Shallow Water Well Conductor Life Extension Strategy

A. Kumar, S. Abdalla, H. Rosli, H. Howells

ADIPEC
Nov. 2013
Abstract:

A number of shallow water well conductors installed during the 1970s-1980s especially in the Middle East (Arabian Gulf) region are approaching or have exceeded their design life. Considering the production rates and economic viability for alternative options, there is an increasing need for life extension on these ageing structures.

This however raises the question of structural integrity given the long in-service usage of these conductors. Age related issues including excessive wall loss and cracking due to corrosion and the associated reduction in strength and fatigue capacity should be addressed.

This paper discusses a strategy for fitness-for-service assessment and retrofit repair designs for various anomalies observed on well conductors. A system of management is adopted for a given group of ageing conductors, the system involves a classification scheme based on the conductor and well design and defect type. All conductors within a given classification are pre-assessed based on the extent of degradation obtained from the measured, empirically modeled or visually assessed inspection records. For every classification, an assessment for generalized strength and stability (in accordance with institute of petroleum guidelines) or localized FEA depending on the anomaly type is carried out for the most degraded conductor identified from pre-assessment. The detailed assessment results are used to develop a generic conductor repair or risk mitigation plan applicable to all conductors within the classification. Real life examples of the defects encountered and associated repair schemes are described.

Learn more at www.2hoffshore.com
The above strategy is successfully implemented for various conductor defects on different well arrangements located offshore in the Middle East. This paper describes the evaluation carried out for normal and extreme weather conditions for wells in production mode. An assessment is also carried out for possible work-over or side tracking scenarios which produce additional axial and bending loads on the ageing conductors and pose further threats to structural integrity. The strategy developed can be adapted for use with a wide range of conductor arrays, on other platforms and in different operating conditions.

INTRODUCTION

Oil & gas production wells are complex systems that may exist onshore or offshore in varying water depths often classified as shallow, deep or ultra-deep water wells. Production wells consist of various concentric casings that penetrate the ground layers to different depths. The outermost casing is referred to as the well conductor or conductor pipe. Depending on the well construction, the conductor pipe may have a broad functionality, serving as an environmental barrier for internal casings to supporting part or the majority of topside equipment and casing loads.

In shallow water offshore environments, the well conductor extends above the water surface to the platform production deck. This makes it possible to inspect the conductor from the topside either visually or through conventional Non Destructive Examination (NDE) techniques. While in service, the conductor pipe is subject to environmental loading due to ocean waves and under-water currents, operational loads such as blowout preventer (BOP) weight during work-over scenarios and corrosive environments. Over time, it is not uncommon for well conductors to have structural defects such as cracks, pitting and wall loss due to corrosion.

Since conductor integrity is an important aspect of the well system integrity, conductor anomalies and their potential consequences need to be dealt with through liaison among all concerned parties. The responsibility for well design often lies with the operator’s drilling team. However, the responsibility for well system integrity is split among different parties within the operating company, each responsible for different aspects of integrity.

This paper discusses how anomaly management, technical evaluation and implementation of appropriate repair and mitigation procedures can lead to conductor life extension. The discussion is corroborated by case studies for conductors existing in shallow water depths ranging from 30 m to 60 m and in operation for over 35 years.

LITERATURE REVIEW

There is limited literature available within the industry or academic circles addressing conductor anomalies and repair. The reviewer needs to go back to first principles and the industry design codes in order to gain an understanding of the conductor defects, and design and engineer the appropriate repair or mitigation.

The basics of offshore conductor design methodology currently used were defined by Stahl and Baur (1980) [1]. A number of subsequent publications built on and improved the theories that are still used today for designing new conductors and assessing existing ones. Manley (1985) presented a design methodology for offshore platform tieback conductors [2]. Imm and Stahl (1988) discussed the design of concentric tubular members where the main application
was for well conductors and the internal casings [3]. Lang and Wood (1994) discussed the aspects of structural design, fabrication, and installation of offshore conductor pipe and concluded that it is possible and beneficial to standardize the design of conductors for conventional depths and applications [4].

