New spar design makes a splash

With spars taking their place as one of the most popular floating production systems in recent times, new designs are making their debuts.

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Although hydrodynamically similar to the truss spar, the ring spar configuration offers a step change reduction in the cost of hull fabrication through an alternative structural system for the hard tank section and several ancillary variations in its marine systems. The hull does, however, maintain the unique motion characteristics of the truss spar, as the outside of the hull remains unchanged. The new structural system, which allows far more work to be completed undercover and with full crane access until late in the fabrication, provides notable weight reduction in the hard tank section but particularly dramatic gains in yard productivity, compared to traditional stiffened plate configurations. This article describes the structural system, the fabrication sequencing and the constructability incorporated into the details.

The new hull configuration addresses the construction issues around the fabrication and assembly of the spar hard tank components. Prior history confirms the complexity and difficulty in fabricating the conventional framing scheme of the classic spar. The method of framing and assembly of the classic spar by building "quadrants" and assembling them on skidways has been found to be quite manhour intensive, while also requiring extraordinary dimensional control processes to maintain tolerances during fabrication. This technique also requires an extensive amount of time in the elements during the fit-up and welding of the "quadrants."

The new hull configuration focuses on improved structural efficiency and constructability. It looks at those areas of difficulty and reconfigures the framing such that it becomes more construction friendly for the contractor. This, in turn, improves the overall cost, schedule and weight of the hull for the customer while also addressing safety issues around compartment confinement, above ground working areas, ease of inspection and increased shop fabrication.

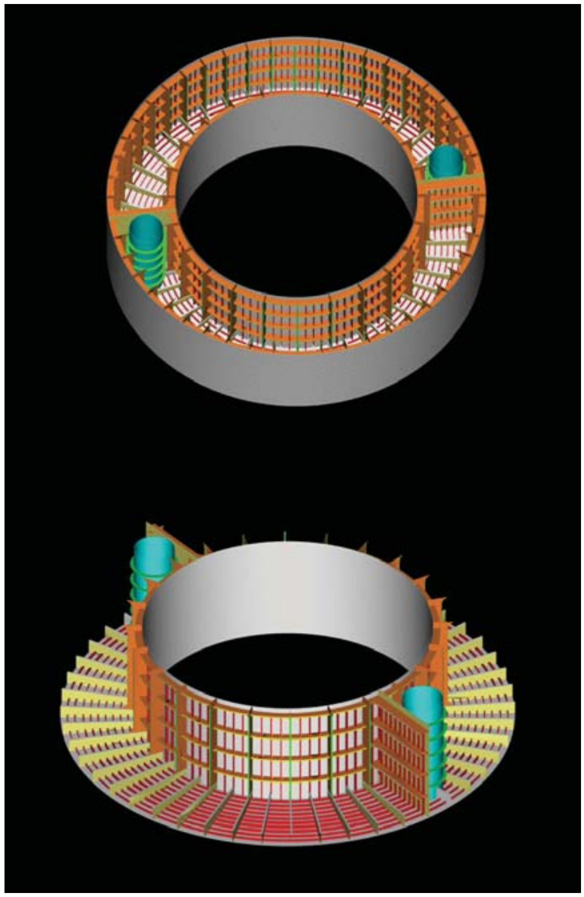

Figure 1. Unique ring spar design features are illustrated in these cutaway views. (All images courtesy of ??????)

Integrated girder framing system

The hull design has an integrated framing system between shells and flats. The primary girder stiffening of the outershell, centerwell and flats is configured as a rigid frame system (such as a Web-frame, ship structure) through proper end detailing. These girder frames are arranged in a radial pattern so all girder frames can be identical in a compartment except the two that interface with the access shaft. In this configuration, there are no global "ovaling" issues or complex girder buckling issues since the longitudinal girders span directly from flat to flat.

The connections at ends of girders use brackets to develop their capacity to work as rigid frames. These frames not only act efficiently to provide bending fixity at the ends of the girders but all the fixed-ended connections aggregate into a sizeable capacity to carry the differential axial loads between the shell plates of the centerwell and the exterior of the hull. This load balancing is augmented with the four radial bulkheads in the top compartment. In some areas, the girders' depths are tapered to more efficiently carry the varying loading along their lengths.

Orthotropic outershell stiffening

The outershell plating has a three-tier, orthotropic stiffening system that is orthogonally stiffened with longitudinal girders (between flats), transverse ring girders through the longitudinal girders and longitudinal stiffeners through the ring girders.

