the sensor indicate that the base plenum tap can influence the predicted velocity, leading to variations in the predicted wind speed. Within this paper, various modifications to the sensor are evaluated with the intention of removing the directional influence of the base plenum tap. Of the sensor geometries evaluated, a sensor geometry with six holes at the base of the central tap was found to remove the directional variations. In addition, the use of holes around the base of the tap provides the opportunity to provide structural support to the tap and reduce the potential for misalignment or bending.

Keywords: Irwin sensor, Pedestrian wind study, Wind tunnel

1. IRWIN SENSOR DIRECTIONAL RESPONSE

In 1980, Peter A. Irwin proposed a simple surface mounted sensor where the pressure difference between a plenum and a raised tap is used to measure the wind speed. These sensors are relatively inexpensive and well suited to be installed in large numbers.

1.1. Irwin Sensor Geometry

A sensor with an internal geometry matching that described within Irwin's 1981 paper was designed and manufactured via stereolithography additive manufacturing. The extended, 'top' pressure tap protruding 4.28 mm was installed to provide a full-scale measurement height of 1.5 m at a 1:350 model scale. The bottom plenum tap was positioned at 180° position relative to 0° in the directional tests (see Figure 1). The sensor with pressure taps installed was carefully inspected to ensure the protruding tap was undamaged and centrally aligned with the plenum.

The sensor body was manufactured as a disk to allow accurate rotation of the sensor within the boundary layer wind tunnel. This ensured a smooth transition from the disk to the sensor geometry, while allowing the sensor to remain in the same position within the wind tunnel throughout the directional testing.

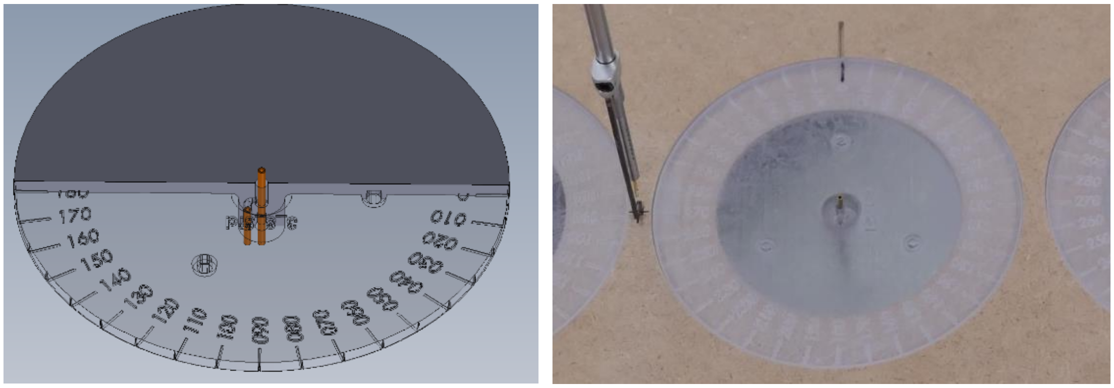

Figure 1. Image of an Irwin sensor (left) and when positioned in a rotatable disk for directional testing (right).

Figure 2. Sensors within the boundary layer wind tunnel including three hotfilm reference sensors.

1.2. Directional Pressure and Wind Speed Measurements

The reference Irwin sensor was tested within CPP's boundary layer wind tunnel as shown in Figure 2. The sensor and disk were rotated in 10° increments for a total of 36 measurements without changing the position of the sensor. A hot-film sensor was positioned near the sensor, as show in Figure 1 with the midpoint of the film positioned at the same height as the top of the Irwin sensor central tap.

The left plot in Figure 3 is the measured tap pressures for each of the 36 measurement directions, as well as the differential pressure. The bottom tap within the plenum has a relatively unsteady response, with the largest pressure change occurring at approximately 110° where a relatively unchanging response would be expected if the sensor were omnidirectional. The right plot in Figure 3 is of the corresponding ratio of the mean speed to the reference pitot. This plot illustrates the variation in measured speed with direction. For comparison, the adjacent reference hotfilm probe had an average velocity ratio of 0.57 across the measurements.

