Dielectric Electroactive Polymers for drag-reducing wall oscillations in low-Reynolds number internal turbulent flows

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Spanwise wall oscillations have been widely investigated since the seminal work of Jung et al.[1] in 1994 as an active means to reduce turbulent skin-friction drag. In spite of its relative simplicity, the spanwise oscillations concept has been tested almost solely numerically, and only few experimental implementations have been attempted[2-7]. Moreover, most of them are proof-of-principle laboratory experiments in which the spanwise wall velocity is achieved by moving the wall through bulky crank-driven mechanisms. Though effective in reaching their aim, such solutions are generally energetically inefficient, require significant modifications of the wind tunnel test section and, most importantly, do not lend themselves to developing a system-integrated, compact solution. Moreover, it has been recently demonstrated[8] that achieving a high Reynolds number, is important to understand the true capabilities of the drag reduction technique.

Gouder et al.[9] realised the spanwise wall oscillation through a novel actuator concept: the dielectric electroactive polymers (DEAP). However they found this technology to be unattractive due to the fragility of the actuators, having a lifetime of only a few minutes[10], and electromagnetic linear motors have been preferred instead.

In the present work, we describe the design, fabrication and wind-tunnel testing of long-lasting spanwise-oscillating active surfaces based on DEAP actuators. We point out some advantages and drawbacks of this particular actuator and verify whether some potential advantages, such as low power consumption, low cost, low weight and simplicity can in fact be realised. Two soft surfaces with integrated dielectric elastomer actuators have been fabricated, capable of producing spanwise oscillations at their resonant frequency of 65 Hz with 4 mm peak-to-peak amplitude. The actuators have a moving surface of 25 cm x 25 cm area. Each actuator has been flush mounted on a Plexiglas plate, located 2m downstream of the inlet of an air channel flow and 1m before its outlet. The rectangular cross-section of the channel has a width-to-height ratio of 12:1 and a height of 25 mm. The two DEAP active surfaces have been mounted on the two opposite walls of the channel at the same spanwise position. Changes in wall skin-friction drag have been measured with highly accurate pressure measurements over a 20 cm long portion of the actuators, while the channel flow has been operated at velocities between 2.7 m/s and 9 m/s, corresponding to Re_τ=150 and Re_τ=450.

The streamwise length of the actuated section, when expressed in wall units, is 4500, therefore shorter than the streamwise onset length of drag reduction, leading to a space-averaged drag reduction of about 3%. On the other hand, their short length combined with the choice of a channel flow geometry make the setup suitable for a Direct Numerical Simulation, in which finite-size actuators are considered. We can thus verify whether the well-konwn differences between numerical and laboratory experiments reduce to a reasonable margin when the effect of the onset transient is taken into account. The final aim of this research is to evaluate the suitability of DEAP for laboratory implementations of spanwise oscillations through fabrication of an array of actuators to control larger sections of the wind tunnel.

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