Effect of abrasion and biofouling on aerodynamic performance of industrial surface coatings

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Experimental setup

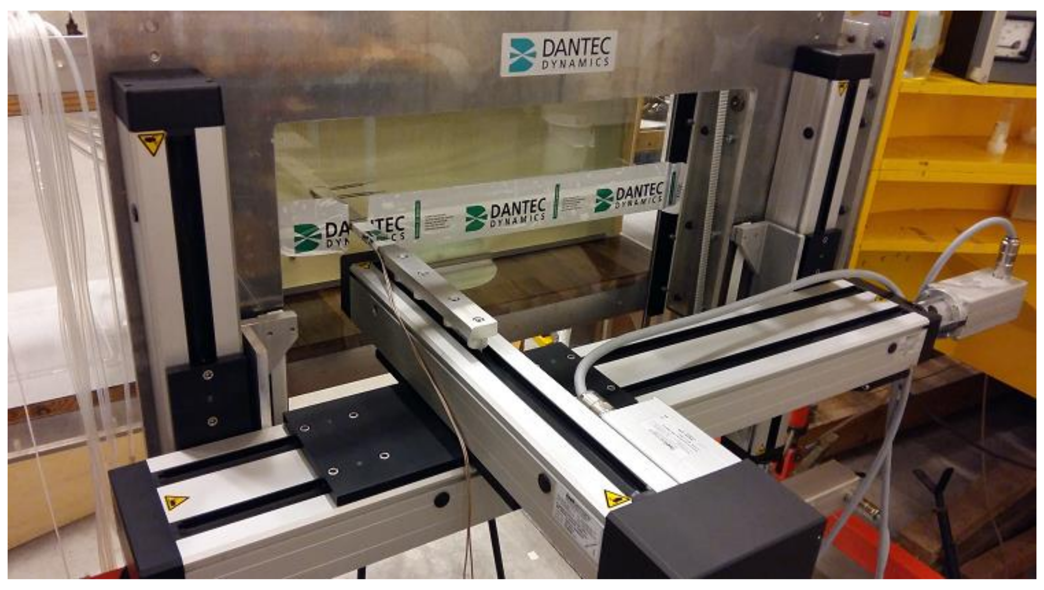

Fig 1a Computer controlled, 3-axis traverse system mounted on the DTU wind tunnel.

Fig 1b Back side of the flat panel during zero-pressure-gradient alignment.

Effect of abrasion and biofouling on the aerodynamic performance of industrial surface coatings is investigated. The test section of the DTU closed-loop wind tunnel (Fig. 1a) is refurbished to perform automated boundary layer stability experiments. The new test section features a sliding front window, a computer-controlled three-axis traverse, angle of attack adjustment, zero-pressure-gradient alignment (Fig 1b), quick test plate replacement and repeatable alignment between plates. In total 11 flat plates were used in pristine, abraded and biofouled states. The measurements were performed using a Dantec Dynamics StreamLine Pro Hotwire Anemometry System with an automatic velocity calibrator, system PC, StreamWare Pro software and a custom-developed LabVIEW program. StreamWare Pro was used for system setup and velocity calibration process, and LabVIEW programs were used for measuring laminar and turbulent velocity profiles. A National Instruments 4-channel simultaneous sampling differential USB A/D converter was used. A Dantec 55P15 boundary layer probe and a Dantec 55P11 freestream probe were positioned at multiple grid points using a computer-controlled 3-axis traversing system. Since the temperature in the test section may rise as much as 5°C during the course of the measurements, temperature correction was performed using a correction procedure suggested by Benjamin and Roberts [1]. Voltages were corrected according to:

$$V_c = V_m\left[1-\frac{T_c-T_x}{T_w-T_x}\right]^{0.55}$$

where V_c is the corrected voltage, V_m is the measured voltage, T_c is the calibration temperature, T_w is the wire temperature and T_x is the elevated ambient temperature during measurements.