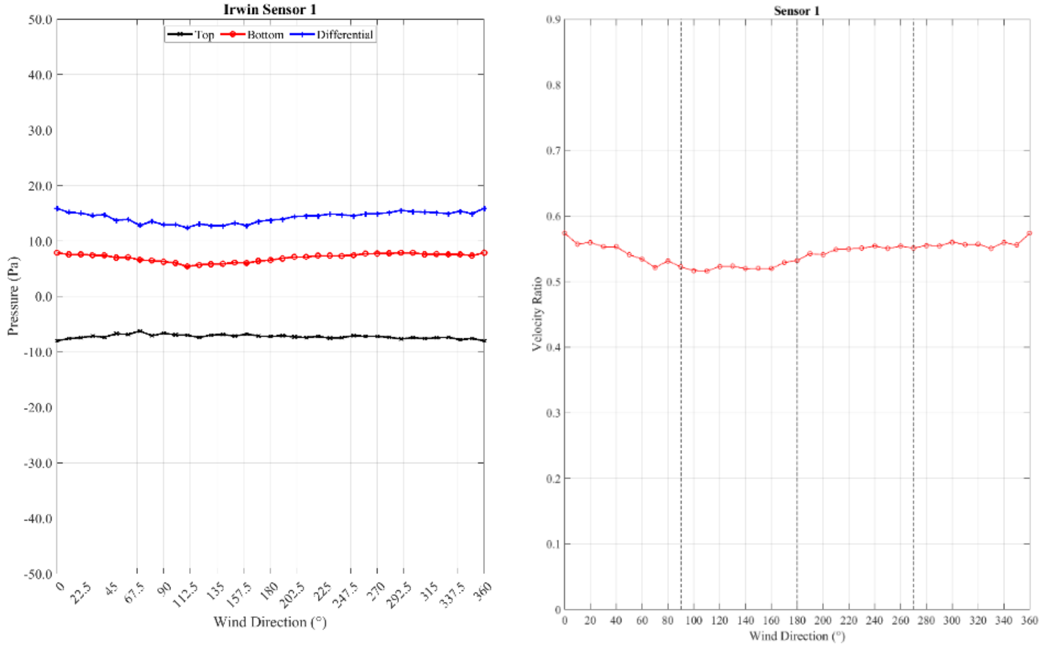

Figure 3. Irwin sensor directionality test results for top and bottom taps as pressure (Pa) (left) and the resulting mean velocity ratio to a reference pitot (right) for each approaching wind direction.

2. GEOMETRY MODIFICATIONS

The mechanisms leading to the change in pressure within the plenum by direction is not definitely known nor the scope of this work. However, the work by Brito et al. provides information regarding wind flow within and around the Irwin sensor.

Various modifications to the geometry of the sensor were tested to see if the directional variations observed could be reduced. These modifications included increasing the plenum volume, including holes at the base of the protruding tap in lieu of the single hole, and a combination of these two approaches (Figure 4).

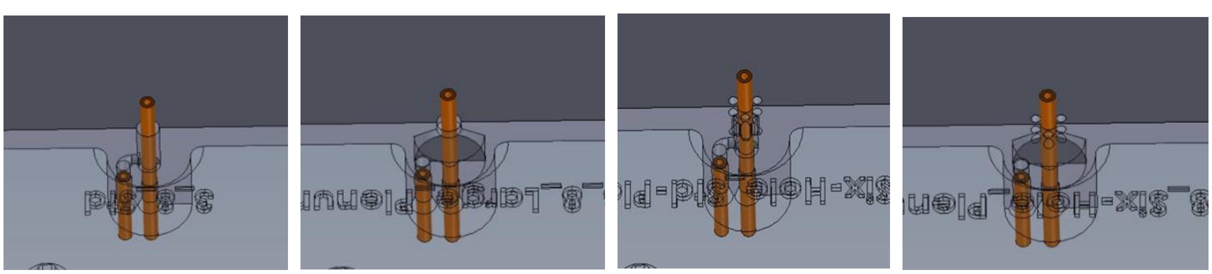

Figure 4. Irwin (1981) geometry (left), increased plenum volume, Irwin (1981) plenum volume with six holes around the central tap, and increased plenum volume with six holes around the central tap (right).

