Development, Verification and Validation of 3DFloat; Aero-Servo-Hydro-Elastic Computations of Offshore Structures.

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Abstract

The aero-servo-hydro-elastic Finite-Element-Method (FEM) code 3DFloat is tailored for nonlinear, full coupling time-domain simulations of offshore structures in general, and offshore wind turbines in particular. The verification and validation histories for offshore wind turbines include the IEA OC3/OC4/OC5 projects, two wave tank tests and participation in commercial projects. Current development examples include implementation of advanced hydrodynamics in the DIMSELO project, implementation of soil/structure interaction macro-elements in the REDWIN project, and optimization of large rotors with sweep in an industry project.

Advanced hydrodynamics in DIMSELO (www.dimselo.no)

The project partners IFE, DTU, NTNU Statoil and Statkraft, develop and implement advanced hydrodynamic models. Figure 2 compares the inline force for a bottom-fixed cylinder with diameter 6m at a water depth of 35m, subject to regular waves with wave height 16.6m and period 11.4s. The 3DFloat Morison and Rainey computations use stream function of order 12 for the kinematics. The Rainey and IFE in-house CFD results agree very well. The standard Morison model underpredicts the peak force by 15% compared to the Rainey and CFD results.

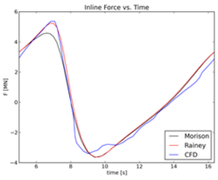

Figure 1. : Comparison of inline force for a bottom-fixed cylinder

Figure 2 shows surge and heave motions for a 80 x 30 x 8m pontoon supported by springs, used in a conceptual design study of a Submerged Floating Tunnel. The sea state corresponds to an effective wave height of 0.5m, and a peak period of 14s in the JONSWAP spectrum. As a first check of the Linear Potential Theory implementation in 3DFloat, corresponding results from SIMO are shown in the same figure.

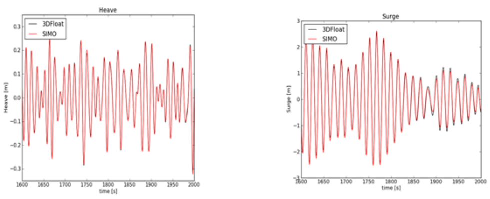

Figure 2. Pontoon heave and surge motions. Comparison between SIMO and 3DFloat results

Conclusions and further work

- 3DFloat is a platform for:
  - Innovation and technical development
  - Research on computational methods
- IFE has allocated resources for helping industrial partners getting started with computations of their in-house designs.
- The next steps for upgrades include:
  - Linear Potential Theory distributed on elements
  - Bluff body aerodynamics

Soil/structure interaction REDWIN (www.redwin.no)

REDucing cost in offshore WINd by integrated structural and geotechnical design is a R&D project supported by The Norwegian Research Council ENERGIX program. The project partners are NGI, IFE, NTNU, Dr.techn. Olav Olsen AS, Statoil and Statkraft. The primary objective of REDWIN is to contribute to reduction of costs in design of offshore wind turbines by developing and implementing soil-foundation models. As a first step, a simplified 1D-macro-element or a force resultant model has been implemented in 3DFloat. The IWAN-type model [1] consist of parallel coupled linear elastic-perfectly plastic springs, each with different stiffness and yield limits. The total load-deformation response is then represented by a nonlinear backbone curve which produce damping from its hysteresis behavior. Figure 3 shows the mudline overturning moment during an extreme operating gust starting at time 150s, combined with regular waves with wave height 3m and period 10s, for the 5MW OC3 Monopile wind Turbine. The time evolution corresponds to moving clockwise around in the hysteresis curve.

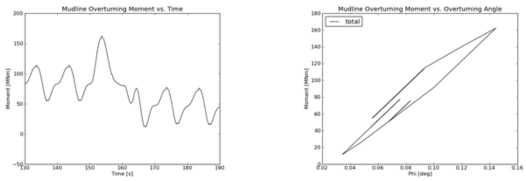

Figure 3. : Mudline overturning moment during wind gust

High-fidelity rotor aeroelastics, Statoil industry project

For long, slender and flexible rotor blades, taking into account offsets between the elastic axis and the shear- , aerodynamic- and mass centres is important. IFE is evaluating and optimizing rotors with sweep in a current industry project funded by Statoil. Figure 4 compares the aerodynamic rotor thrust during a gust for rotors with different versions of sweep. On a rotor with the blades swept backwards on the outer part of the blades, an increase in thrust on the blades produces a torsional moment, corresponding elastic twist, and thereby reduction of angle-of-attack. This reduces the peak load during the gust compared to the baseline blade. To counter the steady-state elastic twist resulting from backward sweep, a version with forward sweep on the inner part of the blade has also been designed. This reduces the peak loads further.

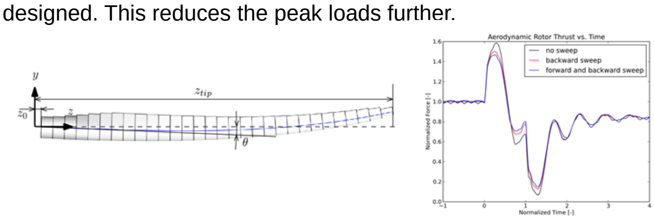

Figure 4. Load reduction during gust by rotor sweep.

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References

[1] Iwan, W.D. (1967). On a Class of Models for the Yielding Behavior of Continuous and Composite Systems. Journal of Applied Mechanics. [Online] 34 (3), 612–617. Available from: doi:10.1115/1.3607751.