Real-Time Monitoring of FPSO Mooring Lines, Risers

Multibeam Sonar Technology Provides Proven Capability To Monitor Mooring Lines, Risers Beneath an FPSO

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Over the past seven years, a number of studies and joint industry projects (JIP) have been carried out to investigate how to improve and better manage the integrity of moorings and riser systems used by FPSOs. Unlike global marine vessels, FPSOs are moored at fixed positions, often for the duration of their design life, which, through life-extension programs, can now be in excess of 20 years.

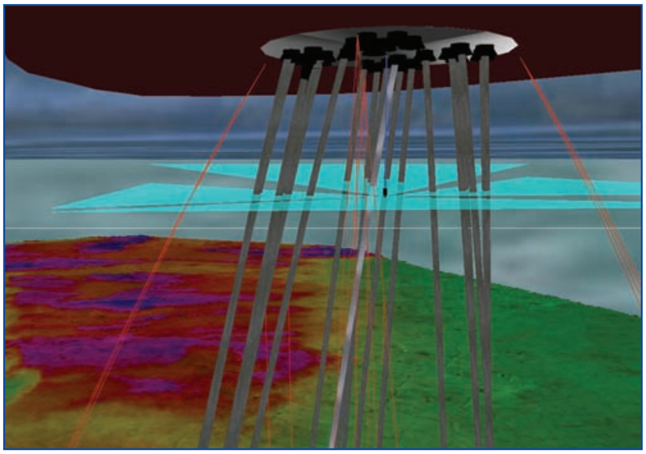
With the exception of those with a disconnectable turret, FPSOs are unable to move off-station and must therefore withstand all weather conditions in situ. A large number of FPSOs are anchored to the seabed through a turret that remains in a fixed orientation and allows the vessel to weathervane around it. The mooring lines, production risers and umbilicals are connected to the turret and therefore remain stationary as the FPSO weathervanes. The moorings are classed as category 1 safety critical systems.

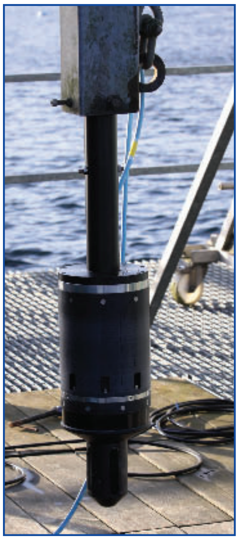
FPSO Design Considerations

During the design phase of the FPSO mooring system, a wide range of factors are considered, including location and environmental conditions. Although they are designed to withstand 100-year storms, very few FPSO mooring systems have much reserve capacity above what is required to withstand them.

Furthermore, it is important to consider that even if an FPSO has been in location without major incident for 20 years and is approaching the twilight years of its design life, it still needs to be able to withstand 100-year storm conditions to maintain class and, therefore, insurance. Therefore, the longer an FPSO is in the field, the higher the probability that it will encounter extreme weather and the more likely the mooring system will fail.

These failures occur on average once every five to six years, although, as operators attempt to extend the field life of FPSOs, it is conceivable to expect the number of incidents to increase. The number of recent incidents of FPSO mooring failures, such as those involving the Gryphon, Banff and Volve FPSOs, highlight what seems to be a growing trend.





(Top) Illustration of Tritech RAMS deployed through a fixed internal turret on an FPSO.

(Bottom) Tritech RAMS 360-degree multibeam sonar head.

Mooring Line Failure

The deterioration of mooring lines over time can lead to an increase in the failure of single or multiple lines. If the deterioration or failure of a single mooring line is not detected, multiple line failure can occur in the next instance of severe weather as a result of increased load on the remaining lines exceeding the design limits. While most FPSOs are designed to cope with the failure of a single line, in the event of subsequent line failures, the increasing loads tend to result in even more lines failing. Multiple line failure may result in a FPSO

