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Multilayer scaling of mean velocity and thermal fields of compressible turbulent boundary layer WEITAO BI, BIN WU, Peking Univ, YOUSHENG ZHANG, Institute of Applied Physics and Computational Mathematics, FAZLE HUSSAIN, Department of Mechanical Engineering, Texas Tech University, ZHEN-SU SHE, Peking Univ — Recently, a symmetry based structural ensemble dynamics (SED) theory was proposed by She et al. for canonical wall bounded turbulent flows, yielding prediction of the mean velocity profile at an unprecedented accuracy (99%). Here, we extend the theory to compressible turbulent boundary layers (TBL) at supersonic and hypersonic Mach numbers. The flows are acquired by spatially evolving direct numerical simulations (DNS). A momentum mixing length displays a four layer structure and quantitatively obeys the dilation group invariance as for the incompressible TBL. In addition, a temperature mixing length behaves very similarly to the momentum mixing length when the wall is adiabatic, with a small difference in the scaling exponents in the buffer layer - consistent with the strong Reynolds analogy. The Lie group based formulization of the two mixing lengths yields a multilayer model for the turbulent Prandtl number, along with predictions to the mean thermal and velocity profiles, both in good agreement with the DNS. Thus, we assert that the compressible TBLs are governed by the same symmetry principle as that in the canonical wall bounded turbulent flows, and its mean fields can be accurately described by the SED theory.

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