Supersonic and hypersonic flows are simulated with either LES using the Approximate Deconvolution Method or DNS on high-performance vector supercomputers with up-to-date numerical methods of high-order accuracy.

At Ma=2.95, a supersonic turbulent boundary-layer flow along a ramp with the angle $\beta=25^\circ$ is investigated with the ADM-LES method developed by Stolz&Adams (Phys.Fluids 13).

Comparison with experiments by Zheltovodov et al. (AIAA 96-1977) show excellent agreement in key features and reveals new details on the separated flow. The low-frequency shock foot motion found in the experiment could be verified. Aside from direct shock–turbulent boundary-layer interaction, a mechanism for turbulence amplification in the external flow above the detached shear layer was found based on downstream-travelling shocklets. This explains the nature of experimentally observed turbulence amplification and details its acoustic mode downstream of a shock wave.

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Fig. 1 Integration domain with streamlines, main shock (grey) and Görtler-type vortices on the upward facing part of the ramp.

Fig. 2 Numerical Schlieren-type image with the spanwise average of the density gradient.

Fig. 3 Numerical skin-friction with the kink of the ramp at $x=0$ showing the Görtler-type vortices at the upward portion of the ramp.

Fig. 4 Comparison of eigenfunctions from compressible linear stability theory (dashed line) and wall-normal Fourier profiles for $Re=2800$ (square root of Reynolds number built with the distance from the leading edge of the plate) (solid line).

The comparison of eigenfunctions from compressible linear stability theory (Mack, 1969) shows excellent agreement with the numerical results of wall-normal profiles (Fig. 4).

Furthermore, it could be shown that the presence of non-equilibrium influences two-dimensional disturbance waves marginally whereas three-dimensional disturbance waves that are also linearly unstable are influenced strongly and show diminished amplitudes (AIAA paper 2005-5136).

In Fig. 3, the skin friction is plotted to enable comparison with oil film flow visualizations. The accumulation and depletion of oil directly shows the shear at the wall. The Görtler-type vortices are clearly to be distinguished.

Fig. 5 Wall-normal/downstream distribution of the pressure disturbance after the blowing/suction disturbance at the wall ($x=3$).

Hypersonic flows are investigated with Direct Numerical Simulations (DNS) that can take into account chemical and thermal nonequilibrium. Flight conditions are of interest as they are found in a typical re-entry scenario of lower earth orbit (LEO) vehicles. Chemical reaction are taken into account with a five species ($N_2$, $O_2$, NO, O, N) model developed by Park. The thermal non-equilibrium can be captured with the consideration of the vibrational temperature in an additional conservation equation for vibrational energy.

For the time being, flat-plate geometries are investigated for the transitional flow. Disturbances are introduced into a steady two-dimensional flow through blowing and suction at the wall (at $x=3$ in Fig. 5).

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