Boswell L. F.[1], Alekhin V.N.[2], Budarin A.M.[2]
[1] City, University of London, School of Mathematics, Computer Science and Engineering
London, UK
e-mail: l.f.boswell@city.ac.uk
[2] Ural Federal University
Yekaterinburg, Rassia
e-mail: referetsf@yandex.ru
[3] Ural Federal University
Yekaterinburg, Rassia

THE JACK-UP PLATFORM FOR OFFSHORE OIL AND GAS EXPLORATION OVERVIEW

Abstract. A Jack-Up platform can float and be transported, it can be elevated when it arrives on location and its legs will rest on the sea bed. After an appropriate and rigorous site assessment the unit will be ready for operation. Due to the compliant characteristics of the structural system difficult challenges must be overcome by designers and operators. Generally, these challenges are more complex than most offshore structures and the later section in this chapter related to the management of hazards endorses this comment. This article is an overview of the main characteristics of these mobile units. A modern Jack-Up can weigh up to 20,000 tonnes and be capable of operating in 150 m of water in a very harsh ocean environment. Jack-Up platforms are designed and constructed to satisfy the rules of classification societies and classification is a comprehensive verification procedure. In this respect they may be regarded as mobile units together with ships and other marine structures. The main structural features are associated with the hull and the legs and foundation. However, separate sections for Jack-Up structural design and foundation design have been included in the Jack-Up chapter. Transportation is a critical stage when the unit can become unstable, but elevating the structure and the process of jacking can also be problematic. Transportation has been considered as a separate section in this chapter and the examples of accidents as case studies demonstrate the dangers associated with the critical stages of operation. Consideration has been given to the use of high strength steel in this review, but sections related to Fatigue and to Fracture Mechanics have been provided separately in the Jack-Up chapter. The section related to Marine Warranty Survey aspects brings together many of the features of Jack-Up operations and the potential of Jack-Up risk and reliability studies for risk assessment of various operating stages has been explored in the Reliability section within this chapter.

Key words: Jack-Up, Classification, Structure, Warranty, Steel, Transportation, Equipment, Foundation, Stability, Site Assessment, Case Histories.

Босвелл Л.Ф.[1], Алехин В.Н.[2], Бударин А.М.[2]
[1]Университет Сити,.
Лондон, Великобритания
e-mail: l.f.boswell@city.ac.uk
[2] Уральский федеральный университет
имени первого Президента России Б. Н. Ельцина
Екатеринбург, Россия
e-mail: referetsf@yandex.ru
[3] Уральский федеральный университет
имени первого Президента России Б. Н. Ельцина
Екатеринбург, Россия

ПЕРЕДВИЖНЫЕ МОРСКИЕ БУРОВЫЕ ПЛАТФОРМЫ ДЛЯ ПОИСКА НЕФТЕГАЗОВЫХ МЕСТОРОЖДЕНИЙ НЕФТИ И ГАЗА

Аннотация. Передвижная морская буровая платформа может плавать и перевозиться, ее можно поднимать, когда она прибывает на место, и ее ноги будут опираться на морское дно. После тщательного обследования конструкции и площадки установки соответствующей и строгой оценки площадки буровая платформа готова к работе. Конструкторы и монтажники должны преодолеть и разрешить все возникающие проблемы установки буровой платформы. В этой статье рассмотрены основные характеристики этих передвижных конструкций. Вес современных передвижных морских буровых платформ достигает 20000 тонн и они способны работать на глубинах до 150м в суровых океанских условиях. Морские буровые платформы проектируются и строятся в соответствии со строгими положениями норм, а комплексная процедура проверки их соответствия нормативным требованиям является сложной задачей. В этом отношении они могут быть отнесены к категории морских судов. Основными конструкциями морских буровых платформ являются корпус, опоры и основание. Наиболее опасной ситуацией является передвижение морской буровой платформы, когда могут нарушиться требования общей устойчивости конструкции, однако в процессе ее подъема также могут возникнуть опасные ситуации. Стадия передвижения рассмотрена в отдельном разделе статьи, где показаны различные опасные случаи. Рассмотрены вопросы применения высокопрочных сталей. Вопросы усталостной прочности и механики разрушения рассмотрены отдельно. Отдельный раздел посвящен анализу риска и надежности в процессе установки морских буровых платформ.