Rea, Hunt and Reed (2007) stressed on the value of adopting a proactive approach for understanding and managing risks for well surface casings and conductors [5]. A better understanding of internal corrosion on conductor and other casings was sought by Munns and Crouzen (2007) through demonstrations of the use of an ultra-slim Pulsed Eddy Currents (PEC) probe to measure wall thickness [6].

ANOmalY MANAGEMENT

When faced with degradation issues over a number of conductors across the field(s), the operator’s first need is implementing a quick and effective anomaly prioritization scheme. For this particular case study, all generalized wall loss instances are pre assessed using a ‘Conductor Screening Tool’. The screening tool uses a spreadsheet based conductor database with all the key well data such as well casing program, nominal wall thicknesses for conductor and casings, shoe depths, cement and mud levels and topside equipment weights. Wall ultrasonic thickness (UT) measurements for each inspected conductor are provided as an input to the screening tool. The Screening Tool provides a preliminary conductor assessment in the form of traffic light indicators. Green indicates no further action required while amber and red indicators require the operator to carry out a detailed structural assessment in varying levels respectively. The Screening Tool provides a condition assessment for each operating scenario such as production, work over or well intervention. This information helps the operator prioritize detailed conductor assessments based on planned operations.

In instances when conductor defects are localized, such as open cracks or failed conductor guides, the Operations team may compare current defect conditions with previous inspection records to see how quickly a particular defect is worsening. Degradation trends along with technical judgment may then be used to prioritize detailed assessments and repairs for local defects.

Corrosion is a major issue with ageing conductors. Common instances may include generalized internal corrosion due to air ingress in the annular space between conductor and surface casing, external corrosion near the water surface, under coating corrosion leading to external corrosion patches or pitting and local internal corrosion due to water ingress through pits or cracks in the submerged conductor section. Other common shallow water conductor defects include cracking which are often a result of fabrication flaws aggravated by long term loads and guide support failure due to corrosion of support members or punching shear of the conductor casing. The examples discussed below are typical of conductors operating past their original design lives.

A 30 inch conductor with an open crack visible below the well head is shown in Figure 1. This particular crack measures 61 inches in length and extends to below the sub-ceellar deck. External pitting corrosion and perforations in a conductor wall are shown in Figure 2. In cases where corrosion is primarily internal, ultrasonic wall thickness estimates such as the one presented in Table 1 can provide wall loss estimates. The presented ultrasonic survey is carried out for a 30 inch conductor with a 1 inch nominal wall thickness at the time of installation. Measurements are taken at various elevations along the un-submerged conductor length and reported at the four principal global directions at each elevation.
Identification of conductor defects allows them to be grouped into major anomaly types as described earlier. An anomaly group such as ‘conductor crack’ may be characterized by a combination of design limits such as operating environments, well casing and design, conductor dimensions, topside loading and severity of the anomaly. The limits are obtained by a review of design and anomaly data of all conductors within the anomaly group. A generic repair design may then be engineered to appropriate design limits and is applicable to the entire group of conductors. A variation in conductor dimensions or extent of the defect may be accommodated by scaling the repair option such as a bolted sleeve design and adjusting the repair sleeve bolt pretensions.
CONCERNS

There are few misconceptions about the well construction and the role of a well conductor within the industry. Some of these misconceptions can lead to design of repairs or mitigations that might not be appropriate or provide only a limited benefit. One of the misunderstandings about well conductors is that they only serve as environmental barriers and have no structural function. While this might be true in some cases, especially for wells that were constructed in the 1970's or before, the correct outlook is that the structural contribution of the various well casings including the well conductor depends on the specific well design and whether there were any modifications to the original design. These modifications may include cementing of the annular spaces between the concentric casings at a later time in the well’s life. The weight of the wellhead along with all the casings is eventually supported by the soil but must pass through the conductor or casing strings. The axial load distribution between the various conductor and casing strings depends on the cement density and cement height between the various annular spaces, among other factors such as casing pretension and individual casing axial stiffness.

