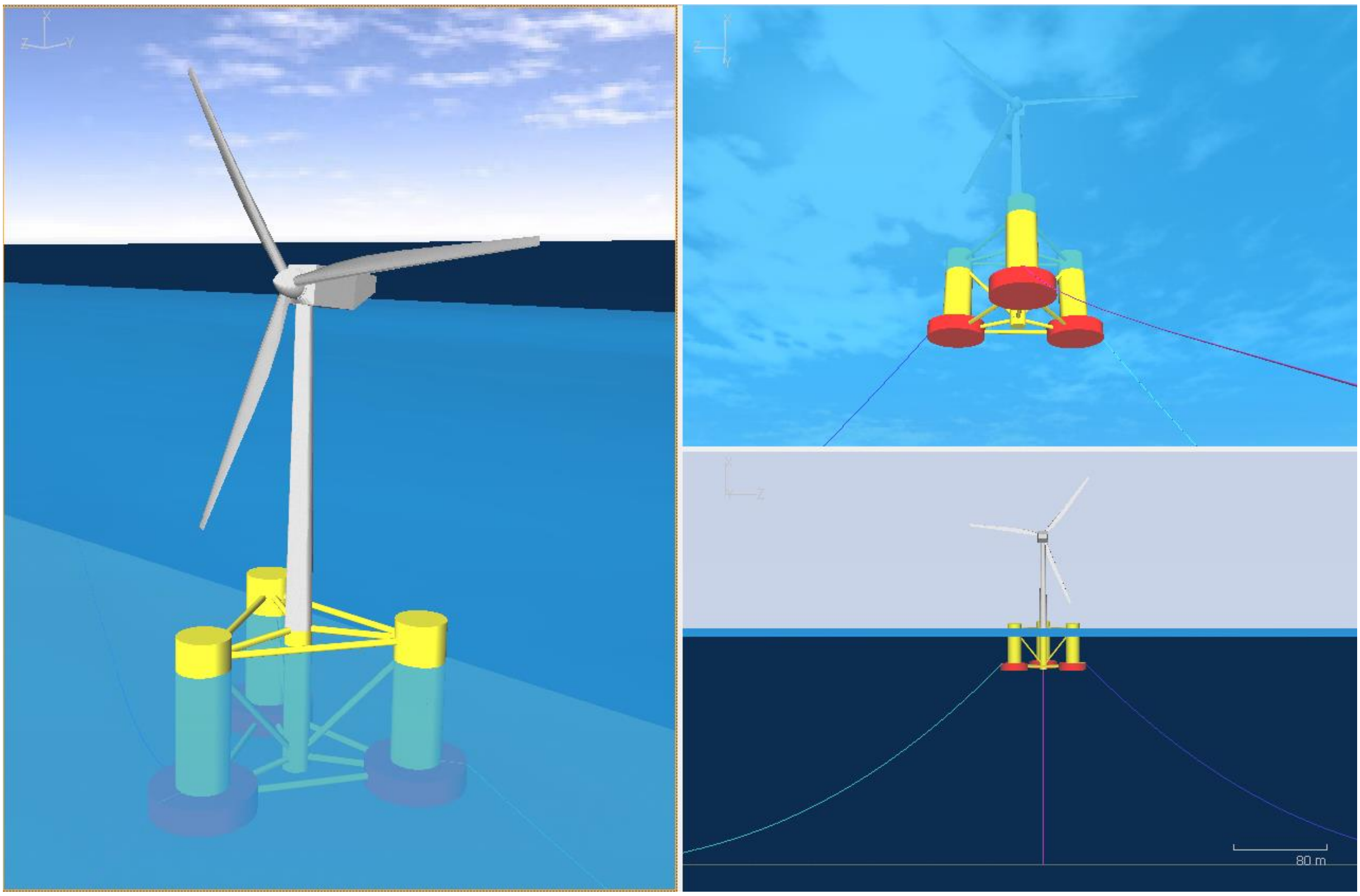
Flexcom Wind

Next Generation Software for Offshore Wind Energy

Powered by Flexcom *and* **FAST**

June 2017



WELCOME

Aengus Connolly
Flexcom Product Manager

I am pleased to announce the release of Flexcom Wind (strictly speaking Version 8.7 of Flexcom).

