Designing Out the Weakest Link

Engineering simulation validates the design of a mooring system component, a critical wheel/chain assembly that holds ships in place during oil and gas operations in the North Sea.

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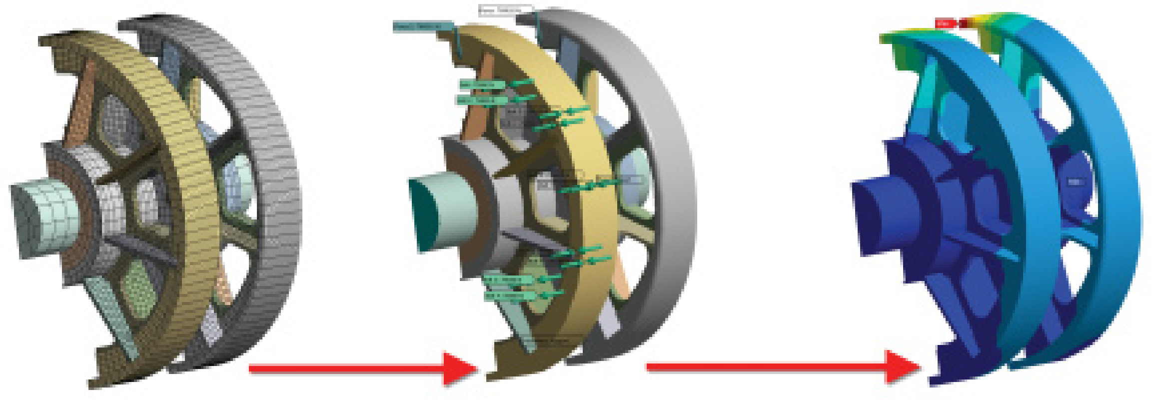
Floating production, storage and offloading (FPSO) vessels take oil or gas from deepwater offshore petroleum platforms, process it and store the material until it can be offloaded onto waiting tankers or sent through a pipeline. To maintain a stable, fixed location — even in rough waters — these huge ships have on-board winch systems that handle mooring chains, which can be hundreds of feet in length and weigh thousands of tons. Critical to the winch system is a central assembly called a gypsy wheel that, together with hydraulic chocks, grippers and interlocks, controls the release, retraction and tensioning of the mooring chain.

To validate the structural integrity of a newly designed gypsy wheel, Whittaker Engineering in Scotland, a company that provides engineering design to the offshore oil and gas industry, approached the engineering consulting firm Integrated Design & Analysis Consultants (IDAC) Ltd. The primary reason for developing a new design stemmed from an earlier design failure that resulted in a mooring chain dislodging from the assembly and consequently sinking to the ocean bed. IDAC was tasked to analyze stresses and deformation associated with the gypsy wheel under both preload and operating load conditions. The cause for the failure fell outside the scope of this analysis.

The challenge in this project was in evaluating whether the wheel and chain locker components of the gypsy wheel, which hold the retracted chain, could withstand various loading conditions as well as whether the size and weight of the assembly could be minimized without compromising structural integrity. The design would have been impossible to load-test safely and difficult to analyze precisely by conventional hand calculations. For these reasons, engineering simulation provided a useful evaluation pathway. Upon validation of the design, the new gypsy wheel assembly was to be installed on board the *FPSO Captain*, a vessel operated by Chevron Texaco in the North Sea.

The simulation process began with the finite element analysis (FEA), in which the geometric model of the new gypsy wheel was meshed using



Overview of the mechanical analysis of a gypsy wheel (left to right): The geometric model of the gypsy wheel was meshed, loading of the wheel was defined and a mechanical simulation was executed in order to validate the structural integrity of the assembly.

