Drag Reduction via Transversal Wave Motions of Structured Surfaces

M. Albers\textsuperscript{1*}, P. S. Meyssonnat\textsuperscript{1} and W. Schröder\textsuperscript{1}

\textsuperscript{1}: Institute of Aerodynamics, RWTH Aachen University, Wüllnerstraße 5a, 52062 Aachen, Germany.
*Correspondent author: m.albers@aia.rwth-aachen.de

The drag and hence the energy-consumption of slender bodies moving in a fluid, e.g., an aircraft, is mainly determined by the friction drag. Thus, there is considerable scientific interest in influencing the flow to gain net energy savings. Generally, such flow control techniques are divided into whether or not external energy is introduced into the system, i.e., passive and active methods to influence the drag. In the present study, a combination of passive and active drag reduction techniques is considered using high resolution large-eddy simulations (LES). That is, a riblet structured surface with optimal riblet geometry is superposed with spanwise traveling transversal surface waves and analyzed in zero-pressure gradient turbulent boundary layer flow. To investigate the effect of the riblet and the transversal traveling wave on the drag four configurations are used in the current work, i.e., a smooth non-actuated reference case, a non-actuated riblet case, an actuated smooth transversal traveling surface wave, and an actuated riblet transversal traveling surface wave. The riblets have an optimal spacing for high drag reduction, i.e., $s^+ = 15$ according to Bechert et al. (1997), where the plus superscript represents inner units, and the traveling wave parameters are a wave length of $\lambda^+ = 1,000$, an amplitude of $A^+ = 30$, and a period of $T^+ = 40$. The Reynolds number based on the momentum thickness is $Re_\theta = 1,000$ and the Mach number is $Ma = 0.2$. The numerical method solves the compressible Navier-Stokes equations on curvilinear grids using the advection upstream splitting method (AUSM) and an implicit LES model. To avoid the simulation of the whole boundary layer including the transition from laminar to turbulent flow, the reformulated synthetic turbulence generation (RSTG) method by Roidl et al. (2013) is used.

The results show a drag reduction of the actuated riblet surface of about 11.4 percent compared to the non-actuated smooth flat plate. This result outperforms the non-actuated riblet case by about two percentage points. The level of drag reduction is comparable to the actuated smooth setup. A more detailed look on the mean streamwise velocity distribution reveals a similar behavior for the actuated smooth and riblet setup. The velocity in the near-wall region is generally reduced in the trough region with only slight increases on the wave crest. Furthermore, the spanwise traveling wave generally lowers the streamwise turbulent intensities at distances close to the wall for the riblet and the smooth surface. However, the secondary flow field induced by the wave motion causes streamwise vorticity fluctuations at the riblet tips that are not present in the smooth wave case. In conclusion, the wave motion shows a positive effect on the flow over the riblet surface, although the drag reduction rates of the non-actuated riblet case and the actuated smooth case cannot be simply added up. Whereas the streamwise velocity gradients and turbulent intensities are lowered by the wave motion, the secondary flow field interacts with the riblet geometry and creates new fluctuations. More simulations are necessary to get a profound understanding of such a hybrid method.

![Figure 1. Coherent structures visualized by the $\lambda_2$ criterion above the actuated riblet structured surface.](image)

REFERENCES