The majority of load sharing happens between the conductor pipe and the first internal casing also known as the surface casing, as all other casings are primarily designed for pressure containment and lack adequate strength against buckling loads when in compression. For instance, in the absence of any cement in the annulus between the conductor and the surface casing, the wellhead is almost entirely supported by the surface casing. However, if the annulus between the conductor and the surface casing is cemented, then the load would be shared between the two strings based on the factors described above.

In general, an assessment for strength or stability on any well component requires an understanding of the axial loading through the component. Such an understanding can be sought by carrying out a detailed axial load assessment of the well construction which must be based on the updated well schematics and takes into account any modifications or reworks during the well’s lifetime.

CONDUCTOR LOAD CONSIDERATIONS

Prior to carrying out any detailed engineering assessment, it is helpful to approach the issue with a fundamental understanding of the forces acting on the conductor and their implications on strength and stability. This approach is as summarized below:

- Local defects such as cracks, pitting and local corrosion (internal or external) cause weakening of the conductor cross-section at a given location. This reduces the capacity of the affected location to withstand the axial and bending loads. A repair for such defects must then be able to relieve the damaged portion of the majority of the axial and bending loads by providing adequate load sharing and strength characteristics;

- Repairs for failed guides must provide enough strength against conductor bearing loads at the given location.

- Generalized wall loss due to corrosion reduces the capacity of the conductor to withstand buckling loads. Repairs and mitigations must therefore be aimed towards improving overall stability and reducing future wall loss.
Further, it is important to understand not only the current loading conditions but all foreseeable conditions which may arise over the remaining service life of the conductor. These conditions may include environmental loads from extreme currents and wave loading during storms and also operational loads from BOP and Hydraulic Work Over Unit (HWOU) during work-over or well intervention operations. In addition, temperature changes from production or injection operations can result in redistribution of loading to give higher or lower axial loading on the conductor.

**CONDUCTOR ASSESSMENT AND REPAIRS**

The axial compressive forces on the conductor are largely static in nature. They depend on surface equipment weight such as the wellhead and BOP and also the load contributions from internal casings generated during well construction. The conductor bending loads on the other hand are predominantly dynamic derived from environmental conditions such as wave and current.

Bending loads along the conductor are obtained by modeling the conductor pipe in a global finite element (FE) analysis software under expected environmental loads. A composite model which uses a single equivalent pipe to represent all concentric casing can be used instead of an otherwise complex multi string model. The axial, bending and torsional stiffness for all conductor and casing strings are respectively added to give equivalent pipe properties. Likewise, conductor and casing weights along with contributions from mud and cement are accounted for to obtain the equivalent pipe weight. In cases where accurate soil data is unavailable, the effect of soil stiffness on global conductor response is approximated by moving the point of bottom fixity below the mudline. A global composite conductor FE model along with guide supports and deck locations is shown in Figure 3.

While an equivalent pipe approach is ideal for global FE analysis as explained above, axial loading on the conductor is obtained by adding axial load contributions from individual casing strings and surface equipment. This is done by analyzing the conductor load step history from a well construction perspective. The load distribution across the conductor and various casing strings is estimated by accounting for the cement and mud densities and their respective column heights. The axial load distribution is further a function of individual string stiffness. A sample axial load history on a given conductor during well construction is presented in Figure 4. It should be noted that the compressive loads acting on the conductor during production and work over are calculated.
Figure 3 – Global Conductor FE Model

Figure 4 – Axial Loads on Conductor during Well Construction

Learn more at www.2hoffshore.com
Once the global axial and bending loads are calculated, they are applied to a local FE model and combined stress distribution about local conductor defects such as cracks or localized corrosion is calculated. A local FE model for a cracked conductor with combined stress contours produced under the application of global loads for extreme environmental conditions is shown in Figure 5. Local stress concentrations or stress ‘hot spots’ where design stresses are exceeded are identified. Identification of critical regions is important in understanding how the defect may progress and to develop appropriate mitigations or repairs which may prevent further worsening of the defect.

