SCR Integrity Management Program using Field Data from a Monitoring System

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Abstract

Over the past several years, the focus of the oil industry has shifted towards Integrity Management (IM) of offshore platforms. A typical IM program of an offshore platform covers subsea equipment, riser/flowline, processing facilities and topsides. However, the integrity of the riser system is especially critical due to its complex dynamic response and as failures have potential to cause significant impact on life and environment. As part of Chevron’s IM efforts on their deepwater floating systems, Chevron has instrumented one of its deepwater GoM platform SCRs with motion and strain monitoring devices. A key objective of the SCR monitoring program is to ensure that the response of the production riser is within safe operating conditions and pre-emptively identify any potential threats to riser integrity.

To maximize the benefits of the SCR IM program, riser monitoring data is processed in conjunction with prevalent environmental, vessel and riser operating conditions. Typically a riser design process contains a standard set of requirements, based on environmental and vessel conditions, that need to be satisfied before the riser is deemed suitable for use. As part of the SCR IM program, additional factors unaccounted during riser design have been identified that have an impact on riser response. Hence the value of a riser monitoring program to account for the limitations of the riser design process and to confirm the overall integrity of the riser system is established.

This paper discusses the methodology used and provides a summary of key findings from the processing of field measurements. The importance of monitoring will be highlighted and recommendations to operators for future integrity management programs will be provided.

Introduction

The list of deepwater production facilities has sky rocketed in the recent past resulting in a large number of highly productive assets. Each of these facilities produce significant amount of hydrocarbons on a daily basis thereby carrying a significant risk to life and environment should a failure occur. The goal of an effective integrity management (IM) program is to provide the operators with assurance that their facilities are operating as intended and to minimize risk of failure, harm to personnel and environment and avert unplanned shut downs. A typical IM program for an offshore platform includes risers, umbilicals, flowlines, hull, moorings, topsides and subsea components such as trees, manifolds and jumpers. For static components such as topsides, trees and manifolds for example, scheduled inspection are typically sufficient to ensure integrity. However, the behavior of dynamic components such as risers and umbilicals is dictated by prevailing environmental conditions and hence a scheduled visual inspection may not suffice to understand the true condition of the component. The following are four of the reasons for the need to monitor riser response to confirm integrity:

- The vessel responses used during design stages are not necessarily those experienced by the vessel in the field;
- The riser design assumes a pattern of environmental conditions based on historical data which may not be representative of current/future conditions;
- The riser response predicted during design includes a number of assumptions including riser properties, hydrodynamic and soil properties. Monitoring the riser response allows these assumptions to be better understood and calibrated;
Additional factors such as impact due to tidal activity, impact of production startup and shutdown are not considered. Monitoring is necessary to identify riser behavior due to factors that are not considered during design.

In addition, riser monitoring can also capture and identify potential problems caused due to incorrect installation and degradation of components such as the VIV suppression system.

Chevron is monitoring the response of one of its production steel catenary risers (SCR) in the Gulf of Mexico (GoM) with the goal to confirm acceptability of response and to benchmark against design software. The SCR is fitted with motion and strain measurement devices at key locations in the riser hang-off and touch-down zone. As part of the Integrity Management undertaking, the riser behavior along length is captured on a continuous basis and measured data analyzed to assess riser integrity.

This paper discusses the methodology used for analyzing riser measurements and some of the findings from the SCR integrity management program.

**Monitoring System**

The monitored riser is an oil production SCR located deepwater Gulf of Mexico at a depth of 4000 ft. It consists of a 9.625” steel pipe with a 2” thermal insulation and VIV suppression strakes throughout the length of the riser. The production SCR is instrumented with motion and strain measurement devices distributed between hang-off and touchdown zones. The motion measurement devices (INTEGRIpod) measure the riser acceleration in 3 directions and angular rates in 2 planes. The strain measurement devices (INTEGRIstick) measure bending strain in 2 planes. The location of all the sensors is shown in Figure 1. A total of 8 data channels of fully synchronized data are continuously collected from each monitoring device at a sampling frequency of 10 Hz.

![Figure 1: SCR Monitoring System](image)

**Methodology**

The riser monitoring data is captured at specific locations along the riser length. Riser motions and stresses are measured and can provide feedback on riser integrity. In order to assess riser integrity at all locations along the length, the measured data needs to be analyzed against measured vessel and environmental behavior and also correlated with operational activities during each period.

Prior to using the monitoring system measurements to assess integrity, the measurements from each sensor at every monitoring station are analyzed to determine reliability of the sensor response. As part of the sensor validation exercise, each

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sensor measurement is compared against its specifications for resolution and noise characteristics. In addition, sensor measurements from each monitoring station are correlated against the others to check for consistency.

The flowchart showing the methodology to assess riser integrity is shown in Figure 2.

The raw device measurements are in the form of sensor voltage output and are converted to physical quantities such as acceleration, angular rates and stresses using the calibration factors determined during the factory acceptance testing (FAT) of the sensors. The statistics, mean and standard deviation, from each sensor of every monitoring station are computed over each 30 minute period. Where significant response measurements are identified the data quality is checked for consistency between adjacent sensors and by comparing against existing environmental conditions and feedback from operations.

