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Master of Science in Petroleum Engineering

Design and Structural Health Monitoring methods of offshore platforms in Azerbaijan

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Abstract

The aim of this thesis is to describe and investigate the main damages and work risks on offshore platforms that are currently operating in Azerbaijan.

This paper consists of Introduction, 5 chapters, and Conclusion:

The first chapter is dedicated to the platform design, installation, foundation and stability.

The second chapter is considering all potential load types that might be present and which are taken into consideration during platform design and construction.

The third chapter describes Structural Health Monitoring techniques and highlights GPS monitoring which is essential for every platform.

The fourth chapter is devoted to the main damage mechanisms present during operating of the platforms especially in Azerbaijani part of the Caspian Sea. The damages mechanisms were discussed and suggested by senior structural experienced engineer who was part of the platform design team and currently working in the operations supporting the same platforms in the Caspian Sea.

The 5th chapter describes the special case study of the unique platform design that present in the Caspian Sea in Azerbaijan.

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Introduction

Offshore platforms are used to examine and handle oil and gas from underneath the seabed. In 1947 the first offshore platform was introduced its was 6 meters depth and is located near the shoreline of Louisiana. Today there are more than 7,000 offshore platforms in water depths of up to 1,850 meters worldwide.[1]

Offshore platforms could be broadly divided into two groups:

- Fixed structures running over the Seabed

Which includes:

- Steel Jacket
- Concrete gravity Structure
- Compliant Tower

- Structures which float near the surface of the water

Which includes:

- Semi-Submersible (SS)
- Ship shaped vessel (FPSO)
- Tension Leg platforms
- Spar Platform (SP)

The deck legs attached to the top of the piles and support the deck structure. Out of all the platforms in the world, around 95% of them are Jacket supported. The jacket platform is a spatially framed structure with tubular elements supported on stacked foundations. It's utilized for sufficient depths of water up to 400 meters. The main deck, a cellar deck, and a helideck are generally contained in the deck structure of the offshore structure. The piles reach out from over the mean low water through the seabed and into the soil. Underwater, the piles are driven through the inside of the jacket structure's legs, that bracing against lateral loads for the piles and additionally used as a reference for the initial pile driving. The natural period of the jacket structure needs to be held below the wave period to avoid wave load amplification. For comparison, the average period of the structure is around 2.5 seconds, while the wave period is from 14 to 20 seconds.[1]

Chapter 1

PLATFORM DESIGN

1.1.Platform parts

The topside is made to save weight and space. It's a flat and open surface with technological and electrical devices. The main types of devices are gas compressors, injection compressors, drilling rigs, gas turbine generators, hoses, HVAC tools, operator accommodation equipment, cranes and heliports.

Mooring and anchors are accustomed to guaranteeing immobility of the platform. Anchors are typically made of steel chains to maintain structural integrity. Also, steel wire rope is possible to be used. It has the shape of a catenary since a lot of weight is installed. With steel ropes, the total length of the rope is longer due to the greater structural weight. In addition to steel anchors, synthetic fiber ropes are also used. Since it is much lighter than steel cable, it has a narrow shape. This is advantageous because the required cable length is short and there is no corrosion.

Risers are numerous supports made as connected pipes. These pipes are used for the extraction, drilling, and export of oil and gas from the seabed. Riser system is a key element in offshore projects. The price and technical problems of riser systems increase considerably with the depth of the water. The design of the vertical system relies on the position of the file, the interface of the container, the properties of the liquid and the environmental conditions. The risers remain tense because of its own weight. The profile should reduce the upper load. The approaches are generally divided into two types: rigid and flexible. Flexible risers permit ships to move due to wave loads and even compensate vertical movements. [1]

Leg types of jack-up platform:

Independent-leg type jack-up unit - is jack-ups with independent legs, spud cans are cylindrical in shape, steel shoes, with pointing ends, similar to cleat. Spud cans are placed on the bottom of each leg, which pushes the spike in the can into the ocean floor, ensuring the platform's stability during service.

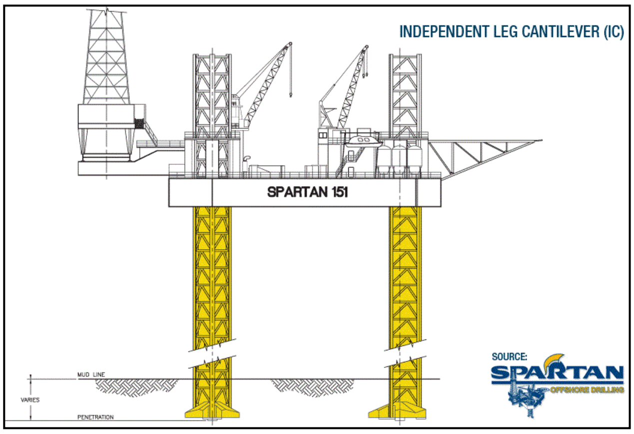


Figure 1: Independent-leg type jack-up unit [1]

Mat style jack-up unit - is a more logical choice for soft floor drilling conditions, mat-supported jack-ups spread the rig's weight across the ocean bottom, like a snow shoe. Generally formed like an "A," mat supports are attached to the bottom of each jack-up to insure that the rig does not bite through the ocean bottom. [2]

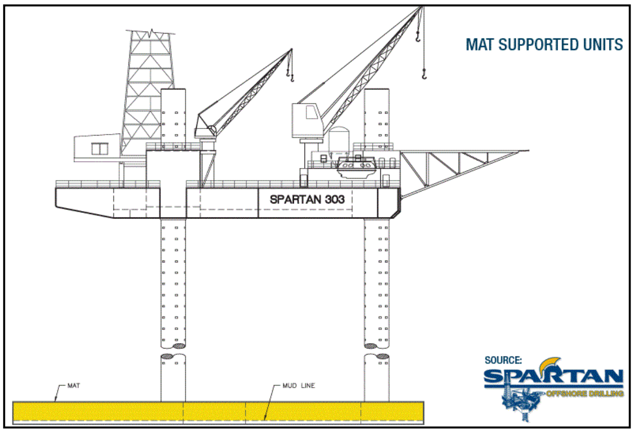


Figure 2: Mat type jack-up unit [1]

1.2.Instalation of platform

For the machines to operate, massive cranes and computerized facilitators are needed, because platforms are immense structures.

Diverse strategies are applied based on resource availability and structure size. For precisely unloading and charging the risers and topsides the barge crane is the most effective and productive machine..

In Flat Over the top side, ballasting of the barge is placed on jackets. Smaller jackets may be introduced utilizing a floating vessel with cranes to lift them off the barge. Massive 400’ x 100’ deck barges capable of conveying as much as 12,000 tons.

1.3.Platform foundation

The piles on the seabed and below should resist the loads created by environmental conditions and by on-board equipment. Soil surveys are critical for the planning of any offshore structure. The Geotech report is developed by conducting soil boring at the specified location and in-situ and laboratory testing. Pile penetrations depend on the size and weight of the platform and soil characteristics, however typically range from thirty meters to around one hundred meters.[3]

1.4. Hydrostatics and stability

Stability is tolerance to capsizing.

Buoyancy's center is situated at the center of the displaced water mass. The center of gravity and center of buoyancy under no external forces are in the same vertical plane. The force of water that directed upward corresponds to the boat's weight, and this weight corresponds to the weight of the water that displaced under the heels of the boat. Therefore Center of Buoyancy moves to float evenly. The straight, vertical line which goes though the new center of buoyancy will run into the Center of Gravity at point M called as Metacenter.

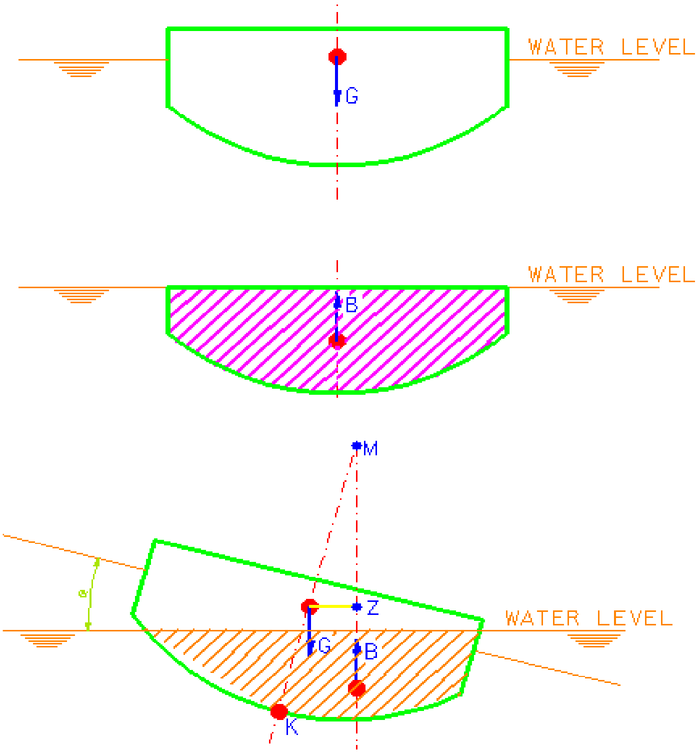


Figure 3: Movement of center of Buoyancy [2]

Intact stability requires the righting moment good enough to withstand wind moments. Damage stability needs a vessel to withstand flooding of selected volume with wind moments. Center of Gravity of partly filled vessel changes, because of heeling. This ends up in a reduction in stability. This phenomenon is called Free surface correction.

