VMS- and OES-based hybrid simulations of bluff body flows

Abstract for the ERCOFTAC Symposium on UNSTEADY SEPARATION IN FLUID-STRUCTURE INTERACTION, Mykonos, Greece, 17-21 June 2013

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Flows past bluff bodies show turbulent near wall behavior in various conditions. For example, for a high Reynolds incident flow, the boundary layer at front side of a circular cylinder may show a transition to a turbulent boundary layer. After separation, the back of the cylinder is in contact with the turbulent wake. Analogously, the turbulent wake of a first obstacle can hit the front of a second one.

As a first example, the flow past a cylinder at Reynolds number 1M is computed with a hybrid model blending a RANS based on a k-epsilon model and a Variational multiscale (VMS) LES formulation. A different blending is applied to the front side turbulent boundary layer and the wake-side one. The same coarse mesh of 1.2M cells is used for stressing the gap between the hybrid model and a too poor RANS modeling (unable to predict the rms Cl’ of the lift coefficient) or a too coarse VMS-LES computation (producing a wrong drag prediction) (Table 1).

		Cl’	Cp_{base}	St	Theta
URANS (1.2M)	0.24	0.06	0.25	0.46	129
VMS-LES (1.2M)	0.36	0.22	0.22	—	—
Hybrid RANS-VMS (1.2M)	0.24	0.17	0.28	0.38/0.17	118
RANS Catalano(2.3M)	0.39	—	0.33	—	—
LES Catalano(2.3M)	0.31	—	0.32	0.35	—
LES Ono-Tamura(4.5M)	0.27	0.13	—	0.4	—
LES Kim-Mohan(6.8M)	0.27	0.12	0.28	—	108
Exp. Shih	0.24	—	0.33	—	—
Exp. Schewe	0.22	—	—	0.44	—
Exp. Szechenyi	0.25	—	0.32	0.35	—
Exp. Guven	0.22	—	—	—	—
Exp. Goelling	—	—	—	0.35/0.10	130
Exp Zdravkovich	0.2-0.4	.1-.15	.2-.34	0.50/0.18	—

Table 1: Bulk flow parameters for flow past a cylinder at Reynolds number 1M.

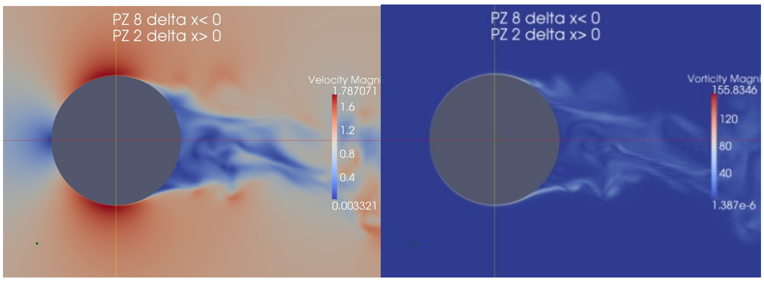

Figure 1: 3D Flow past a circular cylinder at Reynolds number 1M: instantaneous velocity and vorticity in vertical symmetry plane.

Secondly, a tandem cylinder configuration at Reynolds number Re=166000 has been simulated by a DDES approach, where the RANS part has been modified in respect of the turbulence length scale, by using the OES , Organised Eddy Simulation approach, (Braza, Perrin Hoarau, J. Fluids & Structures 2006), Bourguet, Braza, El Akoury (J. Fluids & Struct. 2008, Braza, (2012) (Keynote lecture, EMI/PMC conference, 2012).

The simulations are carried out by the NSMB code on a structured grid of 12,5 M points. The DDES-OES method has provided a good comparison of the predominant frequencies that govern the von Karman vortices, as well as the Kelvin-Helmholtz instability past the separation points, responsible for the acoustic noise (Fig. 2), in comparison with experiments by Jenkins et al, AIAA paper 2006 (Nasa-Langley). The present work is an extended study from the work carried out in the ATAAC European program coordinated by DLR, where the tandem cylinder was one of the stepping stones. The grid was provided by M. Strelets (NTS-St Petersburg).

In the present study, a detailed comparison of new results with the experimental study carried out in the S4 wind tunnel of IMFT by means of the time-resolved PIV, is carried out and will be presented in the symposium. The flow becomes supercritical in between the two cylinders. A bifurcation with specific intermittency between the subcritical to supercritical regime occurs and is analysed.

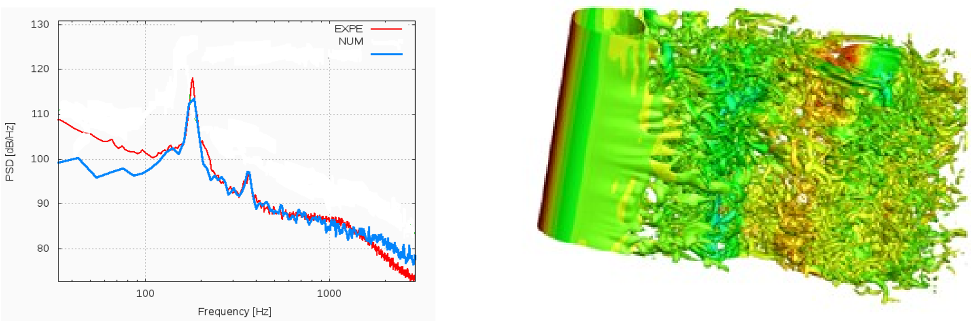

Figure 2: Left: Comparison of the energy spectrum between present simulations and experiments by Jenkins et al. Right: Isovorticity with pressure flood (red= high pressure, blue= low pressure).

The communication will discuss the choice of the two components (LES, RANS) and of the blending function for improving the quality of prediction.