MAKING THE CONNECTION

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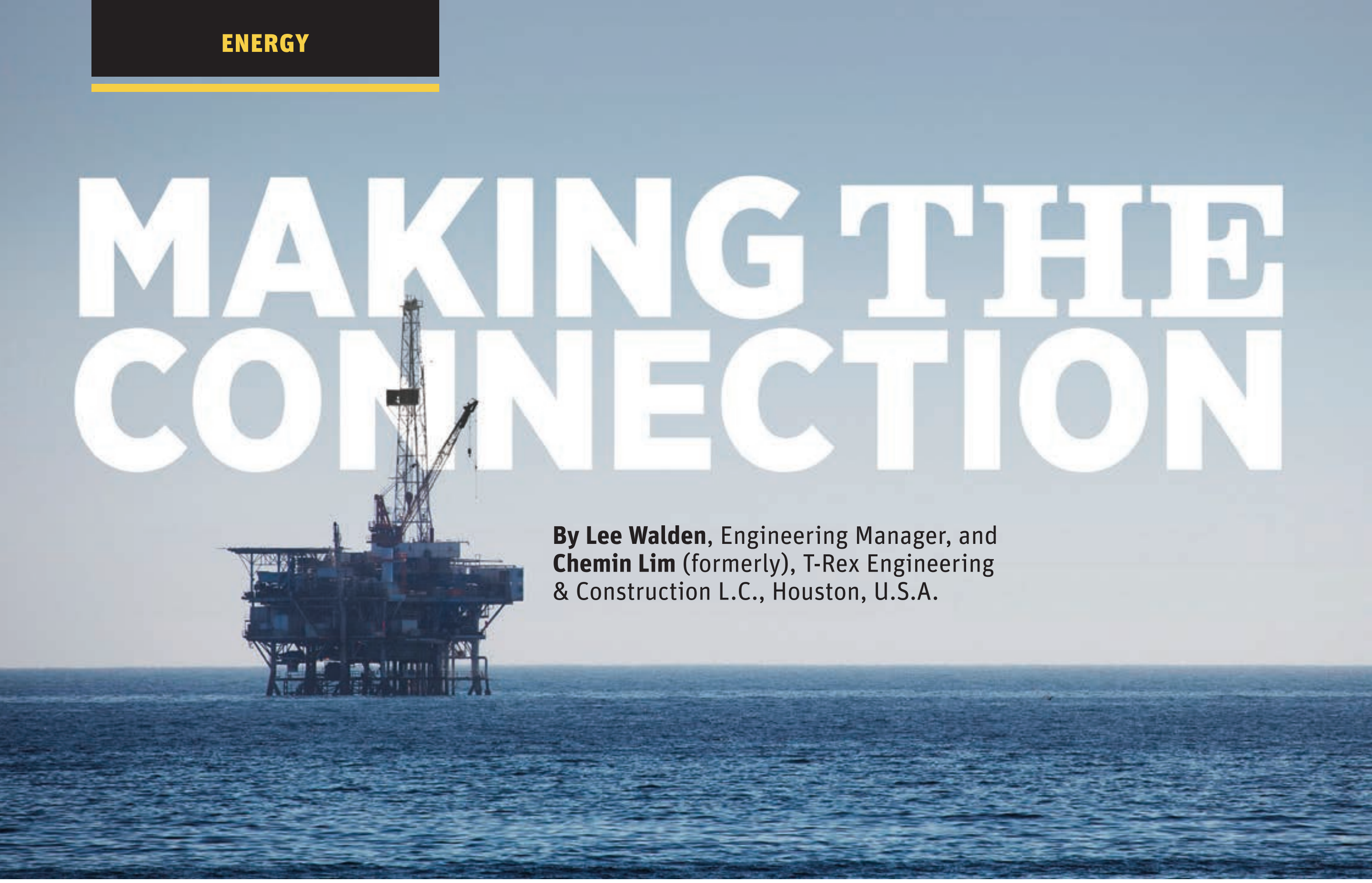

A challenging offshore oil pipeline application leverages simulation to check structural load conditions of an inline sled.