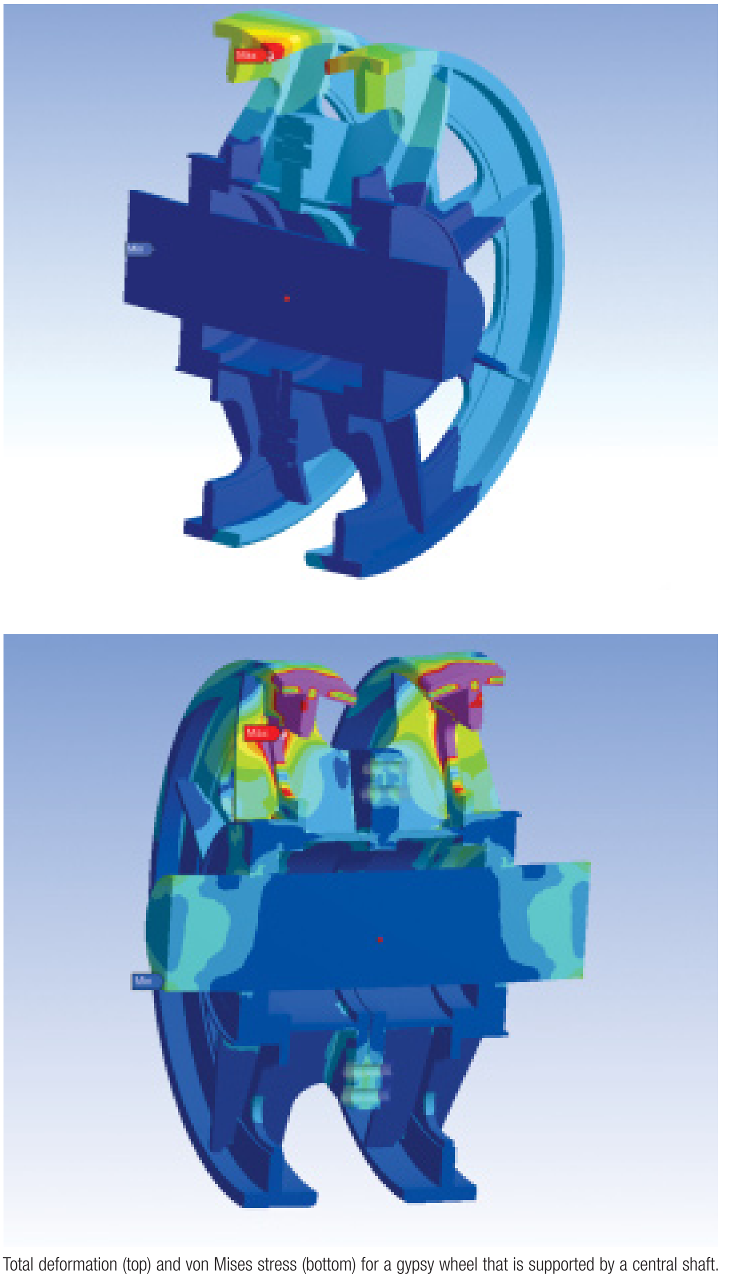
ANSYS Mechanical software. Nonlinear contact elements were generated between the shaft and the wheel, and bonded contact elements were generated between the bolts and the wheel to simulate the bolt preload. As part of the meshing capabilities, contact elements automatically detect contact points and allow for dissimilar meshes between contacting parts. In addition, the mesh is configured to account for joined parts, thus avoiding the task of manually adjusting mesh densities and selecting element types — a process that can be time-consuming.

In the new gypsy wheel design, the mooring chain was guided into the chain locker, thereby relieving the assembly of excessive loads during the mooring process and intrinsically reducing the chances of failure. Per design mandates, the frame of the gypsy wheel was designed to withstand transient and impulse loads for a small period of time. The transient loading cases were conducted to mimic operating conditions, while the impulse loading was done to design the structure for accident scenarios. (An accident had caused the system to fail in the first place, thus demanding FE structural evaluation.) In addition, due to the limitations associated with access and mechanical handling, effort was put into keeping the weight and size of the assembly at a minimum without compromising the structural integrity of the assembly.

Three separate load cases were studied as part of the investigation. The simplest load case was used to evaluate whether the assembly suffered damage under a pre-loading scenario. The other two cases analyzed a normal and angular downward force independently as well as in combination with an out-of-plane force. In each case, the simulations confirmed that the new gypsy wheel design could undergo the pretension and operational loads, with resulting deformation and stresses falling well within the design parameters.

In the end, structural analysis using ANSYS Mechanical software effectively evaluated the new design of the gypsy wheel under the various loading conditions and failure modes. Simulation overcame the inability to perform load tests safely as well as the difficulty of time-consuming and less accurate manual calculations.

IDAC then worked with Whittaker Engineering to produce an engineering package that was acceptable to the ship's certifying authorities. Subsequently, Whittaker Engineering manufactured and installed the eight new chain gypsies, which currently are in service in the North Sea. ■



Total deformation (top) and von Mises stress (bottom) for a gypsy wheel that is supported by a central shaft. From the von Mises plot, it can be seen that the area that supports the chain on the top of the wheel experiences high stresses, as does the shaft that supports the wheel.