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Experimental investigation of the effects of short roughness strip and wall suction on the anisotropy in a turbulent boundary layer

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ABSTRACT

Hot wire measurements have been made in a turbulent boundary layer subjected to a short roughness strip and concentrated suction. The suction is applied through a porous wall strip for a range of suction rate. The aim of the study is to examine the effects of short roughness strip and suction on the anisotropy of Reynolds stress tensor. The result indicates that the anisotropy of Reynolds stress tensor is increased marginally downstream of the combination of suction and roughness strip. Although, roughness strip control the magnitude of the variations of the effect of suction on the anisotropy of Reynolds stress tensor, they act independently on the mechanism of the wall turbulence of the layer. While suction acts to increase the anisotropy, roughness strip act to reduce the anisotropy.

1. Introduction

The ability to interfere with the structure of turbulent flows occurring in various engineering applications is of significant importance and benefit. The study of how turbulent shear flows respond to different perturbations presents interests from both fundamental and engineering points of views. The latter study can lead to an improvement in the effectiveness of flow control techniques [1,2]. From fundamental point of view, such study can improve our basic knowledge of the dynamical response of turbulent shear flows. For example, the manner in which near-wall coherent structures respond to a sudden change in boundary conditions such as the combination of a short roughness strip and suction could provide some insight into the interaction between the wall region and the outer part of the boundary layer. Pearson et al. [3] investigated the response of a turbulent boundary layer to a short roughness strip, using the Laser Doppler Velocimetry (LDV). They found that, relative to the undisturbed smooth wall, the roughness strip increased the turbulent stresses in the region between the two internal layers originating at the upstream and downstream edges of the strip. Smalley et al. [4] showed that, relative to a smooth wall, the drag augmenting roughness reduces the level of an anisotropy. Similarly, Leonardi et al. [5] found that Reynolds stresses and their anisotropy invariants showed a closer approach to an isotropy over the rough wall than over a smooth wall. Oyewola et al. [6] examined the combined influence of Reynolds number and localised wall suction on a turbulent boundary layer. Their results indicated that it is the combination of momentum thickness Reynolds number and the suction rate that controls the boundary layer response to suction. They also found that suction altered the redistribution of the turbulent kinetic energy between its components. Antonia et al. [7] and Fulachier et al. [8] applied suction uniformly over the wall and found that the large-scale motion is altered significantly by suction. Their anisotropy invariant map (AIM) indicated that, relative to the no suction case, suction increases the anisotropy of the layer, with the wall layer mostly affected. Also, Oyewola et al. [9] examined the effect concentrated wall suction can have on the anisotropy of Reynolds stress tensor. Their results indicated that the large-scale motion of the boundary layer was significantly altered by suction, and that the global anisotropy of the layer increases with the suction rate. For example, they found that the shape of the structures near the wall changed from a cigar to a pancake shape when suction is applied. Recently, Oyewola and Tomori [10] studied the combined effect of the short roughness strip and localised wall suction, on the evolution of anisotropy, in a turbulent boundary layer. Although, anisotropy was altered by the combination of suction and roughness, the latter study was not sufficiently wide in scope to assess the full influence of short roughness strip on the suction effect on the anisotropy of Reynolds stress tensor.

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