

## THE DEVELOPMENT AND APPLICATION OF A MOORING LINE MODEL FRAMEWORK FOR CFD ANALYSIS

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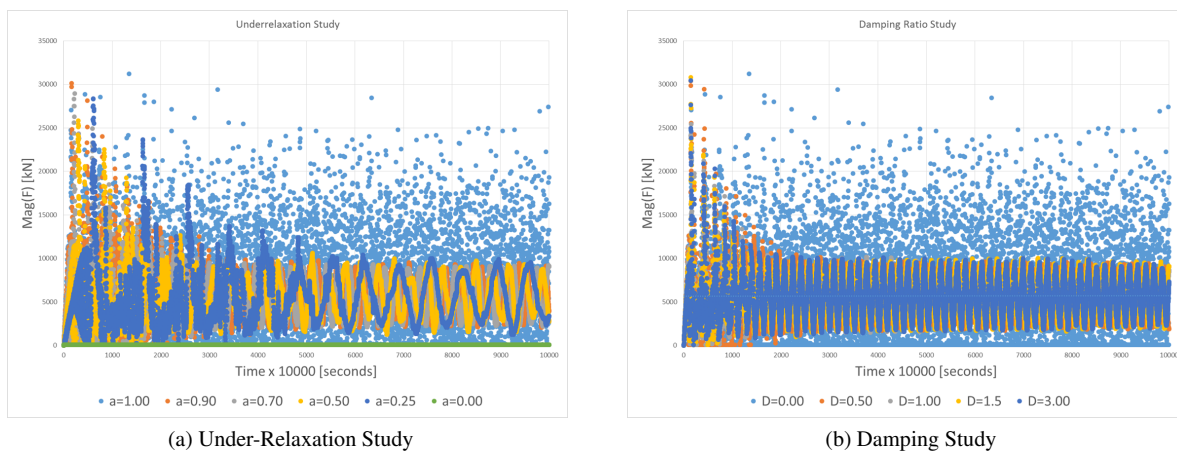
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Mooring lines are an extremely important tool to prevent free movement of a vessel or movable structure when fluid physics may influence the motion of an object. Most commonly, mooring lines are applied in the marine industry to secure a ship to a dock or to minimize movement of an offshore structure (e.g. FPSO, offshore wind farm, oil platform). Subsequently, modelling and simulation of mooring lines is crucial in predicting the movement of floating objects and potential for mooring line failure under certain conditions [1]. This presentation will discuss the theory and application of a mooring line model framework developed for CFD analysis.

The mooring line model framework is designed to respond to internal and external forces; move dynamically in time and space; and provide a coupled-force to an object within a six degrees of freedom (6DoF) solver. The internal tension and damping forces are modelled with a spring-damper system between each node in the discrete cable domain. The external gravity, hydrodynamic drag, added mass, anchor, and fairlead forces are each modelled as separate node or intra-node sub-models. Overall, the motion of each node point and link is governed by the sum of the forces in the mooring line and are integrated explicitly in time with a stable high-order time integration scheme. The resulting forces within the mooring line can be coupled back to a fluid domain rigid-body experiencing fluid-induced motion in a 6DoF solver. Furthermore, the 6DoF body can be coupled to multiple mooring lines that themselves may be modelled as a composite system of lines with multiple properties (e.g. floating or sinking, low and high spring constant, low and high drag). The framework allows for more complex and realistic mooring line systems to be modelled than can currently be carried out with the restraint/constraint system within OpenFOAM, and coupled to 6DoF simulations.

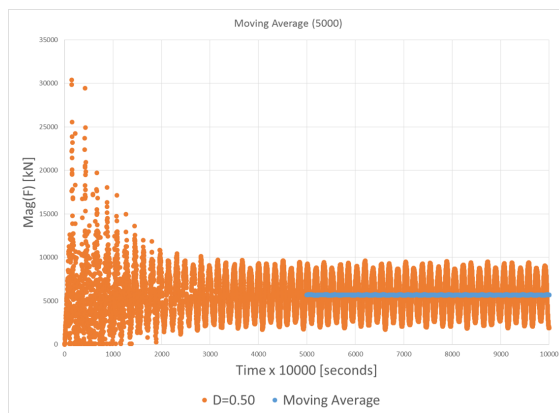
In addition to a discussion on theory, several test cases of both static and dynamic scenarios will be presented. Firstly a quasi-static cable with realistic cable properties with two stationary end points was simulated and the results were compared to an analytical solution. The system shows a clear transition from an initial condition to steadily oscillating solution. A study on the influence of under-relaxation factor and damping ratio was performed. More precisely a study of fairlead force on one end of the cable was calculated and compared for several different under-relaxation and damping settings (Figure 1).



**Figure 1: Quasi-static Cable parameter studies comparing fairlead forces with under-relaxation and damping settings**

The model showed that small oscillations in the fairlead forces converged to the same average force, but at difference rates depending on under-relaxation and damping settings. Averaging the fairlead forces at quasi-equilibrium predicted forces within 0.08 percent of the analytical solution. For this particular case, the convergence rate and averaging window

over the last 5000 iterations is shown in Figure 2. More details of the validation cases, including a dynamic scenario (i.e. situations where quasi-equilibrium is not reached within a fluid time-step) will be provided during this presentation. Other forces and line characteristics that play an important role in stability will be discussed in depth and provide insight gained through the development process.



**Figure 2: Moving average of Fairlead Forces**

Overall, the presentation will cover the theory, application, and methodology of developing and using a mooring model within a CFD analysis. Several validation and test cases will be highlighted and the post-processing strategy within ParaView will be shown briefly. Finally, the current state of the tool as well as the roadmap for development will be provided.

**References**

[1] R.H. Akers. "Why Good Mooring Systems Go Bad: Fatigue Factors in Mooring Systems for Floating Offshore Wind Turbines". MOWII Webinar by Maine Marine Composites LLC. <http://www.mainemarinecomposites.com/> Downloaded December 5, 2015.