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An overview of classifications and incidents/accidents in offshore structures: Oil and gas

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ABSTRACT

Offshore platforms are considered among the most significant structures in the world that humans have ever built, having to function in a wide range of extremely challenging environments and have a major impact on the economy and industrial progress of countries. It is extremely important to properly plan, design, construct, transport and install such offshore structures. In the absence of commitment to this, the consequences could be severe in both economic and environmental terms. An overview of offshore structures is presented in this paper, and its purpose is to offer a consistent vision for the various types of offshore structures to be used for the extraction of oil and gas. In addition, the paper focuses on the expected accidents that may occur during and after construction. Accidents do not only cover the difficult environment where these structures are to be built, but they also cover the impact of climate change on these structures. The approach considered in this paper involves a systematic literature review that deals with reviewing different studies done on the similar research topic. The results found in this study determined that the type of offshore structure to be built or fixed at a particular location in water, depends mainly on the water depth and also on the past and present environmental records. Nonetheless, the outcomes of this study are still general; thus, further studies have to be completed in order to acquire more advanced knowledge in this particular field.

1. INTRODUCTION

At the beginning of oil and gas's discovery in seas and oceans in September 1947, it was necessary for engineers to find a way to extract it, and this was the main point for inventing offshore structures. The goal of its establishment at that time was to extract oil and natural gas from the sea waterbed level in a safe manner without loss of life and property. Given the high financial return from that, the great powers did not hesitate to support all studies in this regard (Joseph et al., 1997).

From that time, the major oil exploration companies in the world are fighting for the manufacture and development of the latest technology to use in oil and natural gas exploration. As per Sadeghi (2007), it has been mentioned how it was able to employ the global navigation system and dynamic positioning system in the manufacture of oil platforms and also noticed the different types of platforms for oil and gas extraction. This depends on the region from which the oil is to be extracted and the weather nature of that region.

Sadeghi and Dilek (2019) mentioned that offshore structures are classified based on water depth of 350 meters, between 350-1500 meters and more than 1500 meters, which are defined as shallow, deep and ultra-deepwater respectively. Based on that, offshore platforms were divided into fixed and movable structures according to the depth of the water to extract oil and natural gas in order to obtain the lowest possible cost. It is not logic to make the platform fixed in a depth of more than 1000 meters due to its high cost.

There are many points to consider during the selection and design of offshore structure facilities; among them, there is the depth of water (shallow, deep or ultra-deep), wind speed, storms, earthquake and temperature (Reese & Johnston, 1962).

In this research, authors shed light on different types of marine installations, the nature of each of them, the appropriate operating conditions, and the main components of these installations. Also, the risks and accidents that may affect this type of facility and the impact of temperature variation are discussed.

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2. METHODOLOGY

The study on offshore structures is not new; it started many years ago, and relevant results have been found. Many studies investigated different topics that focus on a single and specific point. Nevertheless, the present paper gives a general idea on different topics that may be discussed one by one in future studies; some of them are classification, incidents and climate impact on offshore structures. The methodology selected for this paper is a systematic literature review. It focuses on a collection of data from precedent studies; this data is the main root where the results of this research are drawn from. Data has been collected from different sources or database such as Scopus, Science direct, etc. Steps taken for the selection of previous papers are: Search on a database as per the required topic or keywords and choice of best papers that provide required data. Data to be taken shall discuss one of the keywords taken in this paper and shall be in English.

3. CLASSIFICATION OF OFFSHORE STRUCTURES

The classification may be divided into movable platforms and fixed platforms. As their names indicate, movable platforms are portable and fixed platforms are fixed in a specific area (Sadeghi, 2008).

3.1. Movable platforms

3.1.1. Drilling barges (DB)

DB is used in shallow water such as lakes, rivers, canals and shallow areas near the coast with limited depth up to 15 meters because it is unable to resist intense movement in open seas. This type of platform needs to be moved with a tug boat from a location to another (Sadeghi, 2007; Reese & Johnston, 1962).

3.1.2. Jack-up platforms (JP)

JP is like drilling barges on the availability to move from a location to another. The working technique is different than drilling barges which can be summarized that jack-up platforms are connected with steel legs which carry up the platform over the water level at 1.5 meters above, this leads to more safety by preventing the water turbulences. The maximum water depth for this type of platforms is 150 meters; when exceeding this limit, using this type will be uneconomic even though it stills possible (Sadeghi, 2007; Sadeghi et al., 2017).

