An umbilical cable on a drum ready to be placed on a ship for laying.

Analysis of Subsea Umbilicals and Cables

Simulation has enabled JDR to provide its customers with full stress analysis in addition to physical testing. At half the cost for five times the amount of data, this option is now a popular choice.

BY JENNIFER HAND

Deep water pressure, wind and wave forces, and the rough ocean bed — these all have to be anticipated in the design of underwater cables for the offshore oil and gas industry. Known as umbilical systems and housing power, hydraulic control, electric signal, fiber optic and chemical injection links, these umbilicals must be extremely durable, particularly under severe coupled bending, torsional and axial loads. In addition to these harsh conditions, they have to withstand handling under tension as they are reeled out and back numerous times by a winch designed to have a tight radius to minimize its footprint on a ship's deck.

Because umbilicals are long, they need to be strong, and are generally very heavy and difficult to handle. Thus, the physical testing of these cables is cumbersome and expensive. Tim Poole, Design Automation Engineer, is responsible for testing and analyzing products at JDR, which custom-designs and manufactures subsea power cables, umbilical systems and reeler packages for a broad range of applications in the oil and gas and renewable sectors. "In order to understand fatigue properties and performance, a typical fatigue regime for an umbilical is to undergo 100,000 usage cycles around a sheave wheel on a large fatigue rig. At approximately 6,000 cycles per day, plus all the other required testing, it takes at least a month to complete the process and costs between $30,000 and $50,000 for all the resources involved. It is critical that we can predict the behavior of our products to ensure they meet the requirements, so while physical testing is very important, it has its limitations. Apart from the time and cost factors, we cannot replicate conditions 100%."

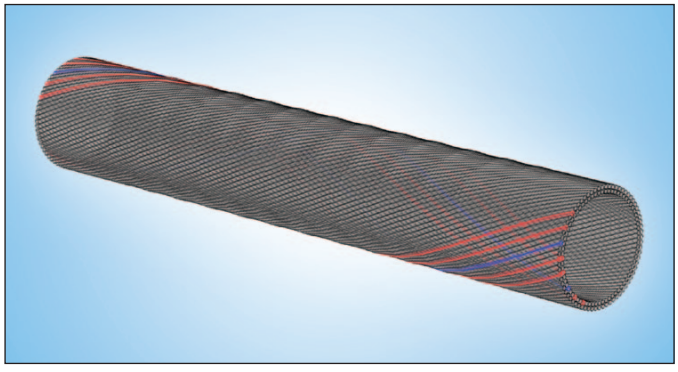

Figure 1. Illustration of the counter-rotating armor layered that includes multiple contact points of individual armor wires.

JDR was already using OrcaFlex, the specialist package designed for the offshore marine industry, for global analysis of the whole system formed by ship, cable, seabed, weather, water and wellhead. After ISO standards were updated in 2009 with new specifications for the analysis of umbilicals, JDR began conducting local stress and thermal analysis of their cables.

Umbilicals, however, pose a particularly complex analysis challenge as Poole explains: "Typically they incorporate multiple layers of wire with helical geometries and multiple contact points, or they contain aramid (Kevlar) braid, a synthetic material that is very difficult to analyze because of its braided construction." JDR therefore turned to COMSOL Certified Consultant, Continuum Blue for some specialist assistance.

Helical Wires with Multiple Contact Points

Dr. Mark Yeoman of Continuum Blue picks up the story. "Our starting point was a 2D cross-section of a cable, including material specifications. What was of con-

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cern was that the cable cross-section had a double armor layered structure with 50-60 armor wires in each layer, where each layer twisted along the length in the opposite direction to the other layer. Building the model to reflect bend and axial load conditions with contact for the internal structures was done, but also included adding in the contact for these counter-rotating armor wires. This resulted in well over 3,000 localized regions of high contact pressure along a unit length of cable, creating high stresses at every point of contact." (Figure 1).

Continuum Blue's answer was to build a bespoke, or customized program, so that JDR could quickly and easily generate the 3D cable structure through COMSOL's Livelink™ for MATLAB® and then build the COMSOL cable model (Figure 2). The MATLAB® code added advanced material properties and relations from Continuum Blue's extensive materials database, and utilized these properties to help define the bespoke contact expressions and parameters that were necessary to solve the contact analysis. Everything was then imported into COMSOL Multiphysics so that it could be solved." Wires were modeled as contact pairs moving between a sliding surface and analyzed for pure bending, pure tension and a combination of both.