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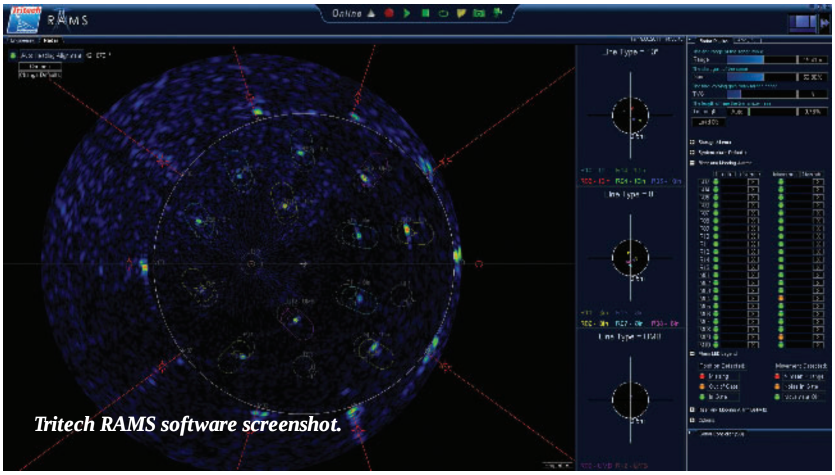

Tritech RAMS software screenshot.

breaking away from the moorings and drifting off-station into the middle of the field.

The cost of a single mooring line failure is significant when the expense of anchor handling tugs, ROV and dive support vessels, replacement parts and lost production are taken into account. These costs have been estimated at a minimum of £2 million for a 50,000-barrel-per-day (bpd) FPSO in the North Sea and many times that for a larger production FPSO operating in a more remote and less serviced area of the world. These costs are, however, nothing compared to those resulting from a catastrophic riser failure caused by loss of station, especially for a pressurized production riser, which would not only damage the reputation of the operator but immediately affect production and lead to possible safety and environmental issues. Industry experts estimate that the cost is in excess of $1 billion and still counting from the incident with the Gryphon FPSO offshore Aberdeen, Scotland, that occurred in February 2011, when it lost position and drifted 180 meters off-station after four mooring lines failed, resulting in significant damage to the subsea infrastructure. Fortunately, there was no loss of hydrocarbons, and no one was hurt. It is clear that the potential cost of not detecting such a failure is far greater than the cost of implementing a real-time monitoring system.

The Case for Regular Inspection and Monitoring

Regular inspection can reduce risk through early detection of issues, and real-time monitoring gives the with the ability to detect the failure of a single line and, in some cases, provides an early-warning system of a change of angle, tension or position, which could be precursors to line failure.

Despite the criticality of the mooring systems, with regulations varying across class societies and codes of practice, integrity management approaches seem to consist only of subsea ROV inspections or diver inspections, with very few FPSOs fitted with any form of mooring line monitoring systems. Where an FPSO is fitted with a monitoring system, these tend to be overcomplicated, poorly understood or unused, and do not provide any real-time capability or allow the operator access to historical data that would aid in assessing asset performance and integrity.

Access to the area beneath the chain table at the interface between the FPSO and mooring line or riser (one of the key areas where failures can occur) is often limited to ROV inspection due to the risk of diving beneath an FPSO. ROV inspection is itself limited by weather windows and access.

If an ROV can access the area beneath the chain table, it can be used to verify the presence of the mooring chains in addition to inspecting the risers and moorings for typical damage and loss of integrity. However, this only represents a snapshot that can be compared against data from the last inspection. There are documented occurrences during ROV inspection when mooring chains have failed sometime after the previous inspection, unbeknownst to the operator. In some cases, multiple lines have been found to have failed, increasing the risk of more failures and the possibility of a major incident. Operators are learning that if they do not inspect on a regular basis or monitor in real time then they will not know for certain if the mooring lines are still in place or if a bend stiffener is still in the correct position.

Technological Developments

Since the first JIP reports on mooring integrity, technology companies have developed products aimed at providing monitoring solutions to complement ROV inspections. Although adapted by relatively few operators to date, they have proven to provide additional information that can assist in overall integrity management and, in some cases, have detected failures, allowing the operator to remedy the fault, reducing the possibility of a major incident.

However, monitoring technologies, even real-time ones, are not the only solution and should be considered as only one aspect of developing an integrity management program. Such technologies are designed to complement regular inspection plans and can provide insight into the degradation process.

Monitoring technologies for mooring lines include inclinometers, in-line strain gauges, tension measurement devices and sonars. Thought must be given to system functionality, reliability, maintenance requirements and ease of deployment, in addition to how to power the sensors and transfer data back to the FPSO. If the data rate is sufficiently low bandwidth, acoustic transmission is possible, removing the need for the sensor to be hardwired back to the FPSO. In either case, the sensors need to be powered, usually by battery, which needs to be changed out by diver or ROV to maintain functionality.

