Requirements to and in service experiences of jack-ups in Norway

Presented at the Thirteenth International Conference, The Jack-Up Platform, Design, Construction & Operation, London, September 13th – 14th 2011.

By Arne Kvitrud, Petroleum Safety Authority (PSA), Stavanger, Norway.

Abstract

The paper outlines some safety aspects when using jack-ups in Norway. The PSA requirements to jack-ups, the Acknowledgement of Compliance (AoC) and system with the consents are described. Further are some in service experiences related to jacking, collision energy, scour situations, vortex induced vibrations and damping described.

Key words

Regulations; AoC; consent; jacking; collision; damping; VIV; scour.

Regulatory framework

The Petroleum Safety Authority Norway (PSA) is responsible for developing and enforcing regulations which govern safety and working environment in the petroleum activities on the Norwegian continental shelf and associated land facilities. The regulations assume that the activities maintain prudent health, environmental and safety standards. They are developed to be a good tool for the industry and for the authorities' supervision. Therefore, the regulations contain a large degree of functional requirements where standards and norms specify the regulations' level of prudence.

As regards jack-up facilities registered in a national ships' register, and which follow a maritime operational concept, relevant technical requirements in the Norwegian Maritime Directorate's (NMD) regulations for mobile facilities [7], such as they read after the amendments in 2007 and subsequent amendments, and with supplementary classification rules provided by Det Norske Veritas (as DNV-OS-C104) [4], or international flag state rules with supplementary classification rules providing the same level of safety, can be used as an alternative to technical requirements laid down in the Facility regulation [20] used for fixed production units. The chosen maritime regulations shall be used in their entirety. This only covers provisions relating to matters of a maritime character that are not directly related to the petroleum function the facility is intended to carry out. The jack-ups shall be used in a manner that makes it possible to use a flag and/or classification practice that involves a calendar-based recertification, including a five-year main inspection. All the present jack-ups in Norway have used this opportunity.

As our references to NMD and classification societies standards is based on a political decision in the ministry, the future ISO 19905-1 will not be a part of our requirements for jack-ups unless the standard is referred to by DNV. We have though made a draft national Norwegian annex to the standard. The annex contains values as action factors (almost similar to DNV-OS-C104), return periods (annual probabilities of 10^{-2} and 10^{-4}) and damping values for FLS analysis.

Acknowledgement of Compliance (AoC)

An Acknowledgement of Compliance (AoC) is necessary for jack-ups to be used in Norway, using the maritime operational concept. The AoC is a decision by the Petroleum Safety Authority Norway that expresses the authorities' confidence that petroleum activities can be carried out using the jack-up within the framework of the regulations. The decision is based on information provided in the AoC application relating to the facility's technical condition and the applicant's organization and management system, as well as the authorities' verifications and other processing.

An AoC in itself confers no right to conduct petroleum activities on the Norwegian continental shelf (NCS). Securing an AoC is essential, however, if a jack-ups registered in a national register of shipping, is to work in the petroleum activities, and is mandatory for drilling facilities, living quarters facilities, facilities for production, storage and offloading, as well as well intervention vessels which are to conduct petroleum activities on the NCS.

An AoC will be issued on the basis of the authorities' assessment of the condition of the facility, measured against the rules and regulations applying to the use of mobile facilities on the Norwegian continental shelf at the time of the AoC. Use of such an acknowledgement in the event of a subsequent application for consent for use, shall be seen in light of how the regulations or the facility's technical condition, the applicant's organization and management systems have changed after the acknowledgement was issued. An AoC encompasses technical matters, relevant parts of the applicant's management system, analyses performed, maintenance programme and upgrading plans.

An AoC will be issued based on the authority's follow-up of the applicant and the information that the applicant has provided about the facility and the organizational conditions. The PSA will, in consultation with other authorities that we co-operate with in connection with AoC, in each individual case decide on the extent of necessary processing. In connection with an application for consent for petroleum activities involving the use of a mobile facility, the operator may make reference to the acknowledgement of compliance issued by the PSA for that facility.