Hydrodynamic response can be rigid body response or structural response.
Structural response is involving structural deformations.
There are six types of rigid body responce, which can be grouped in two grups.
•Translational group includes surge, sway and heave.
•Rotational group includes roll, pitch and yaw.[1]

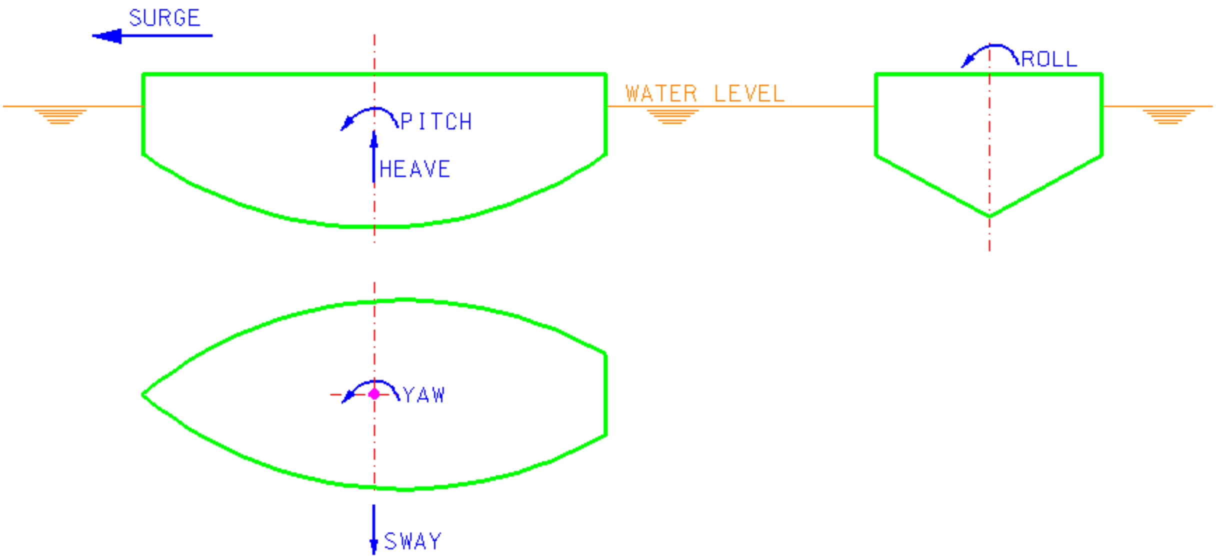


Figure 4: Surge, Sway, Heave, Pitch, Roll and Yaw [2]

Chapter 2

LOADS

2.1. Load types:

The offshore structure is mainly designed according to the impacts of the loads. Loads are divided into the following types:

- Permanent or dead loads
- Operating or live loads
- Environmental loads
- Construction or installation loads
- Accidental loads

Environmental loads are wind load, wave load, and earthquake load. The main impact on the construction of offshore facilities is made by loads from environmental origin, in particular wave load.

2.2. Permanent Loads

Permanent Load is the weight of the structure in air, with the weight of the ballast. Equipment weights and connected structures are included permanently placed on the platform. Also, Permanent loads consist of the hydrostatic forces on the members below the waterline. Buoyancy and hydrostatic pressures are included to these forces as well.

2.3. Operational loads

The weight of all intermittent devices or materials, as well as the forces that occur during the operation of the equipment, are included in operational loads. Operational loads include the weight of drilling equipment, production facilities, housing, furniture, life support systems, helipads, consumables, liquids, etc. as well as forces arising during operation, for example, drilling, mooring of ships, the landing of helicopters and crane work.

2.4. Wind load

Wind load affects the upper part of the platform above the water and any machinery that is placed on the platform such as accommodation, derrick and etc.

The wind speed is also known as gusts with an average time span of less than one minute and sustained wind speeds with average duration of one minute or more. Wind data ought to be modified to a normal elevation, for example 10 metres above the mean water level, with a defined average time, like an hour. Wind data can be tailored to any given average time or height using customary profiles and gust factors. When the quantitative relation of height to the smallest horizontal dimension of the system is greater than five, it is necessary to take into account the complex effects of the wind and also the cyclic wind loads generated by movement due to vortex shedding.

The following ought to considered in deciding acceptable design wind speeds:

If the conditions are normal:

1. The prevalence frequency for each month or season of specified sustained wind speeds from different directions.
2. The persistence of sustained wind speeds above the threshold for each month or season.
3. Possible gusts velocity were linked to sustained wind velocities.

If the conditions are extreme:

Projected severe wind velocities of defined directions and average times should be calculated according to their return interval. The following data must be presented regarding:

1. The location of measurement, prevalence date, magnitude of calculated gusts and sustained wind velocity, and wind direction for the documented wind data used throughout the production of the projected severe winds.
2. The estimated number of times throughout the structure's stated lifetime when sustained wind velocities from defined directions ought to surpass a given lower bound wind velocity.[4]

2.5. Wave load

An offshore platform's wind-driven wave loading is the most significant of all environmental loads because it is the main source of environmental forces on offshore platforms. These waves are abnormal in shape, differ in height and length, and should simultaneously reach a platform from one or many directions. For these purposes, it is difficult to determine the strength and distribution of the forces exerted by waves as a result of the advanced complexity of the technical factors to be considered in the creation of wave-dependent platform design criteria, as well as experienced experts with knowledge of meteorology, oceanography and hydrodynamics. In areas wherever previous information of oceanographic condition is meager, at least the following steps should be taken when designing wave based design parameters:

1. Creation of all relevant weather information.
2. Surface Wind-field projection.
3. Using the analytical model to predict the general deep sea condition along the storm path.
4. Determining the maximum possible marine conditions depending on geographical restrictions.
5. Determination of seafloor topography effects in deep-sea conditions.
6. Prediction of marine phenomena at different time points on the platform using stochastic methods.
7. Creation of wave parameters determined by physical and economic hazards research.[4]

In areas where significant historical data and knowledge of ocean conditions are available, the above sequence can be reduced to the steps required to project this historical knowledge regarding the design parameters needed. The platform owner is responsible for selecting a marine design, taking into account all important environmental factors. When creating sea state data, keep the following in mind:

Normal situation:

1. The probability and average persistence of a number of sea conditions from the directions indicated in terms of the general parameters defining the sea conditions for each month and/or season.

2. Wind speeds, tides, and currents that occur at the same time with the state of the sea (as written in 1st condition).[4]

For extreme conditions:

The determination of extreme sea conditions must give an idea of the number, height and crest elevations of all wave tops above a certain height that the platform site can approach from any direction during the entire life of the structure. These directions must be created and presented based on the expected average repeat interval. The alternative data to be developed are:

1. Estimated range and distribution of wave periods related to extreme wave heights.

2. Other wave heights, maximum peak heights, and the expected distribution of the wave energy spectrum of the ocean condition. Create extreme crests.

3. At the same time as the state of the sea, tides, currents, and winds occur, generating extreme waves.

4. The nature, date, and location of the event that led to the emergence of a historic maritime state involved in the development of forecasts.

Wave theories.

Wave theories describe the kinematics of water waves. They are used to calculate the speed and acceleration of the particles and the dynamic pressure as a function of the height of the wave surface. The wave is considered long-term crowned, in other words they can be represented in two-dimensional fields of flow and are characterized by wave height, period and depth of water.[4]

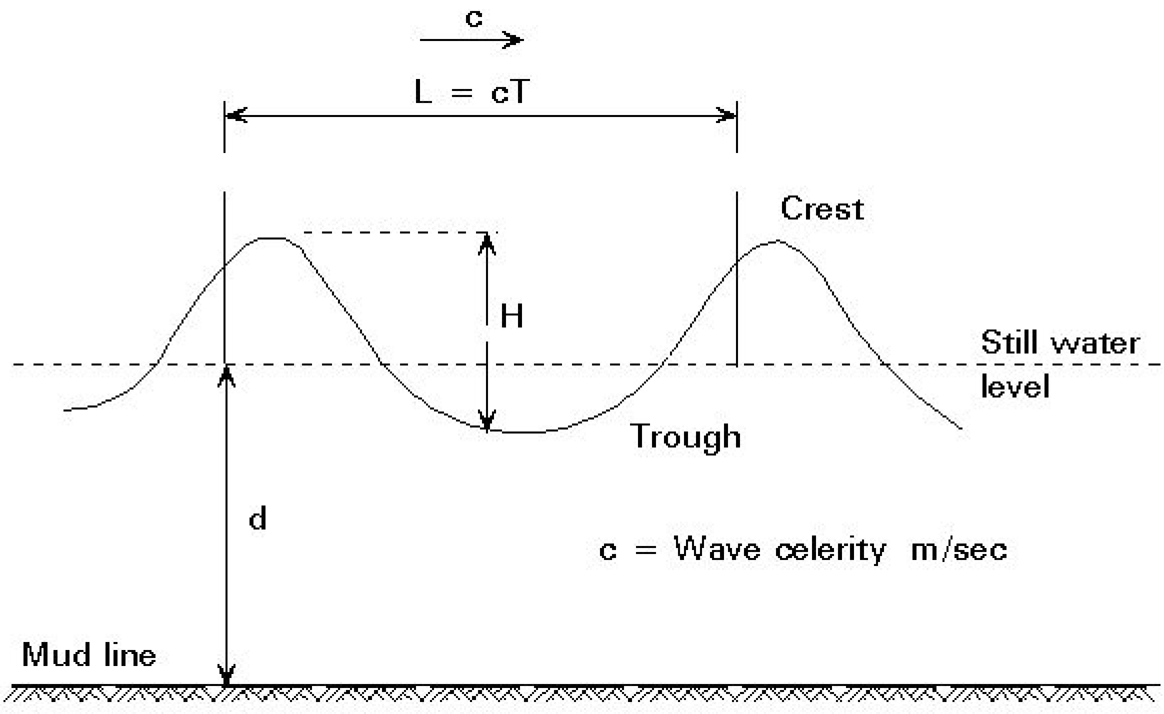


Figure 5: Wave symbols [2]

Wave force on the components

Wave-exposed systems are much more vulnerable to forces than wind loads. Those forces are the product of dynamic pressure and water particle movement. It's two different cases:

1. Large-volume objects called compact hydrodynamic structures influence wavefields through diffraction and reflection. The forces acting on these objects must be determined by calculations of the diffraction theory.

2. The thin hydrodynamically transparent structure has no significant effects on the wave field. Forces can be easily calculated using Morison's equation. Steel shells in offshore construction can generally be considered hydrodynamically transparent. [4]

Generally, when D / L <0.2, the Morison equation can be applied, where D is the element diameter and L is the wavelength.

