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NUMERICAL TRIPPING OF SUPERSONIC/HYPERSONIC BOUNDARY LAYERS

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The generation of synthetic turbulence for the computation of spatially developing wall-bounded turbulent flows has always been a major concern for the Computational Fluid Dynamics (CFD) community. Several classes of numerical methods for turbulence seeding have been introduced, ranging from the seminal work of Lund [1] based on the recycling/rescaling approach (RR) to more recent techniques relying on the digital-filtering (DF) approach [2]. Despite substantial efforts, all seeding methods require some adaptation length to achieve fully developed turbulence. In compressible boundary layers, it is experienced [3] that the extent of this region strongly depends on the Mach number and inlet Reynolds number. In addition, wall heat transfer rate dependence is also expected.

The present work is devoted to compare the performance of the RR and DF techniques in reaching an equilibrium state for the Direct Numerical Simulations (DNS) of turbulent high-speed boundary layers. For that purpose, we have carried out two sets of DNS of supersonic and hypersonic boundary layers, based on previous numerical studies. Quantification of the adaptation length relies on comparison between DNS carried out using typical literature setups and DNS benchmark datasets, obtained from simulations with longer streamwise domains. The adaptation length for the various flow diagnostics (including friction coefficient, maximum shear stress, peak velocity variances, wall pressure variance) is then defined as the distance to observe a prescribed percent deviation from the benchmark. We find that DF yields faster relaxation of the friction coefficient from the benchmark, whereas RR is overall most appropriate to quickly achieve the correct trend of the wall pressure fluctuations. Detailed discussion of the adaptation length for the various flow properties will be presented.

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