Dynamic Analysis of Autonomous Guided Undersea Cables

Advanced LS-DYNA Analysis to Simulate Fluid Drag, Vortex Shedding on Undersea Cables

We really don't have any specialty as FEA consultants except how to figure out how to model complex systems. This project is no different and even its name is complex. What makes it unique is that we are simulating the dynamic movement of tensioned cables as they are whipped back and forth by sea currents during a heavy-lift operation. It is a common problem that we are solving for many off-shore operations where heavy cables are used to moor, lift, pump or tow objects. Figure 1 provides a graphic overview of various sub-sea cable uses. These cables see dynamic loads in operation and from fluid-structure-interaction (FSI) due to vortex shedding and added mass effects. Our work demonstrates a numerically elegant manner to simulate the FSI forces acting on large diameter high-modulus polyethylene rope (Spectra) during a deep-sea heavy lift operation.

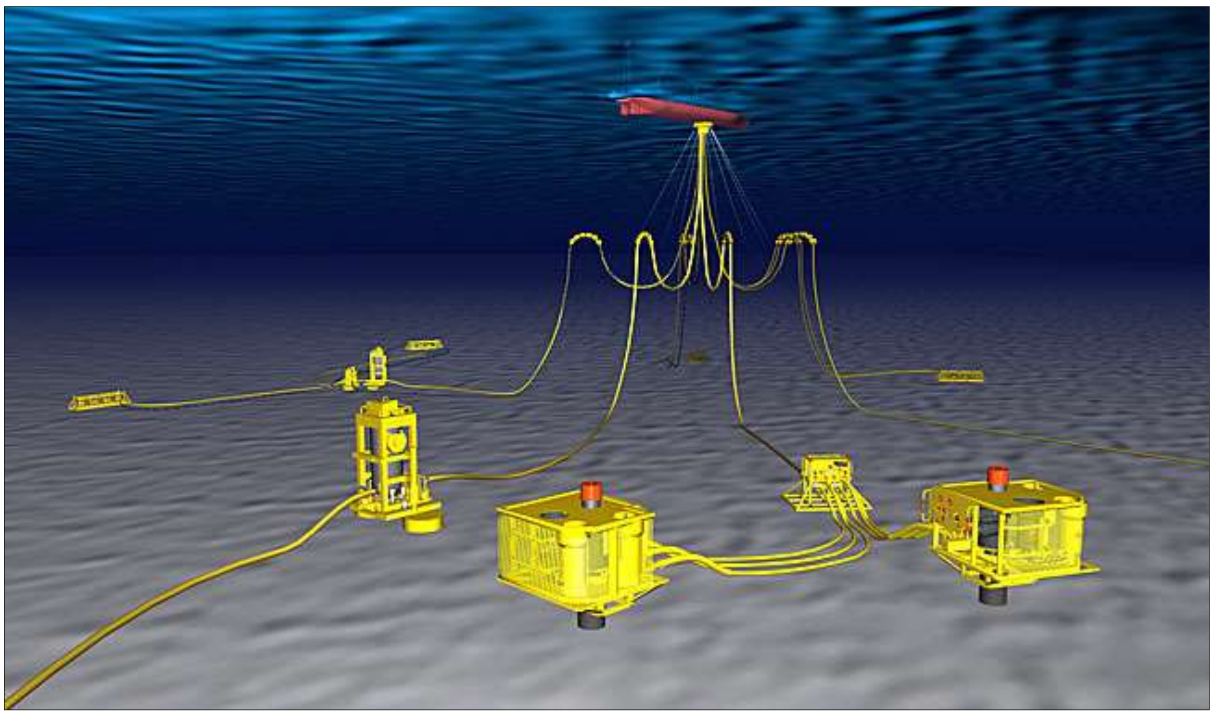
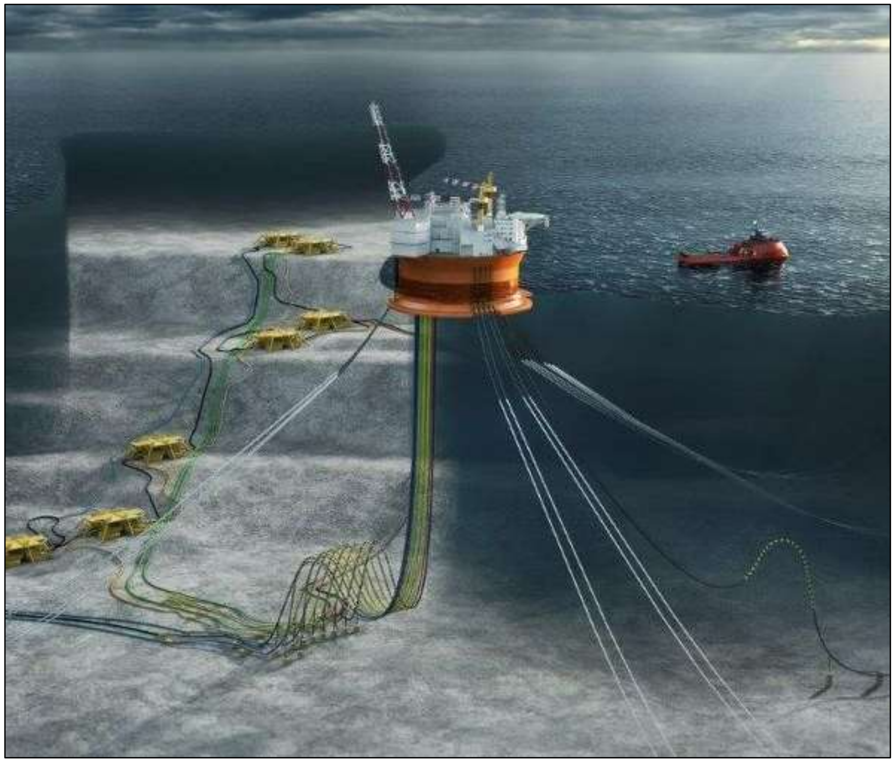
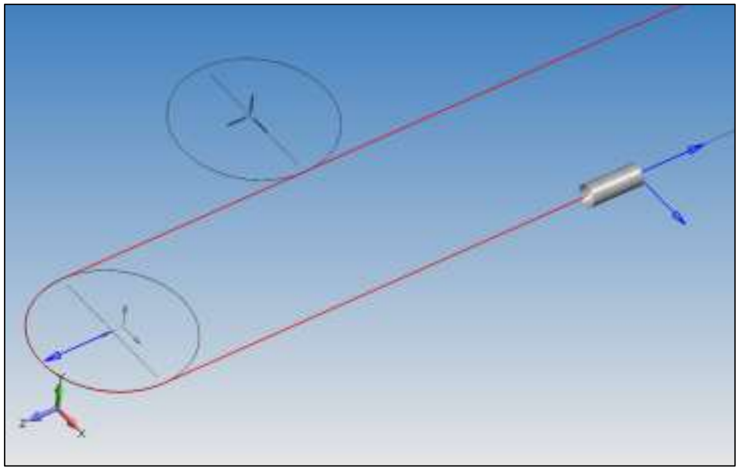