The Morrison equation expresses the force of the waves as a sum of, Inertial force proportional to the acceleration of the particles and Nonlinear resistance proportional to the square of the speed of the particles. [5]

2.6. Seismic load:

When designing platforms for areas identified as seismically active, seismic forces should be considered. Regions are considered seismically active based on historical seismic activity data, both in frequency and in magnitude. Regional seismic activity in the design of offshore structures is assessed taking into account the significant damage that can be caused to these structures.

Local seismic activity can also be determined by detailed surveys. Seismic considerations include investigating soil instability at the platform site due to liquefaction, seabed slippage after an earthquake, proximity to local disturbances, expected properties of soil movement during the life of the platform and risks. There should be acceptable earthquakes depending on the type of work expected. Shallow water platforms that may be subject to tsunamis should be investigated the effects of forces.[6]

Offshore structures are generally designed for two levels of earthquake intensity: Strength level and Ductility level.

Strength level is one of the criteria used to prevent disruption of the platform operations. It mainly calculated and expected to reach the site due to significant structural damage based on measurements. In terms of requirements, the platform is designed for earthquake size which has reasonable expectations that they will not be exceeded during the platform.[6]

Ductility level is examined to understand the potential loss of life and maintain control of wells. This criterion is based on the calculation of the maximum ground vibration, which is unlikely to occur during the life of the platform, so as not to destroy the platform. Check the platform for ductility requirements for less happened earthquakes that are unlikely to occur.

The main task in calculating the strength level is to build barriers against the large cut off in the event of a strong earthquake during the operation of the platform. While the ductility requirements are made to be sure that the platform has sufficient capacity to prevent the complete destruction of the platform in the event of a strong and rare earthquake. [6]

2.7. Ice and Snow Loads:

This is the main problem of the arctic and subarctic marine structures. Sea ice is unique and is material which is near the melting point. This saline solution freezes at an air temperature around -2°C. Ice formation and expansion can create high pressures that cause both horizon and vertical forces. However, large ice blocks driven by currents, waves and winds at velocity of up to 0.5-1.0 m / s can impact the structure and cause shock loads.[7]

2.8.Temperature Load:

Temperature gradients create thermal stress. To cope with these loads, it is necessary to evaluate the extreme values of the sea and air temperatures that may occurrence through the life of the system. The unintended release of cryogenic substances, in addition to environmental sources substances can lead to high temperatures, which should be considered as accidental loads. The temperature of produced oil and gas also need to be taken into account.[7]

2.9. Marine Growth:

Marine growth accumulates in the limbs under water. The main effect is an increase in drag coefficient due to higher surface roughness and an increase in the exposure areas, which increases the power of the wave forces on the elements. This is taken into account in the design with increasing diameter and mass of the element submerged in water. [7]

2.10. Combination of Environmental Loads

If appropriate data are available, the joint probability of environmental loads can be indicated at the specified probability level. Alternatively, the general probabilities of environmental loads can be estimated by a combination of characteristic values for different types of loads according to the table.

In general, the long-term variation of multiple loads can be explained by a scatter plot or a joint density function that includes direction information. Contour curves can be obtained which lead to a combination of environmental parameters which roughly describe the different loads corresponding to a given probability of exceedance.

The load intensity for different types of loads can be selected according to the probabilities of exceedance as indicated in the table.

In a short-term period with a combination of waves and scattered winds, the individual fluctuations of the two loading processes should be considered insignificant. [8]

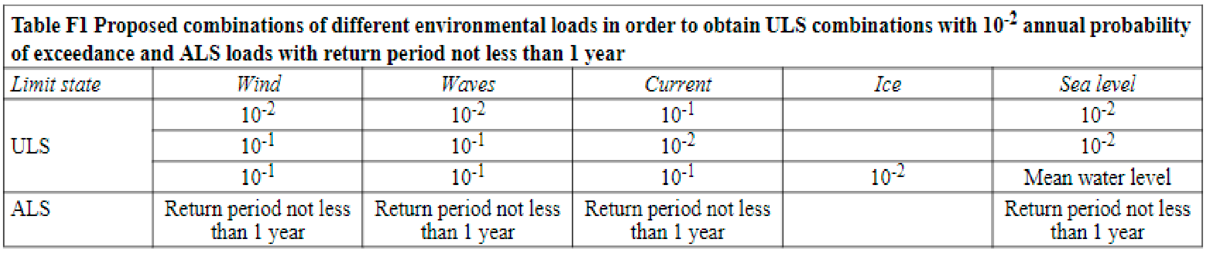


Table F1 Proposed combinations of different environmental loads in order to obtain ULS combinations with 10^{-2} annual probability of exceedance and ALS loads with return period not less than 1 year

Limit state	*Wind*	*Waves*	*Current*	*Ice*	*Sea level*
ULS	10^{-2}	10^{-2}	10^{-1}		10^{-2}
	10^{-1}	10^{-1}	10^{-2}		10^{-2}
	10^{-1}	10^{-1}	10^{-1}	10^{-2}	Mean water level
ALS	Return period not less than 1 year	Return period not less than 1 year	Return period not less than 1 year		Return period not less than 1 year

ULS - Ultimate limit states, corresponding to the ultimateresistance for carrying loads.
ALS - Accidental limit states corresponding to damage to components due to an accidental event or operational failure.

Figure 6: Combination of environmental loads [3]

2.11. Installation Load

This is temporary load that occur while the manufacture and installation of the structur or its parts. While production, assembly hoists of different structural elements generate lifting forces, and during installation the forces generated by loading of platforms, transportation on-site, during launching and lifting, as well as installation-related lifting.

All elements and connections of the raised components must be designed for the forces resulting from the static equilibrium of the raised weight and the tension of the loop.

When the platform is loaded from the production facility to the barge the load-out forces are created. [9]

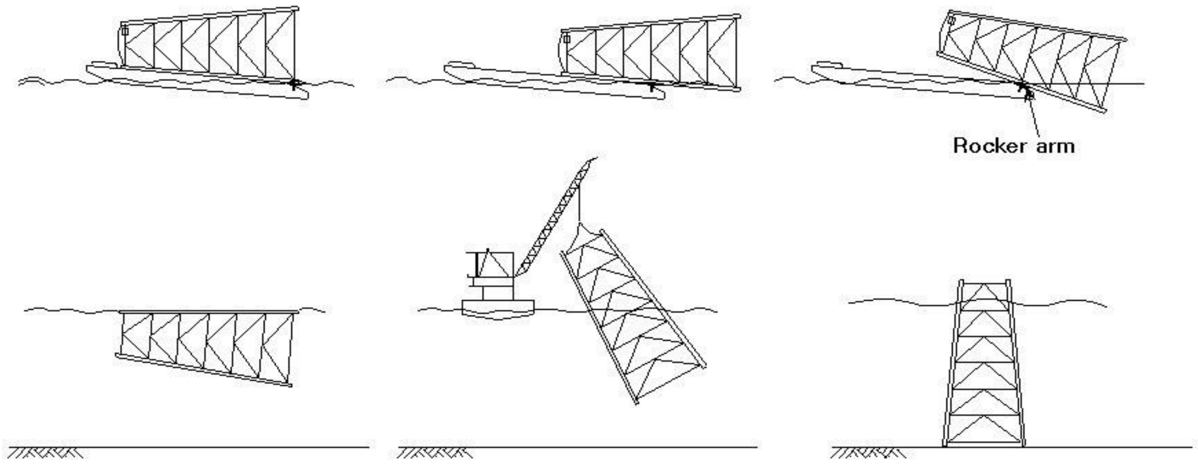


Figure 7: Platform installation [4]

2.12. Accidental loads

Loads related to technical errors or/and abnormal operations are accidental loads. Loads caused by falling objects; collisions; explosions; fires; changes in expected pressure drops; random ships, helicopters or other objects; accidental changes in ballast distribution; breakdown of ballast tubes or accidental flooding of the fuselage compartments; failure to moor the lines, loss of heading due to loss of dynamic positioning system are all examples of accidental loads.

The correct accidental loads should be determined by assessment and experience. With respect to planning, implementation, use and updating of such an assessment and generic accidental loads.

For temporary design conditions, we can provide general values according to actual requirements. The safety level associated with the temporary design condition cannot be inferior to the security level required for the actual design condition.

[10]

2.13. Load Combinations:

The combination of loads depends on the calculation method used, i.e., whether limit state or allowable stress design is used. Recommended load combinations for use with an approved stress procedure:

Normal operations:

Dead loads add to operating environmental loads and add to maximum live loads.

Dead loads add to operating environmental loads and add to minimum live loads.

Extreme operations:

Dead loads add to extreme environmental loads and add to maximum live loads.

Dead loads add to extreme environmental loads and add to minimum live loads.

Environmental loads must be combined to match the overall probability of occurrence. Seismic loads should be imposed in the form of separate environmental influences, in other words, they should not be combined with waves, wind, etc.

Chapter 3

Structural Health Monitoring

3.1 Stuctural health monintoring methods

Structured Health Monitoring methods describe the process of applying strategies and methods to identify and classify damage caused by identified changes. These variations can lead to aging, environmental impacts, and contingencies such as earthquakes and wind reserves.

These methods are important in various fields such as aerospace, marine, civil engineering, and mechanical engineering. For example, bridge monitoring technology is related to offshore technology. However, hostile environments make it more difficult to build surveillance structures at sea than in other industries.

The SHM approach can be viewed as an iterative process divided into four different stages that use a balanced approach to assess the life of the remaining system.

- Planning phase
- Data collection phase
- Data processing phase
- Evaluation phase

[11]

3.2. Planning phase

The planning phase is the beginning of all SHM phases and is part of creating a plan and defining a strategy when the scope is known and needs to be controlled.

The installation of the SHM system integrates all aspects of the planning cycle into a clear and unified process. This ensures that the plan is properly coordinated, stable, practical, and above all, profitable.