3.1.3. Submersible platforms (SuP)

SuP is used for shallow water, and it is same as JP. There is a connection between it and the seabed with special types of foundation to prevent soil settlements. This type of platforms consists of two main parts over each other; the topper contains the actual drilling platform and the working/living area for the workers. The lower part looks like a huge container to help the structure to flow over the water; it is filled with air and when the platform reaches to drilling site the container shall be filled with water to allow it to sink down to the seabed level (Sadeghi, 2007).

3.1.4. Semi-submersible platforms (SSuP)

SSuP is a popular offshore platform type; it combines the advantages of submersible platforms and the availability of using it in deep water. It can be used up to 1800 meters of water depth and contains pontoons as well as columns. Pontoons filled with water lead the platform to partially submerge in water. To make sure that the platform is stable and resist the sea swirl movements, it can be connected with the seabed level with heavy anchors. Another way of controlling the position of the platform is by dynamic positioning. After finishing drillings work at the site, it can be easily transported to a new place (Sadeghi & Musa, 2019; Sadeghi & Dilek, 2019).

3.1.5. Drillships (DS)

DS are types of offshore drilling systems; the first designed drillship was created in 1955; they are used in deep and ultra-deep waters and may be controlled with a very advanced positioning dynamic system which is a motor connected bellow the hull of the ship connected with a computer system to stay vertically above the drilling site. The depth of water below the drillship can reach up to 3650 meters (Sadeghi & Dilek, 2019).

3.2. Fixed platforms

3.2.1. Template (Jacket) platforms (TP)

TP consists of jackets, decks and piles. This type of platform is mainly used in a water depth approximately not exceeding 450 meters; it usually appears in the Persian Gulf with more than 300 platforms. The jackets can be made of steel or concrete as per the designers' requirements; it requires a barge or platform crane to load and erect it. It may take two to three weeks for the erection (Sadeghi & Dilek, 2019).

3.2.2. Floating production systems (FPS)

FPS may be used in water depth up to 1800 meters. It contains petroleum production system in addition to drilling

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equipment. The system can keep its stability through huge or heavy anchors subjected to the seabed or by the dynamic positioning system. In this system, the wellhead is attached to the seabed level instead of the top of the platform (Haritos, 2007).

3.2.3. Tension leg platforms (TLP)

The idea of TLP started in the 1970s, and the first platform was made in 1984 in the North Sea. The concept of this type is to connect the platform body to the seafloor by long and flexible steel cables (tendons) which allow a horizontal movement up to 6 meters with a small amount of vertical movement. This type of platform can be used in water depth up to 2130 meters (Necci et al., 2019; Nouban et al., 2016).

3.2.4. Seastar platforms (SSP)

SSP is a combination between the TLPs and SSuP. It contains a floating part with lower hull filled with water in order to increase the stability of the platform during the drilling process. It also consists of tension legs which are long and hollow tendons such as TLPs under constant tension forces to avoid any vertical movement with allowable horizontal movement to allow the structure to withstand against wind and water movements without breaking the legs. This type is mainly used in mid-depth water up to 1050 meters when using a large platform is uneconomical (Sadeghi, 2007).

3.2.5. Compliant tower platforms (CTP)

CTP consists of a narrow flexible tower (framed structure) supported on piles at the seabed level. It has good resistance for wind and strong waves due to its tower flexibility. This type doesn’t have a capacity to store the extracted oil; so, the oil is transported to the top side of the platform. There are two main types under this category which are the freestanding tower and guyed tower. This type can be used in depth up to 600 meters (Sadeghi & Haladu, 2018; Sadeghi & Guvensoy, 2018).

3.2.6. Spar platforms (SP)

SP is the latest type of offshore structure. The first designed SP took place in the Gulf of Mexico in 1996. This type consists of the upper part, which is the fixed platform and a huge cylinder. The cylinder does not reach the seabed level; it is connected to the seabed by the help of cables and lines to keep its stability. The flexibility shows a good absorption for the wind forces and water currents. There are three main types of spar platforms which are the classic spar, truss spar and cell spar. The depth of these types varies between 600 and 3000 meters (Sadeghi & Dilek, 2019).