The offshore oil exploration and drilling industry strives continually to develop new subsea technologies to meet the rising demands for petroleum products. Since most of the "easy" fields have been tapped, harvesting distant offshore oil becomes more challenging because the pools are situated under thousands of feet of water.

Subsea technology covers a wide range of offshore activities. One main subsea technology is a pipeline system — sometimes more than several hundred miles in length — that transfers oil and gas products from the seabed to other destinations. The pipeline consists of various mechanical, electrical and hydraulic parts that are supported by several subsea structures.

INLINE SLED

A major component of this subsea system is the inline sled (ILS), a pipeline support structure that allows a future pipeline tie-in to be made quickly and efficiently on the sea bed. The sled is dropped over the end of a vessel's stinger — a specialized piece of equipment that is mounted onboard a ship — along with miles of piping. The pipelines are welded together on the stinger to facilitate the process of subsea installation.

The ILS comprises a mudmat platform (ILS foundation module) and a frame system that supports a wye block (a fitting that joins pipelines), branch piping, transition piping, valves, and an end hub support that is integrated into the pipeline. The main oil flows from the right (as shown in Figure 1); the future tie-in oil flow comes from the hub and joins at the wye block. The valves control the oil flow, and the hub is the open connection for future pipeline connections. A tapered transition of pipe is installed at each end of the sled's piping system to resist bending moments caused by the ILS going through the stinger.

SURVIVING CHALLENGING CONDITIONS

The engineering challenge is to design the ILS so it survives under 7,000 feet of seawater, sustains severe environmental loads and resists corrosion — all while minimizing the high risk of damage to equipment and hazard to human life during installation. T-Rex Engineering and Construction conducts studies to fully understand conditions where subsea structures will be constructed. The company's work includes fabrication, transportation, installation and operation. Based on extensive subsea experience, the engineering team collects all possible data to simulate the structure in real-world conditions. In fact, the organization has 15 years of experience in the development and design of subsea structures, all of which are still operating in the subsea field. T-Rex holds the world record for installing the deepest subsea structure.

A subsea structure experiences its worst load conditions during installation because the ILS is subjected to the weight of the suspended pipe (flow line) as well as the floating motion of the vessel. As the vessel lays the pipeline over the stinger, the ILS undergoes severe tension and bending loads at the top and bottom curvature of the pipeline (Figure 3a).