Ключевые слова: Передвижные, классификация, конструкция, безопасность, сталь, передвижение, оборудование, опоры, устойчивость, устройство площадки, возможные опасности.

Introduction.

This section provides an introduction to the Jack –Up drilling platform, which may be used for the exploration of offshore hydrocarbons. However, the flexible and mobile characteristics of the platforms enable them to have other applications in the offshore oil and gas industry in the role of supporting facilities for marine operations in general. Other sections which follow in the Jack-Up Chapter consider more specialised topics of current relevance to the design, construction, the performance and operation of platforms. A useful introduction to Jack-Up units can be found in a technical primer [1].

In addition to their use as exploration drilling platforms, Jack-Ups are used as offshore and wind farm services platforms. They are the most popular and numerous of the various mobile platforms, and currently there are over 600 in operation, but many are over 30 years old. A Jack-Up has advantages that may appeal to an operator, the most important being the cost and efficiency. It is less expensive to construct than other types of offshore structure and has lower operating costs. Also, it usually requires no anchoring, a smaller crew for manning and can be moved using small vessels. Jack-Ups weighing over 20,000 tonnes are capable of operating in water depths of approximately 150 m in adverse ocean and weather conditions with wave heights of over 24 m and wind speeds of up to 100 knots. A recent design for the harsh North Sea environment has extended the operating depth to 175 m. The operating limitations are concerned with safety and water depth. Main disadvantages are associated with transit in which a unit is vulnerable to motion instability, wave damage, shifting cargo and structural damage in the vicinity of the leg support structures. Also, during the installation of the unit sea bed impact must be minimised, and foundation failure avoided.

A Jack-Up is an offshore structure, a type of mobile platform and is regarded as a self elevating unit. It consists of a buoyant hull fitted with a number of moveable legs (most usually 3, but early designs have 4 legs), which are capable of raising the hull above the surface of the sea. They are the most common of mobile units. The buoyant hull enables the transportation by “wet” or “dry” tow of the unit and the variable deck load, including machinery, to the desired location. Generally, rigs are not self propelled and rely on tugs or heavy lift vessels for transportation. Once on location the hull is raised to the required elevation above the sea surface and is supported by the sea bed. The legs of the unit may be designed to penetrate the sea bed, may be fitted with large sections or footings (spud cans) for each leg or may be attached to a bottom mat.

Classification

Jack-Up units are designed and constructed to satisfy the rules of the classification societies such as the American Bureau of Shipping (ABS)[2], Det Norske Veritas (DNV)[3], and Lloyds Register [4], etc. Each society has its own rules for classification, but many of the rules are co-ordinated by the International Association of Classification Societies (IACS)[5]. Classification societies are third party independent organizations.

Classification is a comprehensive verification procedure, which provides assurance that a set of requirements established in rules and standards, which have been recommended by the societies for the design, construction and operation of Jack-Ups, have been met. The rules and standards ensure safety against hazards, concern the health and safety of personnel and provide protection for the environment.

Registration with a Flag State Government Authority is normal for Jack-Up drilling units to implement the statutory requirements of the relevant government. In addition, some governments require compliance with their own rules in addition to the Flag State.

Also, ships and marine structures are of concern to classification societies and in this respect Jack-Up units may be considered to be mobile offshore structures. The approach, which has been adopted in the current Encyclopaedia, has been to consider Jack-Up units together with ships and other mobile structures for classification purposes. This generic approach enables those aspects, which are relevant to Jack-Up units to be explained against a broader marine background. Thus, the specific details of classification related to Jack-Up units are to be found in the section, Marine Classification, in the chapter, Marine Operations.

Structural Features of a typical Jack –Up unit.

The two main structural features of a Jack-Up which are to be considered in a design are the Hull and the Legs and Foundations. A detailed consideration for the design of a Jack-Up is given elsewhere in the Jack-Up chapter. The flexible operating envelops of a Jack-Up implies that a Jack Up can function in many locations. Therefore, the factors to be considered in design are determined by the target capabilities of the unit. These capabilities include the desired deck load during operation, the total load during tow, the maximum operating water depth, the maximum wave height, current velocity and wind speed and the sea bed condition.