During a consent process of jack-up, we typically ask for the following documentation related to structures and maritime systems:

* Valid maritime certificates for the facility, including conditions of class and limitations of natural conditions (temperature, wave heights and water depth).

* We request to know the collision capacity of the facility (in MJ) and wave height used in the damaged state (in meters).

* A brief overview of what training and qualifications personnel on board to do jacking operations, for example in case of significant scour in a storm.

* An overview of steel qualities.

* The calculated safety factors in relation to the Norwegian Maritime Directorate's construction regulations [17] § 6 section 2.1 and 2.4.

* A confirmation that the analysis of vortex induced cross flow vibrations in air is performed in accordance with DNV-OS-C205 [4].

* The main conclusions from the recent inclination test according to estimated weight and centre of gravity (the deviations).

* Have cracks or damage been discovered to the bearing structures and marine systems at the facility?

* A copy of the risk analysis covering collision, structural and foundation failures.

* Lowest calculated fatigue lives and the damping values used in the calculations.

For platforms being more than 19 years we have additional questions, as updated fatigue analysis according to the most recent DNV-standards.

In connections with the AoC we perform audits against the rig manager, the company performing the analysis and physically on the jack-up.

Consent for use of a jack-up

Operators must obtain consent to use a jack-up for each location. The consent scheme has been established to ensure that appropriate status points are established in the operator's activities, and that the authorities have supervision of central decision points in the operator's activities. Issuance of a consent expresses the authorities' confidence that the operator can carry out the activity within the framework of the regulations and in accordance with the information provided in the application for consent. Consents are granted by the PSA, which has a coordinating role vis-à-vis the other authorities.

During consent process we typically ask for - related to structures and maritime systems:

* The main results from the geotechnical laboratory investigations - layering, soil types and properties. Further confirmation that the site investigations are conducted in accordance with NORSOK N-001 [15] and DNV classification note 30.4 [6], and that they are conducted where the jack-up is planned to be located.

* The main results (utilization factors) from the site-specific engineering analysis - geotechnical and structures according to DNV-OS-C104 [4].

* Results from the verification of structural and geotechnical analysis.

* The results from the site-specific ship collision analysis in relation to risk acceptance criteria, and how the NWEA guidelines for the safe management of offshore supply and rig movement [18] will be used, the collision risk, which is intended for visitors vessels, and the data base and analytical methodology used, and the risk mitigation measures for ship traffic.

* How the wave crest is calculated, air gap and what is done to reduce the risk of waves in the hull.

* Measures planned to prevent scour of the seabed around spud cans.

In a few cases we have performed audits during the application process, against the operator and the company performing the analysis. In 2010 an operator was denied consent for a drilling operation with a jack-up.

In service experience of jack-ups

As demonstrated by Jack et al [10] a large number of accidents have occurred to the jack-up fleet worldwide. The accident rates on jack-ups are very high and higher that we would accept in Norway. The rig owners in Norway don't normally de-man the platforms before storms, but one jack-up have evacuation plans due to low deck height.

Except for the West Gamma accident in 1990, jack-ups have been used for many years without major accidents in Norway. In the Norwegian petroleum industry an almost unlimited number of reports exist on unwanted events, cracks and defects. Many of these unwanted events, however, are not such that they will develop to an accident and can only contribute in very unlikely combinations. When reporting incidents our shelf to PSA a rather high level of reporting is applied. A high level is beneficial because our work in reviewing can be limited, and the severity of the events brings us closer to accidents. Based on the reported incidents we also decide if we want more information as incident investigation reports, or if we want to perform our own investigation. About ten investigations are performed yearly by PSA. A disadvantage has been that the detailing is too low to monitor the time development of groups of incidents with a low annual number of events.

I will in the following highlight a few incidents and subject we have observed at PSA.

