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On the wake pressure-footprint and its potential application for wake flow analysis

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Abstract

This poster introduces a new technique called pressure footprint (p-f) method. A square metallic plate with an array of four hundred (20 × 20) pressure taps known as pressure plate was used to investigate the flow around a single and two miniature wind turbine (WT) models. A single WT was located on the geometric center (i.e. origin) of the pressure plate and hub height was varied from 1.0 to 2.5 rotor diameters. Pressure on the plate was measured using a pressure transducer connected to the taps via a scani-valve. Total and static pressures at the hub height were measured using a Prandtl tube. The effect of variation of hub height on the footprint area was analyzed in terms of the pressure coefficient (cp) and the difference of pressure (δp). To analyze the wake interaction, two wind turbines were arranged in the streamwise direction with varying intervals. The results indicated that p-f area decreases in δp but remains constant in cp terms.

Objective

The main objective is to establish this technique as a complementary qualitative and quantitative method for the analysis of wake interaction in controlled environments as well as in field measurements

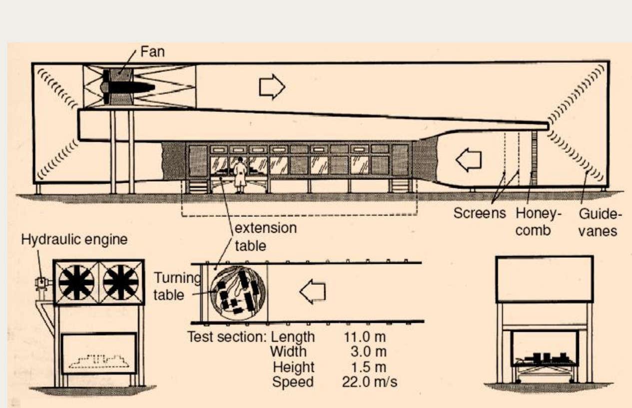
Method

Working Principle

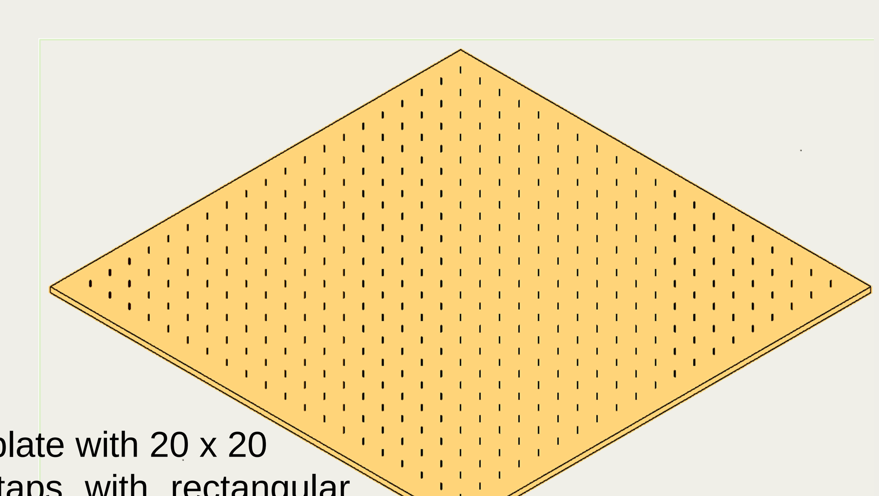
Assumption is that the pressure at ground (measured by pressure taps) corresponds to the pressure at the hub height and pressure footprint on the pressure plate varies with hub height.

Experimental Setup

- Wind tunnel
- Pressure plate
- Wind turbine models
- PIV system with traverse
- Others (Prandtl tube, pressure gauge)



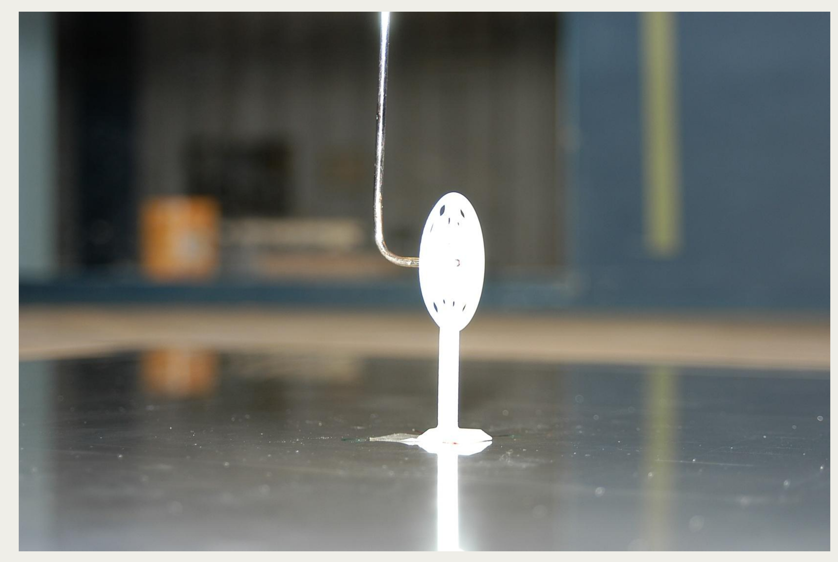
Atmospheric Boundary Layer wind tunnel at University of Gävle



Pressure plate with 20 x 20 pressure taps with rectangular shape (bottom-view)

A single wind turbine model was located on the pressure plate and tested for seven diffferent hub heights from h/D=1.0 to 2.5 with an increment of 0.25 D. Free stream wind speed at the meanline was kept constant at 16 m/s.

