

## RESPONSE OF THE NEAR WALL TURBULENCE TO LOCALIZED UNSTEADY BLOWING PERIODICAL AND DISSYMMETRIC IN TIME

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Key words: Active control, Drag Reduction, Localized Unsteady Time Periodical Blowing

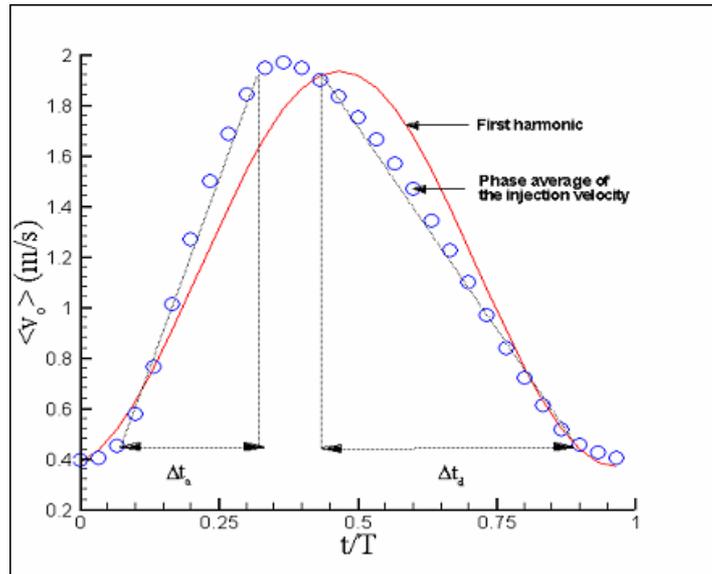
The active control of the near wall turbulence by suboptimal or optimal strategies is plausible, but it requires unfeasibly dense distribution of the sensors and actuators at the wall. One possible way to remedy to this situation is to go through dual control methods. The latter consist of exciting the near wall turbulence locally to render it more predictable and controllable. Such a strategy has been used by Tardu (1998, 2001) who investigated the reaction of the near wall turbulence to a space localized oscillating blowing sinusoidal in time with small severity. He showed that the flow is partly relaminarized during the oscillation cycle until roughly 50 wall units downstream of the slot. This is due to the creation of a positive spanwise vorticity layer that dilutes the negative vorticity existing near the wall. The relaminarized phase is unstable. The diffusion of the induced vorticity layer is constrained into the low buffer layer with limited effect of turbulent mixing, when the frequency of the oscillating blowing is large. Consequently the vorticity concentrates, becomes compact and rolls-up into a coherent spanwise vortex at approximately the beginning of the low buffer layer. It increases the wall shear stress as it is convected downstream, resulting in an important drag penalty compared with steady blowing with the same mean severity.

The relaminarized phase coincides with the accelerating phase (stabilizing) of the injection velocity and the concentrated positive vorticity layer rolls-up during the decelerating (destabilizing) phase. The idea advanced by Tardu (2001), was to use unsteady periodical blowing dissymmetric in time with a rapid acceleration phase followed by deceleration to prevent the destabilization and the set-up of the spanwise vortex that causes the drag increase. Thus a specific new pulsating device was designed and new experiments conducted in the low speed wind tunnel of LEGI. The ensemble of experimental parameters is similar to Tardu (2001). Fig. 1 shows the phase average of the injection velocity. It is seen that the acceleration phase is roughly twice more rapid than the deceleration one. The dissymmetry in blowing is also clearly perceptible through the differences between  $\langle v_0 \rangle$  and its first harmonic. Fig. 2 shows the phase average of the wall shear stress  $\langle \tau \rangle$  normalized by  $\tau_{SBL}$  of the standard unmanipulated boundary layer at 100 wall units downstream the blowing slot. The results corresponding to the sinusoidal injection velocity are shown by the squares. The large peak value of about 2.5 corresponds to the passage of the coherent vortex. The latter disappears when the blowing is dissymmetric as shown by the circles in the same Fig. Thus, the rapid acceleration followed by a slow deceleration phases prevent the formation of the spanwise vortex and suppresses the drag penalty. These results validate our previous arguments and show how the wall turbulence reaction is sensitive to the temporal waveform of localized blowing. It points at possible alternate ways of drag management. Detailed results related to the velocity profiles and turbulent quantities will be discussed in the Symposium. We are also

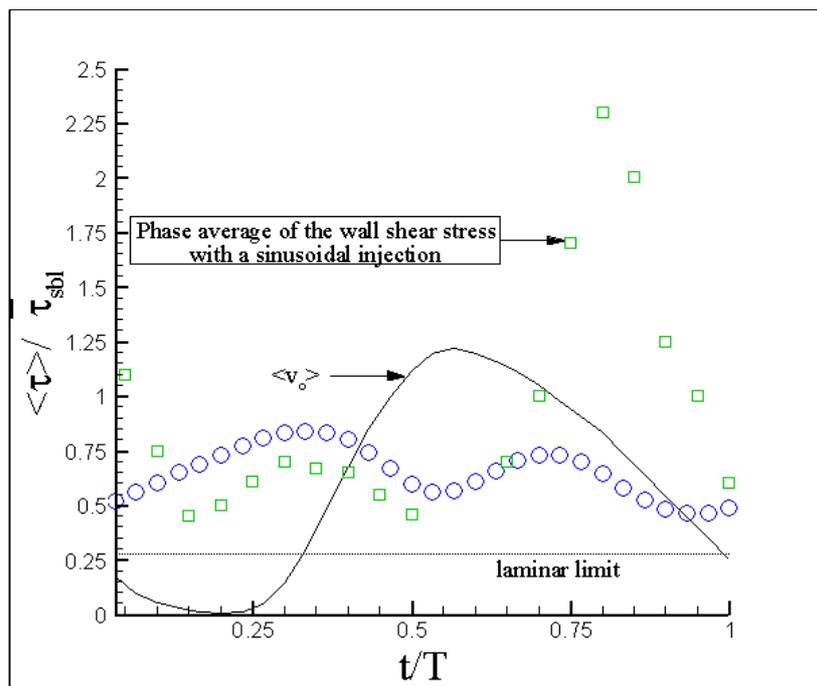
performing Direct Numerical Simulations in a fully developed turbulent channel flow and these results will also be presented.

**References**

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**Figure 1** Phase average of the injection velocity.



**Figure 2** Phase average of the wall shear stress measured at 100 wall units downstream the slot with sinusoidal and dissymmetric blowing velocities oscillating in time.