This means that it is important to collect motivation information and set up failure procedures and monitoring methods, primarily to reduce costs and risks. In addition, using SHM systems instead of ROVs and remote divers can save human risks and expenses.[12]

3.3. Data collection phase

During the data collection phase, information is recorded and measured. This is an actual monitoring process set up to make it easier to facilitate answers. This includes the choice of the measurement method, sensor type, quantity and location, and the choice of hardware for data collection/storage/transmission.

Data acquisition systems digitize analog sensor signals, use a type of data filter, transfer data, record the data, and store it for later analysis. In many cases, the host processor that sends instructions to the equipment that performs these functions is also the processor used to analyze the data in the next SHM phase. [12]

The time interval between data collection is an important part of the data collection process and storage capacity. This depends on the type of error mode and is proportional to the amount of data requested. In other words, the more data that is scanned, the more storage space is required. In addition, data collection can be run at continuous or periodic intervals. Periodic measurements reduce the amount of data collected and automatically reduce storage space, but may require continuous measurements.

For example, if the detection of fatigue crack growth is important when measuring in SHM operation, it is important to constantly monitor changes in structural properties for a relatively short period of time.

It also important tasks to normalize the data for analysis and make it suitable for evaluation. For example, if no data is processed, the evaluation process cannot run. Therefore, a database is created by collecting from multiple data sources, which improves processing. We need to be aware of inaccurate results created by the poor quality of processed data.[12] [13]

Sensors

The SHM detection system consists of all or part of the following components:

1. Transducers that convert changes in the field of variables of interest.
2. An Actuators that can be used to supply some input signal to the system.
3. An analog-to-digital converter converts analog electrical signals to digital. Converters are also needed to convert the specified digital excitation signal to an analog voltage.
4. Signal conditioning.
5. Power
6. Telemetry.
7. Processing.
8. Memory for data storage. [13]

Wired and wireless sensors.

Structural health monitoring, which combines several sensory techniques with data collection and processing capabilities, plays an important role in surveying the state of the structure. The ability to continuously monitor structural stability in real-time can provide additional security for the general public, especially the older structures commonly used today. In addition, the ability to detect damage quickly can reduce the cost and downtime associated with correcting catastrophic damage.[14]

Evaluating the health of localized areas is easy with a single active sensor. However, larger structures require larger sensor systems for powerful surveillance systems that accurately identify and localize damaged areas. Common methods include introducing cables that connect local sensors and a central data monitoring system. These wired frameworks include a high expense related to their administration, establishment, and upkeep, and furthermore, their deployment can take a significant period of time. A significant number of these hindrances vanish if a low-cost wireless sensor nodes network is utilized. Removing the cables makes simpler transfer and checks, and significantly reduces costs. Wireless sensing frameworks can be introduced and uninstalled quickly making brief, crisis arrangements of health monitoring systems possible to be quickly resolved. Unlike conventional wired systems, they offer alluring and conservative options and offer numerous opportunities for development and progress. Indeed, the development of wireless sensor platforms has progressed significantly in recent years, some of which are finally industrially available. In any case, most of these steps are based on passive sensors that record only the structural response. Some portable and wireless electromechanical impedance monitoring systems have been made using Piezoelectric Zirconium titanate. Wireless sensors which have actuation capabilities ought to be more dominant for damage monitoring of the structures, since they would permit, when the user requested, arousing the system to question its health. [15]

3.4. Data Processing phase

The data processing phase is carried out in order to extract information from the collected data and to be able to be evaluated.

Various processing methods are applied to this data, but the most commonly used method is based on the Fourier Transform, which essentially converts the data signal detected by the time domain sensor to the frequency domain.

The output, on the other hand, has to be interpreted to provide useful information. Therefore, selecting valuable data from a large amount of data is a challenge in identifying damage indicators, since their sensitivity depends on the damage caused by the response to vibrations.[16]

Data Normalization

There are several methods of data normalization usually employed with determined vibration data. Often, the average of the measured history is deducted from this signal to eliminate the DC distortion from the signal. The regular variance of the signal is done to normalize the differing amplitude of the signal. The modal analysis experimental approach consists of curve fitting analytical methods to the calculated frequency response function, by fitting the curve into the frequency response function analysis form. Those frequency response functions are created by standardizing a deliberate input response. If the structure is linear this normalization step removes the parameter estimation input effects.

Identification and Quantification

There is no doubt that structural health monitoring applications directly measure all sources of variation that can influence the key points extracted from the measurement data used to distinguish healthy systems from damaged systems. However, the sensors and data acquisition devices that should make these estimates add up to the cost of the system provided. In the same way, as a rule, it is difficult to characterize in advance all the causes of operational and environmental variability that affect certain characteristics. [16]

Data Fusion

The main objective of data fusion method is to associate information received from multiple sensors in order to make a more correct damage detection judgment than is feasible with a single sensor alone. Generally, this method is applied in a stark way like when one analyze notional data among different sensors to acquire mode shapes. In other cases complex examination of data from sensor arrays ,for instance, provided by artificial neural networks are utilized in this method.

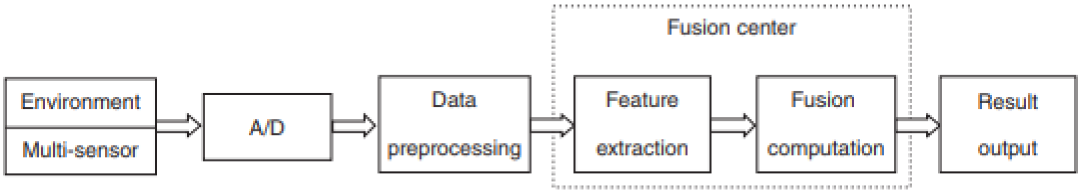


Figure 8: Data fusion process [5]

As seen from figure 8 that the information is obtained from multi-sensor and the unprocessed data is primarily converted from analog info to digitalized form, pre-handled by filtering, averaging and so on; later the processed information is registered to the fusion center. Here, characteristics are taken from the information which is processed, later these are fused together and calculated with the help of fusion algorithms, and finally, fusion outcomes and decision are constructed. Normally, feature extraction and fusion computation is the main way to get a properly functioning data fusion system. With respect to the information-data extraction levels in fusion course, it is possible to categorize data fusion to decision level fusion, eigen level fusion and, finally, pixel-level fusion categories.[17]

- Pixel level fusion. Additionally, used as data level fusion, it is the base level of data fusion whereas the unprocessed accumulated data is summarized and examined prior to the processing. The very evident postulants for this fusion level contain image series by a solo sensor and images from a set of corresponding sensors. Pixel level fusion is generally implemented to multisource image recovery, investigation and image fusion. The main utility is to retain preliminary data from the site maximally and it gives much more knowledge which is not supplied from other sources. On the other hand, because of the vast quantity of data to process , it requires a high summation of funds , also limited real-time capacity and low level of anti jamming.

- Eigen level fusion. It is the middle level data fusion. Subsequent to the processing of raw data from a set of sensors and the extraction of features , these are summed up and processed to gain substantial information. Thereafter, the characteristic information from entire sensors are registered to a specific classifier and the fusion outcomes are constructed/drawn in the end. The value of eigen level lies in realizing sufficient info for compression and it eases real-time processing. Additionally, the given eigen level information is straight ahead connected to decision making process. For this reason the outcomes can supply a great level of useful info for the decision level fusion.

- Decision level fusion. This level is the highest , which is also the eventual outcome of 3 levels. Because of fusion outcome directly influencing decision level, it utilizes decision making outcomes from each sensor fully, for instance, the information from each sensor is processed, sorted and decision making results are drawn respectively, pertinent algorithms of fusion are used to fuse each decision making outcomes from all of the sensors and generate final results of fusion. The advantage of this is that it is more flexible in the data processing.[17]

It is evident that these fusion levels have their own advantages and drawbacks. For example, pixel level fusion can be an extra stage in total information processing. Eigen level fusion can also utilized to supply further characteristics to increment their capabilities of recognition. Moreover, decision level fusion is really flexible in data processing and can be used to reflect various types no synchronous data ,effectively. In the first place, sensor is the base hardware and the core is fusion computation for a data fusion system. The basis of fusion computation is the preprocessing of information and extraction of features. [17]

Data Cleansing

Data cleansing is the process for permissively choosing data to for passing on or rejecting from feature selection procedure or alias is the process of permissively discarding of information which may not symbolize the demeanor of the system. Data cleansing is arduous because this is generally founded by the knowledge of experts , obtained in former data acquisition stages. A typical sample for data cleansing can be when it is found that a sensor is loose, thus, according to experts' jurisdiction , the measures performed by this sensor aren't precise and can put the dataset certainty in danger. Because of this matter , the entire set may be discarded from the procedure of feature selecting. Signal processing methods like re-sampling and filtering can be considered as data cleansing procedures.[18]

Data Compression

Data compression is the way toward lessening the dimension of the measured data. The operational usage of the measurement technologies necessary to perform SHM characteristically delivers a lot of information. A condensation of the data is favorable and vital when correlations of many capabilities acquired over the lifetime of the structure are imagined. Also, in light of the fact that data will be gained from a structure over an all-inclusive timeframe and in an operational situation, robust data reduction strategies must be created to hold feature affectability to the structural changes of interest for the nearness of natural and operational fluctuation. To give further guide in the extraction and recording of the high quality information expected to perform SHM, the factual significance of the features should be portrayed and utilized in the consolidating procedure. [18]

3.5. Evaluation phase

The evaluation of the data processed is the last step to evaluate the situation in the structure on the basis of norms and standards and evaluate the immediate results, as well as the long-term impact on the overall performance of the structure. The damage can be classified and quantified using a numerical model. Damage detection methods can be divided into four levels:

- 1st level- Determination of the presence of damage in the structure
- Includes all written above and determination of the damage's geometric location
- Includes all written above and quantification the seriousness of the damage
- Includes all written above and prediction of the remaining life of the construction [19]

3.6. SHM Techniques

We can categorize SHM techniques into two types: Global SHM methode and Local SHM methode.

