MODU mooring systems in cyclonic conditions

Key points

- Under the provisions of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act), the obligation for ensuring that OHS, well integrity and environmental risks are reduced to a level that is as low as reasonably practicable (ALARP) rests with the duty holders. In the context of Mobile Offshore Drilling Unit (MODU) mooring systems, operators must identify the hazards, risks and controls with regard to mooring system failure and must clearly understand the actual operating envelope of the mooring system, as installed, with respect to cyclonic and non-cyclonic conditions.
- Mooring system risk assessments should be completed early at the mooring design stage. The risk assessment should evaluate the likelihood and safety and environmental consequences of a MODU loss of position event, including consideration of the MODU proximity to surface and subsea hydrocarbon infrastructure or environmentally sensitive areas. The results of the risk assessment, incorporating appropriate, relevant historical met-ocean and seabed data, should be used to determine the design environmental return period and the detailed mooring system design.
- There should be adequate provisions for early communication between the facility operator, titleholder and contracted mooring service providers in establishing agreement on the selected mooring system standards, installation assurance processes and the sharing of location-specific technical information. Effective early communication involves commitment and cooperation by the mooring subject matter experts representing all of the parties involved.
- MODU mooring systems are typically identified as technical control measures to prevent loss of position major accident events (MAEs) and as such, must be described within the facility safety case for the MODU. Descriptions of the MODU mooring system, including any pre-laid or third party provided components, should address the physical features of the system and the elements of the operator's safety management system employed at the facility, which prevent, reduce or mitigate the risk of a mooring failure.
- The MODU operator must ensure that risks are reduced to ALARP. This can only be achieved with respect to mooring systems by the selection of an adequate design environment condition, mooring system installation assurance, management of change and the associated integrity assurance processes linked to defined performance standards. The operator must assure itself of the actual integrity and operating envelope of the system.
- The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) must be reasonably satisfied that a duty holder's facility mooring system risk controls reduce the risks associated with loss of MODU position or loss of stability events to a level that is ALARP.

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Abbreviations

ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
BOD	Basis of Design
BSEE	Bureau of Safety and Environmental Enforcement (United States Department of the Interior)
DISC	Drilling Industry Steering Committee
GPS	Global Positioning System
ISO	International Standards Organisation
MAE	Major Accident Event
MODU	Mobile Offshore Drilling Unit
GOM	Gulf of Mexico
IADC	International Association of Drilling Contractors
NWS	North West Shelf
OHS	Occupational Health and Safety
OPGGSA	*Offshore Petroleum and Greenhouse Gas Storage Act 2006*
SME	Subject Matter Expert
TC	Tropical Cyclone
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UPS	Uninterrupted Power Supply

Introduction

NOPSEMA conducted an investigation into an incident that occurred on 12 March 2015 approximately 100 nautical miles north-west of Dampier where a moored semi-submersible MODU was blown some three nautical miles off location during Cyclone Olwyn.

On 20 August 2015, NOPSEMA held a workshop with members of International Association of Drilling Contractors (IADC) and Australian Petroleum Production and Exploration Association (APPEA) aimed at providing insight into the contributory, causal and other relevant factors of the mooring failure incident, identifying best practices, opportunities for improvement and regulatory requirements and perspective. This information paper describes some of the common approaches and possible areas for improvement in managing mooring risk that were identified at the NOPSEMA workshop.

The purpose of this information paper is to help duty holders understand their obligations with respect to effectively managing the risks of a moored MODU mooring failure in cyclonic conditions. Only once all location-specific mooring system related hazards have been identified and the associated risks have been assessed will duty holders be able to reduce the risks of a mooring system failure to ALARP.

The information paper discusses good practice and suggests possible approaches to improve management of MODU mooring risks, drawing on existing collective industry knowledge and established mooring system codes and standards. Furthermore, whilst a selection of possible approaches are put forward in this paper, they are not exhaustive and duty holders may choose to use other approaches in demonstrating that MODU mooring risks have been reduced to a level that is ALARP.