The hull is usually made of a stiffened plate box structure, which may consist of an upper deck, an intermediate deck for equipment and a bottom deck. The flat plate is stiffened by closely spaced angle and flat sections. These sections span across frames or beams, which are continuous across a section to form a closed structure around the box section. The frames span between bulkheads, which are positioned in locations of high loading and provide adequate stiffening to the frames. The bulkheads provide a load path to the leg wells in the hull and provide a means for transferring loads to the legs. Gear units, guides, rack chokes and pins are used to transfer these forces. The hull components are arranged to transfer loads on the hull into the legs through the hull legs intersection into the chords. Axial and horizontal loads are transferred into the legs through the hull leg interface connections and chords. A bulkhead terminates at each leg chord location.

Usually located at an elevated level above the main deck is the drill floor or drill deck. It is mounted on a cantilever support structure. The drill floor or both drill floor and cantilever can be moved with respect to the hull such that the well centre can be moved along a line or in a plane, respectively. The drill floor supports the derrick or drilling mast and the other equipment used during a drilling operation.

The structural components of the hull and their function may be summarized as follows:

– Support points for jacking and holding units.
– Upper and lower guides which provide a moment connection between the legs and hull.
– Longitudinal, transverse and inner perimeter bulkheads for load transfer of the hull to the legs.
– Upper, intermediate and lower deck stiffened plating.
– Cantilever beams to support the moveable drill floor.

The legs and foundations are steel structures that support the hull when the rig is in the elevated operational mode and provide stability to resist lateral loading. The foundations or footings increase the bearing area and reduce the bearing stress on the seabed. The more recent rigs have trussed legs with either three or four chords. The chords are connected by a system of horizontal and diagonal braces and are normally circular in cross section. The arrangement of the members is to minimize the hydrodynamic loading and they are designed to resist fatigue and overload using high strength steel. Gear racks are an integral part of the chords.

Two important stages determine the forces being applied to the legs, when the rig is in transit and when the rig is in the elevated operational position. For the transit or afloat stage, gravity loads, wind forces and inertia forces due to vessel motion must be resisted. The pitch and roll motions of the transportation barge will induce fatigue stresses in the legs and welded joints of the tubular members. The unit, cargo, grillage (temporary structural members supporting the unit to distribute the vertical load on the barge) and sea fastenings should be designed to withstand the motion and forces during transit. Restraining reactions from the locking system in the hull can induce high moments into the legs.

The legs must resist a different set of forces in the elevated operational position. Compression forces are generated by gravity loading on the hull and the reactive couple caused by overturning moments on the rig. Moments are induced in the hull due to the horizontal displacement of the hull and the moment connection between the leg and hull. Wave, current and wind action induce horizontal forces on the leg members. Due to the slenderness of the structure the P-delta effect in the leg must be considered. Very high local stresses can be induced due to force transfer mechanisms between the guides and rack and pinion arrangements. The dynamic nature of the environmental forces induces fatigue effects and welded joints with the associated stress concentration factors, will be particularly vulnerable.

The Jacking System

In general, there are two systems for elevating the deck of a rig. The first uses hydraulic cylinders equipped with moving and stationary pins. The cylinders extend and retract to climb up and down the legs of the Jack-Up rig. The second system employs a rack and two pinion gears that are turned to move the legs up and down for continuous jacking.

Usually the jacks in the elevating system are sufficient to raise and lower the hull. However, during operation and adverse weather conditions the bending moments caused by horizontal wind, wave and current forces are transmitted to the main body of the hull. Some units rely on the elevating pinions to transfer these loads in all modes of operation, while others use the pinions primarily for jacking operations and use a fixed system to transfer the loads the majority of the time other than jacking operations. These moments are resisted at guides above and below the rack and pinion mechanisms that raise and lower each leg.

Although new rigs are being built current construction is associated with rig modification to enhance working capability. However, in both cases the topside loads being transmitted to the Jack-Up legs through the jacking system is increasing. The challenge for designers is to design a jacking system that safely picks up and sets down these higher loads thus avoiding the risk of punch through and the technical limits of the system. It is important to understand how the weight of the hull is distributed in the rack and pinion system. An optimal design requirement is to achieve an even distribution to increase overall reliability and to improve the fatigue life of specific pinion teeth. Smooth, constant speed control systems with variable torque are to be recommended in this respect.

