Deep Thinking

ANSYS structural mechanics helps save years in designing the first steerable conductor for enhanced oil recovery.

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One of the biggest challenges in offshore drilling is accurate placement of the conductor casing. This component is a several-hundred-meter-long tube that is pile-driven into the ground prior to drilling to prevent mud from collapsing around the hole. At offshore locations, soils tend to be relatively soft with highly variable seabed properties; these factors contribute to accurate placement, since traditional conductors follow the path of least resistance.

Engineering consulting firm Cognity Limited has addressed this problem by developing a steerable conductor that can provide real-time accurate positioning. This device must withstand compressive forces of up to 600 tons as the conductor is pounded into the ground; it also must provide an unobstructed bore once it is driven to depth. Soils increase in strength with depth, which increases the moment and loads on the conductor as it is driven into the seabed. By using ANSYS Mechanical software in the ANSYS Workbench platform, Cognity engineers doubled the load-carrying capacity of the steering mechanism, allowing the conductor to be maneuvered in very deep soils. In addition, the team finalized the design in five months, a time frame months or possibly years less than would have been required using traditional design methods.

In drilling, each conductor must be positioned accurately to help maximize field production. For example, conductors might be spaced along a 2.5 meter grid at the platform with the goal of driving them into the seabed at an angle, spreading out to cover a predefined area. Since the drilling process weakens the soil, new conductors are naturally drawn toward existing wells — which might result in abandoning the conductor if it veers too close to a live well. Poorly positioned conductors, known as "junked slots," can result in a production company incurring lost time and additional expense in sidetracking them. A worst-case scenario can occur if a conductor is placed so close to an existing well that the

Rendering of steerable conductor

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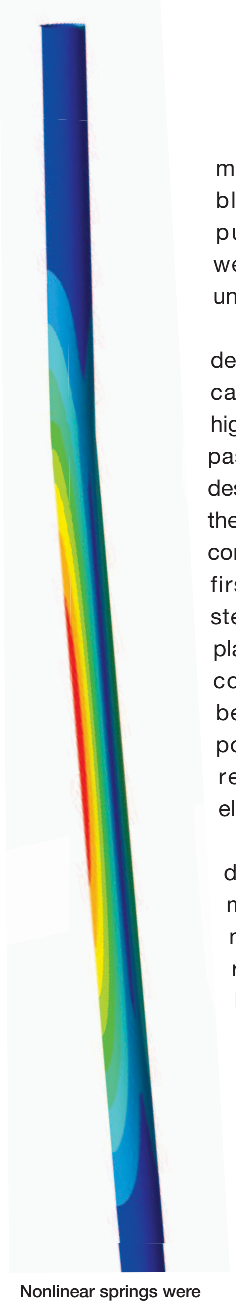


Nonlinear springs were used to represent soil forces acting on the conductor.

milling tool removing the shoe — the blunt nose of the conductor — punctures a nearby producing well. Such a scenario may risk an uncontrolled release of hydrocarbons.

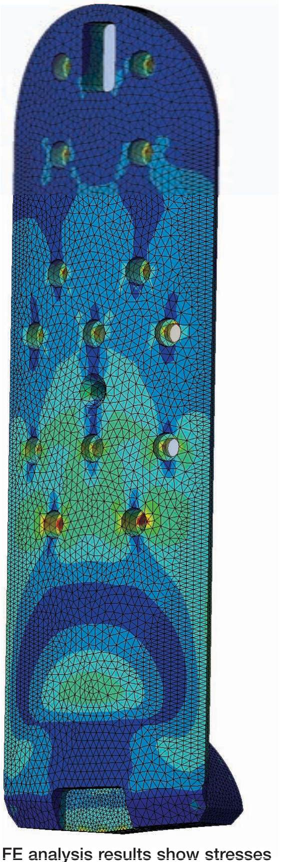
On behalf of a client, Cognity developed a fully steerable conductor capable of accurate placement in highly variable soil conditions. Over the past decade, the industry has trialed designs that passively vary the angle of the shoe in response to changes in soil conditions. But Cognity's design is the first to allow the conductor to be steered in real time from the drilling platform, which enables very accurate control of the final position. The benefits of such a system include possible increased production and reduced drilling costs through elimination of junk slots.

Design of the new steerable conductor presented major challenges: The most noteworthy is that the device must withstand the enormous forces required to drive a blunt object hundreds of meters into the soil. A traditional design approach would have required numerous full-scale prototypes, each tested to failure — a very expensive, time-consuming process. It would have taken several years for the Cognity team to develop a workable design; engineers would have had to settle for the first design that met minimum requirements rather than aiming to optimize the design.

Cognity took a different approach by using ANSYS Mechanical simulation software, developing virtual prototypes to evaluate alternative design performance. Cognity selected the ANSYS Workbench platform because of its ability to move new design ideas from computer-aided design (CAD) into simulation, then send proposed design improvements back to CAD — critical to meeting the project's tight time schedule. ANSYS Workbench offers bidirectional connectivity with popular CAD systems, including Autodesk® Inventor®, which Cognity uses.

ANSYS Mechanical software is also more applicable to design and optimization than other finite element (FE) analysis packages that Cognity evaluated. For example, an engineer can set up contacts with a click of a mouse, and these contacts will automatically update when the geometry changes. This feature saved Cognity considerable time in developing the device, which involves large assemblies of moving parts with multiple contact faces. The ANSYS structural mechanics software also provided excellent scalability on nonparallel machines, which helped to support fast turnaround times required for development.