A configuration of two wind turbines aligned in streamwise direction was tested with varying spatial intervals. The results were corrected for the temperature effects and pressure gradient in the wind tunnel.



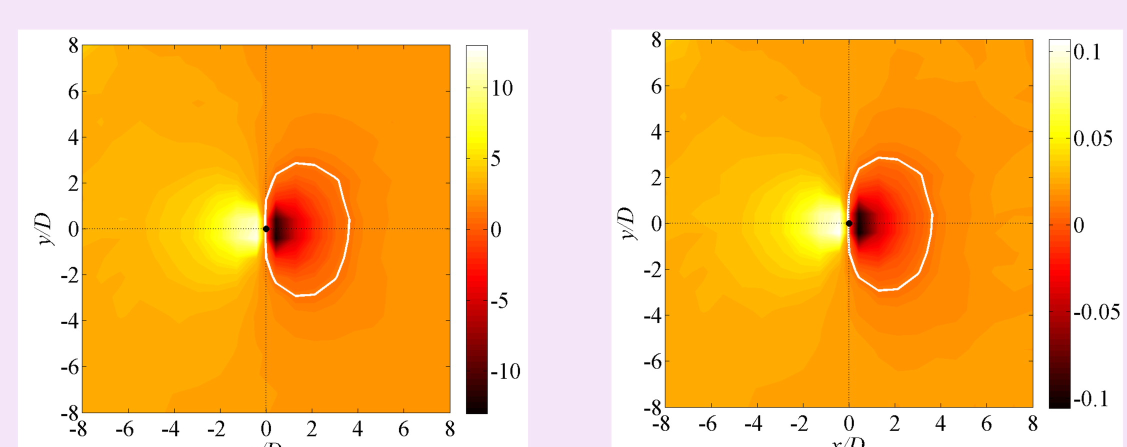
Single wind turbine model located at the geometric center of the pressure plate

The results were plotted and analysed in terms of pressure coefficient and pressure difference footprint area. In the figures, the wind direction is from left to right or otherwise specified in the caption