Rack Phase Difference (RPD) is a direct result of the jacking operation in the chords and braces of the legs and is the differential vertical displacement in elevation between rack teeth of the chords of any single leg of the rig. The two main causes are due to load eccentricity and leg offset. High bending moments can be induced between the upper and lower guides as a result of RPD, causing the leg braces within the guides to buckle. RPD can be measured and monitored to provide an indication of brace loading. This is a recommended practice for reducing the risk of a structural failure.

High Strength Steels for Jack-Up Construction

The use of high strength steel for the construction of offshore structures is driven by the need to reduce weight leading to considerable savings in support substructure. Other benefits include fabrication costs, which can be minimized by using reduced plate thicknesses [6].

The construction of Jack-Up legs may vary, but will generally consist of chords, braces and racks of different steel quality. Chords and racks use high strength steel with nominal yield strength of around 700 MPa and yield strength of 800 MPa. The chords, which are quenched and tempered, are tubular and typically 1m in diameter and 35mm wall thickness. The racks are cut from plates 125-150 mm thick. Braces may have the same strength as chords and racks, but in some cases, the strength may be lower. High strength is necessary to keep section sizes convenient and to limit weight. This is particularly important in legs as they may impair stability during transit. For operations conducted in a cold environment a toughness requirement is imposed .The chemical composition of 700 MPa steel is normally based on a Cu-Ni-Cr-Mo-V-Al-B alloy composition. Carbon levels are usually just over 0.1% and manganese just below 1%. Nickel levels tend to be higher, at the expense, particularly of Carbon and Vanadium, in higher toughness grades, and Sulphur is kept as low as possible.

Welded joints in Jack-Up legs need to meet strength and toughness requirements in weld metal and heat affected zones. Material related fabrication problems may include lamellar tearing, hydrogen cracking, solidification and stress relief cracking. However, hydrogen cracking is probably the major concern when welding high strength steels and needs to be avoided in heat affected zones and weld metal for some critical locations. Since the legs will be subjected to dynamic loading a check on the fatigue capacity is necessary at locations such as the leg-spud can interface, the leg structure in and around the splash zone and the leg and hull jacking structure around the leg to hull connection.

A dynamic analysis is carried out for a Jack -Up unit subjected to random waves to obtain the wave spectrum and associated design fatigue curve for critical locations. The subject of Fatigue is considered in detail in a later section of this Chapter. The Health and Safety Executive (2003) [7] has reviewed the design features and field performance of both drilling and production Jack-Ups to provide feedback on issues that may require further attention to recognise the special problems with the use of high strength steel in an offshore environment.

In order to determine design life prediction and failure, fatigue crack propagation rates in a particular environment and operating conditions have to be determined. This may require the use of Fracture Mechanics fatigue tests to determine the values of material constants. The subject of Fracture Mechanics is considered in a later section of this article.

Jack-Up Transportation and Modes of Operation

By definition, Jack-Up platforms are mobile rigs and have three modes of operation:

– Transit from one location to another
– Elevation on its legs and
– Jacking up and down between afloat and elevated modes.

Each of the above has specific precautions and requirements to be followed to ensure a safe operation. The stages for transportation may be summarised as follows:

– Preparing for going off location
– Transit from one location to another
– Arriving on location
– Soft pinning the legs
– Final going on location and jacking
– Preload operations

To achieve the elevated operating condition, the unit is jacked up to the full air gap.

Transit may be achieved using “wet tow” for which the hull floats and is towed directly by barges or “dry tow” when the hull is placed on a floating vessel which is towed. This is a critical stage in the operation of a Jack-Up and there have been many instances of rigs being lost due to instability. In particular, the motion criteria during tow should be carefully evaluated. The floating stability of Jack-Ups is considered as a separate section in this Jack-Up Chapter. A tow may be classified as a field tow, which is less than 12 hours or an extended tow, which is always within 12 hours of a safe haven.

Upon completion of the transit mode the rig arrives on location and prepares for the elevated mode. Soft pinning the legs or standing off location (temporary positioning) is the stage prior to the final positioning, such as next to a fixed structure. A stop point has been reached when the leg has been lowered and the spud can just touches the sea bed. A check is made on the met ocean conditions before the final approach to the working location is made. Preparations are made for the preload and all independent leg units must perform a preload operation before they can jack to the design air gap. The legs must load the soil that supports them to the full load to be expected, which is usually the storm survival load. The unit may be jacked to the operating air gap when preloading is successfully completed and the system is locked.

