Direct numerical simulation of a turbulent rough-walled pipe AN-
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of turbulent pipe flow have been conducted at low to medium Reynolds numbers.
The surface of the pipe is varied from a smooth-wall pipe to a rough-wall pipe,
where the roughness is comprised of three-dimensional sinusoidal elements. Para-
metric tests were carried out to analyse the effects of the height and the wavelength
of the sinusoidal surface. An analysis of the mean statistics convincingly supports
Townsend's outer-layer hypothesis. Higher-order statistics such as skewness and
flatness are also gathered and show reasonable collapse in the outer layer of the
pipe for different roughness cases. Even at a mean-to-peak roughness height of 2.5
wall units, which is within the viscous sublayer of the pipe, the roughness effected
a centerline velocity shift of 0.50 friction velocities. When the roughness height is
increased to a mean-to-peak roughness height of 20 wall units, the flow can be con-
sidered to be in the fully rough regime, with a centerline velocity shift of 7.1 friction
velocities.

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