The structural health monitoring comprises deciding the area and seriousness of damage in structures. Notwithstanding, the state-of-the-art method of health monitoring doesn't give adequately exact data to determine the level of damage. At present, these methods can just determine if the damage is current in the whole structure. These methods called ‘‘global health monitoring’’ techniques. They are significant in light of the fact that simply realizing that damage has happened is sufficient for further examination of the structure in request to locate the accurate area and seriousness of the damage that can be taken.

Non-destructive assessment techniques are utilized to find the damage. Strategies, for example, ultrasonic guided waves to quantify the state of stress or eddy current procedures to find breaks can determine the definite area and degree of the damage. These techniques are ‘‘local health monitoring’’ strategies. Non-destructive evaluation

(NDE) is frequently tedious and costly, and access isn't constantly possible. Thusly, both global and local health monitoring is important. [19]

NDE-based utilizing localized or visual experimental techniques current are most used damage-detection strategies, for example, radiography, magnetic field techniques, ultrasonic or acoustic techniques, thermal field strategies and eddy current strategies. These exploratory methods necessitate that the region of the damage to be identified from the earlier and that the part of the structure being examined is promptly available. These experimental strategies may identify damage on or near the surface of the structure subject to these restrictions. In any case, surface estimations made by most typical NDE techniques can't give data on internal members' health without expensive dismantling of the system. Besides to the local inspection strategies, there has been an apparent requirement for numerical global damage mitigation tactics which can be implemented to complex structures. In addition to other things, this has prompted the advancement of and proceeded with an investigation into, techniques that inspect shifts in the structural vibration characteristics. As examined before, the essential reason for vibration-based damage identification is that damage can modify the rigidity, energy dissipation properties or mass of the frame, which, thusly, change the deliberate global dynamic reaction properties of the framework. In spite of the fact that the reason for vibration-based damage detection seems natural, its genuine application presents numerous huge specialized difficulties. The key problem is how damage is normally a local phenomenon and cannot have a fundamental effect on the lower-recurrence global reaction of a structure generally measured during vibration tests, particularly when the reaction is estimated to include excitation. Expressed another way, this central test is similar to that seen in many engineering fields where there is a need to capture the structure reaction on widely fluctuating longitudinal scales, and such modeling and estimation of the system has been problematic. [20]

3.7.GPS for SHM

Technological progress is constantly growing in all areas of technology and the need for greater accuracy, efficiency, and improvement in measuring strain is growing, geodetic engineers are constantly looking for better monitoring methods and to improvedeformationanalysis methods. The advancement of space technology, such as GPS, has opened a new dimension in data collection. This includes offshore structures, such as oil and gas platforms, located hundreds of kilometers from the coast. Appropriate data collection methods should introduced in order to record observations with high accuracy and determine the results of strain analysis. To build a network of control points on ground and offshore platforms, require measuring instruments which are able to provide the very accurate and reliable data needed for deformation or subsidence monitoring. Control points should be installed on land and offshore platforms to measure basic vectors (ΔX, ΔY, ΔZ). GPS is considered the best method for detecting and calculating the vertical displacement or lowering of offshore platforms in order to determine the relative position between control stations, since it can achieve the desired precision for monitoring the for subsidence.

Technique of GPS Observation

The fundamental idea in offshore platform's subsidence monitoring is to use GPS for the relative position of the offshore platform in relation to a secure ground control station. The method used to observe GPS is a relative position method that includes a ground control station and three control stations installed on an offshore platform. To achieve the required accuracy for such long baselines, static GPS observations were made at 15-second intervals for 24 hours. Relative GPS positioning was performed to establish the command point coordinates relative to an established fixed point. Command points are allocated control points on the basis of GPS observations given by reference points.

Strategy for Detection of Subsidence

Bernese's GPS software processes GPS data across all command points which perform basic calculations and network adjustments. For each observation period, the output of the Bernese GPS program generates the approximate coordinates of all control stations and their co-variance matrix. Analysis of subsidence is next carried out using an internal computer software designed to detect subsidence.

Data Processing

Because baselines are hundreds of kilometers long, high accuracy results require sophisticated data processing software. Data from GPS receivers on onshore and offshore platforms is processed by using Bernese GPS software. This program is appropriate for scientific topography analysis, which requires great precision. This software can correct some errors and correct the ambiguities of high-precision basic processing to achieve providing of accurate GPS results andanalysis. This software can provide basic solution and network coordination. For network coordination, use a free network solution to determine geodetic coordinates without needing to be fixed or completely restricting specific site coordinates.

Deformation Strategy

The strain detection process by using IterativeWeighted Similarity Transformation. Analysis of the control station's vertical displacement will shift after the calculated station heights and heights matrix from the Least Squares Calculation (LSE or network adjustment) process is obtained. In the LSE process, each epoch observation performed at the control station is set independently from each other, and the corrected height of each station is calculated. The vertical shift of the control station is obtained as follows:

$$d_i = {H_i}^{(2)} - {H_i}^{(1)}$$

${H_i}^{(1)}$ and ${H_i}^{(2)}$ Is the height adjusted for the same control station obtained during the LSE epoch 1 and epoch 2 cycle. And another co-factor:

$$Q_d = Q_1 + Q_2$$

Q_1 and Q_2 Is the co-factor of station heights obtained during the Epoch 1 and Epoch 2 LSE phase

The posterior variance ratios are calculated from the residuals for both campaigns as follows:

First:

$$\hat{\sigma}_{01}{}^{2} = (\sum_{1}^{n} P_i \hat{v}_i{}^{2})/df_1$$

Second:

$$\hat{\sigma}_{02}{}^{2} = (\sum_{1}^{n} P_i \hat{v}_i{}^{2})/df_2$$

Where n is the number of observation; df_1 & df_2 is the degree of freedom.

The null hypothesis H_0: $\hat{\sigma}_{0_1}{}^{2} = \hat{\sigma}_{0_2}{}^{2}$ with significance level$\alpha$is tested using:

$$[F(\alpha/2\,; df_2, df_1)]^{-1} < \hat{\sigma}_{0_1}{}^{2}/\hat{\sigma}_{0_2}{}^{2} < [F(\alpha/2; df_2, df_1)]$$

The pooled variance factor $\hat{\sigma}_{0_p}{}^{2}$ and its degrees of freedom df_p are computed by using:

$$\hat{\sigma}_{0_p}{}^{2} = \frac{[df_1(\hat{\sigma}_{01}{}^{2}) + df_2(\hat{\sigma}_{02}{}^{2})]}{df_p}$$

where: $df_p = df_1 + df_2$

The datum parameter in a vertical network is the vertical translation amount t_z . To meet the requirements $\{\sum_i |w_i - t_z|\}$ is the minimum.

The W_r weight matrix is chosen by putting all w_i in a series of increasing algebraic values, the t_z value is the middle value. A central station or a pair of stations weighs 1 and the rest is zero.

The new displacement vector d_r and its cofactor matrix Q_{dr} for the control stations and its station height cofactor coefficient are converted using the following equation into a rising datum:

$$\widetilde{d_r} = \left[I - H_r \left({H_r}^T W_r H_r \right)^{-1} {H_r}^T W_r \right] d_r = S_r d_r$$

and

$$Q_{dr} = S_r Q_{dr} {S_r}^T$$

The change of each station is then tested at a confidence level of 95 percent to decide whether the control station has changed or remains stable. [21]

Chapter 4

Main damages mechanisms

4.1 Boat impact

By asking experienced engineers from BP company in Azerbaijan I found out that the main type of accidental loads is Boat impact.

Collision scenarios

Collision events can be classified based on the type of shipment or the total amount of collision energy involved:

- Low-energy collisions: Caused by small vessels at a faster rate than normal movement when the vessel approaches or exits the platform. Occurance frequency is more than 10^{-4} per year.

- Accidental collision: Usually made by an uncontrolled drifting ship in the worst marine conditions, when the vessel operates near the platform. Occurance frequency is around 10^{-4} per year.

- Catastrophic collision: Mass, impact velocity, or a combination of these caused by a vessel or other type of object provides enough kinetic energy to destroy the entire platform. Occurance frequency is less than 10^{-4}per year. [22]

In the event of an accidental collision, documentation of the structural integrity platform can be done by ensure the following:

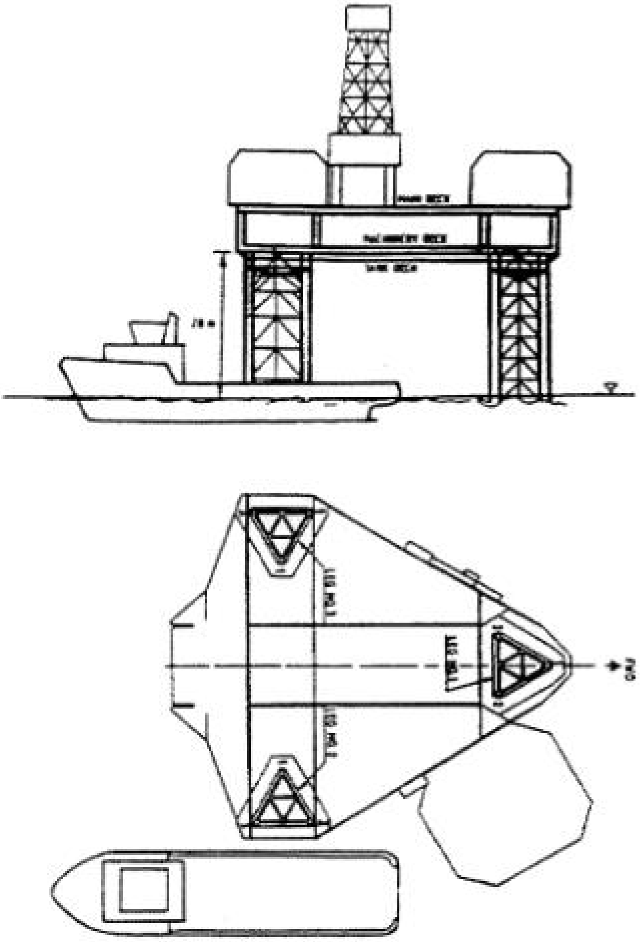
- ability to absorb energy,

- general integrity in case of damage,

- global integrity at the time of impact

The impact situations should be selected by taking into account the worst events and their occurrence's probability.