Please note: Information papers provide information, background and practices to foster continuous improvement within industry. NOPSEMA acknowledges that what is good practice, and what approaches are valid and viable, will vary according to the nature of different organisations, offshore facilities and their hazards.

Scope

- Design, including pre-laid systems
- Installation, Management of Change, Assurance of installation
- Operations, Inspection and Maintenance
- Emergency preparedness and response
- Cyclone season 2015-2016
- Regulatory requirements and perspective

1 Design

1.1 Industry codes and standards

A review of moored MODU safety cases that are in force indicates that the majority make reference to established codes and standards that underpin the design of their mooring systems. In fact, common industry practice for MODUs operating in Australian waters is to design mooring systems to meet the requirements of American Petroleum Institute (API) Recommended Practice 2SK *Design and Analysis of Stationkeeping Systems for Floating Structures (*API RP 2SK). The API guidance outlines a deterministic approach to establish the strength of the mooring design. Typically, commercial software programs are used to evaluate mooring system responses such as line tensions, rig offsets and anchor loads for a selected design environment that is defined by a return period (5, 10, 20, 50 years etc.). These predicted mooring system responses are then checked against the mooring component strength and anchor holding capacity to ensure that a selected factor of safety against overloading of the mooring system is attained.

Appendix G of API RP 2SK also warns that mooring designs based on the above deterministic approach may have significant differences in the probability of failure because of the uncertainty associated with location-specific environmental conditions. This factor of uncertainty is relevant to MODU drilling operations in Australian waters where a tropical revolving storm (cyclone) may have varying intensities.

The consequences of a mooring failure at facilities moored in proximity to surface and subsea infrastructure may result in a significant loss of hydrocarbon containment event, harm to the environment and/or a safety risk, for example damage to a pipeline if anchors are dragged over the pipeline or a collision with a platform or FPSO facility/vessel. To reduce the risks of mooring failures in proximity to other structures, a number of the established codes and standards for mobile facility offshore moorings recommend the use of higher design environment return periods, and hence higher safety factors, to reduce the likelihood of failures due to mooring system overloading, particularly for longer drilling campaign durations and a higher mooring failure 'consequence class' (API RP 2 SK *Design and Analysis of Stationkeeping Systems for Floating Structures*, Appendix K; ISO 19901-7 *Stationkeeping systems for floating offshore structures and mobile offshore units*, Annex B; and DNV –OS-E301 Offshore Standard Position Mooring are some widely recognised examples of applicable standards).

Following a number of total and partial failures of MODU mooring systems during hurricanes in the Gulf Of Mexico (GOM), the API, in conjunction with the industry, developed supplementary guidance on GOM MODU mooring practice for the hurricane season (API RP 2SK, 2008 addendum, Appendix K). The guidance also recommends selection of higher return period environment conditions for higher consequence categories based on the MODU distance to surface and subsea infrastructure. For example, a return period varying between 10 and 50 years is recommended for consequence classes C1, C2 and C3 respectively.

Similar reviews of mooring practice have taken place in the North Sea sector. Further to the lessons learned from mooring failures on the United Kingdom Continental Shelf (UKCS), the UK Health and Safety Executive (UK HSE) recommends that the 100 year return period storm conditions (increased from the previously recommended 50 year return period) should be applied to the design of mooring systems of mobile offshore units as per the technical requirements of ISO 19901-7 Annex B-2 (*UK HSE Offshore Information Sheet Number 4/2013*). The information sheet reports that the 100 year return period is supported by location analyses in the UK. It is understood that further work is being done by the UK HSE in conjunction with industry to evaluate the outcomes from implementation of the higher mooring standards.

In summary, in designing MODU mooring systems duty holders should take into account the extensive guidance provided by a number of recognised industry standards and design codes that cover MODU moorings. However, it is acknowledged that while compliance with mooring standards may provide a sound design basis for mooring hardware it does not replace the requirement for risk assessments to adequately address location-specific hazards and reduce risk to levels that are ALARP.