Towing

The West Gamma accident occurred August 21th 1990 [22]. The jack-up had been used as flotel at Ekofisk, and was towed southwards to B11. Near B11 the weather became significantly worse, and the towing vessel could not hold the jack-up in position. Soon after, the towing line failed. The significant wave height was estimated by the captain to be 9-11 meters. At 12.30 half the helicopter deck was torn off by a large wave. Lifeboats were torn off by waves, and caused again manholes of two tanks and one ventilation channel to be torn off by the liveboats. The jack-up began taking in water and listed. It was compensated by ballasting, but a change in the direction of the platform caused a heavy list. At 1400 all 49 on board jumped into the sea with survival suits on. The helicopter deck could not be used, and the evacuation by lifeboat was impossible due to the weather conditions. Everyone was saved, and the jack-up sank.

After the accident the NMD established a group giving recommendation to improve the stability of jack-ups in their regulations. New regulations on stability were issued 20.12.1991 [17].

Damping

We have reviewed damping ratios used in fatigue analysis. Damping ratios of typically 7-9 % have been used in the analysis. Our review of published data indicates 7-9 % to be too high.

Hambly et al [7] calculated damping on Rowan Gorilla II in Arbroath in the North Sea at a water depth of 93m. A damping ratio of 2% of low sea states to 5% for high sea states was found. The natural period varied from 3.9 sec to 4.4 sec. The largest ocean state that was measured was Hs = 8m.

Brekke et al [2] found a best estimate of the damping of 1.8 to 2.8% for the Mærsk Guardian. They had waves up to 7.5 m at the Silver Pit.

Sterndorff [19] have examined the Mærsk Guardian for winter 1990/1991 at Ekofisk. He states the first own period to be 5.95 seconds in the largest storm. I have plotted his damping values against Hs (in meters) as in figure 1.

Karunakaran et al [11] has considered and analyzed measurements from the West Epsilon. It was equipped with a skirt. It was analyzed for three stormy times with HS of 9.0 to 9.3 m. To make the calculations to comply with the maximum response they got 3.5% damping. For subsequent waves use the 4.5%. If they assumed no current 5.5% gave the best fit. Currents were not measured. Morandi et al [14] have also analyzed the West Epsilon data. Their best fit was 5.5% damping.

During some AoC processes of two jack-ups in 2011 we have requested measurements of response to be performed during the 2011-2012 winter season and new calculations of damping based on the measurements. This is to get a better data basis to stipulate the damping ratio, and to be a basis for future fatigue analysis.

Vortex induced vibrations (VIV)

26 cracks have been found in "span breakers" in the legs of Mærsk Innovator (built 2003) and 24 cracks on Mærsk Inspirer (built 2004). The legs of the platforms are fabricated according to the same drawings. The cracks are of varying sizes and the largest 400mm long. The cracks are in the span breakers and in the nodes connecting the span breakers and the braces. The cracks are in air, and the main cause is cross flow vortex induces vibrations.

The span breakers have a length of 8.6m, diameter of 152mm and a thickness of 12.5mm. The measurements [8] show a main vibration frequency of 12Hz. The largest measured acceleration on a span breaker was about 6g, but the "normal" vibrations are significantly lower. The largest measured velocity was 0.9m/s and the largest displacement vertically 12mm. The span breakers got vortex induced vibrations at a frequency of 12Hz at wind velocities about 10m/s. The measurements gave damping as a function of the displacement, 0.1 % at insignificant displacements and 0.2 % with larger amplitudes. The fixity was calculated based on the natural frequencies to be 97% of rigid. The braces are much stiffer than the span breaker (D=355mm and t=28-35mm).

Some of the braces have a natural period of 24Hz. ”Parametric excitation” - the relation between the periods was 1:2 (12Hz / 24Hz) between the span breakers and the braces, may have amplified the excitations (“parametric excitation”). Measurements of vibrations from machinery foundations in the vicinity show that they too have energies at 12Hz and 24Hz. This may also have amplified the vibrations [8].

The VIV problems are solved by injecting concrete into the span breakers. This increased the mass and reduced the natural period. Measurements show that the accelerations are reduced significantly.

In 2010 five cracks were also observed in the West Epsilon jack-up.

In several of our new jack-ups, several structural elements do not comply with VIV requirements in DNV-RP-C205 [5]. It has caused discussions if the DNV is unreasonable conservative or not. PSA have requested measurements to be performed on one new platform during the winter season 2011-2012.

Jacking system

Since year 2000 three incidents have been reported to PSA on problems with jacking systems.