Offshore wind is already an established source of energy in the global energy mix, and consequently a range of software products are available which support the design of offshore wind turbines. However, feedback from industry suggests that an optimal tool does not yet exist for floating wind turbines - some products are overly simplistic, some are strong technically but weak in terms of user experience, and the few tools that appear to be genuinely fit-for-purpose command premium rates. Based on our combination of marine engineering and software development skills, Wood Group identified an opportunity to develop and deliver a state-of-the-art simulator.

User feedback is an essential part of our software development process. We invite you to join the conversation and welcome your opinions and suggestions which will in turn help guide future development. Feel free to call me at the number below, or simply email any suggestions to software.support@woodgroup.com.

We hope you enjoy Flexcom Wind.

Best regards,
Aengus.

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Background

Renewable Energy & Flexcom

Although traditionally used in offshore oil and gas, Flexcom is a versatile application which also has applications in the renewable energy sector. As far back as 2009 in fact, Flexcom 7.9 saw the introduction of the Floating Body coupled analysis feature, which enabled the analysis of floating devices. Since then Flexcom has been successfully utilised in the optimisation of wave energy devices, and results from the numerical simulations have been validated with empirical data derived from model-scale tank test facilities. In response to the growing interest in offshore wind, and floating wind in particular, Flexcom 8.7 sees the introduction of a wind turbine modelling feature.

Development Strategy

Rather than independently developing a brand new aerodynamic modelling capability, the Flexcom development team decided instead to team up with the National Renewable Energy Laboratory of the United States Department of Energy. Since circa the year 2000, NREL have been progressively developing a software product called FAST (an acronym for Fatigue, Aerodynamics, Structures, and Turbulence), a tool for simulating the coupled dynamic response of wind turbines. The software is highly regarded from a technical perspective by leading experts in the wind industry, and the research goals of NREL are well reflected by the state-of-the-art analytical solver which they have produced. Given that development efforts have focused exclusively on technical aspects of the solution, FAST does not have any conventional user interface associated with it (all user inputs are defined via a series of plain text input files), so it is not perceived as being overly user-friendly, particularly for first time users. This is not surprising as FAST was not designed to be a commercial software product. Instead NREL have generously made the software freely available as an open-source product, with the aim of aiding and accelerating the global development of the floating wind industry. On a practical level, FAST is effectively a modularised framework of several component software modules. From a Flexcom perspective, the module of primary interest is its aerodynamic solver, AeroDyn, which serves as an ideal complement to Flexcom's long established structural and hydrodynamic modelling capabilities.

Software Installation

The Flexcom 8.7 installation pack is available for download from our website.

Download Flexcom

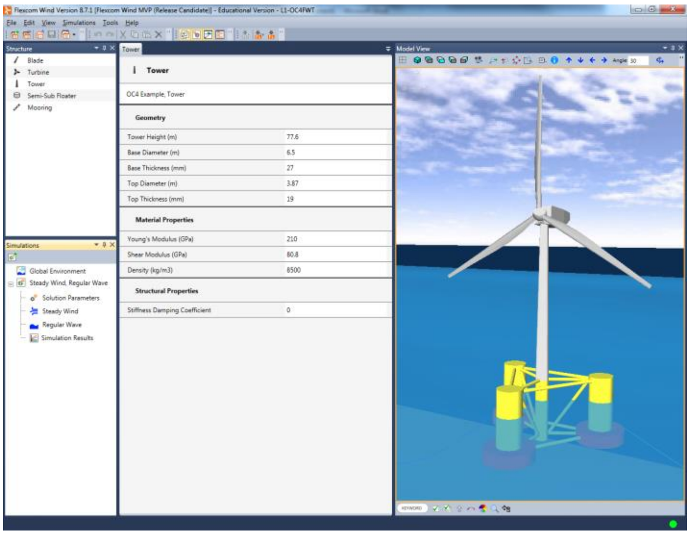
To install the upgrade, save the ZIP file to a temporary folder on your hard drive, unzip the contents, run 'InstallFlexcom.exe' to launch the Setup Wizard, and then simply follow the on-screen instructions.

