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PLASMA STREAMWISE VORTEX GENERATORS FOR FLOW SEPARATION CONTROL ON TRUCKS

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INTRODUCTION

The aerodynamic drag accounts for more than 20% of the total energy loss of heavy duty vehicles and around half of this drag is induced by the tractor when considering a zero degree yaw angle. The flow separation from the truck in the region of the A-pillars (front corner of the tractor) is believed to substantially increase the overall drag of the truck. In the 80s, rounded corners to replace squared A-pillars were implemented. A radius of 300 mm was demonstrated to be optimal to control the flow separation [1]. However, this value is only appropriate for a zero degree yaw angle. Active methods with feedback control would probably improve the separation control when considering that trucks on the road are subjected to varying yaw angles.

Dielectric Barrier Discharge (DBD) plasma actuators have shown effectiveness in controlling flow separation [2] for geometries such as airfoils or cylinders. Recently, they have also been used to control flow separation and reduce drag when used to 'inject' momentum in the streamwise direction close to the separation line [8]. However, they were found to only be capable of reducing the size of the recirculation bubble for freestream velocities close to the electric wind velocity. Furthermore, it was shown that the capability of the actuation was strongly dependent on the relative position between the separation line and the position of the actuator which could lead to difficulties when applying the technique to flow cases of non-fixed separation position. To overcome these limitations another configuration of the plasma actuators is tested here: an array of DBD plasma actuators creating streamwise vortices is studied to control the flow separation downstream a cylindrical bump. These vortices are similar to the ones induced by geometric vortex generators (VGs) as apparent from figure 1 and was studied in Ref. [5].

In the present work we are studying the possible use of DBD plasma actuators for separation control of a turbulent boundary layer over a bump which serves as a generic geometry for a trucks A-pillar. To control the flow around the A-pillar is an important aspect of vehicle aerodynamics [see e.g. Ref. 4, 7]. Both laminar and turbulent boundary layer flows approaching a 2D bump, have been studied extensively, due to their combined effect of surface curvature (including abrupt changes) as well as adverse and favourable pressure gradients. Nonetheless, most of these perturbations have been comparably mild, i.e. the perturbation height is much smaller than the length of the perturbation. In the present case instead, the bump height is half of the bump length since the geometry is that of a half-cylinder resting on a flat plate. The Reynolds number along the flat plate is high enough so that the boundary layer that approaches the half cylinder is turbulent.

A detailed parameter study of steady and unsteady, spanwise and VG type DBD plasma actuator arrangements have been performed in the generic geometry mentioned above. These measurements were conducted in the Boundary Layer (BL) wind tunnel [6] at the Fluid Physics laboratory, at KTH in Stockholm, by means of two-dimensional Particle Image Velocimetry (PIV) as well as stereoscopic (stereo) PIV. Additionally, as a final proof-of-concept application, an array of DBD-VGs has been mounted on a actual truck model (see figure 2) and balance measurements in the Lola cars aerodynamic wind tunnel [3] have been performed to directly assess the drag under no-control and control conditions for various velocities and yaw angles. The results of these two investigations will be reported at the workshop.

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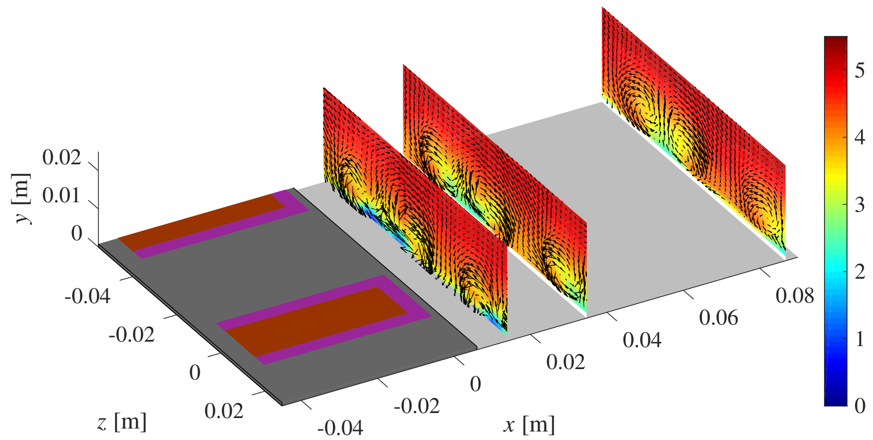

Figure 1: Streamwise vortices produced by DBD-VGs. Case with a freestream velocity of 5 m/s. The colour-scale represents the streamwise component of the velocity in m/s and the arrows the in-plane motion. The dielectric of the actuator is represented in dark grey, the brown rectangles are the electrodes and the violet part the induced plasma. Flow is from left to right.

Figure 2: Picture from the wind tunnel experiments at the Lola cars aerodynamic wind tunnel [3] with the truck model equipped with an array of DBD-VGs (left image) and a zoom-in of the trailer during control (right image).

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