Situations when the jack-up legs collide: stern and sideways collisions for chords and for the bracing. Given the waves, tidal heights and air currents of the ships, it can be assumed that strikes occur everywhere in the collision zone.[22]



The size of a typical displacement vessel of 5000 tons with respect to the jack-up platform.

Figure 9: Size comparison of vessel and platform[6]

It is necessary to distinguish between the centeral impact where the force vector crosses the center of gravity and the offset impact. Offset impact may be the only option, depending on the geometry of the collision structure. Part of the initial transmission energy in this case is converted to rotational energy, which can cause side effects such as secondary impact. The main impact is considered the worst in the construction sector and is therefore recommended.

At the point of impact the contact area can be determined by the ship's and platform's spatial features. The dimensions of the contact surface constantly change during the phase of deformation, and the distribution of impact forces on this surface also changes. Given the different crash circumstances that may arise, a crash may be represented by a point or a linear load. In general the collision can essentially be determined from the impact charge at the first point of contact.

Characteristic collision loads

The task of evaluating suitable design of accidental crash loads can easily become v ery extensive due to many potential accident scenarios. The guiding figures and methods most widely used are described below.

The impact energy that depends on the collision load is calculated by:

- vessel scale
- mass added
- velocities the collision

Vessel scale

The supply vessel's size is usually between 1,500 and 5,000 tonnes. However, it is known that the size of the supply ship increases. The size of tankers and other diversion ships can vary significantly from supply ship size and can range from 100,000 to 150,000 tons.

The HSE guide defines a standard size of the vessel as 5,000 tons of displacement. The size of the ships shall be determined by service ships, tankers, transit ships and other vessels destined to operate in the area. If the movement of the vessels in the immediate vicinity of the structure is limited, the size of the vessels can be reduced.

Mass added

The total weight of the ship used in the collision model comprises both the ship's weight and the additional weight.

Assuming a fairly short period of the collision, it can be assumed that the total weighting factor is 1.4 for side impacts and 1.1 for front or rear impacts. These values are most often used in the analysis of collision.

Ship collision velocity

The speed of collision used in a project is often associated with a drift source ship.

The following empirical relationships can be used, in conjunction with the HMSO Guidance Notes:

$$v_s = 0{,}5H_s; [m/s]$$

v_s - the velocity of impact [m/s]

H_s - is the peak wave height for near platform operation [m]

The HSE Guidance Notes also suggest a peak impact velocity of 2 m / s as a standard value for the construction of supply ships. This means that the peak wave height near the platform permitted for offshore operations is 4 meters.

Collision mechanics

When assessing the energy of impact of a collision, it is necessary to take into account the relative movement between the ship and the impact structure. In general, only horizontal translation motions in horizontal plane are taken into account.

Study of the collision mechanism typically is based on a solution of the differential equation of the dynamic equilibrium. The problem is answered if the initial duration of the collision is significantly shorter than the usual movement span concerned. Second, the approach can be based on an almost static solution using the dynamic conservation and energy conservation theory.

The determination of the impact kinematics and the transfer of energy during the impact movement can therefore be distinguished from the study of the energy dissipation of the deformation of the collisioning bodies.

The ratio of the collision duration(t) to the normal vibration time for leg impact(T) may entail complex effects at moderate water depths for typical jack-up platforms. Static analysis is commonly considered acceptable when account is taken of the correct dynamic magnification coefficient. For t/T ratios ranging from 0.5 to 2, a dynamic expansion coefficient of up to 1.5 may be appropriate. Typically, a dynamic expansion coefficient of 1.0 is used for higher t/T ratios.

The described dynamic impact is for the first impact on the leg. A more critical dynamic influence is the platform swing. The dynamic amplification component can't solve this complex effect. The distinction between these two complex impacts is important to grasp:

- The initial impact on the legs: $t/T_G \cong 0,$ which avoids the typical vibratory movement when lifting during the first impact.

  T_G - is the natural period of the platform, usually 8 seconds.

  In these vast natural period, the upper weight works under the initial impact as second support for each leg of the ship and creates a force in the upper part.

- Dynamic effects depend on what happens after initial impact.

By assuming that the vector of force acts through the centre of gravity we can use the following formulas for momentum conservation and energy conservation.

The formulas that are used here are mostly from basic physics of school program, but they are very conservative.

Conservation of momentum

$$m_v v_v + m_p v_p = (m_v + m_p) v_c$$

m_v - mass of vessel;

v_v - velocity of vessel;

m_p - mass of platform;

v_p - velocity of platform;

v_c - common velocity of vessel and platform after collision.

From this formula we can find the common velocity:

$$v_c = \frac{m_v v_v + m_p v_p}{m_v + m_p}$$

Conservation of energy

The energy conservation equation which assumes a central collision becomes:

$$\frac{1}{2} m_v {v_v}^2 + \frac{1}{2} m_p {v_p}^2 = E_v + E_p + \frac{1}{2} (m_v + m_p) {v_c}^2$$

$$\frac{1}{2} m_v {v_v}^2 + \frac{1}{2} m_p {v_p}^2 = E_v + E_p + E_K$$

E_v - the strain energy which the vessel dissipates

E_p - the strain energy which the platform dissipates

E_K - general kinetic energy following first collision.

Combining conservation of energy equation with the conservation of momentumequation, the following equation for strain energy can be generated:

$$E_v + E_p = \frac{1}{2} m_v {v_v}^2 \frac{(1 - \left({}^{v_p}/_{v_v}\right))^2}{1 + \left({}^{m_v}/_{m_p}\right)}$$

The equation shows that the division of the structural strain energy represents the kinetic energy difference before and after the first collision cycle. In addition to the expansion energy, the residual the kinetic energy follows the first impact must be considered. In the case of a jack-up platform, the kinetic energy causes the platform to react after the first collision if the boat and platform speed are common after the first collision. For design purposes, the following equation can be used to dissipate the ship and platform strain energy after the initial accident period:

- For vessel and jack-up platform structures with rising velocity after first impact: $(v_p = 0, v_c > 0, E_k > 0)$

  $$E_v + E_p = \frac{1}{2} m_v {v_v}^2 \frac{1}{1 + ({}^{m_v}/_{m_p})}$$

- For lifting systems where all kinetic energy is believed to be transformed in the vessel and platform into stain energy before impact:

  $(v_p = 0, v_c = 0, E_k = 0)$

  $$E_v + E_p = \frac{1}{2} m_v {v_v}^2$$

If the collision duration is much less than the average global vibration period, we can use the above formulas for jack-up the structures.

The above equations, obtained from the principles of momentum and energy, do not provide details on the ship's and platform's conduct during the collision. For this, it is necessary to solve the nonlinear differential equations of the system. Since collisions with ships are not well-defined events, a simplified analysis method may be required. In general, a simple system with two degrees of freedom is enough to represent a collision of a vessel with a jack-up platform.

Dissipation of strain energy

The variance in strain energy is estimated by measurement of structural analysis. For this analysis you need to create a force-deformation curve to determine the impacted and striking object. The region underneath each curve represents energy absorption at a specific load point. The distribution and degree of damage is determined by adjusting the state of equivalent collision force acting on the collision structures and the total energy consumed is equal to the quantity of kinetic energy dissipated in the form of stress energy. Forced deformation curves are not generally linear and need a method of iterative solution.

Energy absorbance can be expressed as:

$$E_v + E_p = \int_0^{\delta_v} P_v(\delta)\, d\delta + \int_0^{\delta_p} P_p(\delta)\, d\delta$$

P_v - force-deformation relationship for vessel

P_p - force-deformation relationship for platform

δ_v - the deformation of vessel

δ_p - the deformation of platform

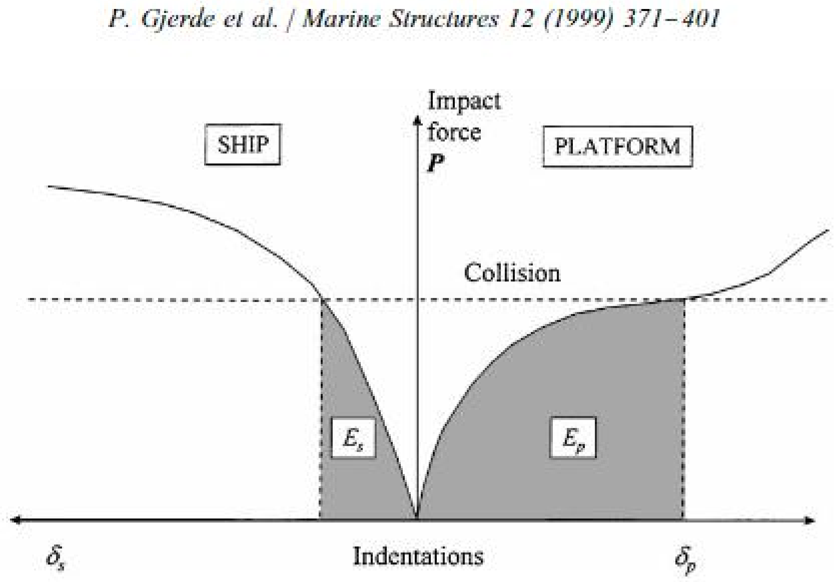


Figure 10: Illustration of force deformation curves and the absorption of energy in ship and platform systems [7]

Global integrity during impact

In the absence of a progressive disintegration mechanism, local damage is acceptable. This section provides guidelines and procedures to prevent the development of a global progressive disintegration mechanism during impact. In most cases, general strength tests are performed using static and linear methods. If the performance or instability criteria outside the collision zone are not violated, appropriate linear analysis is performed. Otherwise, verifying global coherence requires nonlinear finite element analysis or manual calculations that compensate for mechanisms of plasticity.

Kinetic energy after impact

The first natural period of jack-up platform during sway translation is usually from 5 to 9 seconds, depending on the depth of the water and the fixity conditions. Associated reactions and movements occur after the first impact, the first reaction and possible local damage to the affected leg have taken place.