1.2 Risk-based approach

NOPSEMA does not prescribe the minimum design environment return periods applicable to the variety of mooring types and durations possible within NOPSEMA waters. Recognising the variability of influencing factors, facility operators may choose to adopt a risk-based approach to establish the site-specific design environment conditions. For example, by using a risk-based approach, a location-specific environmental return period may be established to give risk levels equivalent to those of systems designed to meet the higher environment return periods recommended by the recognised mooring codes and standards. The Cyclone Olwyn mooring failure incident has highlighted the need to strengthen requirements with a view to improving the situation in areas where cyclonic activity can exist.

Within Australian Commonwealth waters, the observed increase in the duration and number of moored MODU drilling operations being conducted in proximity to surface and subsea hydrocarbon infrastructure has emphasised the importance of an appropriate risk management process for MODU mooring systems. Any risk assessments should take into account any uncertainties due to a lack of knowledge with respect to mooring system failures. As with any risk management process, suitable uncertainty analysis including sensitivity analysis should be performed to provide a level of confidence in the results.

It should be recognised that environmental forces causing varying responses must be considered in the analysis; wind dominant storms such as hurricanes and cyclones will produce different extreme conditions than wave dominant storms such as those prevalent in the North Sea, and as such are not directly comparable. Consideration of both wind and wave forces should be taken into account. Generic risk assessment tools and acceptance criteria should therefore be avoided.

For a risk-based approach to be robust and effective, it will be necessary for the industry to share the same knowledge base of location-specific met-ocean conditions, soil data and infrastructure environment. Subsequent to the NOPSEMA mooring workshop, the APPEA Drilling Industry Steering Committee (DISC) has initiated a joint industry project to prepare an integrated database of tropical cyclone met-ocean information, geotechnical data and hydrocarbon infrastructure types for use as inputs to the various mooring risk assessment tools that are currently available.

Risk assessments must take into account the likelihood of safety and environmental consequences of a mooring failure at the drilling location including damage to nearby surface or subsea infrastructure. Furthermore, risks should be reviewed periodically or when there is a change of circumstances; for example, in circumstances where an inert pipeline in proximity to the MODU is subsequently made operational with hydrocarbon during the MODU work programme.

The established codes and standards for mooring address factors related to overloading of the mooring system. The standards make a link between the selection of higher design environment return periods and the ability of the mooring system to withstand higher loads imposed by reasonably predicted extreme conditions. Accordingly, for MODU moorings in proximity to hydrocarbon and subsea infrastructure, adoption of a risk-based approach should adequately demonstrate that the resultant selected location-specific design environment return period provides for a reduction in the level of risk that is equivalent to the higher return periods recommended by established industry codes and standards.

The objective of considering higher return periods is the prevention of mooring failure and subsequent consequences. Maximising return periods generally means maximising the strength and holding capability of the mooring system to withstand higher loading during severe storm conditions. This may be achieved by the use of pre-lay systems and stronger components complying with higher safety factors compatible with the MODU's winching systems, without the need of permanent hardware upgrades.

It is noted that current codes and standards do not address Australian North West Shelf conditions specific to higher sea water temperatures and higher corrosion rates due to oxygenation. Consideration of these factors should be taken into account for systems deployed for extended periods.

In adopting either a risk-based approach or a combination of measures specified in the selected codes and standards, a facility operator should be able to demonstrate to NOPSEMA that the application of higher return period cyclonic conditions with higher safety factors was appropriately considered in the design of mooring systems for drilling operations that occur in proximity to surface and subsea hydrocarbon infrastructure. As a minimum, justification for the choice of environmental return periods and associated performance standards will have to be described in the facility safety case.

