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SEPARATING FLOW IN A 3D DIFFUSER: COMPARATIVE ASSESSMENT OF LES, ZONAL HYBRID LES/RANS AND URANS METHODS

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The separation from a solid boundary is the most encountered flow phenomena in engineering practice. The flow in the shear layer that separates the main stream from the recirculation is dominated by the organized, large-scale coherent structures, influencing to a large extent the overall flow behaviour. It should be recalled without going into details that the conventional, time-averaged RANS (Reynolds-Averaged Navier-Stokes) methods, almost independent of the modelling level, unlike in some flows separated from the sharp-edged surfaces (as e.g., in backward-facing step geometries characterized by a fixed separation point), perform fairly poor in the flows separated from continuous surfaces exhibiting a number of features typically associated with an unsteady flow separation: highly intermittent separation and reattachment regions, highly unsteady separated shear layers, flow recovery, pressure gradient alternation, etc. These issues motivated the present work, in which an LES utilizing both the standard and dynamic Smagorinsky subgrid-scale models, a zonal hybrid LES/RANS scheme (Jakirlic et al., 2010) and an instability-sensitive Unsteady RANS model (Maduta and Jakirlic, 2011), the latter two computational schemes developed by the authors, were comparatively assessed with reference to the flow in a three-dimensional diffuser featured by a separation of the three-dimensional boundary layer generated at the intersection of two sloped walls. The diffuser configuration represents an incompressible flow developing fully in a three-dimensional duct and then expanding into a diffuser, whose upper wall and one side wall are appropriately expended. Reference database has been provided experimentally (Cherry et al., 2008, 2009) and computationally by means of DNS (Direct Numerical Simulation; Ohlsson et al., 2010). Two three-dimensional diffuser configurations differing in terms of the values of the expansion angles - the upper-wall expansion angle is reduced from 11.3^o (diffuser 1) to 9^o (diffuser 2); the side-wall expansion angle is increased from 2.56^o (diffuser 1) to 4^o (diffuser 2) – were considered. These slight modifications in the diffuser geometry led to substantial changes in the flow structure with respect to the onset, location, shape and size of the three-dimensional separation pattern associated with the corner separation and corner reattachment, Figure 1. The inflow in both considered cases is characterized by a Reynolds number $Re_h = 10000$, based on the inlet duct height. The comparative assessment of afore-mentioned computational approaches is performed in terms of their capability to accurately capture the size and shape of the three-dimensional flow separation pattern and associated mean flow and turbulence features. In addition, the computational activity focusing on a plasma-actuated flow control towards pressure recovery enhancement with respect to flow reversal weakening in a 3D diffuser configuration is presented, Maden et al. (2013).

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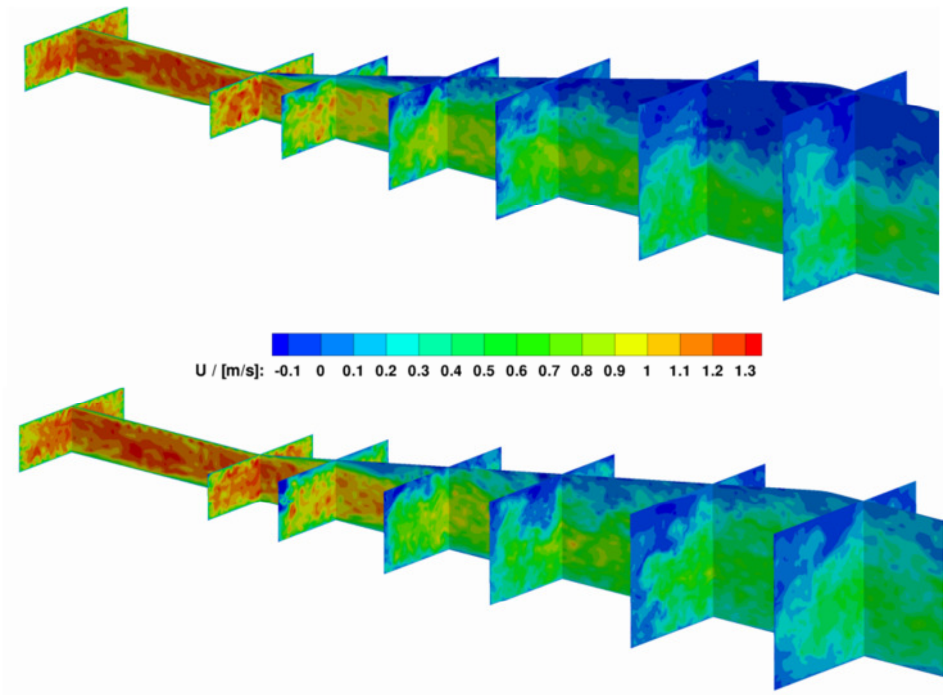

Figure 1: Instantaneous velocity field in both diffuser configurations, diffuser 1 (upper) and diffuser 2 (lower), obtained by a zonal hybrid LES/RANS model, illustrating different flow separation patterns. Whereas the separation zone spreads over the upper wall in the diffuser 1, it occupies the deflected side wall in the diffuser 2