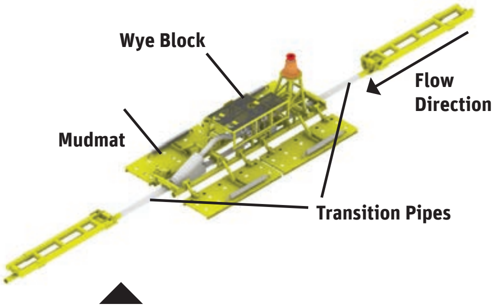

Figure 1. Inline sled structure

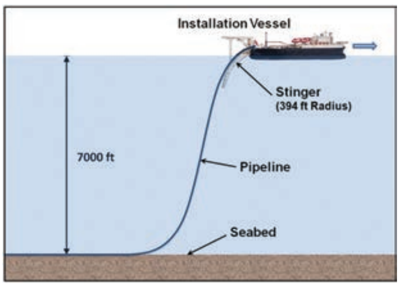

Figure 2. Installation of S-laying pipeline

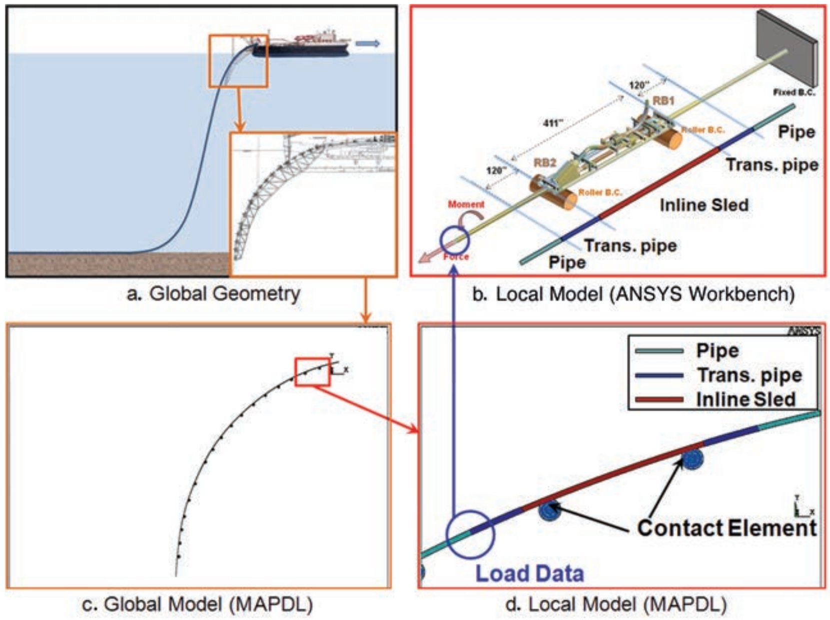

Figure 3. Analysis

T-Rex engineers determine the tension and bending load values to ensure a robust and safe design that will withstand the installation process. Analyses are performed to predict whether excessive stresses and deformation in the ILS system arise during the installation process.

SIMULATING THE SYSTEM

Simulations determine load conditions on the pipeline; they also help engineers design the ILS to handle that specific load. In one application, T-Rex engineers used ANSYS Mechanical APDL (MAPDL) to analyze a 2-D global model to determine these load conditions. They used ANSYS Workbench to apply these load conditions to the local 3-D solid model of the ILS. This type of systems modeling with ANSYS tools enables T-Rex to ensure the robustness of the design.

The team used beam elements to complete the 2-D global model of the pipeline and ILS, as shown in Figure 3c. To determine the beam element stiffness of the ILS, a separate 3-D solid model was simulated with ANSYS Workbench (Figure 3b).

For the 2-D global model, contact elements defined the contact conditions between the pipeline and the stinger's contact points, which are the group of bearing rollers (Figure 3d). Plane elements were used to model the rollers located on the stinger. This global model depicts the pipeline deformation on the stinger. The displacement load was applied at the end of the straight pipeline until the pipeline was in full contact with the stinger's roller boxes. To determine the local model's load condition — tension load and moment — reaction forces and moments were output at the end of the ILS on this global model.

The team used Autodesk® Inventor® 2010 to generate a detailed (local) 3-D model and directly imported it into ANSYS Workbench. The transition from Inventor to Workbench was smooth, and every component was imported without problems. The local 3-D Workbench model comprised 177,991 elements, including contact elements. Engineers used the sweep method to generate the mesh, and then the critical areas were refined. ANSYS Workbench automatically detected the contacting areas to generate surface-to-surface contact elements. Most of the contacting regions were defined by bonded contact behavior. The high-quality mesh produced in Workbench facilitated the convergence, calculation time and accuracy of results.

To simulate the roller box contact load conditions, frictionless support

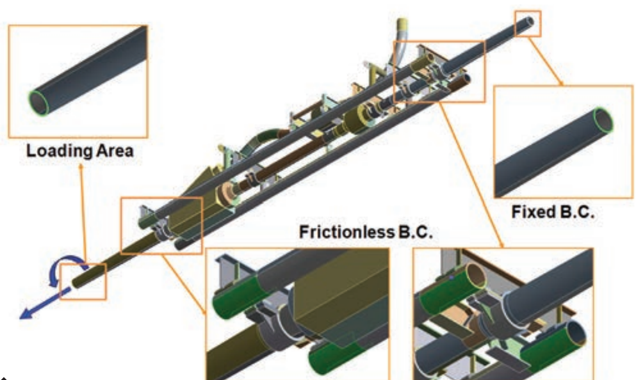

Figure 4. Boundary conditions

Using systems modeling with ANSYS tools enables T-Rex to ensure design robustness.

conditions (load tension/compression) were applied at both ends of the rail pipes, and the fixed boundary condition was applied at the opposite end of the structure. The load that was collected from the global MAPDL model was applied at the opposite end of the structure, as indicated in Figure 4.

As the design progressed, several components' geometries were changed, based on the stress results. For example, the connection between the pipeline and the ILS had a huge difference in stiffness, which caused a high stress concentration in that area (Figure 5a). At the end of this process, the new design reduced the peak stress by over 80 percent compared with the initial design (Figure 5b).