Contents

Model Construction

Flexcom Wind Module

A dedicated floating wind turbine module is provided with Flexcom 8.7, which may be launched from the *Tools* menu in the main Flexcom user interface. Software inputs are defined in engineering terms and logically grouped into familiar components, such as blade, tower, floater and so on. The philosophy is to allow detailed models to be created quickly and easily, allowing the user to concentrate on the engineering design. Automated post-processing features present the designer with key information such as power generation, platform motions, and stresses in dynamic cables and mooring lines. Learn More >



User experience is somewhat different to the standard Flexcom package (there are no keywords!) as the module is effectively aimed at new users who would typically have a background in offshore wind engineering, but no prior experience of working with Flexcom.

Migrating to Flexcom

While simulations may be performed directly within the floating wind module itself, experienced Flexcom users may prefer to use the new module for initial model construction only, and then switch to the main Flexcom environment as it provides greater modelling flexibility. Migrating is as easy as flicking a switch, and the new module produces a well-structured, heavily parameterised keyword file which can be subsequently customised to meet your own individual requirements.

The structural components of the model, such as the floater, tower and mooring lines, are all constructed in standard fashion using established Flexcom modelling capabilities. The aerodynamic inputs are all neatly organised in a new section of the keyword file called $AERODYN, and a new *AERODYN DRIVER keyword provides the key link between the structural and aerodynamic models. So apart from learning a few new keywords, experienced Flexcom users will not have any difficulty in building their own floating wind turbine models. Additionally, a dedicated aerodynamic section has been added to the *TIMETRACE command to facilitate extraction of turbine specific information, such as power, rotor speed, aerodynamic forces and moments etc.

Applied Loads

Blades and Tower

There are three primary load components in a Flexcom wind turbine simulation:

- Aerodynamic loads on the turbine blades and supporting tower
- Hydrodynamic loads on the floating platform
- Structural and hydrodynamic loads imparted by the mooring lines

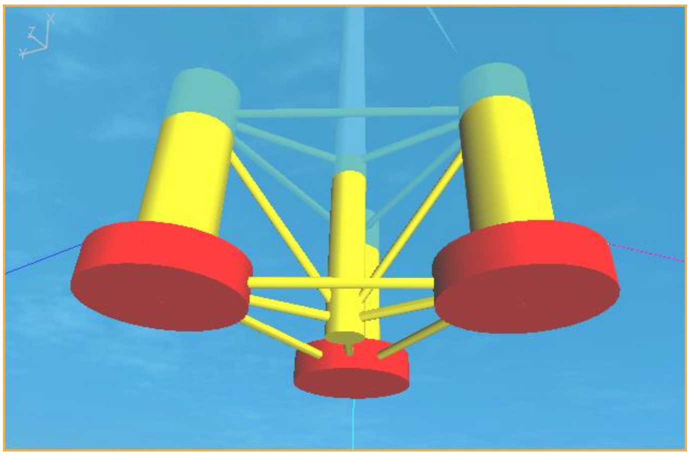
Aerodynamic loads on the blades and tower are computed directly by AeroDyn. The aerodynamic calculations are based on the principles of actuator lines, where the three-dimensional (3D) flow around a body is approximated by local two-dimensional (2D) flow at cross sections and the distributed pressure and shear stresses are approximated by lift forces, drag forces, and pitching moments lumped at a node in a 2D cross section. Analysis nodes in AeroDyn are distributed along the length of each blade, the 2D forces and moment at each node are computed as distributed loads per unit length, and the total 3D aerodynamic loads are found by integrating the 2D distributed loads along the length. The total loads on the rotating blades are then assembled at the hub, and passed to the Flexcom solver for input into the global force vector on the right hand side of the equations of motion.

The wind load on the tower is based directly on the tower diameter and drag coefficient and the local relative wind velocity between the freestream (undisturbed) wind and structure at each tower analysis node in AeroDyn. These loads are then passed to Flexcom, where they are applied to the corresponding tower node in the structural model, and the global force vector is augmented accordingly.