![Stress Contours around a Conductor Crack](image)

Figure 5 – Stress Contours around a Conductor Crack

For single isolated defects, where local stresses exceed design stresses under extreme loads, sleeve repairs are effective in sharing the load across the affected conductor region and thereby relieving high stresses during extreme events. A bolted split sleeve design is shown in Figure 6. When the split sleeve bolts are preloaded to appropriate values, the sleeve repair alters the axial and bending load path through the damaged conductor section and carries the majority of the extreme loads. By isolating the conductor from the extreme dynamic and transient operational loads, further worsening of the defect is prevented. The reduced stresses across the conductor under extreme environmental loading where the bolted sleeve repair is installed are shown in Figure 7.
As for global conductor issues such as generalized wall loss caused due to internal corrosion, local repairs like the ones described above may be ineffective. One of the key concerns for conductors with weakened walls is the subsequent decrease in resistance to buckling loads. All conductor pipes under compression have a tendency to buckle at the spans between guide supports. As the wall thickness decreases over the service life, the capacity to withstand buckling decreases. The common factors which contribute to buckling are as follows:

- Surface equipment weight;
- Internal casing weight;
- Internal casing eccentricity induced bending moments;
- Environmental load induced bending moments.
Conductor stability is assessed under the calculated buckling loads as per recommendations provided by Stahl and Baur in their paper on “Design Methodology for Offshore Platform Conductors” [1]. Stability is assessed for two loading scenarios, storm and durability. Stability checks under storm loading take into account bending moments due to extreme wave and current events. Given the short duration of extreme loading, a higher allowable stress criterion is used. The durability check addresses long term stability concerns ignoring any extreme environmental loading but uses a more stringent allowable stress criterion.

Decreased stability between guide supports may be addressed by use of a mid-span clamp repair which provides additional support from an adjacent platform leg or conductor. The clamp repair decreases the overall span length hence restoring conductor stability. A guide support concept for improving conductor stability is shown in Figure 8.

![Figure 8 – Conductor Guide Support](image)

**RISK MITIGATION**

Regardless of stability concerns, generalized wall loss indicates a corrosion issue which needs to be addressed to reduce risk of failure. An effective approach to managing wall loss is conducting parametric analysis for different conductor wall thicknesses. This leads to a proactive identification of conductor spans which for a given wall thickness are susceptible to buckling in the future. The limiting wall thickness values for which conductor buckling is just prevented are fed into the conductor Screening Tool discussed earlier. The Screening Tool then performs a comparative assessment of the measured wall thickness data against identified limits. Detailed analysis and corrective steps may then be taken based on the Screening Tool traffic light indicators.

Learn more at www.2hoffshore.com
Structural integrity is typically managed by implementation of an integrity management plan. Plan activities may include regular visual inspections to check for local structural issues such as cracks, perforations and buckling. Additionally, regular UT measurements are taken to identify wall loss trends. Further worsening of the conductor can be managed by introducing corrosion inhibitor in the annular space between the conductor and surface casing or possibly cementing the annulus to ensure load sharing. External corrosion can be mitigated by buffing and polishing the corroded areas and reapplication of the corrosion coating or paint.

CONCLUSIONS

As more shallow water fields continue to produce beyond the original design life, there is an increasing need to manage well integrity. Conductors are critical well components often supporting the majority of the well loads and protecting the inner casings from environmental loading. Since the number of ageing wells on a given field(s) may be large, it is important to have an anomaly management strategy which can be used to prioritize defects without the need of complex analysis. Prioritized anomalies can then be grouped together under a holistic repair scheme.

A detailed understanding of the various conductor loads and their implications on conductor strength and stability is important in engineering appropriate repairs. This understanding, together with regular visual and NDE inspections and corrosion management is the key to ensuring successful conductor life extension.

REFERENCES