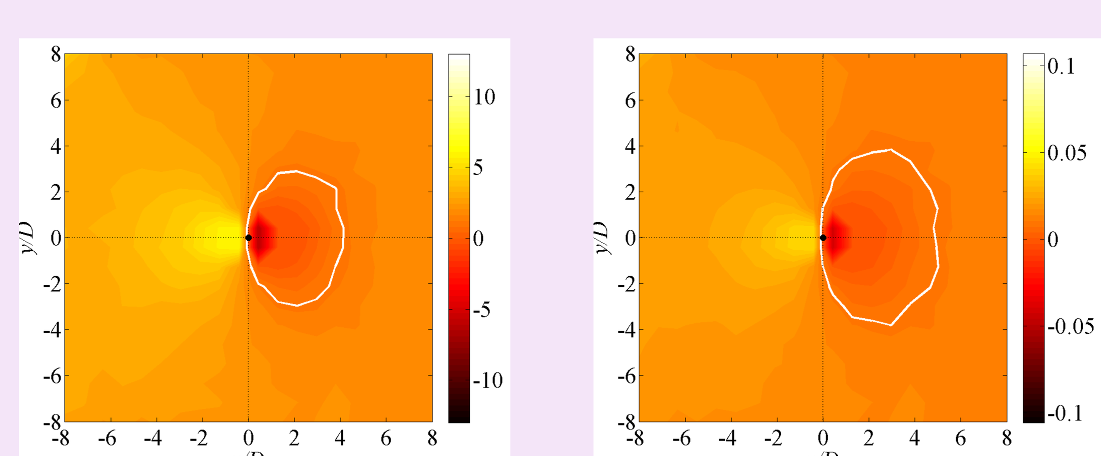
Results

$$c_p = \frac{\delta p}{p_{hub} - p_{ref}}$$

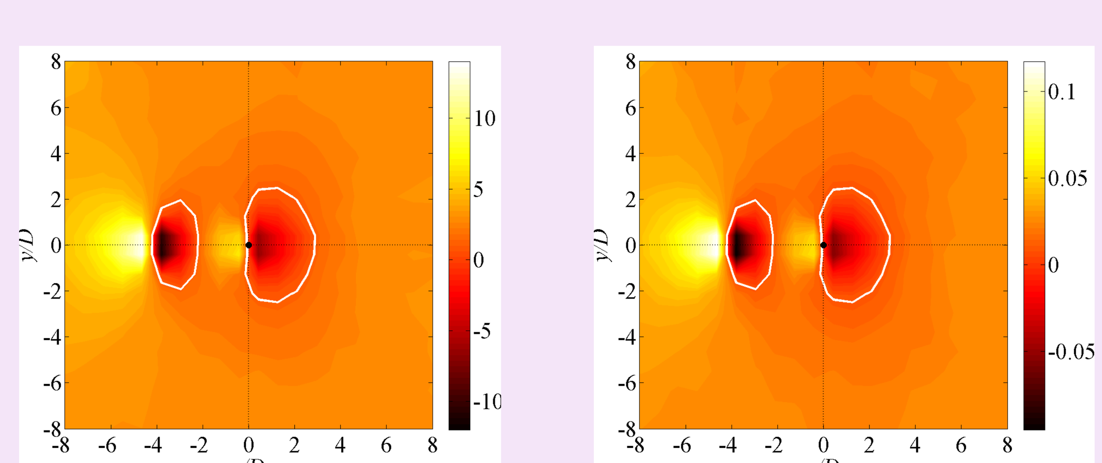
$$\delta p = p_i - p_{ref}$$



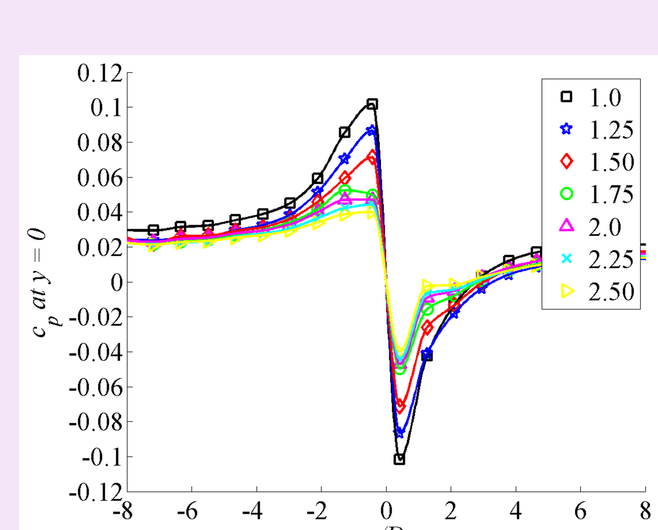
(right) contour plot of coefficient of pressure (left) contour plot of difference of pressure of a single WT at h/D=1.0



(right) contour plot of coefficient of pressure (left) contour plot of difference of pressure of a single WT at h/D=2.5



(right) contour plot of coefficient of pressure (left) contour plot of difference of pressure of two WTs with an interval of x/D=4.0



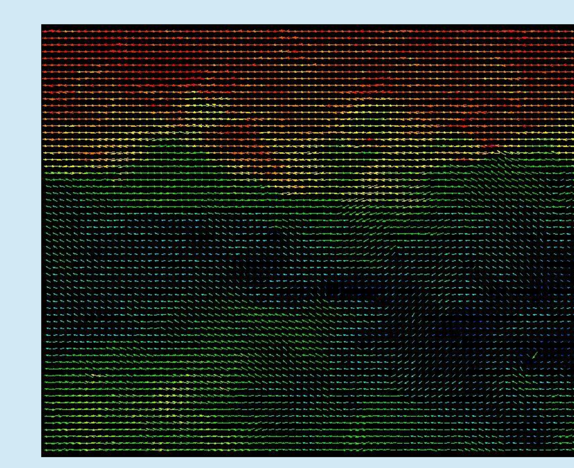
Centreline pressure variation with hub height provides a quantitative comparison and clearly indicates that the pressure footprint decreases in terms of cp as the hub height increases

Conclusions

- The pf-area information can be used for the placement of micro-barometers. The pf-area as hub-height function can be used to determine relation between the pressure measured on the ground and at the hub-height.
- This method provides valuable images of the horizontal pressure field.
- The resolution depends on the number of taps and inter-tap spacing i.e. number of taps per unit surface area of the plate.
- The method is simple, non-intrusive, economical and a fast measuring technique that can be used for field measurements using micro-barometers.
- This technique provides pictures of the wake in -plane (i.e. horizontal plane) and thus regions with strong interaction can be identified immediately.
- We conclude that pressure footprint (pf) method provides new perspective to the research on wake interaction.

What's Next

- Measurement of the velocity in the wake using particle image velocimetry (PIV) has been started
- Correlation between the pressure and velocity in the wake
- Extension of pf-method to the full-scale real-world wind farms using micro-barometers
- Optimal operation of the wind farms using pf-method



PIV image in far-wake region of a single WT with a overlap of 50 %. Wind direction is from right to left

References

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