UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

NUMERICAL STUDY OF MACH NUMBER EFFECTS IN COMPRESSIBLE WALL-BOUNDED TURBULENCE

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The aim of this work is to improve the present understanding of compressibility effects in wall-bounded turbulence and to provide data for improving models. A family of wall-bounded compressible flows has been investigated using direct numerical simulation (DNS). The research is divided into two aspects: a study of the intrinsic compressibility effects in isothermal-wall channel flow and a study of the impinging shock/turbulent boundary-layer interaction. For the channel flow, an energy sink is introduced in the energy equation to effectively eliminate the compressibility effects caused by mean-property variation, isolating the intrinsic compressibility effects induced by fluctuations of the density and temperature (and pressure, dilatation, etc) fields. Centreline Mach numbers, M_{cl}, up to 6.2 have been considered, for which we find that both explicit compressibility terms in the TKE equation such as the pressure-dilatation and dilatational dissipation, and the implicit compressibility such as Reynolds-stress-anisotropy tensor begin to become important. An oblique shock/turbulent boundary-layer interaction at free stream Mach number $M_{\infty} = 2$ is also investigated. Central to this work is the need to quickly obtain a fully developed turbulent boundary-layer over the shortest possible downstream distance, for which a quasi-deterministic inflow strategy is used. Then an oblique shock is impinged on to the fully developed turbulence boundary-layer and the flow separates. Explicit and implicit compressibility effects become important and the TKE budget is altered completely within the interaction zone. The interactions of shock with the separation bubble and the vorticity are also addressed.