Equipment

The International Association of Drilling Contractors, (1993) [8], have provided a standard format equipment list for Jack-Up units. The list has been developed to provide a comprehensive summary of all relevant items to assist contractors and operators.

Every well and site have their own equipment requirements, but many items are common to most situations. Variable Deck Load (VDL) includes any item of weight that is not included in the lightship of the basic vessel. The lightship is the basic weight of the general rig, including all equipment considered permanent such as; Draw works and associated equipment, Derrick substructure and hoisting equipment, High and low pressure mud pumps, Rotating system, Top drives, Rig power plant and emergency generator and items that cannot be readily lifted from the unit.

VDL includes the drilling contractors Tubular drill string, handling tools and fishing equipment, Well control/subsea equipment, Blow Out preventer, Instrument and communication equipment and spare parts, fuel, potable water and anything loose on board. Safety equipment and facilities for pollution prevention may also be regarded as VDL. The remaining VDL is for the operator’s consumables including, logging units, casing, bulk and liquid mud, cement, handling tools, items for storage, product.VDL. In general, Jack-Ups have the least VDL capabilities of Mobile Drilling Units.

The Jack-Up Foundation

The success and safe operation of a Jack-Up platform is dependent upon the integrity and satisfactory design of the foundation, which is the demise of geotechnical engineering. A section devoted to the detailed design of Jack-Up foundations has been provided in the Jack-Up chapter of this Encyclopaedia. However, it is worth considering some points in this overview related to the different types of foundation, and the installation and function of the foundations.

The legs of a Jack Up have footings to distribute the bearing pressure on the sea floor. There are two types of footing, mats and individual spud cans. A mat connects all legs on a common, usually rectangular mat incorporating buoyancy chambers. The larger mat area means that the associated bearing pressures transferred to the sea floor will be lower than those transferred by individual spud cans. A mat rig Jack-Up provides the ability to work in a very wide range of soils to include the softest clays and silts because of the low bearing pressure. The large mat area also provides stability against overturning. Also, mats provide additional buoyancy during the afloat transit mode, which implies an additional load carrying capacity. The incorporation of mats in Jack–Up design comes with disadvantages. The sea floor must be even to prevent large moments being induced in the mat and then transferred to the legs. Obstacles such as pipelines and debris must be avoided. Work overs can be difficult to carry out for a unit with a large mat area since it is desirable to be as close as possible to, say, a fixed offshore structure. This restriction also applies to drilling activities for which long cantilever beams to support the moveable drill floor will be required to extend beyond the mat. Sliding of the may be a potential problem. During the transition from the floating to sea bed positioning, the mat must be flooded and this is a difficult stage in the transitional stability of the unit.

The footings of legs associated with individual and separate foundations are called spud cans. They have the advantage of functioning in a variety of sea bed conditions, hard and soft soils, uneven sea bed and locations with pipelines, for example. The ballasting stages for units with spud cans are much simpler than mat footings. During transit the spud cans are able to retract flush with the hull for dry transportation. Higher bearing pressures are associated with spud can foundations and the penetration into the sea bed may leave a footprint after operations. Operators should be made aware of this situation if the location is revisited on a subsequent occasion. Such footprints can be a source of foundation failure. There is a tendency for a new spud can to slip into existing footprints. This unintended movement without a corresponding adjustment to other spud cans can cause large moments to be induced into the legs and the possibility of failure. Careful procedures are required should this be a possibility.

At the beginning of operations the rig is towed to the desired location with the legs in the elevated position. At the location, the legs are lowered to the sea floor and jacked into the foundation soils until the bearing capacity is sufficient to support the unit. The hull is then raised out of the water and the unit is pre-driven or pre-loaded to a weight, which results in the vertical loads under the spud cans equaling or possibly exceeding by some margin the anticipated vertical load expected during storm conditions.

Pre-loading is achieved by pumping water ballast into the hull tanks for three leg platforms. Jack Ups with four legs typically achieve foundation pre-load by carrying the full weight of the hull on pairs of legs in turn and is referred to as pre-drive. The pre-load ballast is dumped and the hull is raised to the operating height above the sea level, after the pre-loading procedure has been completed.

