Recent Progress in Bluff-Body Flow Control

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This paper describes a compilation of data from several experimental studies (Fig. 1a and a 2D circular cylinder), demonstrating the enhanced effectiveness due to the combined effect of steady suction and pulsed blowing, applied at close proximity to the separation point. Both methods are known to be effective separation control tools, but the application of the two active flow control (AFC) methods in close proximity is novel. A single no-moving-parts actuator generates both AFC effectors in an efficient, effective and robust manner. Several experiments on bluff bodies were performed recently and the emerging results are highlighted, emphasizing the combined effect.

It was found that the sensitivity to the location of the steady suction, applied through an array of holes for practicality, is quite strong and can lead to enhanced drag if applied downstream of the mean separation location. The pattern of the suction holes is also of significance in creating effective drag reducing 3D patterns.

When adding the pulsed blowing downstream of the suction location, but still upstream of the separation location, a significant increase in the separation delay was observed (Fig. 1b). The forcing frequency should be of order Strouhal number of 0.4-0.5, about twice and more the natural shedding frequency, if exists. Spanwise waves of length 1-2 typical separation length is optimal for effective drag reduction.

Experimental results measured on a variety of 2D[1], axis symmetric[2] and simplified as well as half and full scale truck-trailer configurations will be discussed. Significant separation delay was observed, e.g., from the 85% length to the trailing edge of an axis symmetric configuration (Fig. 1), to 60% drag reduction of a circular cylinder at transitional Reynolds numbers and 5% fuel savings on a full scale truck at road tests. Overall system efficiency was increased by 10-20%, taking the actuation power into account.

Keywords: active flow control, bluff-body, drag reduction, energetic efficiency.

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[1]. Shtendel and Seifert., Proc. of the 52[nd] Israel Aero. Conf., Feb. 2012. Submitted to *Phys. Fluids.*

[2] Wilson et al, AIAA paper 2012-0072 Jan. 2012. Submitted to *AIAA J.*

(a) 

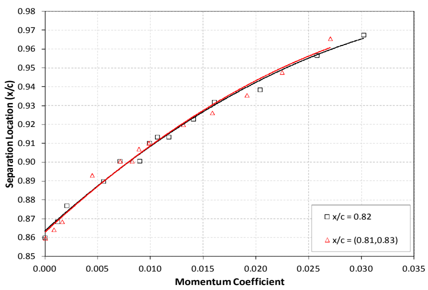
(b) 

Figure 1: (a) The 3D mounted on sting stand. Roughness located at x/c = 0.25. (b) Separation location vs. momentum coefficient using the SaOB actuation system at Re = 3.0x106. Baseline drag was 0.065. Cd nullified for $C\mu$=0.025. Suction location in legend, blowing at x/c=0.85.