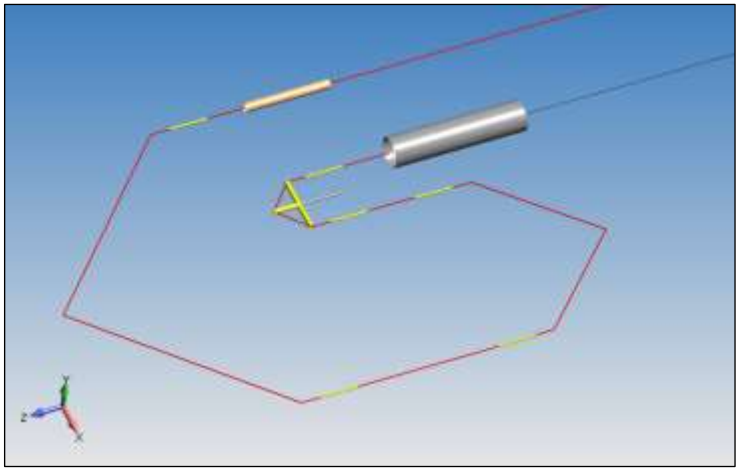
Figure 1: Examples of undersea cables subjected to dynamic forces due to FSI

Idealization of Multi-Kilometer Subsea Lifting System

EXAMPLE OF UNDERSEA CABLE USAGE	FEA MODEL OF DEEPSEA LIFTING SYSTEM



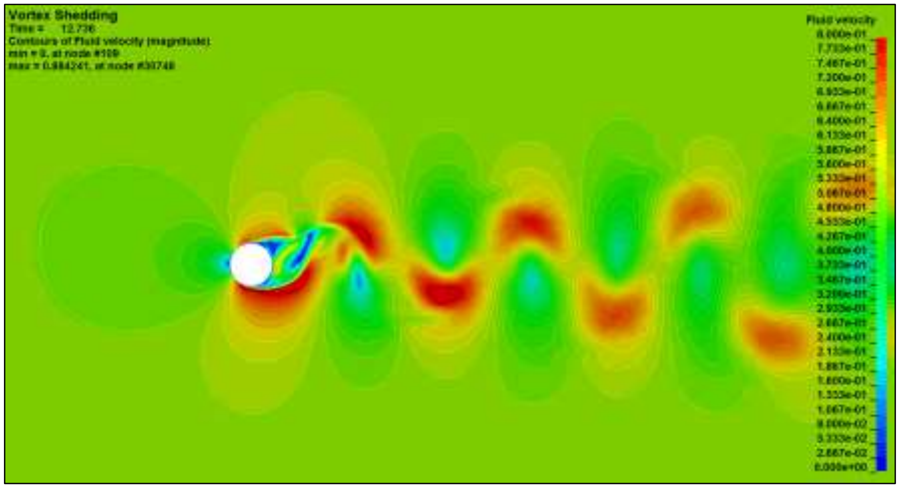




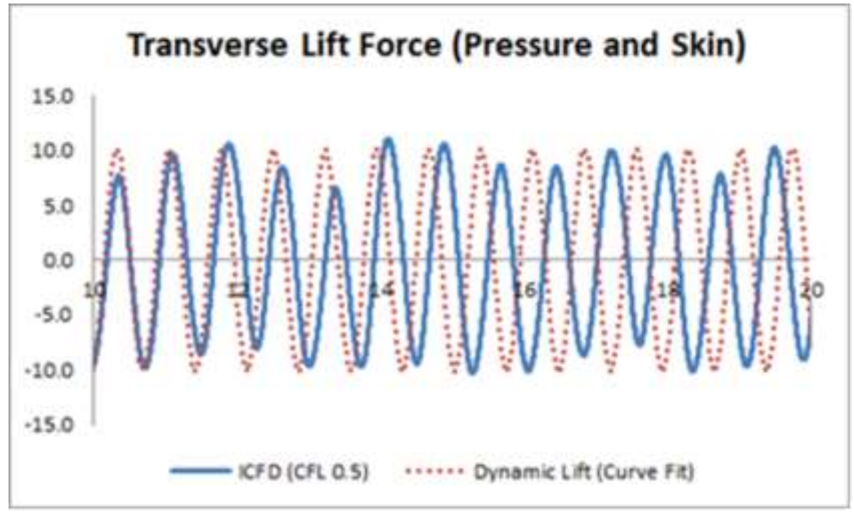
The subsea lifting system under investigation has a multi-kilometer rope circuit and lifts a heavily-laden cylindrical structure (termed “flyer”). A communications cable connects to the flyer and allows operators on the surface to control guide vanes at the top and bottom of the cylinder. These guide vanes allow the operator to direct the flyer as it ascends or descends during operation.