Thanks to vibration, kinetic energy is consumed by the strain energy of the platform's elastic or elastoplasty. Therefore important to consider and take into account the local damage to the affected leg after the first impact.

Global integrity check

General consistency checks are often performed when the collision load is at maximum. If this does not meet the condition of maximum damage, it is necessary to consider the possible combination of harmful load and damage conditions in case of an accident.

Elements that undergo membrane deformation must be expected to have no power. The impact loads at the edges of the element can be described by the respective load effects.

Elements that act predominantly in bending can be considered partially efficient. It is possible to model the effect of lateral deformation by splitting the initial component to 2 new components with a node offset equivalent to a constant beam offset.

Using a non-linear analysis such as the G approach where USFOS software used, the analysis can include the deleterious effects of members' yielding and buckling during initial exposure.

On-bottom stability and infrastructure disruption are often part of the global assurance of credibility. [22]

4.2 Dropped objects

Each offshore asset contains a large number of devices and outfitting equipment. The risk assessment for dropped object hazards on offshore assets focuses primarily on the aforementioned devices. This includes derrick pins, pulleys, towbars, lights, antennas, handrails, tools and more. All items are recorded in a risk profile which includes their weights and heights, exposure to energy sources, work procedures and detailed information about the procedures. Including, the time staff spends under it. All equipment in Equipment and Outfitting Register is assessed for risk potential and its consequences.

In addition, depending on the risk assessment, the dropped object risk zones may be set up to control access to risk zones. The DROP examination plans need to be designed to perform scheduled inspections.[23]

Dropped Objects Risk Assessment

Risk assessment for falling objects is performed in three stages:

- Identification of the Risk
- Analysis of the Risk
- Evaluation of the Risk

Risk Identification

A danger of the released object asset is performed to identify the origin of the potentially doped object and the corresponding scenario.
Planned scenarios include (but not limited only to this):

- Objects that fall on the hoisting equipment while lifting.
- Objects dropped during installation and maintenance of the device.
- Objects have fallen during the drilling process.
- Droped equipmentss such as hand tools that are used at height.
- Vibration.
- Equipments connected with screw at the height.
- Collision of equipments at hight.
- Parts fall out due to device failure.
- Temporary derrick tools.
- Environmental: rain, wind, snow, ice, hail, lightning, movement of the sea, etc.

As far as possible, accidents with falling objects are completely characterized by:

1. Opirations or work in progress.
2. Description of the dropped object:
    - Description of the structure, position, and mass of the object
    - Characteristics of drop
3. Definition of the scenario of the dropped object:
    - Energy sources or environmental conditions
    - Preventive administration
    - Possible consequences for personal safety, material damage or environmental damage

- Availability of mitigation measures

Risk Analysis

Because dropped object risk analysis is an assessment of the level of risk associated with the identified dropped objects, great care is taken to prevent or reduce the recurrence of high-risk events. If necessary, additional plans need to be created to avoid dropped objectsto avoid even low-risk events. Risk is a function of hazard probability and consequence severity. In determining the degree of risk, the effectiveness and efficiency of existing prevention and mitigation measures are also taken into account. For the purpose of the fall prevention program, the risk assessment may be a qualitative assessment.

Falling object risk analysis assesses the consequences of personnel safety, material and environmental damage. For each accident involving a falling object, the risk assessment process consists of determining the least desirable consequences that can derive from danger. For example, if the identified risks have potential consequences from mild first aid to death, the most severe case, the risk identified as death, should be selected based on this result. The likelihood of this happening may be based on current industry statistics and/or practices.[23]

Risk Evaluation

The results of a risk analysis of the dropped objects can be compared with the eligibility criteria approved by ABS to determine acceptable and unacceptable risk levels.

The owner defines the acceptance criteria for objects that have been dropped in the DROP program. Acceptance criteria determine the acceptable risk of accidents involving a falling object, taking into account both the frequency and the outcome of the event. Acceptance criteria take into account possible effects on staff safety, the environment, and property. The risk acceptance criteria set by the owner are presented and approved by ABS before the risk assessment starts. The frequency of accidents involving an object fall can be estimated from historical data. If the appropriate frequency data cannot be found, it may be necessary to estimate the frequency using an analytical model. The DROPS calculator provides general reference information to classify the severity of potential consequences for personnel safety in the event of falling objects. This DROPS calculator as a tool for evaluating results has been approved by the DROPS working group. The DROPS calculator uses the weight of the fallen object and the height of the fallen object to classify the severity of the potential result in terms of first aid, medical cases, injuries during the holidays or mortality. Fallen objects can also cause material damage. Analytical methods can be used to assess damage to property.

Due to a large number of identifiable events, the review process is usually used to exclude incidents related to low-risk objects that should not be analyzed in detail. The methodology and logic of the validation process must be documented as part of the risk assessment report. Other events must be considered for a detailed risk assessment. This facilitates the creation of areas at risk of falling objects and also determines whether existing mitigations are appropriate or if additional control measures are needed to reduce the risk of events.[23]

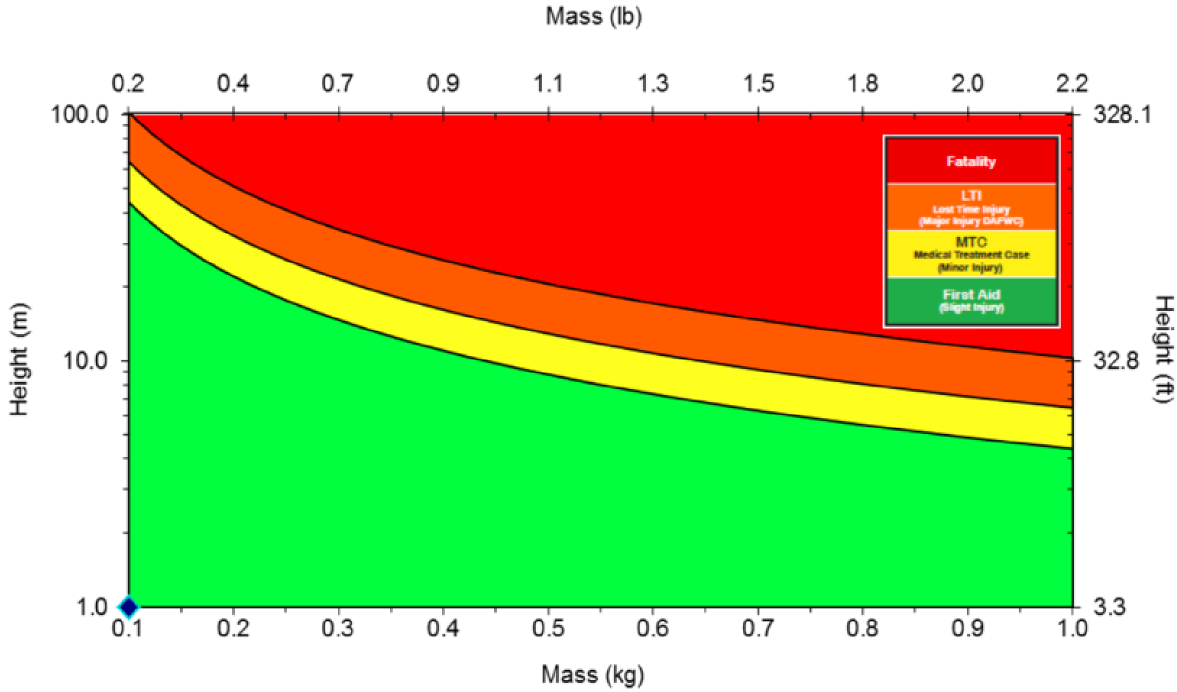


Figure 11: Risk zones depends of height and mass [8]

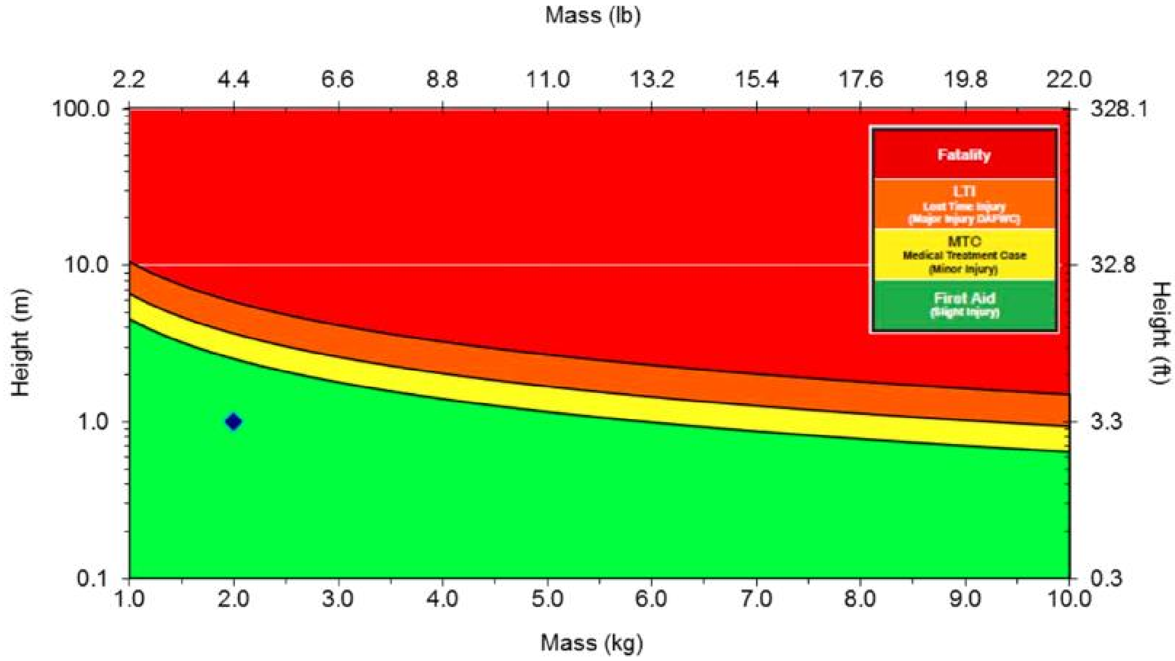
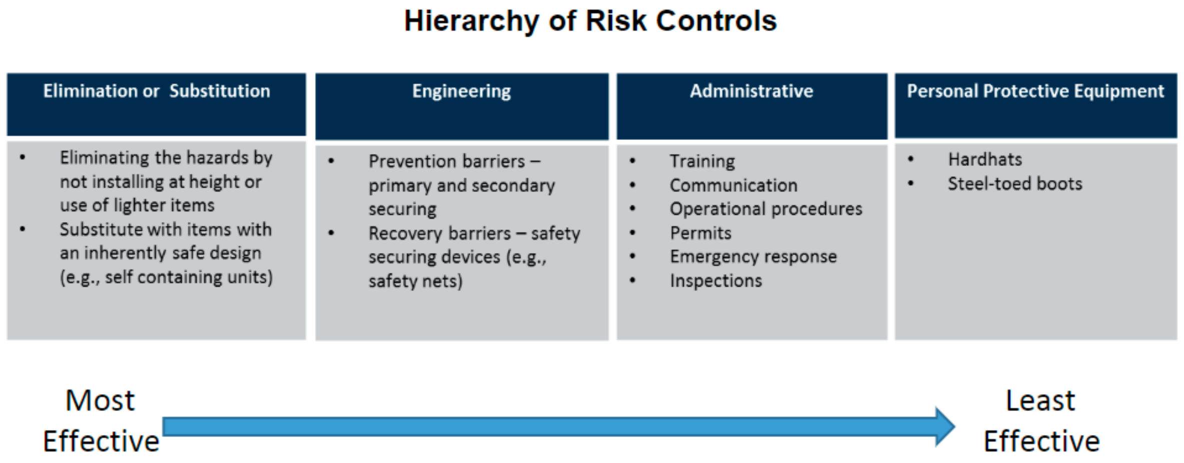


