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An analytical formulation for the 1D energy spectra in equilibrium wall-bounded turbulence YIFENG TANG, RAYHANEH AKHAVAN, University of Michigan — While a number of analytical formulations exist for the inertial and dissipation range 3D energy spectra in homogeneous, isotropic turbulence, none of these formulations can be directly applied to the near-wall region of equilibrium wall-bounded flows due to the strong anisotropy of the turbulence structure in the near-wall region. In homogeneous, isotropic turbulence, the 1D spectrum is related to the 3D spectrum through $E^{1D}(k/k_d)/(\varepsilon\nu^5)^{\frac{1}{4}} = 2\int_{k/k_d}^{\infty} E^{3D}(\tilde{k})/(\varepsilon\nu^5)^{\frac{1}{4}}\frac{d\tilde{k}}{\tilde{k}} = 2\int_{k/k_d}^{\infty} A_K\tilde{k}^{-\frac{5}{3}}F(\tilde{k})\frac{d\tilde{k}}{\tilde{k}}$, where A_K is the Kolmogorov constant, $F(\tilde{k})$ is the dissipation range correction to the Kolmogorov spectrum, ε is the volume-averaged rate of dissipation, and $k_d = (\varepsilon/\nu^3)^{\frac{1}{4}}$ is the Kolmogorov wavenumber. It is shown that an analytical formulation for the inertial and dissipation range 1D energy spectra in equilibrium wall-bounded turbulence can be obtained from $E^{1D}(k_\alpha/k_{d,\alpha})/(\varepsilon_\alpha\nu^5)^{\frac{1}{4}} = 2\int_{k_\alpha/k_{d,\alpha}}^{\infty} A_K\tilde{k}^{-\frac{5}{3}}F(\tilde{k})\frac{d\tilde{k}}{\tilde{k}}$, where $\varepsilon_\alpha(z) = \langle 3\nu[\frac{\partial u_i}{\partial x_\alpha}\frac{\partial u_i}{\partial x_\alpha} + \frac{\partial}{\partial x_\alpha}(u_i\frac{\partial u_\alpha}{\partial x_i})]\rangle$ denotes the contribution of the gradients in the α-direction to the total dissipation at wall-normal location z, $\langle\ .\ \rangle$ denotes an ensemble average, and $k_{d,\alpha} = (\varepsilon_\alpha/\nu^3)^{\frac{1}{4}}$. The validity of the proposed formulation is demonstrated using 1D spectra obtained from DNS databases of turbulent channel flow with $180 < Re_\tau < 2000$.

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