1.3 Interfaces during mooring system design: effective communication

The MODU mooring system installed at some locations may comprise of a combination of client/contractor supplied pre-lay mooring components and the rig's own mooring equipment. It is common practice for pre-laid moorings to be installed by contracted service providers and pre-laid mooring spreads are becoming increasingly prevalent.

The mooring system design stage is where requirements are identified and the construction and quality standards are defined through technical specifications, mooring analysis and the mooring installation procedures. The MODU facility operator and or the titleholder may involve a number of specialist mooring service providers in the execution of the design. Accurate information relating to the location-specific environment, local hydrocarbon infrastructure and geotechnical conditions is necessary in establishing the construction aspects of the mooring system. Effective engagement between the MODU facility operator, titleholder and the various contracted mooring service providers early in the design process is considered essential in assuring the delivery of a robust mooring system design.

Preparation of a document at the mooring design stage detailing the Basis for Design (BOD) for the mooring system is seen as a useful tool for mooring integrity risk management. The key engineering parameters and operating philosophy for the mooring system set out in the BOD document should be used for engineering control during the design, installation and operations phases of the rig mooring system. Triggers for engineering change requiring review and agreement should be specified.

The BOD document should be agreed between the MODU facility operator, titleholder and service providers through an effective engagement process undertaken at the mooring design stage.

1.4 Critical component positioning

Mooring designs generally require a portion of the mooring line to be in contact with the sea floor. A known cause of mooring component degradation is the excessive wear that can occur in any mooring chain, wire, fibre rope or connection at the sea floor touch down zone when the mooring line frequently alternates between the slack and tensioned condition. Some MODUs may work at a particular location for an extended period of time with critical mooring system components subject to cyclic contact with the sea floor and fibre ropes are prone to damage due to abrasion with hard soils and sand ingress.

Hence, in addition to considerations of mooring system overload and fatigue, the mooring system analysis should include consideration of mooring component positioning, seabed clearance and degradation due to cyclic contact in the touchdown zone over a period of time.

Mooring integrity risk assessments should be completed to address the hazards to specific components within a mooring system and the failure modes at component level. Considerations should include unequal tension between mooring lines due to an asymmetric mooring layout and components that may be subject to a different set of hazards like degradation in the sea bed touch down zone over time.

1.5 Material selection considerations

Mooring wire and chain, synthetic fibre rope, common links, anchors and connections are critical mooring system components and should be able to withstand their full component design load when the facility is subject to cyclonic wind, wave and current loading conditions. Such equipment should comply with strict acceptance criteria with robust quality control procedures in place. Component construction, testing and approval should be to recognised industry standards.

Material selection of mooring leg components should take into account relevant Australian location-specific conditions such as the detrimental impacts of higher sea water temperatures and the effects of oxygenation on mooring equipment corrosion rates.

2 Installation and assurance

2.1 Mooring installation and early engagement

Inadequate procedures for mooring deployment and retrieval can significantly weaken the components of a mooring system. Mooring wires and fibre ropes may be damaged by contact with the sea bed. Anchor holding failure can occur if anchors are not correctly installed to suit the site-specific soil conditions.

Mooring test loading for the installed MODU moorings should be completed in accordance with the mooring design standards selected in the BOD. The selection and planning for suitable mooring installation vessels should be carried out sufficiently in advance of the operation so that the defined testing can be carried out effectively.

Pre-laid moorings are often installed months before the MODU arrives on location. Verification of the integrity of the pre-laid mooring spread may be necessary prior to taking the system into service.

Changes to the mooring arrangement may become necessary during the deployment of the system. Acceptable installation parameters should be pre-defined and specified. Deviations from the pre-defined engineered processes and procedures or the BOD should be risk assessed and reviewed using a defined Management of Change (MoC) process prior to implementation of the deviations.

Therefore, it is essential to have a pre-determined agreed, clear change management process (MoC) for dealing with anomalies, assessing risk, managing results and reporting to the relevant duty holders. The MoC procedures and clear lines of communication should be agreed and established between the facility operator, titleholder and the contracted service providers as part of an effective engagement process between the relevant parties.