The riser monitoring system specification is designed such that response of interest exceeds the noise floor of the sensors. Hence, only periods with sensor response above noise floor are considered for determining riser integrity. The following series of activities are performed as part of SCR IM program:

- Compare riser, vessel and environment measurement against design and fatigue ‘amber’ and ‘red’ performance limits;
- Correlate riser measurements with environmental/vessel parameters such as wave heights, current speeds, vessel offset conditions to improve understanding of riser behavior;
- Convert riser strain measurement stations to stresses at measurement locations and determine fatigue damage usage at measurement locations;
- Measured riser accelerations during all periods are compared against the threshold limits to confirm riser integrity;
- Riser measurements are limited to a select number of locations along the riser length. Hence, to extrapolate response to the entire riser length finite element analysis (FEA) is performed based on measured vessel motions during periods of high measured stress to confirm that all sections of the SCR are within safe limits;
- Periods of high recorded riser response are analyzed in frequency domain to identify the driving factors such as low frequency vessel drift effects, wave response and the potential occurrence of VIV;

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**Warning Levels**

As part of the SCR integrity management program, the riser/vessel and environmental parameters are tracked against the following limits to SCR integrity.

The amber or preliminary warning is defined as measurements that represent predicted behavior during a 10 year hurricane. The amber limit is indicative of normal operating conditions without immediate integrity concerns but prolonged riser response exceeding the amber limit would require further action depending on the exceeding parameter.

The red limit is the critical limit and refers to the predicted response during a 100 year hurricane and if multiple parameters exceed the red limit during single storm/period, immediate inspection/other diagnostic activities are recommended.

**Comparison of Riser Response Against Environmental Measurements**

Measured riser response is compared against environmental parameters such as wave heights and currents to evaluate factors that drive riser response. Comparison of riser accelerations against wave heights in Figure 3 shows waves to be the primary contributor to riser response. The knowledge from the correlation is valuable as it helps predict future riser response from measured seastates. Hence, a period of minimal wave activity and high riser response can be flagged as its atypical behavior identifies the need for further investigation.

![Figure 3: Comparison of riser response against wave height](image)

**Fatigue Accumulation in the Riser**

Bending strain is measured at a series of locations in the riser hangoff and touch down zone. The measured riser bending strain is converted to bending stress and then to fatigue damage rates based on the fatigue curve used during design. The short term fatigue damage rates help identify periods of high riser response that can be tracked to ensure that riser stresses don’t exceed threshold limits. In addition, the calculated fatigue damage rates are used to track fatigue damage accumulation over time as shown in Figure 4. The red and amber limits for accumulated fatigue damage are 50 and 10% of total fatigue life and hence provide an indication of when riser nears its fatigue life.

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Figure 4: Track fatigue damage accumulation over time

**Track Riser Accelerations Against Threshold Limits**

Measured riser accelerations along length are tracked against threshold limits to identify potential concerns to riser integrity, as shown in Figure 5. As observed below, riser response during typical operations are well below the threshold limits.

![Figure 5: Riser accelerations tracked against threshold limits](image)

**Evaluate Global Performance of the Riser**

SCR fatigue response varies significantly along its length based on distance from the touch down point. As limited sections of the riser are instrumented with monitoring stations extrapolation to the global riser behaviour is required to confirm riser integrity. To achieve this, finite element analysis is used to obtain the fatigue response along the riser length for a particular vessel response. Subsequently, the measured vessel response over time is used to determine. A sample plot of fatigue damage rates along the length for a specific period of high response is shown in Figure 6.
In addition to the above, the field measurements are used to benchmark and calibrate the riser finite element analysis tools. This improves the accuracy and confidence in the global response prediction and design tools.

Possible Occurrence of VIV

The riser being instrumented is installed with Vortex Induced Vibration (VIV) suppression devices along its entire length. Hence, if the suppression devices are functional, significant VIV is not anticipated.

The occurrence of riser VIV is evaluated by comparing measured riser response against current measurements, as shown in Figure 7. The comparison shows that riser response does not correlate with current measurements. The peaks in measured riser response actually correlate with increased wave heights. Hence, the measurements to date confirm that the VIV suppression is functioning as planned with negligible VIV.

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Vessel Response

In addition to measured riser response, vessel response is also tracked against its threshold warning levels since it has a direct effect on riser integrity. Sample plot of vessel offsets during a particular monitoring period is shown in Figure 8 and confirms that vessel did not drift beyond allowable limits during the time period considered.

Observations of Interest

One of the advantages of monitoring is that it helps identify factors not typically considered during design that can impact riser response. Two such observations determined using the monitoring system discussed herein are:

- Effect of tidal variation on riser TDP stresses;
- Riser torsional rotation during production startup and shutdowns.

Review of measured riser TDP stresses revealed a cyclic behavior. Upon further investigation, it is observed that the cyclic response has a period of one day and correlates with tidal heights measured at a nearby location as shown in Figure 9. Although the measured riser stress cycles are fairly large, it is computed that they do not have a significant impact on fatigue life due to their infrequent occurrence (just 1 cycle a day).
Review of measured riser inclinations showed torsional rotation variation of up to 30 degrees in the touch down region. An example is shown in Figure 10. The review of vessel and environmental parameters did not show any factors that might contribute to such a change. Operational feedback confirmed that the changes coincide with production start-up and shut-down. The rotation is believed to be due to thermal expansion of the flowline. The effect of riser torsional rotation on riser integrity has been assessed and found to not be significant.

**Conclusions**

A well executed integrity management program provides valuable feedback regarding the riser integrity and its acceptable behavior. Evidence from such a program that uses riser, vessel and environmental measurements on one of Chevron’s deepwater GoM assets has been illustrated in this paper.

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To confirm riser integrity, it is not sufficient to solely look at the riser monitoring data but measured riser response needs to be analyzed in conjunction with vessel and environmental conditions. It is also necessary to derive appropriate threshold levels for each monitored parameter in order to understand the complete implications of measured response.

Not only does a monitoring program help confirm the riser design process, but it can also identify factors not considered during design that have an impact on riser integrity. Thus, confirming the overall integrity of the riser.