Jack-Up legs must be firmly implanted on the ocean bed and stay there during the drilling operation. Two major problems can arise. First the legs may not be long enough to accommodate the water depth and some penetration into the sea bed sediments. Second during drilling, one or more legs may suddenly punch through a weak soil formation with the possibility of damaging the legs and causing a general instability of the structure.

Most Jack-Up units have three legs each of which is fabricated from a K lattice tubular steel arrangement. The extremities of the legs are place on the sea bed and rest on spud cans. The spud cans which reduce the bearing pressure can be circular or polygonal in shape and are profiled to enable penetration into the sea bed. Jack-Ups can be designed to allow penetration of typically 10 m. In exceptional circumstances the penetration can be much greater. For very soft sea floors the legs may be connected to a steel floor mat to ensure an even and reduced bearing pressure.

Once operations are completed in the elevated mode, the unit is restored to the afloat mode by retraction of the legs. This stage can be difficult if the spud can penetration is great or there is considerable overburden pressure on the foundation. Usually water jetting along the length of the leg and in the spud cans can be employed together with enhanced buoyancy. This is provided by jacking the hull such that the draft is greater than the afloat draft to produce a resulting upward force. The process of retrieving the legs should be undertaken with great care to ensure that the hull is level at all stages during this critical stage.

The Stability of a Jack-Up unit

The ultimate design criteria for a Jack-Up rig, is that it must remain stable once it has been jacked up in the most hazardous conditions, which have been considered in the design. Engineers must ensure that the unit’s gravity load can withstand the horizontal forces of wind, wave and current. Wind can provide the majority of the overturning moment and the load increases as the square of the wind velocity. Wave forces depend upon the wave height and period of the waves and the water depth. Ocean current load is difficult to predict since velocity and direction vary with depth.

A rig is built to satisfy a set of design criteria to include water depth, wave height and period, surface current and bottom current, wind speed, air gap and ocean floor penetration. Safe operation will depend upon local conditions and if the design criteria are exceeded, the rigs stability needs to be re-evaluated. Laboratory data and model calculations are required. For an example, leg penetration is predicted by taking samples from the sea floor and obtaining the un-drained shear strength. In deep water, safe penetration is limited by leg length. In shallow water, the legs will extend high above the deck and jack house, thus increasing wind loads. Water depth and air gap must be estimated to calculate wave and current loads.

The met-ocean forces acting on the Jack-Up will produce an overturning moment and this must be resisted by the stabilizing moment of the rigs gravity load. A Jack-Up unit remains upright if the overturning moment is less than the stabilizing moment. Certifying authorities require a factor of safety to ensure a sufficient margin during the operation of a rig.

Site Assessment of a Jack-Up Unit

The operating requirement for a Jack-Up is that it should perform its design function in several locations during its service life. Thus, a unit will be expected to operate in several water depths, encounter different environmental loading conditions and foundation soil types. Site Specific Assessment is the evaluation of a unit in the elevated mode to satisfy agreed standards of structural strength and stability and the establishment of the foundation strength for the particular location to determine a safe operating envelop for subsequent drilling or construction activities, [9].

A standard, SNAME Technical and Research Bulletin 5-5A (2008) [10], has been developed as a "Recommended Practice" for the assessment of the suitability of a unit to operate at a particular location and to provide relevant date for the operation. An International Standards Organization document, "Site Specific Assessment of Mobile Offshore Units" (2012) [11], has also been produced to assist the Site Assessment process. At the outset of an assessment the body responsible for the rig will be given the environmental conditions to be satisfied together with the sea floor foundation conditions.

The SNAME document has been formulated as a result of a joint industry project involving all sections of the industry. Its purpose is to assist in the assessment of a unit to operate at a particular location in the elevated mode. Thus, the objectives are:

- Establish the geometric suitability of the Jack –Up with respect to leg length, airgap and leg penetration.
- Establish that the Jack-Up is structurally adequate for its intended application.
- Ensure that the foundation can offer suitable support to meet this objective.
- Ensure adequate overturning stability.