Floating Platform

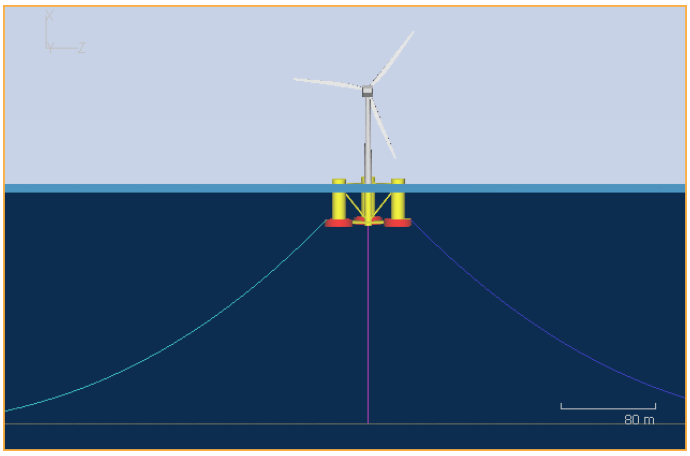
Hydrodynamic loading on the floating platform includes the various items listed below. The loads are computed for the floating body as a whole, and then applied at an appropriate location in the global force vector (e.g. at a node which corresponds to the centre of gravity).

- First-Order Wave Loads (high frequency) derived from Force RAOs
- Radiation damping loads. An important issue arises with respect to the Added Mass and Radiation Damping terms associated with the floating body, and how these are modelled in the time domain. The frequency-dependent nature of these terms is accounted for using the established impulse response approach developed by Cummins (1962), and its implementation in Flexcom is described in detail by Connaire et al. (2003) and Lang et al. (2005). Specifically, the frequency-dependent damping term is replaced by a convolution integral of retardation functions and velocity time histories in the time domain. Learn More >
- Viscous Damping Loads derived from Viscous Damping Coefficients
- Second-Order Wave Drift Loads (low frequency) derived from Quadratic Transfer Functions (QTFs)
- Current Loads computed via Current Coefficients
- Wind Loads computed via Wind Coefficients
- Hydrodynamic Loads determined according to the theory of manoeuvrability



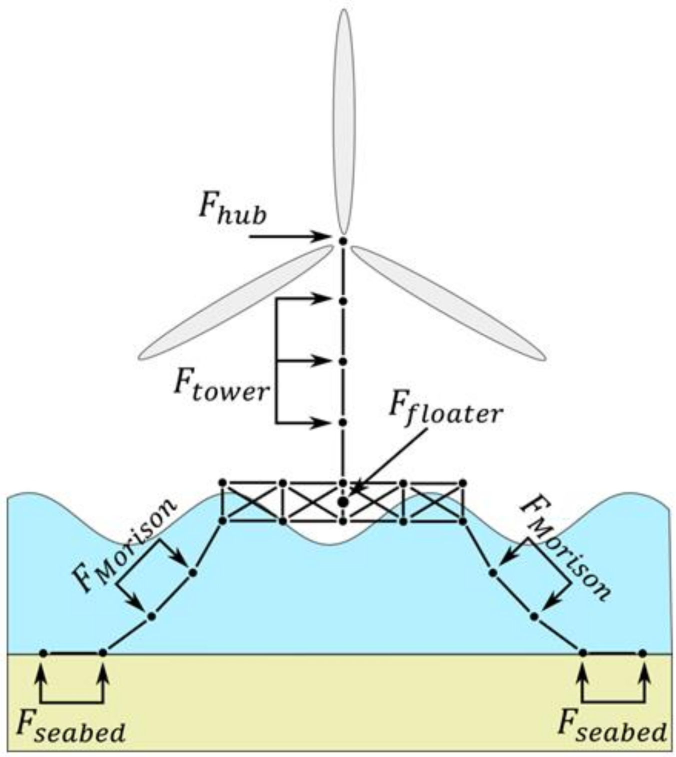
Mooring Lines

Mooring lines are modelled in the standard fashion using beam elements. These elements form a natural part of the overall finite element solution, so their effect on the floater is handled automatically. Specifically, effective tensions in the mooring lines induce point loads on the floater at the fairlead connection points. In addition to the axial loads, mooring lines are subject to self-weight and Buoyancy Forces. Hydrodynamic Loading is based on Morison's Equation, including the fundamental components of drag, added mass and hydrodynamic inertia. Contact algorithms are used to simulate Seabed Interaction with the local seabed topography.



Coupled Solution

The *AERODYN DRIVER command provides the key link between Flexcom and AeroDyn. Here the user indicates to Flexcom some fundamental pieces of information, including (i) the location (node number/label) in the finite element model which corresponds to the hub location in the aerodynamic model, and (ii) the portion (set of elements) of the finite element model which represents the tower. The hub location is particularly crucial. It is the central point for information exchange between the two solvers for all data pertaining to the aerodynamic loading on the rotating blades. Similarly, the tower nodes facilitate the inclusion of wind loads on the tower in the structural model.

