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Scrutinizing Conventional and Eddy-resolving Unsteady RANS Approaches in Computing the Flow and Aeroacoustics past a Tandem Cylinder

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A differential, near-wall Reynolds stress model (RSM) employed in an Unsteady RANS (Reynolds-Averaged Navier Stokes) framework, coupled with the equation governing the inverse turbulent time scale relying on the so-called 'homogeneous dissipation' rate ($\omega_h = \varepsilon_h/k$) was applied to a tandem-cylinder flow configuration characterized by the in-between spacing corresponding to *L=3.7 D* for which the reference experiments have been performed by Jenkins et al. (2005, AIAA-2005-2812) and Neuhart et al. (2009, AIAA-2009-3275); see also Lockard et al. (2007, AIAA-2007-3450). The corresponding Reynolds and Mach numbers based on the cylinder diameter *D* and velocity of the oncoming flow amount *166000* and *0.1285* respectively. Complementary to the 'conventional' Reynolds stress model based on the Jakirlic and Hanjalic's (2002, *J. Fluid Mech.* 439: 139-166) formulation (denoted by RSM), its version sensitized appropriately to account for the turbulent unsteadiness was also applied. The latter eddy-resolving model, formulated by Jakirlic and Maduta (2015, *Int. J. Heat and Fluid Flow* 51: 175-194), is termed as Instability-Sensitized RSM model (IS-RSM). The capturing of instabilities is achieved by a selective enhancement of the turbulence production in line with the SAS (Scale-adaptive Simulation) proposal (Menter and Egorov, 2010, *Flow, Turbulence and Combustion* 85: 113-138). The flow characteristics relate to the so-called bistable behaviour corresponding to a configuration in which the flow structure at/behind the first cylinder switches from the continuous shedding resembling the well-known "von Karman" vortex street to a continuously separated shear layer reattaching temporarily at the front side of the rear cylinder; behind the second cylinder a continuous vortex street develops. In the time-averaged sense it is analogous to a recirculation zone characterized by a free reattachment point situated in the gap between cylinders; the post-reattachment stream resembles a jet hitting the front side of the downstream cylinder, followed by an intensified turbulence production within the impingement region. The final outcome is an appropriate shortening of the recirculation zone behind the rear cylinder, influenced by an enhanced turbulence activity in the gap between cylinders. The present instability-sensitized RSM formulation has been shown to be capable of capturing all important mean flow and turbulence features of the configurations considered, including also the intermittent (bistable) behavior of the flow in the gap between cylinders. The unsteady pressure field is the most important flow variable acting as the noise-source representative. Its unsteady feature is represented through the root-mean-square of the fluctuating pressure on both cylinders. Additionally, aeroacoustic computations are conducted by using a hybrid approach with Curle's acoustic analogy. Conventional RANS models traditionally fail in predicting the afore-mentioned features because of their time-averaging rationale. All computations were performed with the Finite-Volume-Method-based open source OpenFOAM® code.