12.5.2001 Rigmar 301 (present COSLRigmar) suffered damage of the legs and jacking system during a jacking operation at Harestadvika outside Stavanger [21]. After the jacking had started, “loud noises” were heard, and soon the jacking motor on leg 2 was “smoking and sparking”. Because of the noise level, information of the events was not received by the jacking control. Soon after jacking on leg 3 started. “Large banging noises” were heard. Shortly after the banging had ceased there was a rapid increase in the volume and pitch of the jacking gear. The jacking control was again asked to stop the jacking, but again there were too much noise. Five seconds after leg 3 was started, leg 1 started. About 30 seconds after the start, an isolated bang was heard, and material could be seen flying across the jack house. At about the same time, sparks and flame were seen from the jacking motors. After 45-60 seconds the jacking speed was very high and a few seconds later smoke came from the electrical motor. The jacking control became aware of the very high jacking speed. The stop buttons and the emergency stop buttons were used, but nothing happened. As the hull took the water, volume and pitch of the noise associated with its descent, decreased. The hull was descending at a slower rate. The sparks and flame from the jacking had ceased. As the hull got deeper in the water, the descent continued until it stopped. The whole descent had taken about three minutes.

All electrical motors were burnt and had various degree of mechanical damage, and all the brakes were damage beyond repair. One gear was broken from the floating gear and one motor broken from a mounting plate. Damage were made to legs and racks at several locations as indented chord plates, damaged teeth with cracking and deformations by overloading.

Quelery and Veer [21] concluded that the main reason for the incident were the high descending speed (1.5 feet per minute), combined with the attempt to stop the jacking process by pushing the stop or the emergency stop button. The power generated was unstable with respect to voltage and frequency. High frequencies were demonstrated to increase the descending speed. The in service conditions of the brakes were unknown because they had never been inspected. It is possible that when the brakes were activated they could not withstand the dynamic forces and burned down. If the electrical load was too low, there would be insufficient brake capacity. The procedure required four generators on board, but one was removed for repair.

A second reported incident was during rig move of COSLRigmar from Ekofisk 2/4-Q to 2/4-X in 2008. One of the Westinghouse gear boxes wrecked because wrong lubricants were used. The lubricants were then not distributed to one of the two chambers (the lubricants were only injected on one side). This in turn caused that one of the teeth’s were torn off (about 10m below the surface) and some damage was made on the next tooth.

The third event happened during the jacking of Haven in Eydehavn 22.4.2011, binding and noises were experienced and the operation was stopped. Haven remained elevated with an air-gap of approximately 28m to the sea level for several weeks. The jacking system in Haven consists of a rack and pinion mechanism. There are eight pinions per chord and tree chords per leg. In total 96 pinions. The pinions are engaged by electrical motors. After an investigation the causes were found to be [13]:

- Upper and lower guides not aligned through centre line of pinions.
- Opening / distance between left and right plates on upper guides was not within prescribed design value.
- Deviations from design drawings on the shape of upper guide plates.
- Loose upper wear plates due to clearances to stopper plates.

- Legs were fabricated outside tolerance limits on rack to rack distance, outside tolerance and leg global shape outside tolerance.
- Jacking tower and hull were outside the building tolerances.

After the investigation the following modifications were made [13]:

- Re-alignment of the upper guides by machining or shimming.
- Smoothing lower slope in the upper guides.
- Grinding of edges (steps) between the lower and bolted lower guides and adjusted to a smoother slope.

Soil conditions

In general the soil conditions for jack-ups on the Norwegian Continental shelf are good. During several ice ages the ice sheets have compacted the soil. The upper soil layers (as in the Ekofisk, Ula, Gyda, Valhall and Hod areas) are typically fine or medium fine sand. The area coincides with the area which was dry land during and immediately after the last ice age. The sand (loss) is probably first transported by melt water from glaciers, and then transported by strong winds from the glaciers [9]. The loss has probably covered the landscape, giving varying thickness on top of the older soil layers. This loss is exposed to scour. On some locations we can find geological structures as buried river channels, having different soil properties with punch through possibilities.