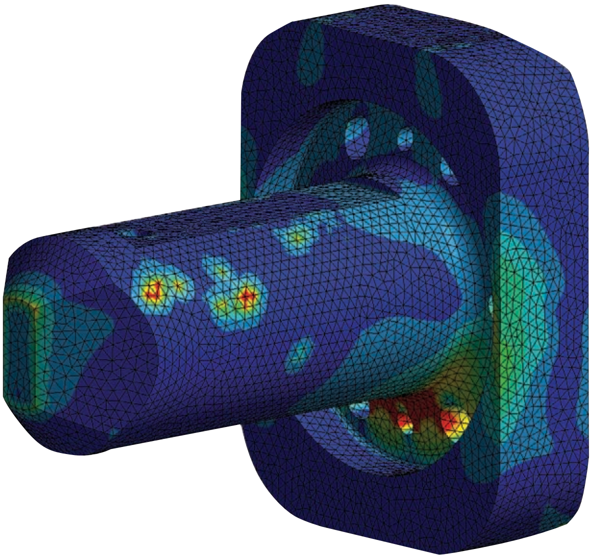
One factor critical to success was accurate modeling of the soil. Cognity engineers modeled various conductor concept designs and evaluated their performance when driven into a virtual environment: soil of varying properties. Soil has a highly nonlinear response, providing only compressive resistance under lateral loads. Friction acts on the outer surface of the conductor, creating drag forces that resist axial movement. Soil shear strengths vary with depth and specific location, and Cognity used actual soil test data to increase simulation accuracy. The engineers modeled the soil by using nonlinear springs connected to the conductor, tuned to provide the same stiffness as the soil at a particular depth. Mimicking soil, the nonlinear spring provides resistance proportional to the force up to its shear point; from that point on, the force is constant.



FE analysis results show stresses on the tendon.

One of the first tasks required was optimization of the conductor's shoe length. During drilling, the operator steers the conductor by changing the angle of the shoe. The shoe moves plus and minus 3 degrees in both x and y axes. A longer shoe better provides maneuverability in soft soil; however, it increases both the reaction force and resulting moment on steering components that connect the shoe to the rest of the conductor.

Cognity engineers modeled the conductor being driven into the ground with a 600-ton force from the hammer, then used analysis results to establish



Stresses on radial locking pads that hold HDH in place

the maximum generated moment and loads from the soil reactions at the shoe. This helped Cognity engineers to identify the loads on the critical steering assembly.

The next step was to apply these loads to the conductor's principle components so they could be optimized to resist the forces. One critical component is the hydraulic deflection housing (HDH), a 4-ton assembly within the 27-inch bore of the conductor. The HDH is responsible for holding the shoe in position and resists the forces generated by the soil. Analysis showed that the shock loading on this assembly is of the order of 150 g, which necessitated a 600-ton-capacity locking mechanism to hold the HDH in place. After the conductor is driven into the ground, the HDH is recovered, inspected and refurbished so it can be used again.

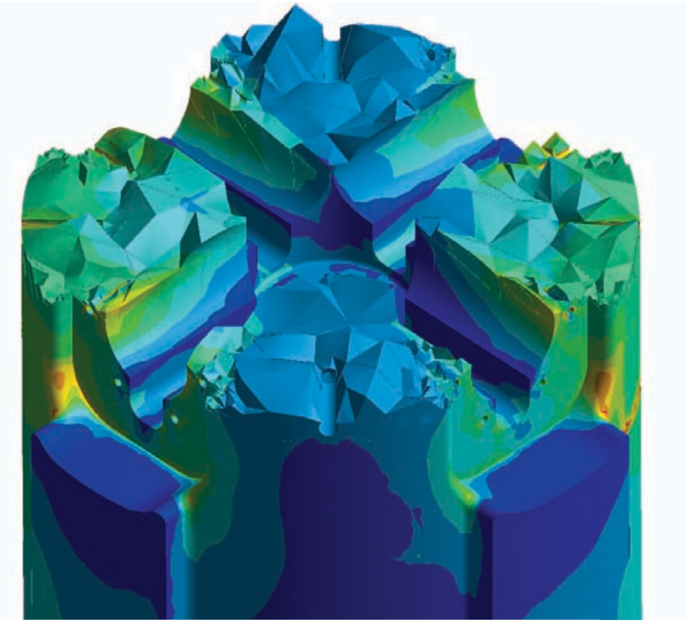
HPC Expedites the Design Process

The use of high-performance computing was critical to meeting delivery-time requirements of this project. Cognity runs structural mechanics software from ANSYS on a Dell® T7500 workstation with 12 cores and 24 GB RAM with RAID 0 SCSI drives for optimal disk speed. A typical model with about 750 K elements and many contacts can be solved in an hour or less, compared to about six hours without parallel processing. Parallel processing makes it possible to evaluate five to 10 design iterations per day, enabling Cognity to rapidly improve their design.

Cognity applied ANSYS Mechanical software to determine the stresses and deflections on the forging that makes up the HDH's body. The primary measure of its performance is its moment capacity, which identifies the ability to generate side load at an equivalent length. Engineers optimized the shape of the HDH, increasing its stiffness by adding material to high-stress areas and removing material from low-stress areas through an iterative process.

The HDH protrudes into the shoe; it is tapered to provide clearance for the shoe to move in both the x and y axes. Guided by structural mechanics analysis results, Cognity engineers found a more efficient way to taper the HDH and added supports in high-stress areas. As a result, the team was able to double the length at which the HDH connects to the shoe, effectively doubling the system's load-resisting capacity.

The original design used custom hydraulic cylinders that cost about $160,000 each and required four months for delivery. Using engineering simulation, Cognity engineers demonstrated that the custom cylinders could be replaced with the internal parts from off-the-shelf hydraulics that cost only $7,000 each and could be delivered within one month. For the overall project, Cognity was able to complete the design in only five months, approximately 70 percent less time than would have been required using conventional methods. ■



Stress analysis of the HDH helped Cognity engineers double system capacity by optimizing design.