To meet these objectives, data are required for each site location, to include, Rig Data, Site Data, Environmental Data, and Geotechnical data. The configuration or mode of operation must be described together with the Airgap and Leg Length Reserve. The loadings or loading cases to be considered include Wave and Current forces, Wind forces and Foundation forces. Other forms of loading must also be considered if relevant, such as Earthquake loading. Resistance checks are required to include, Overturning stability, Foundation and preload and Structure integrity (including fatigue). The effect of the interaction of a unit with adjacent structures must be considered.

The SNAME document provides guidance on the assessment of the input data, calculation methods are provided for hydrodynamic and wind forces, for structural engineering, for geotechnical engineering, for determination of responses and for acceptance criteria. Once the process of site assessment has been completed the Unit will be declared suitable or unsuitable.

Case Histories and the Safety of Jack-Ups

The particular characteristics of Jack-Up mobile structures and their operations mean that they are vulnerable to accidents and possible loss of life. A study conducted for the Health and Safety Executive, (2004)[12] examined over fifty accidents.

One third of Jack-Up accidents have been associated with foundation problems. Causes are classified to categories such as punch through (during preloading or hurricane/storm events), uneven seabed/scour/footprint, sea floor instability/mudslide/sea bed slide, volcanic activity, sliding of mat foundation, unexpected penetration and others [13].

The study records a wide range of damage from accidents from no damage at all to total loss. A number of observations were made.

Punch through has the highest rate in incident cases, representing fifty three percent of all accidents. Punch through problems can be further divided. Eight percent of all incidents are associated with punch through caused by hurricanes. Fourteen percent of incidents with punch through during preloading and thirty one percent, with no stated cause of the punch through.

The second highest rate of incident cause is for uneven seabed/scour/footprint. About fifteen percent of all incidents are in this category.

A comparison of legged and foundation mat Jack-Ups seemed to be appropriate. Sliding of the foundation has been the major problem of mat foundations, while punch through is restricted to Jack-Ups with spud can footings. In five of the six mat foundation incidents, the Jack Ups moved in position during a hurricane. The remaining incident was due to mud slide or seafloor instability.

Other incident causes include soil failure, overturning and tilting and they account for eight percent of all failures.

From 24 fatalities reported in 51 incidents, 19 are due to punch through failure. The other 5 occurred in 1983 due to volcanic activity.

Of the 6 recorded incidents in the North Sea, 5 are due to seabed instability/scour/footprint and the remaining incident due to punch through. There has been no fatality attributed to Jack Up foundation problems reported.

Jack-Up rigs are particularly vulnerable during the transit mode of operation. The design and construction of a unit can be adequate and, therefore, acceptable, but improper towing can result in the total loss of a unit.

There has previously been a number of major incidents and losses of Jack-Ups undergoing wet tow after they had encountered a severe storm during the tow. The Health and Safety Executive has published a review which cites several case histories, (2003). Many issues arise which are related to the transit mode and have been linked with loss or damage and the most important are:

- Reduction in the stability of the unit caused by flooding, or caused by harsh environment conditions;
- Watertight integrity, wave impact loads may cause damage;
- Cargo movement on the deck;
- Structural damage to the leg and leg support structure due to inertia loading.

There is obviously a requirement to eliminate the risks associated with these issues.

Conclusions

The understanding of the behaviour of Jack-Up platforms for drilling and production, and the various stages that a unit undergoes to perform its function have made enormous advances during the last 30 years or so. The capability of a unit is checked against site specific conditions, which might include problematic soil profiles in addition to the design satisfying met-ocean conditions, water depth and air gap for the location under consideration. In addition, transportation and the installation and removal of a unit are also critical stages in the function of platforms. Owners require a certificate of approval in order to satisfy insurance demands to cover all aspects of function. Without this approval there would be no development.

This overview section introduces the essential elements of the technology and engineering practice to support the industry standards for safe and successful operation. Subsequent sections in the Jack-Up chapter develop specific themes. Improved materials and new computational tools are being developed to assist in this process. The development of the understanding of the characteristics and behaviour of Jack-Up platforms has considerably enhanced the understanding of the marine environment in general.

Every two years since 1985 until 2017, international members of the Jack-Up industry have gathered at City, University of London to discuss their common interest in developing their understanding. These conferences, “The Jack-Up Drilling Platform” are source references for much of the current industry practice and many papers will be of considerable importance to the profession.

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