Dynamic Fluid-Structure Interface Coupling

LS-DYNA ICFD Vortex Shedding Analysis



Extraction of Forces with Comparison to Analysis Results

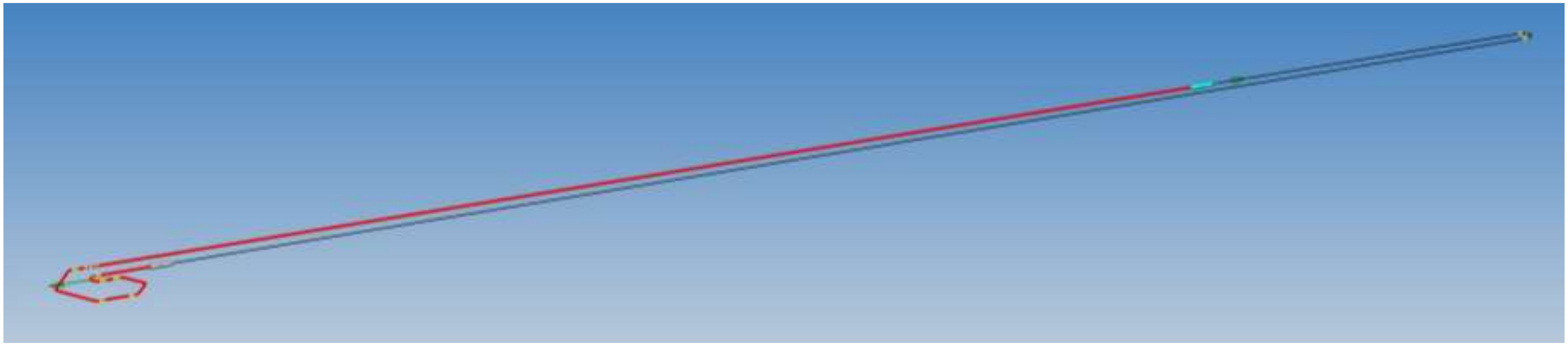


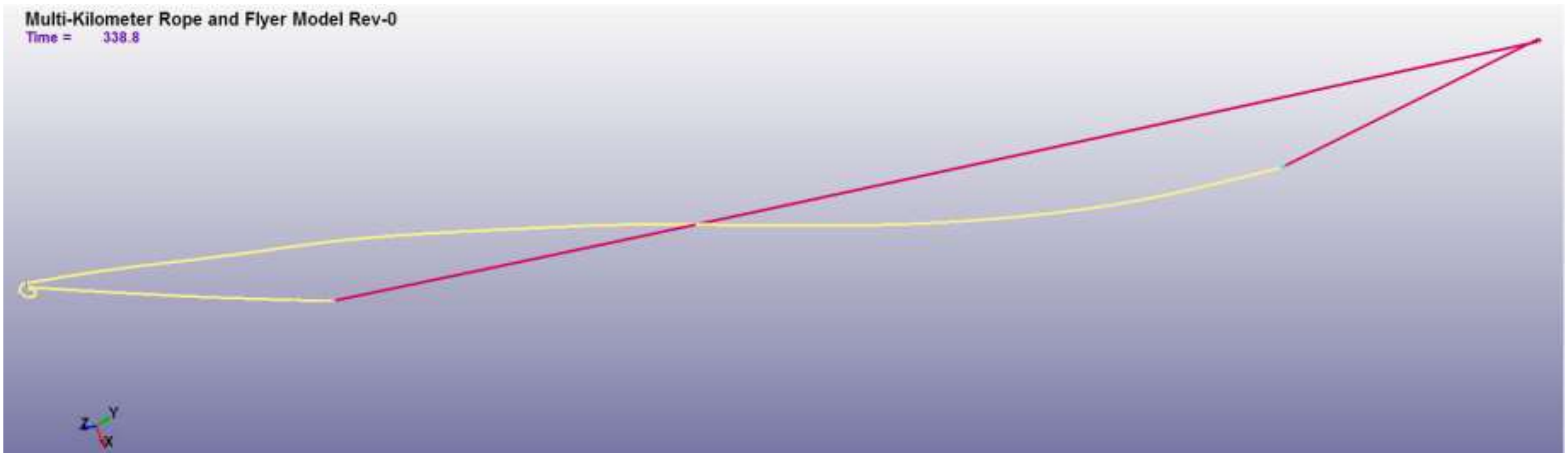
For a structure to fail due to vibration, it must be excited by a sinusoidally varying force. For cylinders immersed in a fluid, such a force exists due to vortex shedding whether the cable moves or the fluid moves. This fluid-structure coupling is well known in the marine world and well-documented failures have occurred where cables break during lifting or towing operations due to strumming-induced vibration.

In our system, we have kilometers of cable immersed in sea water and constructing a fully coupled fluid-structure-interface (FSI) model of the system would be a bit numerically overwhelming and run times could be in weeks. Searching out a more elegant solution, we developed an alternative solution where the forces due to the surrounding fluid could be numerically coupled to the dynamic solution through a LS-DYNA User Routine (LOADUD). The algorithm interrogates the model as it is dynamically lifting the cable and extracts nodal positions and velocities. Given this data, the corresponding vortex and drag forces are calculated and then applied to the model. This procedure then fully couples the fluid-structure interaction without the expense of having to do a computational fluid dynamics analysis.

In our work, we used the CFD capabilities of LS-DYNA (ICFD) to calculate the vortex shedding forces around our virtual cable and then compared these forces with an analytical calculation. Good agreement was shown and a look-up table was created to allow the program to map relative velocities between the cable and fluid toward corresponding vortex shedding forces.

FEA Modeling of Heavy-Lift Deepsea Cable System





The ability to dynamically couple the fluid forces to the FEA model while it was solving allowed us to simulate the FSI behavior without the cost of coupling into the analysis a CFD solution. This was a huge advantage since the model could then run in minutes. What we like about this technique is that it is done real-time within the solver. It is a true coupled simulation between the fluid forces and the dynamic response of the synthetic rope or all the benefits without the burden. We feel that this technique could easily be leveraged toward modeling wave action against submerged or floating structures and even toward wind-loaded flexible structures.