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BLUFF BODY FLOW CONTROL THROUGH PIEZOELECTRIC ACTUATORS

M. Orazi[1], **D. Lasagna.**[1] **and G. Iuso.**[1]

[1]Dipartimento di Ingegneria Meccanica e Aerospaziale, Politecnico di Torino,
Corso Duca degli Abruzzi 24, 10129, Torino, matteo.orazi@polito.it

INTRODUCTION

An active flow control tecnique is proposed to delay flow separation on bluff bodies. This tecnique is based on "smart-tabs", that are retractable and orientable multilayer piezoelectric tabs which protrude perpendicularly from the model surface. They are characterized by six control parameters: the oscillation frequency f and amplitude A, the height h, the incidence γ, the angular position on the model α and the input waveform. The key features of such actuators are their low energy absorption and the energy recovery feature which makes them promising also for real applications. Considering their control characteristics and their frequency responce, the piezoelectric tabs are suitable for closed-loop control strategies.

In the present study the experiments were conducted on a 200 mm diameter circular cylinder. A 22 mm wide 0.6 mm deep flattening was made along one cylinder generatrix to host a row of 11 smart-tabs spaced 40 mm (see Figure 1). The model was equipped with 28 pressure taps in the middle section to estimate the aerodynamic coefficients and three spanwise rows of 11 taps spaced 20 mm. Furthermore, a second section of the cylinder is equipped with 15 electret microphones to measure the fluctuating pressure.

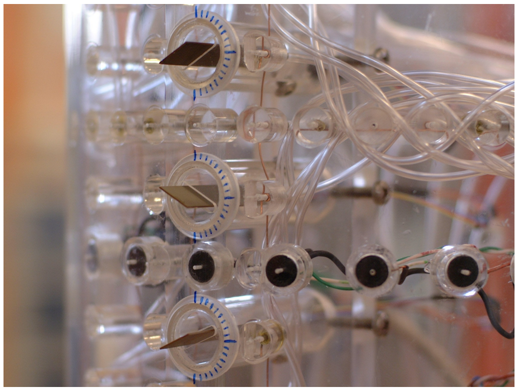


Figure 1: Smart-tabs on cylinder ($\gamma = \pm 30°$)

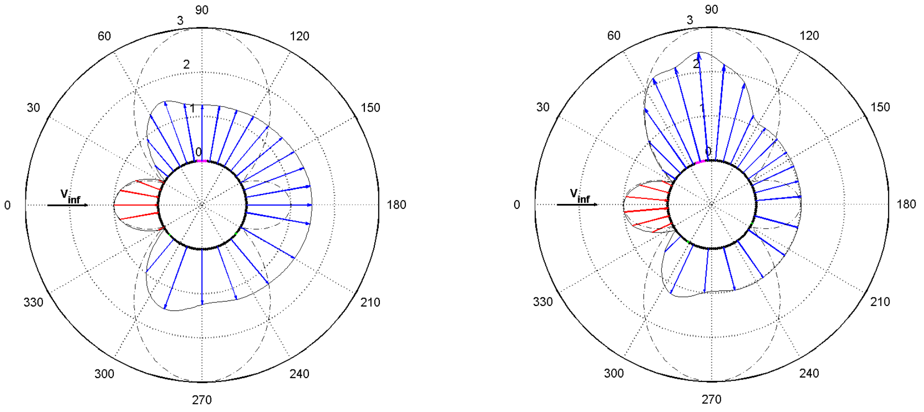
RESULTS

Some preliminary results concerning pressure distributions in controlled and uncontrolled conditions are presented for subcritical and supercritical Reynolds numbers. In order to achieve turbulent separation at a lower Reynolds number, namely $Re = 110000$, a turbulence generating grid was added after the contraction section.