2.2 Assurance

Independent analysis is noted to be effective in providing assurance of mooring systems. Such analysis need not necessarily come from a separate organisation; MODU facility operators may use internal or external subject matter experts or technical authorities to assure themselves that the location-specific mooring analysis and mooring installation procedures are fit for purpose. In particular, the MODU facility operator’s verification and assurance process must be robustly implemented where mooring analysis and installation work is being performed by a client titleholder or a client’s contracted service provider. In such cases it is good practice for the MODU facility operator to run an independent mooring analysis and formalise the approval process that is undertaken by its own mooring subject matter experts.

3 Operations, inspection and maintenance

3.1 Operations

Mooring line tensions should be measured and recorded during normal operations. There are advantages in being able to record mooring line tension and environmental conditions experienced at the MODU during a cyclone event. The information can be used by the operator to confirm that the MODU mooring system is operating as predicted in the mooring analysis and it may also be useful in establishing the root causes of a mooring line failure, should one occur.

A reduction in mooring line pretensions for survival conditions in preparation for cyclones is common practice. However, depending on the location-specific mooring system design, an existing unbalanced load distribution between the mooring lines could be made worse by inappropriate slackening of all mooring lines. This is particularly the case for asymmetric mooring patterns. It may be necessary to adjust the individual line tensions as defined in the mooring analysis to achieve a balanced load distribution during storm conditions.

Operations procedures for reduction in mooring line tensions should be in accordance with the instructions for line tension management defined in the site-specific mooring analysis and not based on generic practice.

3.2 Performance standards - Inspection and maintenance

Mooring lines are generally degraded by time in service. Corrosion of wire ropes, abrasion of line components at the winch, fairlead and at touch down points are some areas of concern. Mechanical failures of mooring winches, brakes and fairleads can also occur.

Fibre ropes procured from third parties may be used in the make-up of mooring legs in pre-laid mooring systems. Detailed records of fibre rope inspections, rope age and usage history should be available and examined to provide assurance that they are fit for purpose.

A robust competency assurance system should be in place for personnel inspecting and maintaining the mooring system equipment to ensure that they are trained, competent and able to apply knowledge of critical components and critical inspection areas of the equipment.

The MODU mooring system is a technical control measure for the prevention or mitigation of potential MAEs. Mooring system component maintenance and inspection tasks should be adequately defined in the performance standards described in the MODU safety case to provide assurance of the ongoing availability and reliability of the mooring system. Should a risk-based inspection regime be adopted, it should be appropriately defined and linked to the performance standard.

Inspection and maintenance programmes must be informed by an understanding of the system’s weakest links and local degradation.

MODUs may be moored at the same location for an extended duration leading to consideration of the deferral of maintenance of safety-critical mooring equipment. Such considerations must include a suitable risk assessment process.

4 Emergency preparedness and response

A MODU loss of position event in proximity to subsea and surface hydrocarbon infrastructure will result in an emergency (in relation to a facility, means an urgent situation that presents, or may present a risk of death or serious injury to persons at the facility). Predictions of how a drifting MODU will behave in severe environmental conditions will have inherent uncertainty.

Emergency response procedures for such an event should be defined. Practice emergency drill scenarios should include considerations that involve operators of the other adjacent facilities that may be impacted by such an event.

As discussed in Section 3.1, procedures for an adjustment in mooring line tensions in advance of cyclonic weather or on moving to survival draft should be defined and their implementation properly verified prior to the MODU being evacuated.

Generally, power generation is shut down and the MODU fully evacuated in response to a confirmed cyclone threat. The MODU facility operator may have no reliable means of ascertaining the position of the MODU during and after a cyclone evacuation. The inability to identify a loss of rig position in a timely manner may exacerbate the risk of a collision with hydrocarbon infrastructure or shipping in the vicinity.