To extend the battery life of these sensors, data are normally collected in short bursts and transmitted to the surface on a scheduled basis; therefore, they are not real time. Common issues with this type of setup include interference with acoustic transmissions due to the in-water noise beneath the turret and loss of sensors and questionable reliability due to harsh subsea conditions. If a single sensor fails, it is impossible to know without inspection if the mooring has failed or if it is the sensor itself that has failed.

Tritech RAMS

In 2003, Tritech International Ltd. (Aberdeen, Scotland) responded to an open invitation from BP plc (London, England) to develop a multibeam sonar technology to detect mooring line failures in real time. Tritech developed a system that allows the operator to visualize the area directly beneath the turrets chain table in a 360° plane, creating an instantly updating

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radar-type display. Unlike mechanically scanning sonars that scan the sonar beam 360° and have a completion time dependent on desired resolution and scan range, Tritech’s system, RAMS, provides range and bearing measurements to all visible targets: mooring lines, risers and umbilicals. No longer having to scan to build a 360° picture, the multibeam sonar provides subcentimeter positional accuracy of all targets up to 15 times a second.

During installation, the operator provides detailed positional and exit azimuth and declination information for each target. This is converted into a search grid in the software to which the sonar returns are automatically compared in real time. If a target is missing or has moved outside its maximum allowable design envelope, the system can automatically trigger an alarm notifying the operator. In addition, unlike individual sensors mounted on each mooring chain or riser, the multibeam technology is dual purpose, allowing the operator to install the sonar at a position beneath the turret, where it can monitor the mooring lines and risers concurrently. This allows for real-time statistical analysis and historical comparison of targets against their neighbors to quickly determine aberrant behavior. These data provide the operator with an instant alarm in the event of a single line failure or information that may indicate a potential problem; in effect, an early-warning system. With the RAMS system deployed, no additional sensors are needed, and the sonar can be installed and maintained by recovering and deploying through the turret, removing the need for battery changes and eliminating issues regarding transmission of data packages from individual sensors.

RAMS Testing and Field Trials

The RAMS multibeam sonar was put through an extensive test and evaluation process by BP that included tank and offshore sea trials. The tank tests involved positioning sections of smooth cylindrical ducting of varying diameters to represent risers and umbilicals, and sections of recreational marine anchor chains and wire rope to represent mooring lines. Sections were configured to correspond with the positions of all the lines for a quadrant of an FPSO turret. The RAMS sonar was positioned in the same way that it would be deployed through a spare-tube on an FPSO.

The riser and mooring line targets were moved in 1-centimeter increments across the tank using the overhead gantry frame. First, the accuracy of the position measurements were calculated under static conditions and found to be within 10 millimeters, with the standard deviation of the measured X and Y positions greater than 1,500 pings found to be better than 0.2 millimeters. Next, the dynamic performance was calculated by moving the targets by 10 centimeters. Their positions were monitored for 30 minutes, allowing the targets to settle. The RAMS technology detected relative movements at the submillimeter level and measured large movements to an accuracy of less than 10 millimeters.

The RAMS technology then completed sea trials on the Schiehallion FPSO in 2007. The objective was to determine if the system was capable of detecting all the moorings, risers and riser bend stiffeners in real time while simultaneously logging their relative motions in an offshore environment. In addition to achieving the same levels of position accuracy found in the tank tests, the system was found to be able to record the motions to an accuracy level suitable for fatigue analysis.

After successful sea trials, RAMS was installed on Teekay Corp.’s (Vancouver Canada) Foinaven FPSO operating in a BP field 190 kilometers West of Shetland in the North Sea in 2009. Since deployment, it has successfully detected failures.

Future Work and Applications

In addition to detecting mooring line and bend-stiffener failure in real time, it has been found that when correlated with environmental and motion information, RAMS data can be analyzed to allow the operator to validate mooring line performance against design criteria, assisting with future designs and more accurately predicting in-field life and time between failures.

Data from other nonreal-time sensors could be combined with RAMS data and displayed in one central software program to provide a real-time overview of the whole below-turret environment to improve overall integrity management.

References

For a full list of references, please contact Angus Lugsdin at angus-lugsdin@tritech.co.uk. ■

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