Subcritical Regime

As shown in Figure 2, in subcritical conditions, at $Re = 52000$, the effect of the smart-tabs is basically to promote the boundary layer transition and to reduce the vortex shedding as also evidenced by the spectra of the pressure fluctuations and as highlighted by many authors in bibliography (Park et al. [1]). As a result of the different pressure distribution, the forcing leads to a drag reduction of about 30%. Interestingly the in the case of static smart-tabs (not reported) the pressure distribution is only marginally affected with respect to the natural flow case (Figure 2a). Therefore the large variations showed in Figure 2b are introduced by the oscillation on the smart-tabs. Is has to be noted that the asymmetry in the pressure distribution of Figure 2b is due to the asymmetric forcing. A further drag reduction may be obtained by installing one smart-tabs row on each sides of the cylinder as done by Shtendel & Seifert [2]. Finally it is noteworthy that the above mentioned asymmetry leads to the generation of significant lift ($C_l = 0.607$ for the case reported in Figure 2b).

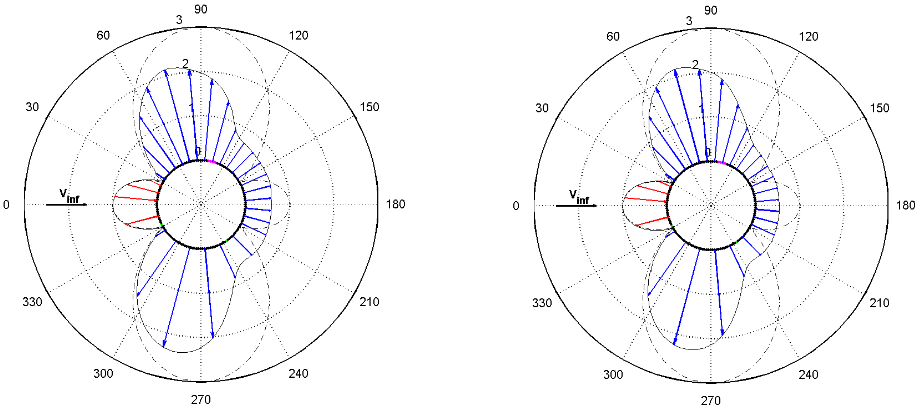
Supercritical Regime



(a) $h = 0mm$, $\gamma = 0°$, $f = 0Hz$ (b) $h = 5mm$, $\gamma = 0°$, $f = 80Hz$

Figure 2: Subcritical ($Re = 52000$) C_p distributions: a) Natural $C_{d_p} = 1.341$; b)Forced $C_{d_p} = 0.943$

An effective flow control in supercritical conditions is a much more challanging objective as mentioned by Amitay et al. [3]. Figure 3 reports the pressure distributions for the natural and the forced cases. In the latter the smart-tabs were set to an alternate incidence of 30° ($\gamma = \pm 30°$) with a height of 10 mm. It can be seen that the separation point is moved from about 115° in Figure 3a to about 125° in Figure 3b. This causes a slight increment in the base pressure which, in turn, gives a drag reduction of about 10%. However in static conditions a drag reduction of about 7% was already achieved. Despite of the asymmetrical forcing, in this case the pressure distribution remains symmetrical resulting in a zero lift condition.



(a) $h = 0mm$, $\gamma = 0°$, $f = 0Hz$ (b) $h = 10mm$, $\gamma = \pm 30°$, $f = 100Hz$

Figure 3: Supercritical ($Re = 115000$) C_p distributions: a) Natural $C_{d_p} = 0.466$; b)Forced $C_{d_p} = 0.423$

CONCLUSIONS

The smart-tabs have shown good potential in controlling the wake of bluff-bodies over a wide range of flow conditions. In particular at subcritical Reynolds numbers, for $\gamma = 0°$, it appears that the smart-tabs oscillation is the main responsible for drag reduction. On the other hand, in supercritical conditions, seems that the oscillation gives rise to a smaller contribution to drag alleviation with respect to the contribution introduced by the tabs in static configuration. Nevertheless, the effect of the numerous control parameters has not been fully investigated yet. Moreover, further research involving other model shapes (bluff or streamlined) should be taken into account.

REFERENCES

[1] Park, H, Lee, D., Jeon, W-P, Hahn, S., Kim, J et al. (2006). *J. Fluid. Mech.* **563**, 389-414.

[2] Shtendel, T., & Seifert, A., (2012), *EFMC9*

[3] Amitay, M., Honohan, A.M., Trautman, M., & Glezer, A. (1997), *AIAA Fluid Dynamics Conference*