Boundary layer measurements

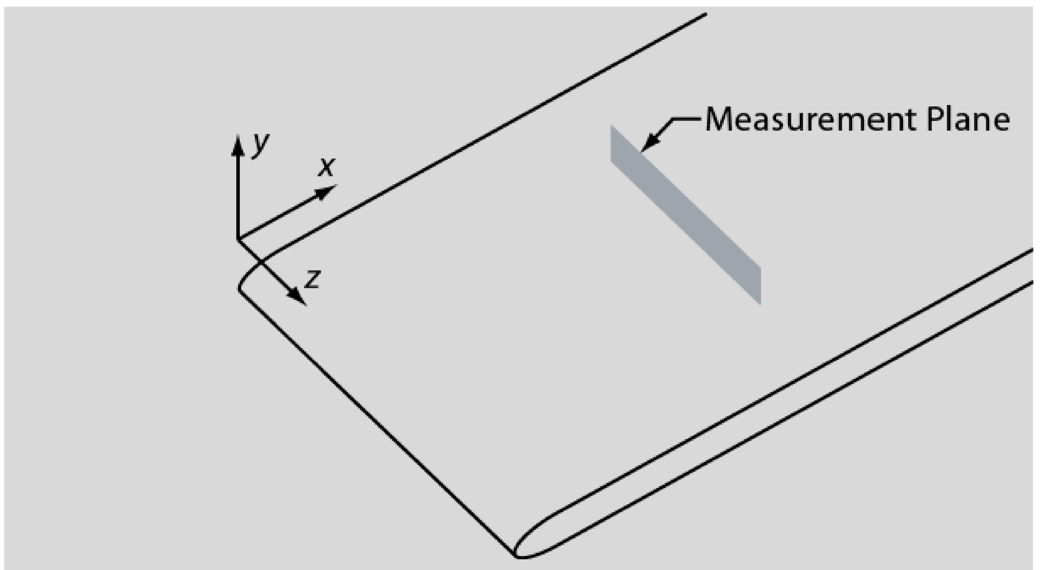

Fig 2a The flat plate schematic, the assumed coordinate system and the measurement plane.

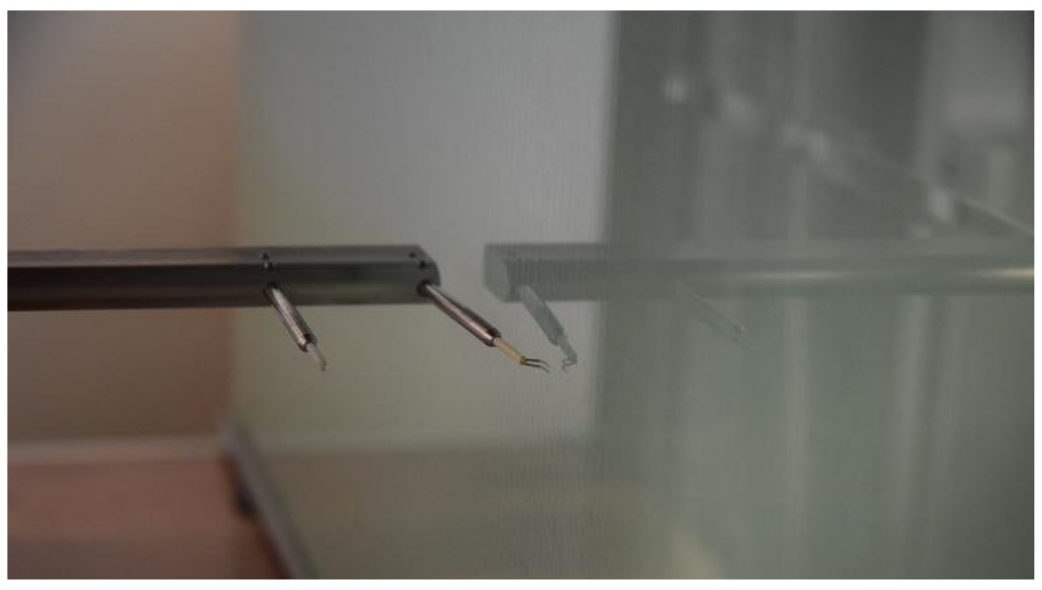

Fig 2b Hotwire probes during boundary layer measurements.

Boundary layer profile measurements were taken at 4 measurement planes (Fig. 2a) for each plate; 125mm, 250mm, 375mm and 500mm from the plate leading edge. Two single-normal sensor probes are mounted on the traversing mechanism using the hotwire support arm (Fig. 2b). Boundary layer velocity values were normalised with the freestream velocity values in order to minimize the effect of freestream speed fluctuations. The boundary layer type was identified for each plane before the actual experiment by measuring a boundary layer profile on each edge and in the middle. The measurement height was set to either η=8 (laminar) and η=16 (turbulent) depending on the boundary layer type. Corrections of arbitrary wall normal coordinates were performed according to White and Ergin [2]. Wall position at each spanwise location is estimated by fitting a line to the velocity profile between data points where the velocity is 18% and 30% of the freestream velocity, U_{fs}; and extrapolating to zero velocity. Then a quadratic fit is performed on the wall positions vs. spanwise coordinate (*y* vs *z*) and this information is used for correcting the wall-normal positions of the acquired data. Due to the presence of distributed roughness, all spanwise positions were used for the quadratic fit. This is useful in two aspects: first the number of data points is increased for a better wall location estimate, and second this approach provides an unambiguous definition of an effective wall surface in the presence of distributed roughness. Finally the data files are saved in .txt format compatible with Tecplot. Both laminar and turbulent profiles were observed during experiments, but results of only two plates are reported where a combination of both flow fields are observed.

