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Simulation of multi-mode transition to turbulence in compressible boundary layers using high-order methods

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Although supersonic turbulent boundary layers (TBL) have been extensively studied both numerically and experimentally, hypersonic TBLs are not yet well understood, particularly transition to turbulence. Recently, Ritos et al. [1, 2] presented implicit Large Eddy Simulations (iLES) results of a supersonic TBL showing that high-order iLES can provide accurate and detailed description of TBL directly comparable to available DNS, while utilising significantly less computational resources. In the present paper, we have used a modified (for transitional flows) 9th order accurate WENO scheme to simulate hypersonic transition (and turbulence) over a flat plate. Most importantly, the present simulations have been conducted for an atmospheric (von Kármán) multimode energy spectrum instead of simple single mode perturbations. The computational study has been performed in the framework of implicit Large Eddy Simulations (iLES). Simulation results are presented for Mach numbers 4, 6 and 8 and different inflow turbulence intensities. Figure 1 shows that even a relatively small value of turbulent intensity triggers bypass transition and turbulence at a downstream location. We have investigated the effects of grid resolution, Mach number, and turbulent intensity on the transition point, turbulent structures, and pressure fluctuations over a flat plate. Further insight into the transition mechanism and the underline physical processes is provided along with numerical evidence on the accuracy of the modified 9th-order WENO method in transitional hypersonic flows.

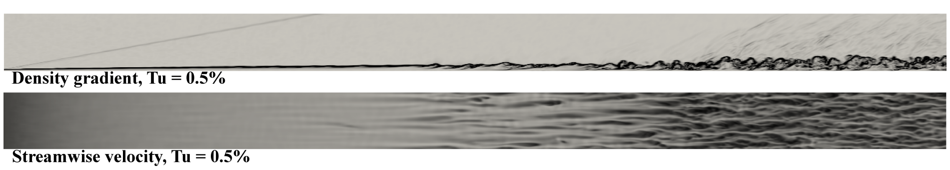

Figure 1: Instantaneous density gradient (side perspective) and streamwise velocity (top-down perspective) of the boundary layer at $M = 6$ and $Tu = 0.5\%$ at the inflow.

REFERENCES

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