ACCURACY ENSURES SAFTY

The combination of ANSYS Workbench and ANSYS MAPDL successfully simulated the field pipeline installation load conditions on this project. The analysis made it possible to obtain the exact load conditions for this complex geometry. It would have been almost impossible to obtain this level of accuracy required to improve the design without using ANSYS software products. This systems simulation procedure provides a wide range of solutions for pipeline installation process analyses. Furthermore, safety is an important factor. Subsea pipeline systems must be designed to be safely installed and maintained during oil production. The simulations in this application helped ensure that the subsea structure adhered to safety requirements.

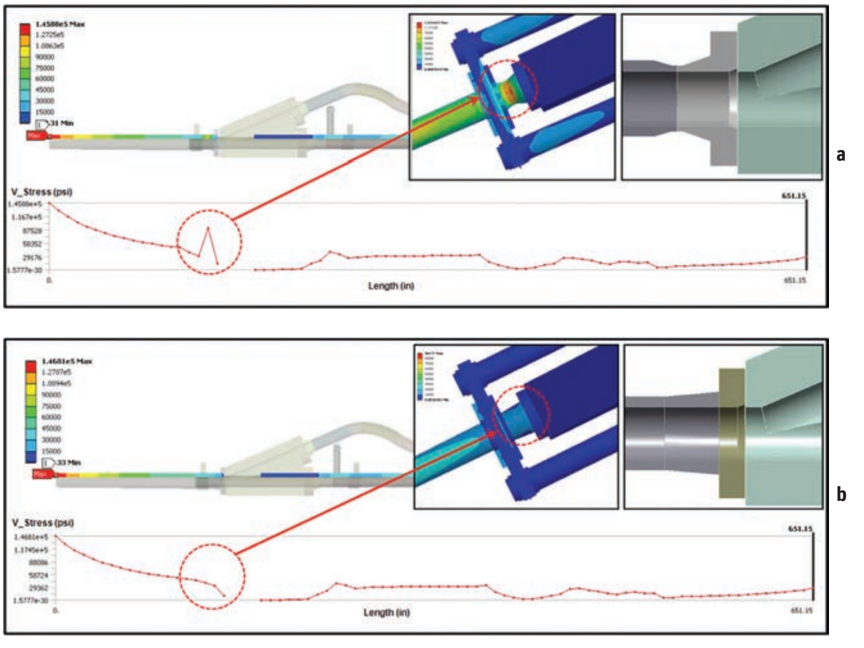

Figure 5. Initial model (top) and final model (bottom) of the connection between pipeline and ILS show stress contour through the inside pipeline. The new design decreased peak stress by over 80 percent.

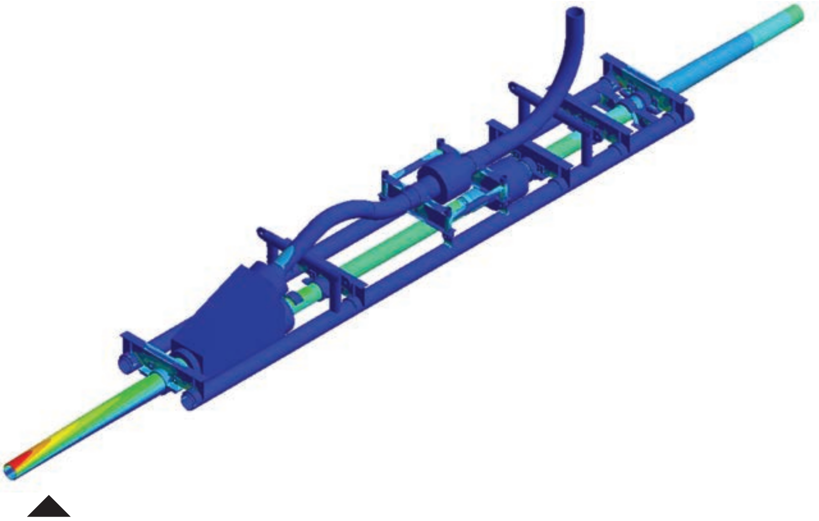

Figure 6. Von Mises stress contour