2.1. Directional Pressure Responses

The pressure responses for each of the sensor geometries are plotted in Figure 5, with the Irwin (1981) geometry having the most pronounced variation in lower plenum pressure with test direction. Increasing the plenum size appears to reduce the magnitude of the directional variation in response.

The sensor geometry that incorporated 6 holes positioned around the central tap appears to remove the variation in directional response. The magnitude of the plenum pressure is also reduced, resulting in a lower differential pressure.

The sensor geometry which includes both an increase plenum volume and 6 holes around the central tap also appears to remove the variations in directional response, while resulting in a further reduction in pressure within the plenum.

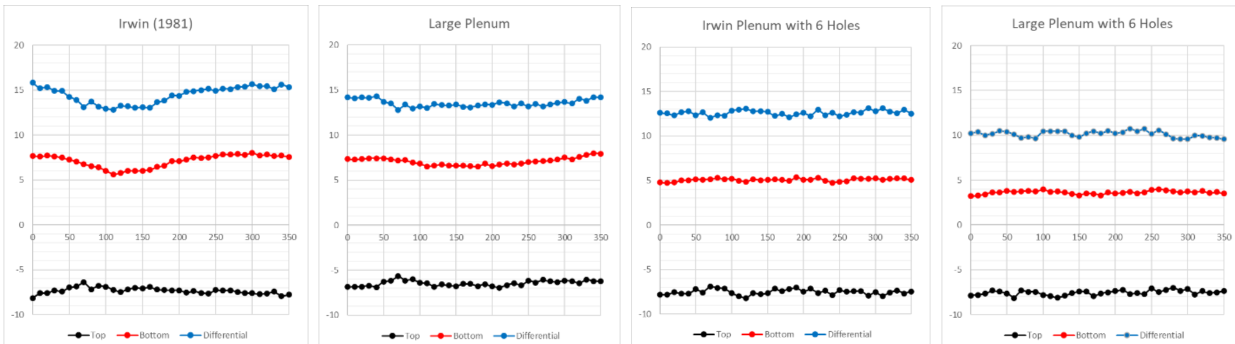

Figure 5. Pressure responses for the Irwin (1981) geometry (left), increased plenum volume, Irwin (1981) plenum volume with six holes around the central tap, and increased plenum volume with six holes around the central tap (right). Shown are the extended top pressure, plenum pressure and differential pressures in Pascals.

2.1. Directional Velocity Responses

The mean velocity as a ratio to the reference pitot is plotted for the Irwin (1981) geometry (left), and the modified sensor with six holes around the central tap (right).

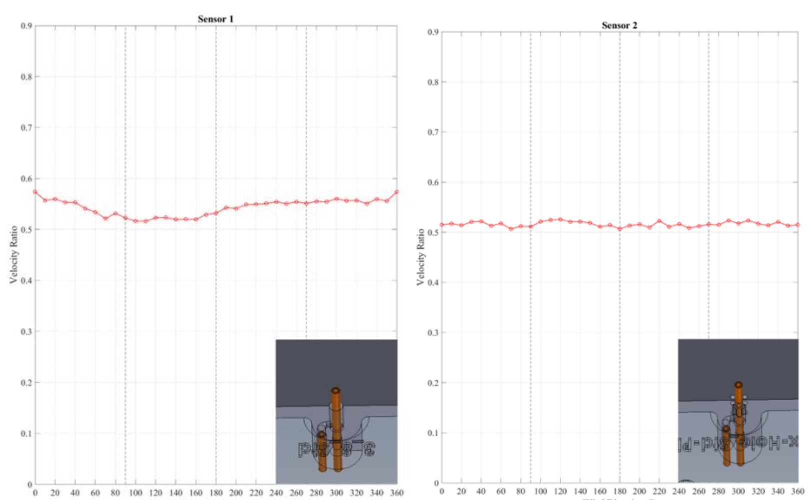

Figure 6. Irwin Sensor (left) and modified Irwin sensor with standard plenum volume and 6 holes around the central tap (right). Mean velocity ratio to the reference pitot. The mean hotfilm velocity ratio to the reference pitot was 0.57 and 0.52 at the Irwin, and modified sensor geometry, respectively.