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Fluid structure interaction of hairy surfaces

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ABSTRACT

During the last decades, flow control has attracted lots of researchers developing and investigating innovative devices, either active (*e.g.* synthetics jets) or passive (*e.g.* riblets). For this purpose, biomimetics is a clever approach to enhance global performances of hydro and aerodynamical vehicles, such as lift, noise and drag improvements. The idea is to mimic the skin properties of flying or swimming animals: the riblets of sharks skin allow to improve significantly the performances, the compliant skin of dolphins shows promising effects on the transition to turbulence. However, hairy surfaces such as those of birds or seals, have to be studied to gain more insight on their interaction with a fluid flow. Different effects can be expected:

Figure 1: Passive shape adaptation: skua feathers popping up during landing phase.

- the irregular coating of hairy surfaces, especially in the spanwise direction (Itoh *et al.*, 2006) can lead to either a riblets-like behavior, or a vortex-generator surface,
- a compliant-like behavior due to the flexibility of the hairy medium,
- another effect, which we term passive shape adaptation, due to the alignment of hair with the flow in the presence of big coherent structures (Bechert *et al.*, 2000).

- in the context of water flows, the effect of an air layer trapped in a hairy medium has not been investigated and could lead for example to significant skin friction reductions (Kodama *et al.*, 2000).

The aim of this communication is to present a model for this type of hairy media, using an homogenized approach. The capability of this surface to achieve shape adapation in separated flows is investigated, and its benefits are discussed in the context of separation control.

Practically, to solve this fluid/structure interaction problem we use a partitioned approach based on the direct resolution of Navier-Stokes equations together with a non-linear set of equations describing the dynamics of the hairy surface. A volume force, estimated as the drag of a thick cluster of hair, provides the link between the fluid and the structure problems.

For the structure part, a subset of reference elements approximates the whole layer. The dynamics of these elements is governed by a set of equations based on the inertia, elasticity, interaction and dissipation effects of articulated rods (Lindström, *et al.*, 2007). For the coupling, experimental and theoretical results on flows going through densily packed arrays of cylinders are used to estimate the drag volume force (Howells *et al.*, 1998).

The configuration chosen si that of the flow past a circular cylinder, a simple and well documented test case. This communication shows quantitatively how a hairy surface coating can change the Strouhal number, the drag and the maximum lift for steady and unsteady laminar regimes. A parametric study will highlight the most efficient set of parameters (length of elements, density, flexibility, etc.) with respect to the control of boundary layer separation.

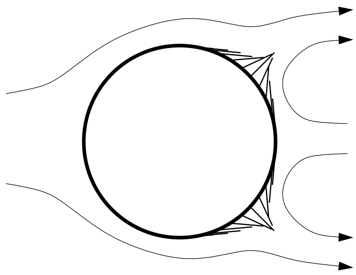

Figure 2: A cylinder half-coated with a hairy-like surface.

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