Using FE analysis to Develop Optimal Repair Strategies

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Introduction

With an ever-increasing focus on increasing operational efficiency within the Oil & Gas sector, there is a growing need to make well informed decisions regarding repair or replacement of ageing assets. Structural integrity management of these assets, which operate under ever-changing, severe ocean and environmental conditions, poses huge engineering challenges. Due to the complexities involved in assessing such an ageing structure, the use of advanced numerical analysis methods in these studies has proven very useful. These analyses can assist in choosing the most efficient remedial methods with minimal impact on continual operation of the asset.

Finite Element Analysis (FEA) in the Oil & Gas Industry

Finite element analysis (FEA) methods are now being employed increasingly to determine safe operating period of the damaged asset. This information is used to decide an optimal repair schedule with minimal impact on operational efficiency and production. Furthermore, the FE analyses are also beneficial in assessing effectiveness of the repair method and in predicting remaining life of the asset after the repair has been completed. Over the years, MMI has successfully used advanced numerical analysis methods such as computational fluid dynamics and FE analysis to solve challenging, complex engineering problems. This approach provides a more accurate, robust basis for designing a structure or developing more efficient repair methodology than the traditional methods of using analytical solutions based on conservative assumptions or user experience, a widespread practice within Oil & Gas industry.

Conductors carrying intermediate and production risers form a complex system which operates under severe ocean and environmental conditions. Conductors undergo cyclic bending due to ocean current and, as a result, are subject to accelerated fatigue damage when strong ocean currents are present. Risers located within conductors are integral component of an offshore platform and their failure can result in expensive production losses, spillage and pollution. A study on failure data associated with operation of North Sea pipelines until 2000, reports a loss of containment incident frequency of 10-2 to 10-3 per year for risers. In the event of a conductor failure, the casings within the conductor can get overstressed which can, in turn, lead to their failure. It is therefore a common practice in Oil and Gas industry to repair or replace a damaged conductor as soon as it is practicable. It should be noted that whilst numerical methods such as finite element analysis, are widely used in the designing conductor systems, these methods are not widely used as decision making tools during a remediation process.

Project Example

A recent example of the use of FE methods by MMI in developing optimal repair strategy for conductor system was to analyse a severed conductor and its interaction with the casings within. In this study, the commercial FE software, ABAQUS, was used to generate a beam model of the failed conductor and casings. Figure 1 illustrates a representative FE model of a conductor connected with the wellhead at the top and the BOP unit near the seabed. Sea state is shown as the meshed surface at mean sea level.

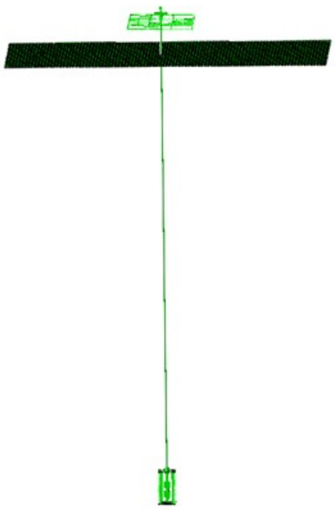

Figure 1. FE model of the conductor

Conductor systems are dynamic structures typically designed for load effects including first order wave effects, second order floater motions, vortex induced vibrations and thermal and pressure induced stress cycles. Integrity assessment of these systems therefore requires an assessment methodology which includes studying the mechanical behaviour of the conductor under all these loads. Use of a less sophisticated analysis method may not be truly representative and can lead to the use of less onerous stress state in assessing the system. Therefore, the first order wave effects which included direct wave loading on the conductor, were studied by carrying out ABAQUS/Aqua analyses. In an ABAQUS/Aqua analysis, drag and inertia loading on the immersed body are calculated using the fluid particle velocities and accelerations. Based on the fluid surface elevation specified by the user, partial immersion of the structure can be modelled wherein drag and buoyancy loadings for parts above the fluid surface or below the seabed level are omitted in the analysis.

The displaced shape of the representative conductor system with axial stress contours obtained from the ABAQUS/Aqua analysis is shown in Figure 2.

