11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

CO-SIMULATION OF WIND-STRUCTURE INTERACTIONS

R. Wüchner[*1], H. AlSofi[1], M. Andre[1], S. Sicklinger[1], T. Wang[1], K.-U. Bletzinger[1], R. Rossi[2], P. Dadvand[2], M. de Mier Torrecilla[3], A. Michalski[4]

[1] Chair of Structural Analysis, Technische Universität München (TUM), Arcisstr. 21, 80333 Munich, Germany, wuechner@tum.de, http://www.st.bgu.tum.de/
[2] Centre Internacional de Mètodes Numèrics en Enginyeria (CIMNE), Gran Capità s/n, Edifici C1, Campus Nord UPC, 08034 Barcelona, Spain, rrossi@cimne.upc.edu, http://www.cimne.com
[3] Abengoa Research, Campus Palmas Altas, c/ Energía Solar, 1, 41014 Seville, Spain, monica.mier@research.abengoa.com, http://www.abengoa.com
[4] SL-Rasch GmbH, Kesslerweg 22, D-70771 Leinfelden-Echterdingen, Germany, alex.michalski@sl-rasch.de, http://www.sl-rasch.de/

Key Words: *wind-structure interaction, interface treatment, partitioned solution schemes, software modularity, atmospheric boundary layer flow modelling, numerical wind tunnel.*

Numerical simulations for the investigation of wind-induced effects on large engineering structures (like membrane roofs, shells, wind turbines, etc.) are a promising complement to the classical approaches used in structural engineering, like physical wind tunnel tests or the use of tables and standards. Moreover, in the case of very light-weight and flexible structures, the typically large deformations and the potentially occurring flow-structure interactions restrict the application of physical testing in model scale due to the inevitable scaling laws. Thus, the preparation of a numerical wind tunnel is necessary to support the design process of light-weight and optimized structures which are nowadays technically feasible due to the existence of high-performance materials and innovative construction principles. Even in cases which can be investigated by classical testing, the numerical wind tunnel can be effectively used to screen the design space, i.e. to quickly evaluate design alternatives, in order to reduce the number of costly physical experiments. In these cases the both approaches of advanced simulation technology and physical testing can also be beneficially combined to a “hybrid wind tunnel”. Apparently, the required level of detail of the information about the structures’ behavior under wind load is significantly different depending on the design phase and also the expected wind-induced effects. This ranges from fast evaluations of mean pressure distributions up to detailed investigations of nonlinear coupled transient movements of complicated structures. These tasks can even be extended by structural optimization procedures or the simulation of fluid-structure interaction (FSI) including structural control e.g. to mitigate undesired structural motions.
To realize a numerical wind tunnel for these very different scenarios and for a variety of structures, ranging from e.g. complex-shaped stiff rigid building structures up to highly flexible and severely moving wind turbine composite blades, different mathematical models and solution schemes with their specific advantages must be combined in a versatile manner. As a consequence, a modular coupled simulation environment needs to be developed which allows for the coupling of different fluid and structural mechanics solvers, each of them having its own, independent modeling approach. Within this work, the actual partitioned realization of the computational FSI is centrally based on a generic coupling tool EMPIRE (http://empire.st.bv.tum.de/) capable to conduct the coupled co-simulations. It allows for the

use of different coupling strategies (e.g. explicit and implicit with different solution approaches) to guarantee stable and efficient simulations. Besides, it can also handle correctly various non-matching grid situations at the interface (e.g. finite volumes, finite elements, isogeometric elements) to enable the use of best-suited numerical models with their specific discretization and geometry description, respectively.In this contribution, the background of this coupling tool will be presented and some promising combinations for specific target applications will be shown and investigated: these are e.g. on the one hand the coupling to an embedded fixed-grid fluid solver which allows for very fast model generation and very large structural movements and is expected to give adequate results for bluff bodies with sharp edges, or on the other hand the coupling to an ALE-based flow solver which enables a very accurate representation of the flow near the wall as it is needed for the simulation of e.g. wind turbine blades, but for the prize of tedious and exhaustive mesh and model generation for complex geometries. The fluid codes are the open-source software packages KRATOS (http://www.cimne.com/kratos/) and OpenFOAM (http://www.openfoam.com/), whereas the nonlinear structural dynamics with standard finite element discretization and also isogeometric elements is done with the in-house code CARAT++.

Further key components for the numerical wind tunnel will also be shown: the proper modeling of the atmospheric boundary layer flow with the correct statistics is of utmost importance, which necessitates particularly a specific inlet generator module for the simulation of the inlet data. Finally, to ensure predictive capability of the computational wind-structure interaction co-simulation, validation either with very expensive real-scale tests (Michalski et al. (2011)) or simulation and wind-tunnel measurements at model-scale can be performed. To summarize, this contribution will show the required components and their coupling for predictive partitioned multifield simulation for analysis and design of free-form, light-weight structures subject to wind.

The authors wish to acknowledge the support by Abengoa Research (Seville, Spain), SL Rasch (Stuttgart, Germany) and the ERC (project uLites (FP7-314891)).

REFERENCES

[1] M. Breuer, G. De Nayer, M. Münsch, T. Gallinger, R. Wüchner, (2012) Fluid–structure interaction using a partitioned semi-implicit predictor–corrector coupling scheme for the application of large-eddy simulation, *Journal of Fluids and Structures*, Vol. 29, pp. 107-130.

[2] Bazilevs, Y., Hsu, M.-C., Kiendl, J., Wüchner, R. und Bletzinger, K.-U. (2011) 3D simulation of wind turbine rotors at full scale. Part II: Fluid–structure interaction modeling with composite blades, *International Journal for Numerical Methods in Fluids* 65: 236–253.

[3] A. Michalski, P. d. Kermel, E. Haug, R. Löhner, R. Wüchner, K.-U. Bletzinger. Validation of the computational fluid-structure interaction simulation at real-scale tests of a flexible 29 m umbrella in natural wind flow, J. Wind Eng. Ind. Aerodyn., Volume: 99, Issue: 4, pp. 400-413, (2011).

[4] Kupzok, A., Wüchner, R. und Bletzinger, K.-U. (2009) Numerische Methoden zur Simulation von Wind-Bauwerk-Wechselwirkung bei Membrankonstruktionen, S.221-232, in: *WtG-Berichte Nr. 11 – Windingenieurwesen in Forschung und Praxis, Peil (Hrsg.)*, Windtechnologische Gesellschaft, Aachen.

[5] R. Wüchner, A. Kupzok, K.-U. Bletzinger, (2007) A framework for stabilized partitioned analysis of thin membrane-wind interaction, *International Journal for Numerical Methods in Fluids*, Vol. 54, pp. 945–963.