SPECTRAL CHARACTERISTICS AND NEAR-WALL DYNAMICS IN HIGH REYNOLDS NUMBER TURBULENT BOUNDARY LAYERS

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High Reynolds number data over the Re_θ range between 4,100 and 23,700 were acquired by Hites[1] in a zero pressure gradient turbulent boundary layer over an axial cylinder in the National Diagnostic Facility. In this paper we examine the results from long time series measurements of velocity and the wall shear stress. The velocity time series were acquired for 10 distinct y^+ locations, and 3 locations of y/δ and y/θ each; i.e., a total of 16 time series for each Reynolds number. Detailed spectra computed from long time series of the streamwise velocity revealed a bi-modal distribution of energy in the boundary layer close to the wall. The change from a one modal higher frequency, scaling with inner variables, to another larger scale peak within the viscous and buffer layers defines this bi-modal behavior. This confirms that the large scale, low frequency, motions of the boundary layer are important in the dynamics of the near wall region. The RMS shear stress intensity at the wall displays an initial Re_x dependency but asymptotes to about 32% for higher Reynolds numbers. Instantaneous velocity and Reynolds stress time series were filtered, based on the collapse of the streamwise velocity spectra into a bi-modal structure, in order to extract details concerning the inner and outer scaling of the turbulence quantities. Comparison of outer scale contribution to the filtered RMS levels of streamwise intensity demonstrates that the larger scales are becoming more dominant with increasing Reynolds number. In the overlap region, the contributions to the Reynolds stress from the smallest and largest scales are not easily separated, and only the intermediate scales appear to be the sole source of turbulence production. This may be the explanation for conclusions reached by others that the dynamics of wall bounded turbulence scale best with ”mixed scaling.” The data reveals that for the streamwise turbulence, and the Reynolds stress, the overlap region grows continuously with Reynolds number. Further, the near wall turbulence bursting frequency was investigated using the same filtering techniques and the results revealed that scaling with inner variables alone collapsed the bursting frequency very well when the large scales are filtered from the time series. This leads us to conclude that the low-frequency larger scales present near the wall are a reflection of the outer scales and that mechanisms for production near the wall must account for them while maintaining appropriate inner scaling for newly generated structures.

References

[1] M. H. Hites, *Scaling of high-Reynolds number turbulent boundary layers in the national diagnostic facility*, Ph.D. Thesis, Illinois Institute of Technology, 1997.

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