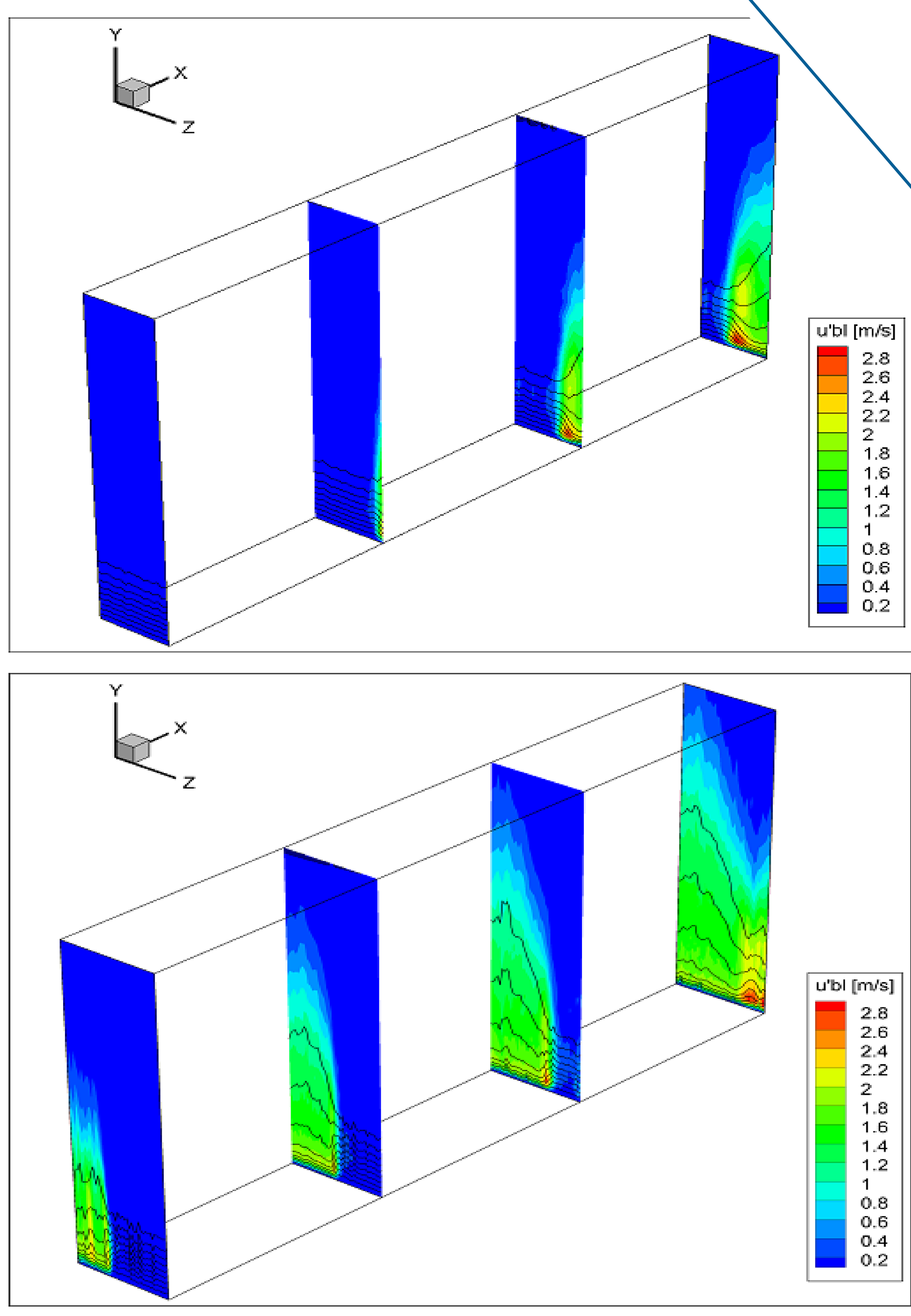

Fig 3 Turbulent flow field over 2I coating in Pristine (top) and Biofouled (bottom) state.

A success criterion is defined for the aerodynamic performance: If the coating can produce a laminar boundary layer in its pristine state and can keep this type of flow in its aged state, the coating is successful. In contrast, if a coating cannot produce a laminar boundary layer profile in its pristine condition or keep it in its aged condition, then the coating is not successful:

- Coating 2 which does not contain nanoparticles is the most successful since it is able to produce a laminar boundary layer and keep this flow condition in its aged state (both biofouled and abraded).
- Coating 2O and 2R are successful since they are able to produce a laminar boundary layer and keep this flow condition in their abraded state. Since these panels were not bio fouled, no definitive conclusion can be made on their success in the biofouled state.
- Coating 2I is unsuccessful as it produces a turbulent boundary layer in its pristine and aged state (Fig. 3). Since this panel was not abraded no definitive conclusion can be made on its success in the abraded state.

Acknowledgments

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[2] EB White, FG Ergin "Using laminar-flow velocity profiles to locate the wall behind roughness elements" Experiments in Fluids 36 (2004) 805–812