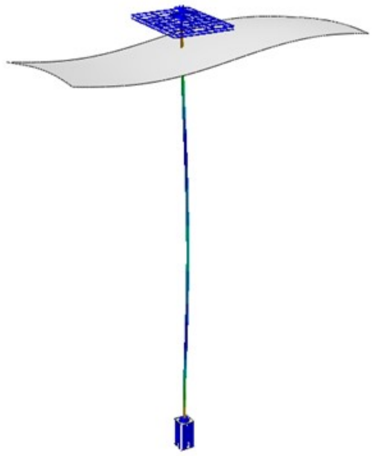

Figure 2. Displacement of the conductor under wave loads.

Similar analysis of the severed conductor predicted higher axial stresses in the casings and at coupling locations near the conductor failure elevation. These stresses were subsequently used in a fatigue assessment based on design S-N curves. Cumulative fatigue damage in the casings since the time of conductor failure was determined using site-specific metocean data for the duration. The study showed that the intermediate and production casings had a very low cumulative fatigue usage from the time of conductor failure to date due to relatively fewer larger waves during the period. The integrity of the casings located within the conductor was not adversely affected by its failure. The results also provided useful information regarding the available time scale for any future remedial process. Whilst it is a safe practice to repair the conductor as soon as possible, there was no immediate requirement based on the effect of severed conductor on the integrity of the casings within. Such information can be vital in scheduling an effective repair programme with minimal impact on continual operation of the asset. As a remedial measure, a temporary centraliser was installed at the failure location to limit lateral displacement of the free ends of the conductor. The effectiveness of the temporary centraliser was assessed by carrying out a similar ABAQUS/ Aqua analysis. For this purpose, the FE predicted stresses before and after the installation of the temporary centraliser were compared. As shown in Figure 3, the stresses in the conductor assembly were reduced by approximately 5 times by installing temporary centraliser.

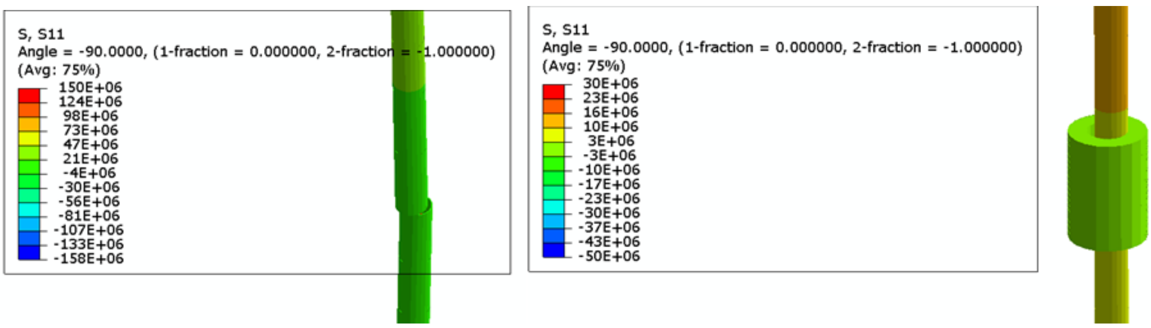

Figure 3 Axial stresses in the conductor assembly, (a) before, (b) after temporary centraliser installation.

Summary

The analysis therefore demonstrated effectiveness of the temporary centraliser in limiting conductor displacement and significantly reducing axial stresses in the casings under wave loads. The remnant life of the casings within the conductor with temporary centraliser was calculated to be greater than the planned asset life again showing that the repair was fit for purpose.

This study underlines the effectiveness of advanced numerical analysis tools in studying mechanical response of the systems under severe loading conditions and ever-changing environment. Using numerical analysis techniques in lieu of analytical solutions based on conservative assumptions or user experience, can provide a more efficient repair methodology. In addition, these analyses can assist in maintenance planning without affecting continual operation of the asset. An effective integrity management programme required for complex offshore assets must include, together with inspection and remediation plans, the use of numerical analysis methods as key decision making tools. The analysis results can be effectively used to review current integrity management scheme and in its further optimisation.