Operators should consider installing a system that provides a reliable means of real time position indication in the event of MODU loss of position events. See BSEE notice OMB Control Number: 1014-0013 NTL No. 2013-G01 *Global Positioning System (GPS) for Mobile Offshore Drilling Units (MODUs),* specifying Global Positioning System (GPS) equipment for mobile offshore drilling units.

The installation of a suitable uninterrupted power supply (UPS) to provide vital power to the position monitoring systems and mooring line tension recording systems whilst the rig is evacuated for cyclone response should also be considered.

A drifting MODU may require to be urgently taken under tow to prevent damage to subsea and surface infrastructure. It is usually necessary to have rig crew on board to deploy the forward and aft MODU tow bridles to the assisting tow vessels. There are significant safety risks for personnel boarding a drifting MODU that is in proximity to hydrocarbon infrastructure. Consideration should be given to making provisions for emergency pre-rigged towing bridles that can be safely engaged without placing personnel on the MODU following a mooring failure.

5 Cyclone season 2015-2016

Further to the learnings from the Cyclone Olwyn mooring failure incident and the NOPSEMA mooring workshop conducted in conjunction with industry, facility operators should ensure that they have sufficient and suitable controls in place to reduce the risks associated with a MODU mooring failure during the 2015-16 tropical cyclone season to a level that is ALARP. In assuring themselves, it is reasonably expected that facility operators take into account the good practices and opportunities for improvement identified in this information paper.

6 Regulatory requirements and perspective

NOPSEMA is aware of four incidents between 2004 and 2015 where the impact of cyclone activity has resulted in the loss of position of a moored MODU in Australian waters. Furthermore, there are six documented instances where MODU operators have failed to execute their plans to de-man facilities in the face of a cyclone threat.

A NOPSEMA review of operator commitments made in safety cases that are in force and some recent planned inspection findings relating to moored MODUs indicate that mooring failure risks may not be well understood and managed by the industry.

Primary responsibility for managing MODU mooring risk lies with the MODU facility operator. The MODU facility operator is the person or corporate entity that has day-to-day management and control of the MODU and its operations and who has been registered by NOPSEMA as the operator of the facility. The facility operator must take all reasonably practicable steps to ensure the facility and its activities are safe and without risk to health.

Under the provisions of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGSA), the obligation of ensuring that occupational health and safety (OHS), well integrity and environmental risks are managed to levels that are as low as reasonably practicable (ALARP) rests with the various duty holders. The OHS and integrity obligations extend to ensuring that risks at or near a facility are reduced to a level that is ALARP.

In the context of managing the risks of MODU mooring failures, the facility operator, titleholder and service providers supplying various mooring services all have obligations under the provisions of the OPGGSA and therefore have a role to play in ensuring the health and safety of persons at the facility.

MODU mooring failure risks for foreseeable cyclonic conditions must be adequately described in the facility safety case. NOPSEMA's published safety case guidance notes provide further guidance on the regulatory requirements. NOPSEMA has also implemented a focussed topic based inspection program for loss of position events during the 2015-16 year.

References, acknowledgments & notes

Offshore Petroleum and Greenhouse Gas Storage Act 2006

Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009

ISO 19901-7: 2013 *Stationkeeping Systems for floating offshore structures and mobile offshore units*

API RP 2SK (2005, Addendum 2008) *Design and Analysis of Stationkeeping Systems for Floating Structures*

DNV-OS-E301 (2013) *Offshore Standard Position Mooring*

UK HSE Offshore Information Sheet No 4/2013 *Offshore Installation Moorings*

US BSEE Notice NTL No. 2013-G01 *Global Positioning System (GPS) for Mobile Offshore Drilling Units*

Australian Government Bureau of Meteorology Tropical Cyclone Warning services
http://www.bom.gov.au/cyclone/about/warnings/

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For more information regarding this information paper, contact the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA):

- Telephone: +61 (0) 8 6188 8700, or
- e-mail: information@nopsema.gov.au