Figure 12: Risk zones depends of height and mass [8]

Risk Control Measures

Risk management measures are generally available controls that are generally associated with tasks in accordance with procedures, company policies, practices, etc. A more reliable strategy for risk reduction if existing control measures do not reduce risks to an acceptable level. There is a hierarchy of controls that can be implemented to reduce risk. The effectiveness of adequate control measures is assessed and justified in the context of a risk assessment.



Hierarchy of Risk Controls

Elimination or Substitution	Engineering	Administrative	Personal Protective Equipment
• Eliminating the hazards by not installing at height or use of lighter items • Substitute with items with an inherently safe design (e.g., self containing units)	• Prevention barriers – primary and secondary securing • Recovery barriers – safety securing devices (e.g., safety nets)	• Training • Communication • Operational procedures • Permits • Emergency response • Inspections	• Hardhats • Steel-toed boots

Figure 13: Hierarchy of Risk Controls [9]

Several risk management measures can be implemented for each identified risk of falling objects to reduce the likelihood or consequences of falling object risks. The following are examples of prevention and mitigation measures:

- Replace or remove devices and structural elements at height to reduce the possibility of objects falling during operation.
- Adding a structural protection device to the device.
- Modification and optimization of new project designs.
- Work restrictions during abnormal weather.
- Reinforce structur exposed to potentially damaging from falling objects.
- Application of additional measures and safety measures for secondary security. [23]

4.3. Corrosion control

The following five approaches to corrosion management of offshore structures are usually used:

- Without Protection
- Coatings for Protection
- Bare steel cathode protection
- Coated steel cathode protection
- Metallic or plastic corrosion resistant

These days in industry the common protection of the underwater parts of the jacket platform and the top of the piles within the earth is cathodic protection, which uses sacrificial anodes. The sacrificial anodes consist of zinc-aluminum rods, which are cast around a steel tube and welded to the structure. Usually about 5% of the weight of the shell is used as the anode. The metal structure of the projection surface is usually protected from the element by a sacrificial wall with a thickness of 12 mm.[24]

Corrosion Control Coatings

Modern technologies include the use of high zinc primers, compliant epoxy resins, and polysiloxane coatings. Switching to an organozinc-rich primer is based on cost and planning considerations. Organozinc primers are cheaper than zinc silicate and can be used in a variety of environmental conditions. Higher build epoxy intermediate coats offer many benefits for the environment, production, and productivity. Formulations with higher build usually have lower VOC and HAPS than formulations with higher solvent content. Higher designs require fewer coats to achieve the required thickness and pattern to keep the edges sharp. Polysiloxane coatings are designed to provide a durable, abrasion-resistant, abrasion-resistant, weather-resistant surface. Recently, thermal spray aluminum or TSA coatings have been used on offshore structures. TSA manufactures high-performance coating systems, but may not be suitable for all structural areas. Especially in the area of immersion, TSA acts as an anode and is sacrificed to protect bare steel. Even on structures that are 10-15 inches thick, the the sacrificial actionwill quickly consumes the TSA coating, leaving the steel bare. The remaining bare steel increases the galvanic reaction on the remaining TSA.[24]

Coating Evaluation and Maintenance

Structural corrosion at sea can lead to significant operating costs for the user and/or owner of the platform, especially depending on the age of the structure. Assessing efficiency and relative cost is important in making investment decisions to extend the lifetime and integrity management of old structures. MMS recognizes the importance of corrosion and corrosion protection in all maintenance works. MMS does not evaluate structures at the level of detail required to manage effective maintenance but regulates inspections based on API RP-2A requirements, which are best practices for the planning, design, and construction of fixed offshore platforms. API RP 2A requires an annual inspection of protective coatings, cathodic protection, and other anti-corrosion systems. Requirements have many interpretations, but generally contain the following features:

- Multi-stage examination, including basic visual inspection with advanced tests, if necessary.
- The audit work is sufficient to identify immediate security threats and critical concerns and prioritize the needs of the remainder of the structure.
- A relatively simple evaluation system for supporting and archiving results with a variety of visual and written documents.

Maintaining offshore structures includes many problems that are unique to the physical environment in which the work is performed. Perhaps most importantly, the logistics requirements of working in remote and narrow locations put a lot of pressure on visible processes, such as coating maintenance. If the job is difficult, having to live and work 24 hours a day for several weeks can aggravate the relationship between painting staff, inspectors and property managers. Due to the remoteness of the workplace, it is very difficult to change personnel, purchase additional supplies and equipment or postpone decision-making in the “chain of command”. Of course, platform operations and other maintenance works are carried out simultaneously with the coating process. In order to limit accessibility, resources should be used efficiently and workspaces may need to be separated from other activities. Therefore, planning and coordination are important to minimize unnecessary resources. Once the workers and equipment are mobilized on the platform, the owner pays for those assets until they return to the coast. If the work cannot be carried out as planned due to weather conditions or other complications, it is necessary to draw up an emergency plan including alternative work options. These plans cannot be created temporarily. Good planning is essential to ensure that the necessary tools and materials are available in an emergency. Project planning on the high seas begins during loading, long before crews arrive in the area. It is very useful for inspectors, artists and owners to discuss matters at the beginning of the mobilization process. If possible, they should agree that the equipment has been delivered to the platform and that it is adequate and working properly before leaving the coast. In order to minimize downtime after the commencement of work, it is necessary to identify sufficient coating materials and other equipment for the planned work and possible cases during mobilization. [24][25]

Chapter 5

Chirag platform

5.1 Chirag platform case study

Chirag is an offshore oil field in the Caspian Sea, about 120 kilometres off the coast of Baku and is a part of the larger Azeri-Chirag-Guneshli oil field which is also known as ACG project. It is part of the ACG production share agreement signed between Azerbaijani goverment and 11 international oil companies (AMOCO, BP, McDermott, UNOCAL, SOCAR, Lukoil, Statoil, TPAO, Penzoil, Ramco, Delta) in September 1994 and named the contract of the century. The production, drilling and quarters platform (PDQ) Chirag has been the first platform producing the Early Oil from the ACG field in this project and it is in operation since 1997.

The construction of Chirag platform begun before 1991, when Azerbaijan was under the Soviet Union(USSR), because of this the initial construction was done by Soviet Union's GOST (ГОСТ) standard.After colapse of the soveiet union and Azerbaijan independance in 1991 constuction stopped and only resumed after above mentioned contract was signed. After initial engineering assesment and agreement with new stakeholders decision was to use this partially complete platfor however from now on follow internation and western construction codes.

One of the main difference of the Chirag platform construction of which was started during Soviet's was its jacket to platform guide connections. After careful engineering assessment it was decided to modify jacket part by adding flanges and construction frame under the platform with pin guides.

Usually top side and jacket of platform are connected by using male tofemale connection. As shown on the photo:

Figure 14: Platform legs and topside connection [10]

But in Chirag's case the flange connection was used, and it's the only platform in the world which constucted halfly in western style (internation standards) and the other half is Soveit style (GOST/ГОСТstandard).

Flanges are external or internal rim orridge for added strength to connect to iron beam such as I-beams or T-beams, or to attach another object such as steam hoses, steam cylinders, a rail car tram wheel and other objects. Thus, a flange wheel is a one-sided wheel flange that keeps the wheel from coming off the rail. The term "flange" is also used to indicate the type of tool used to form the flange. Flanged pipes can be easily assembled and disassembled.

Figure 15: Chirag platform with highlighted flinge part [11]

In this photo we can see the Chirag and can easily identify the difference of legs with other normal platforms made in western style.[26]

Conclusion

The importance of platforms for the exploration and development of oil and gas in the offshore, oil and gas industry offers significant investments in the development of this technology. Offshore platforms face many challenges because of harsh environmental conditions that endanger the behavior of healthcare facilities. Premature deterioration of physical properties can lead to complete structural damage. There is a policy regarding these large structures, greater reliability and safety is reguired because of the failures of previous structures have occurred and their catastrophic effects for the environment and human health. To effectively analyze the dynamic behavior of a structure, you need to monitor the state of the structure. It is very important to control full lifcylce of the platform starting from it's initial Inherently safer desing till the end of the life in order to have better, safe, compliant and reliable operation of the platfroms.

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