It has only been reported two incidents on the Norwegian continental shelf related to the soil conditions of jack-up units:

West Omicron was placed next to the 2/4-K jacket, connected with a bridge [1]. 1.2.1995 at 00.00 had winds of 60-65 knots and wave heights of 10 to 12m. One of his legs had penetrated the sea floor and had a slope of about 0.2 degrees. Jacking of the legs was started at 02.00. The slope of the rig was then in excess of 1 degree. The leg was jacked down four feet to be horizontal. At 10.00 the same day was leg jacked down another foot, for a slight tilt in the opposite direction. The spud cans in the front was penetrated 3.15 m and 4.25 m. It was up to 2m scouring of the seabed around the two sides of the spud can on the leg.

After the installation of Kolskaya at Hod 12.12.1990 – scour was observed around one leg. It had been a storm and the rig had moved a little. They conducted an inspection where they found scour. The rig sank 15-20 cm on one leg. This was corrected by jacking up the foot. It was then made daily ROV surveys and the scour increased for each day. Large sand masses disappeared. The cause was believed to be a strong local current. A lot of sand bags were dumped near the legs during several days.

During 2010 and 2011 a few cases have occurred with difficult (possible punch trough) soil conditions on our shelf. Some of them have been solved by installing a gravel layer on the sea floor.

Collisions

Since 1982, 115 collisions have been reported on the Norwegian Continental Shelf, with varying degree of severity. In the period 2001-2010 there have been 26 reported collisions [12]. None of the collisions has caused loss of lives or personnel injuries. The economic consequences however have been significant, especially one collision in 2009 with a jacket. Five collisions on jack-ups are reported: Mærsk Guardian in 1998, 1999 and 2000, and West Epsilon in 2000 and 2008.

According to the Facilities Regulations [20], facilities must be designed for a collision with an annual probability of 10^{-4} per year. It has been common for jack-ups to be designed to withstand, as a minimum, a collision with a 5,000 ton supply vessel with a speed of 2 m/s, corresponding to a collision energy of 14MJ (as in [3]). These 14MJ are also a guiding criterion in NORSOK N-003 [16] for production facilities. During the last decade, we have had about one thousand platform years on the Norwegian shelf. During the same period [12], we have had three vessel collisions with more than 20MJ energy (West Venture 2004 → 39MJ, Ekofisk 2/4-P in 2005 → 23MJ and Ekofisk 2/4-W in 2009 → 70MJ). This indicates that the 14MJ collision energy as a design load could be too low in relation to what is actually observed in terms of collision energies and collision frequencies.

We have asked the NORSOK committee and DNV to re-evaluate their guidance on 14MJ. We have also requested improvements in the industry, and highlighted ([19] and [12]):

a) The safety culture in the vessel industry is not good enough – procedures are not followed.

b) The vessels get more sophisticated technical equipment on the bridge, not all crew on the bridge are adequately trained to use it. The crew has too much confidence in the DP systems, and when errors occur the bridge crew are not sufficiently attentive to correct errors in time.

c) Equipment is not sufficiently adjusted to the needs of the users, and has inadequate barriers. A tendency is that the bridge equipment becomes more and more complex, and more difficult to use correctly.

d) The platform owners do not monitor the ships entering the safety zone sufficiently.

