Case Study
First Subsea
Structural Analysis and Fatigue Assessment of a Subsea Mooring Line Connector

Company Profile
The UK's leading supplier of subsea connection systems, First Subsea Ltd is an innovator in subsea connection and mooring systems for deepwater platforms, Floating Production, Storage and Offloading vessels (FPSOs), subsea field buoy, pipeline and turret architectures and marine energy.

The first company to develop and deploy ball and taper-based mooring technology, First Subsea's Ballgrab® connection system is currently used for buoy moorings, diverless bend stiffener connectors, pipeline recovery tools, and production risers. New markets include marine energy moorings and handling solutions for wind, wave and tidal devices. First Subsea products offer high standards of safety, reliability and engineering excellence, thus ensuring they are the first choice for many national and international blue chip companies.

Research and development into new products and solutions is an essential part of the motivating force behind the company. In 2004 it received one of the UK’s most prestigious business awards; Queen's Award for Enterprise.

Background
First Subsea uses its ball and taper technology to offer a range of innovative and versatile tools. The simple ball and taper principle, with its unique self-activating mechanism, enables rapid deployment. Having been guided into position and engaged, the tool can only be released once the load has been removed. One such tool is the Ballgrab mooring connector. It is used as a quick connection/disconnection system in permanent mooring lines, being particularly effective for deepwater use.

Designed and tested in accordance with certifying authority standards, these bespoke engineering products have been extensively tested to ensure a long-term consistent fatigue life. Each project has unique parameters of dynamic load and design life criteria; and so all Ballgrab mooring connectors are designed to meet specific project criteria.

Analysis
First Subsea designed a Mandrel-Receptacle mooring line connector for the Thunder Hawk Regional Development project and required idac to perform the following analyses:

- Analyse the structural response of the Mandrel-Receptacle assembly
- Assess the fatigue responses of the Mandrel and Receptacle in accordance with the DNV standards document, DNV-RP-203 (Fatigue Design of Offshore Steel Structures – August 2005), using the fatigue load data as supplied by First Subsea. The figure to the right shows the tension histogram (tension range versus yearly cycles).
The solid geometries of the Mandrel, Receptacle, Pins and Shackles were supplied to IDAC in Autodesk Inventor format. The assembly was then imported into ANSYS DesignModeler and reduced to a quarter symmetry model, allowing a finer mesh density to be used in the analysis. The assembly was imported into ANSYS Workbench Simulation where a mixed hexahedral-tetrahedral mesh was generated.

A nonlinear finite element analysis was carried out to investigate the structural response of the Mandrel-Receptacle assembly under two load steps: the Peak Cable Load and the Design Load at the quoted Minimum Breaking Load (MBL); allowing the most critical locations, stresses and strains in the Mandrel and Receptacle to be identified. The nonlinear characteristics in the analysis were large deflection effects, nonlinear material behaviour (metal plasticity) in the Mandrel and Receptacle, and also nonlinear contact (with opening and closing behaviour) between the different parts, except those at the Ball and Taper Connection where bonded contact was used.

The graphics to the right show the maximum equivalent stress on the surface of the pinhole at 90 degrees to the loading axis at the Peak Cable Load. These equivalent stresses away from any stress singularities were used for the assessment of structural integrity in the Receptacle and the Mandrel.

The fatigue life of the entire assembly was calculated using the most critical component, which was found to be the Receptacle. The maximum absolute values of the principal stresses were used for the actual fatigue calculations. The fatigue damage calculations were performed using the S-N curves derived from Equation 2.4.3 of DNV-RP-C203 shown here on the left. Based on the S-N curve derived from this equation the predicted number of cycles to failure for all events could be evaluated at the selected locations. It is a requirement of First Subsea that the design life of the components shall be 20 years and a safety factor of 10 shall be applied to the calculated fatigue life, this corresponds to a minimum fatigue life of 200 years when the fatigue limit of 1 is reached. It was concluded from the analysis that the receptacle, being the most critical component of the two would first reach a fatigue damage of 1.0 after an estimated period of 9,735 years.

Stress linearisation was carried out at locations identified as critical sections, based on stresses obtained. The stresses at these locations were linearised, so that the membrane and bending stresses could be derived. The linearised stresses could then be compared against the allowable design stress intensities for the particular material and a safety factor derived. The graphic to the right shows the stress linearisation path through the critical areas on both the Mandrel (top right) and the receptacle (bottom right).

**Design Benefit**

IDAC and First Subsea have worked closely together on a number of projects covering a wide range of designs and load cases. The use of FEA allows First Subsea to not only optimise their designs but to also prove their load carrying capacity and fatigue life. These FEA results have been confirmed by in house physical testing of the connectors.