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SIMPACK News

VOLUME 13, FIRST ISSUE

JUNE 2009

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Fluid-Structure Coupling for Wind Turbine Rotors

Today, the structural behaviour of wind turbines can be simulated using modern multi-body simulation codes such as SIMPACK. For aerodynamic simulations, computational fluid dynamics (CFD) methods have been developed. This project contributes to the development of the next generation of design tools based on a coupling of those advanced codes and aims to improve the quality of numerical simulations of the fluid-structure interaction process, which leads to a better understanding of the underlying physics.

MOTIVATION

In the current design process, aeroelastic simulation of wind turbine dynamics is performed with special software codes developed solely for this application. These codes often use only a few modal degrees of freedom to describe the structural dynamics. The simulation of rotor aerodynamics is based on the blade element momentum theory (BEM). Since SIMPACK can be used for more detailed analyses of the structural dynamics of a wind turbine and its components, and because simulation tools for calculating the rotor aerodynamics have reached a high level of sophistication, the next logical step was to link both developments. The resulting approach, which fully couples fluid-structure computations based on computational fluid dynamics (CFD) and multi-body simulation (MBS), is presented in this article.

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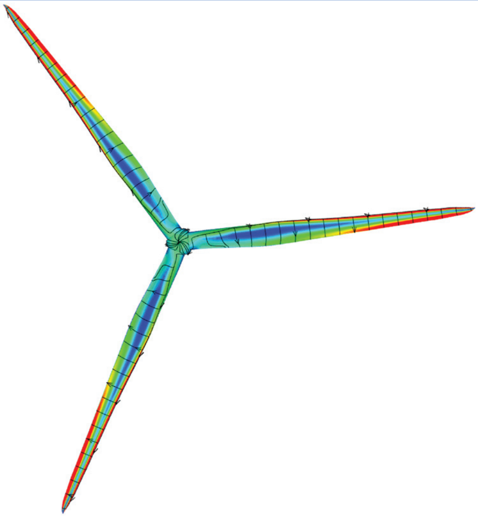

Fig. 1: CFD Rotor model

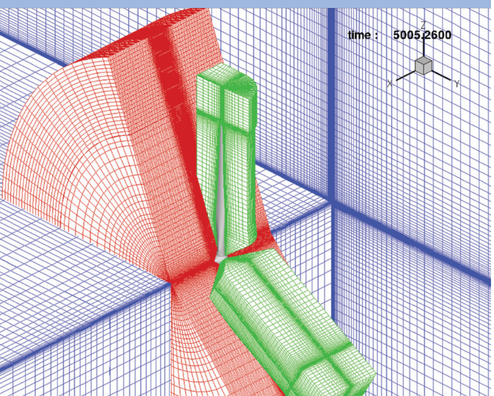

Fig. 2: Chimera grid

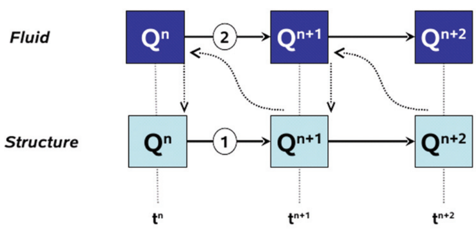

Fig. 3: Implicit-explicit coupling scheme

THE STRUCTURAL MODEL

This project focuses on the fluid structure interaction and does not consider overall wind turbine dynamics yet. Therefore, the structural model only consists of a rigid hub and flexible rotor blades. SIMPACK offers a number of strategies to build rotor blade models. In addition to rigid blade models, flexible models can be created using beam elements. To create the structural model, the SIMPACK rotorblade generator is used. This blade generator employs an input file to generate the model with the specified characteristics. Three of those blades are linked to the rigid hub. With the help of several markers distributed along the blade length, the blade deformation and the aerodynamic loads can be exchanged with the aerodynamic model used.

THE AERODYNAMIC MODEL

The aerodynamic simulation is based on the CFD code FLOWer that has been developed to solve the three-dimensional, unsteady Euler or Reynolds averaged Navier-Stokes (RANS) equations. The equations are formulated in a hub-attached, non-inertial rotating frame of reference with explicit contributions of centrifugal and Coriolis forces. Different turbulence models are available in FLOWer. However, as it has proved useful in other studies, the k-ω SST turbulence model is the sole model used for the present study. FLOWer features the Chimera technique allowing for arbitrary relative motions of aerodynamic bodies. Applying the Chimera technique, three blade grids and a hub grid are placed inside a background grid, which covers the whole computational domain; see Fig. 1 and 2. The blade grid is deformed based on the SIMPACK calculations.

FLUID-STRUCTURE COUPLING

In this project, a so-called strong coupling is used which means that the aerodynamic loads and structural deformations are exchanged at each time step. The coupling schemes are classified by the type and order of the integration scheme used for the fluid and the structure, respectively. This project focuses on a first order implicit-explicit scheme which basically consists of the following two steps (see Fig. 3).

1. <u>Explicit step:</u> Computation of structure state at timestep n+1 based on current state of fluid and structure.
2. <u>Implicit step:</u> Computation of fluid state at timestep n+1 based on state of fluid at timestep n and state of structure at timestep n+1.

CONCLUSIONS

An approach for strong coupled fluid-structure simulations between a CFD solver and an MBS code has been implemented and shown to work properly. In the next steps, the detailed structural dynamics of a complete wind turbine will be taken into account by the SIMPACK model. CFD computations will be extended to a complete wind turbine in order to account for the tower influence. Additionally, coupling scheme refinements and improvements in force and displacement exchange are anticipated. With a suitably refined and validated fluid structure interaction approach, computations including turbulent inflow in the case of the CFD computations will be investigated.

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