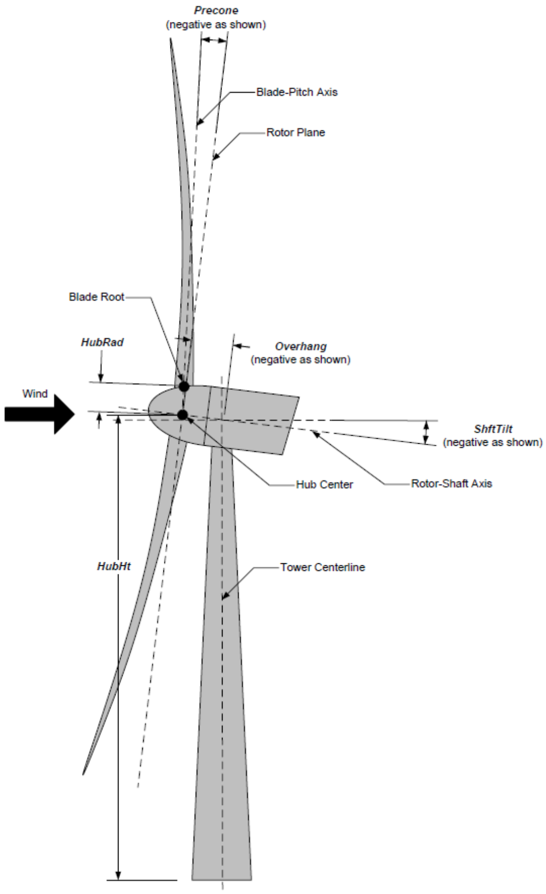


At the beginning of a dynamic simulation, Flexcom passes all information pertaining to the blades and tower to AeroDyn - such as the initial hub location in terms of global XYZ coordinates, the initial shaft tilt angle, the initial nacelle yaw etc. AeroDyn then computes the aerodynamic loads using blade element momentum theory as outlined above. The total loads on the rotating blades are assembled at the hub, and passed back to the Flexcom solver where they are added to the global force vector on the right hand side of the equations of motion. Similarly, wind loads on each tower node in the AeroDyn model are passed to the corresponding structural node in the Flexcom solver, and the global force vector is augmented accordingly.

Once all the constituent terms have been assembled, Flexcom solves the finite element equations of motion, and the global solution vector (predominately consisting of displacement terms) is populated. The updated locations for the hub and tower nodes are then passed back to AeroDyn, and the aerodynamic computations are performed again, before the updated wind loads and passed back to the structural model. This solution progresses in an iterative manner until solution convergence has been achieved in the structural solver. The solution time is then advanced by one time step and the whole process recommences. The iterative nature of this solution scheme ensures that full coupling between the structural and aerodynamic models is achieved.

AeroDyn

Aerodynamic calculations within AeroDyn are based on the principles of actuator lines, where the three-dimensional (3D) flow around a body is approximated by local two-dimensional (2D) flow at cross sections and the distributed pressure and shear stresses are approximated by lift forces, drag forces, and pitching moments lumped at a node in a 2D cross section.



(image courtesy of NREL)

Analysis nodes are distributed along the length of each blade and tower, the 2D forces and moment at each node are computed as distributed loads per unit length, and the total 3D aerodynamic loads are found by integrating the 2D distributed loads along the length. The actuator line approximations restrict the validity of the model to slender structures and 3D behaviour is either neglected, captured through corrections inherent in the model (e.g., tip-loss, hub-loss, or skewed-wake corrections), or captured in the input data (e.g., rotational augmentation corrections applied to aerofoil data).

AeroDyn consists of four submodels: (1) rotor wake/induction, (2) blade aerofoil aerodynamics, (3) tower influence on the wind local to the blade nodes, and (4) tower drag. Learn More >

Software Modelling Limitations

There are a number of limitations associated the modelling capability as it currently stands. The ability to model floating wind turbines is a relatively recent addition to the software, and the feature will grow and develop over time. In the meantime, users should be familiar with the underlying assumptions which the current model is based on. Learn More >