In assessing the buckling capacity of the local panels, all the elements of the orthotropic structure work together in a most efficient manner. In this regard, the local panel on the outershell, consisting

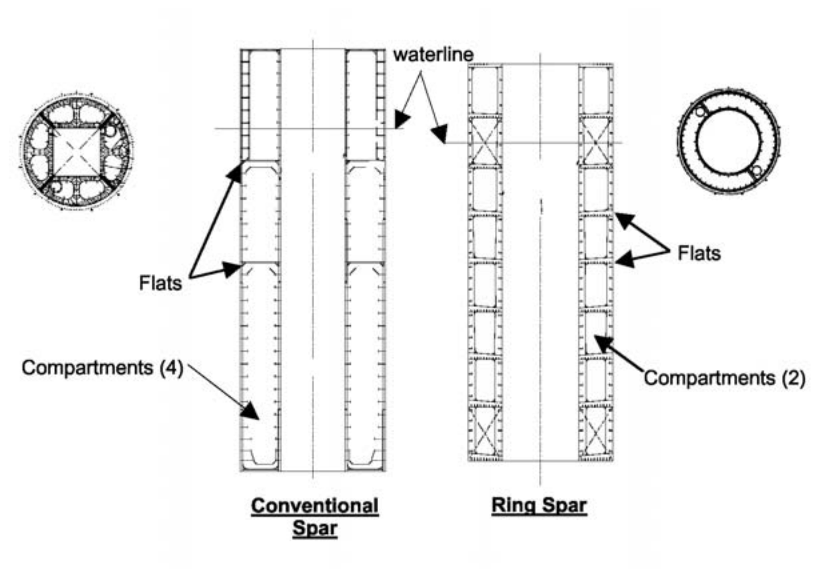

Figure 2. Ring spar (right) shows its svelte profile in comparison with a classic design (left).

of the longitudinal stiffeners and transverse ring girders, has a robust buckling capacity for the lateral pressure and transverse loads due to hydrostatic pressure as well as the longitudinal loads due to global motion. Also, the independent nature of the individual longitudinal girders on the outershell stiffening system offers significant reserve strength in case of member failure due to collision damage to one or several of these girders.

Longitudinal stiffeners

The longitudinal stiffeners provide increased buckling capacity of the outer shell plate but the area and geometry of the shell plate itself, in combination with the longitudinal girders, provides ample section modulus to carry the global axial and bending loadings of the outer shell. Thus these stiffeners do not need to be continuous through the plate which eliminates considerable amounts of specialized detailing and fabrication.

Longitudinal girders

One of most important structural elements in the hull design is the longitudinal girder. The key design loads for the hull hard tank are transverse stresses due to hydrostatic pressure and the longitudinal stresses due to global bending moment. In the most severe cases, the scantlings of the hard tank may be controlled by buckling of panel under the above two stresses. The longitudinal girders are the key structural element preventing local panel buckling while also supporting the ring girders and working with the shell plates to carry longitudinal loadings in the stiffened shells.

Circular flooded centerwell

The centerwell is stiffened by only longitudinal girders. Without radial bulkheads, this stiffened shell is in tension under all loadings over nearly all its length. To prevent the buckling of the longitudinal girders from axial compression due to global bending and hydrostatic pressure on the bottom of the hard tank, tripping brackets are included at the midspans of these girders.

Radial bulkheads

The four radial bulkheads are in the top compartment and provide the following structural and installation functions.

Shear transfer structure from the outershell to centerwell for the global loads.

Support structures for the topside leg connections and for the girders spanning the top of the centerwell that support the pull tubes.

Compartmentation to contain seawater ballast in one section to provide roll stability for the wet tow operation.

Reinforcing bands

Previous hull designs used local sections of thicker material inserted into the shell plates at each location of an equipment and leg foundation. These foundations were complex and labor intensive.

To simplify this and smooth out the load transfer into the hard tank, continuous bands of thicker plate replace the regular shell plate at the top and bottom of the hard tank. As shown in the outer shell plate expansion, the thickness and grade of material within a band can vary and still retain the fabrication advantages of the bands compared to individual inserts at each foundation.

Constructability

Through the use of constructability, techniques have been improved for the fabrication and assembly of the hull components. Optimization of these techniques results in lower cost and improved schedules.

There are several key areas of improvement from the previous spar designs:

- Ease of assembly;
- More accessibility;
- Less Engineering effort;
- Centerwell — round vs. square;
- Flats — simplified and systematized;
- Compartmentation — flats vs. radial bulkheads;
- Girders — vertical girders vs. ring girders;
- Struts — eliminated completely;
- Minimized bevel welds; increased fillet welds;
- Longitudinal stiffening — does not penetrate the flats;
- Hard tank assembly;
- Full compartments vs. quadrants;
- Assembled under roof;
- Vertical assembly vs. horizontal assembly;
- Repetitive vs. highly varied framing patterns;
- Hard tank piece count — 30% less; and
- Hard tank fabricated weight — 15% less. E&P