References

[1] Breivik Reidar G: Penetrering av legg på West Omicron, letter from Phillips Petroleum, 2.1.1995.
[2] Brekke J N, J D Murff, R B Campbell og W C Lamb: Calibration of jack-up structural analysis procedure using field measurements from a North Sea jack-up, OTC 6465, Houston, 1990.
[3] DNV: Safety Principles and Arrangements, DNV-OS-A101.
[4] DNV: Structural design of self-elevating units (LRFD method), DNV-OS-C104.
[5] DNV: Environmental Conditions and Environmental Loads, DNV-RP-C205.
[6] DNV: Classification Note 30.4 Foundation.
[7] Hambly E C, G R Imm og B Stahl: Jackup performance and foundation fixity under developing storm conditions, OTC 6466, Houston, 1990.
[8] Hansen Svend Ole: Mærsk Innovator, Vibrations of leg structures, Copenhagen, 2. July 2007.
[9] Idland Mari Anne: Erosjon rundt jacketer, Norwegian Petroleum Directorate, report OD-93-24, Stavanger, 1992.
[10] Jack R L, M J R Hoyle, R J Hunt og N P Smith: Jack-Up Accident Statistics: Lots to Learn!, The eleventh international conference - The jack-up platform, design, construction & operation, London, 2007.
[11] Karunakaran D, M Bærheim og N Spidsøe: Measured and simulated dynamic response of a jack-up and a large jack-up platform in North Sea, OTC 8827, Houston, 1998.
[12] Kvitrud Arne: Collisions between platforms and ships in Norway in the period 2001-2010, OMAE, paper OMAE2011-49897, 2011.
[13] Master Marine: Haven - Second Jacking Trial, Technical Note, Oslo, 16.6.2011.
[14] Morandi A C, D Karunakaran, A T Dixon, M Bærheim: Comparison of full-scale measurements and time domain irregular sea analysis for a large deepwater jack-up,
OTC 8828, Houston, 1998.
[15] NORSOK standard N-001: Integrity of offshore structures, revision 7, June 2010.
[16] NORSOK standard N-003: Actions and action effects, revision 2, September 2007.
[17] Norwegian Maritime Directorate: Regulations for mobile Offshore Units. Available on http://www.sjofartsdir.no/en/Legislation_and_International_Relations/Translated_Norwegian_legislation/Regulations-for-Mobile-Offshore-Units/
[18] The North West European Area (NWEA) Guidelines for the Safe Management of Offshore Supply and Anchor Handling Operations, updated June 2009.
[19] Petroleum safety Authority (PSA): Risk of collisions with visiting vessels. Press release 5.1.2011. Available on www.psa.no.
[20] Petroleum safety Authority (PSA) and others: The framework regulation + the facility regulation, all of them from 2010. Available on http://www.psa.no.
[21] de Quelery F and J. van der Veer: Rigmar 301 ID. NO. 17502, Damage investigation survey report, DNV, Rotterdam, 7.11.2001.
[22] Stavanger byrett: Sjøforklaring vedrørende havarert boligplattform ”West Gamma”, Stavanger, 28.8.1990.
[23] Sterndorff M J: Note on ringing effects for the Mærsk Guardian, DHI, Hørsholm, 24.9.1993.

Figure

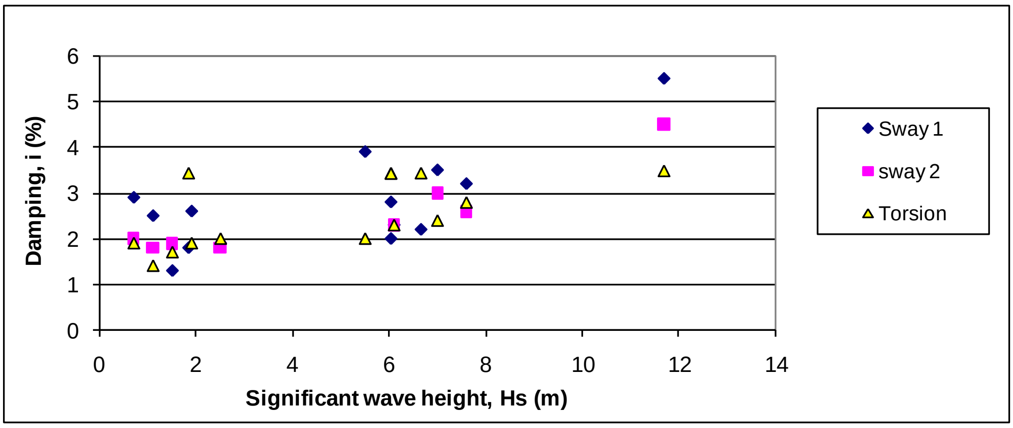

Figure 1: Damping in % for the first three vibration modes of Mærsk Guardian on Ekofisk 2/4-W and Silver Pit plotted against Hs (in meters), based on information in [23] and [2].