According to Dr. Yeoman, the beauty of COMSOL and multiphysics analysis is the option to explore many loading conditions on various cable designs, and compare the results in a very short space of time. "It now takes two days to build a full 3D cable model ready to solve from an initial design and 2D drawing, and from there it is left to COMSOL to solve the various load conditions needed to be assessed. We can conduct seven or eight different types of analyses. For example, we test different axial load conditions and various bend radiuses. This allows JDR to assess many design scenarios, where comprehensive stress, strains, and contact analysis plots can be analyzed, ensuring cable survival during laying and use. This improves the life of the cable, while reducing the costs involved in testing and manufacture." (Figure 3).

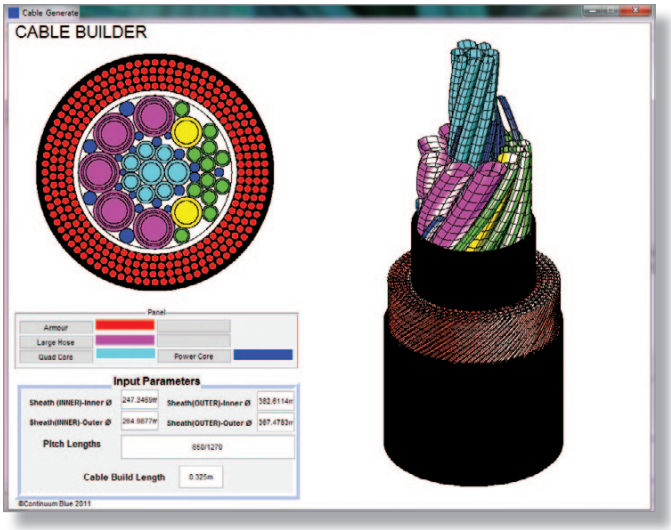

Figure 2. Screenshot of the bespoke Cable Building code, illustrating Schematics of Cable Cross Section (top left), input parameters (bottom left) and sectional 3D Structure (right). Colored regions indicate various components within a subsea cable that include armor layers (red), various hose types (large high pressure (magenta), medium pressure (yellow) and low pressure (green)), quad core structures for power and data transmission (cyan) and various filler elements (blue).

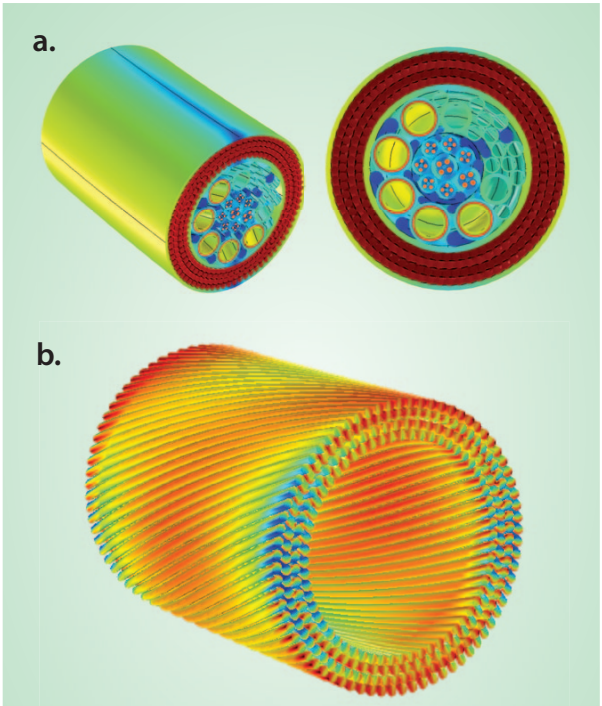

Figure 3. a) Stress analysis of subsea cable components under combined bend and axial load conditions (isometric & front view), b) detailed stress analysis of armor layered structures only.

More Information, Less Cost

"The first time we adopted this approach it worked really well," comments Poole. "The models were clear, the local stress analysis was reliable and we were able to feed the values obtained into our OrcaFlex models." JDR has now worked with Continuum Blue on developing its capabilities, and JDR can now analyze subsea cable structures with multiple internal counter-rotating structures and up to six protective armor layers with ease. From ten weeks on the original project, turn-around time is now down to two weeks and the amount of data produced has risen five fold. "Not only are we able to analyze the fatigue characteristics of our umbilicals using COMSOL, we are also able to analyze thermal characteristics."

Analysis can be half the cost of physical testing. While some of JDR's customers still choose physical testing, others are opting for a combination of global and local analysis. "We are simply providing our customers with a choice and we plan to extend our use of COMSOL so that we can continue to give them more information," concludes Poole. ■