3.2.7. Concrete gravity platforms (CGP)

The idea of this type of platforms is to have an advantage from the huge weight of the platform. The main idea is to build a platform by using concrete mass rested on the seabed level under its own weight. This type is considered under fixed type platforms. It’s also called ConDeep platform. It is majorly used in the Brazilian sea and the North Sea due to its high resistance against water currents and wind forces (Sadeghi et al., 2018).

4. FACTORS LEADING TO INCIDENTS OR ACCIDENTS IN OFFSHORE STRUCTURES

Offshore structures are known to operate under adverse environmental conditions leading to their difficult performance during and after the construction process. According to DNV GL (2020), the awareness of events that result to accidents or incidents in offshore structures is of importance because it permits to be familiar (in term of knowledge) with possible risks that may occur during and after construction. Furthermore, this knowledge permits to understand hazards that may happen and from that, measures to mitigate them may be taken (Chandrasegaran et al., 2020; Det Norske Veritas and Germanischer Lloyd (DNV GL, 2020). Garcia (2017) reported that one of the main reasons resulting in accidents in offshore is the condition of works where employees are subjected to different types of weather conditions outdoor. Additionally, he mentioned that accidents’ rate is lesser in other types of jobs when compared to those in offshore structures.

4.1. Events or factors leading to accidents or incidents

Considering the information mentioned above, it becomes necessary to identify different types of events that cause incidents or accidents in the offshore field. Health and safety executive (HSE, 2009) reports them as follow:

4.1.1. Problem due to blowout, explosion and fire

Blowout event is the effect that leads to unrestricted flow or leakage of oil, gas or other types of fluid from the reservoir. This situation may result in an explosion that leads to fire; thus, causes an accident in the offshore structures.

4.1.2. Capsizing and collision

Capsize event is the effect in which a unit loses its stability and results in overturning; as a result, an accident may happen. In contrast, a collision is an event that causes incident when there is contact amidst passing marine vessel (such as fishing or cargo) and offshore unit. To avoid a

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collision, dolphins are of great importance in order to secure the platform.

4.1.3. Failure of anchor

In the offshore field, there is a type of incident that may occur as a result of mooring device, anchor or anchor line failure. When designing, all these parameters should be taken into consideration.

4.1.4. Crane, falling objects and failure of machinery

Crane event is the situation that leads cranes as well as lifting equipment to failure. A good selection of equipment as per the intended load to be carried shall be respected. Objects falling from lifting equipment are also responsible for incidents in the offshore field. In case they sink and cannot be found again, they increase the need to replace the equipment, thereby increases the cost. Another possibility is the loss in human life from those falling objects. Failure of machinery is another event causing problems to the propulsion system of the machine.

4.1.5. Foundering, grounding and list

Foundering is the event that causes sinking or loss of buoyancy to units whereas grounding refers to an event that causes floating equipment to sink up to the bottom of the sea. List event causes an uncontrolled or unrestricted unit's inclination.

4.1.6. Structural failures and off position

Structural event causes failure to equipment or structures as a result of fatigue or damage to supports. These failures may be due to weather problems such as climate change (higher or lesser temperature) or improper design of equipment. Off position, the event happens when equipment is positioned at a place where it is not intended to be or when it drifts out of its own control.

4.1.7. Helicopter and towing failure

Helicopter event is the one that causes an accident when helicopter strikes the platform after missing to land on the helideck. Towing event is the one that causes failure or accident of towline.

4.1.8. Leakage, spill and others

Leakage event causes accidents or incident as a result of water leakage in the filling shaft or other units, thereby leads to foundering. This situation causes loss of stability or buoyancy to components. Spill event is the one that causes leakage or release of gas or fluid from vessels or tanks, enabling pollution or explosion risk that may lead to a fire. Other events are those, which are not indicated in this paper.

4.1.9. Climate change and environment

Climate change is one of the most critical events that lead to many issues in the offshore structure. Workers are subjected to work under this situation which finally affects them; as a result, they commit mistakes that lead to big incidents or accidents in the field. Necci et al. (2019) found that severe weather conditions and bad environmental situation result in fatigue of offshore facilities due to extra stresses exerted, for example, in case of a strong storm. Halim et al. (2018) said that it is risky to perform work in a congested environment having more pipelines and other important equipment. In case a small mistake is made, it may be converted into a catastrophe.

4.2. Major incidents in the history of offshore oil and gas field

This section provides some accidents or incidents that happened in offshore structures. It includes the accident's place, year and the main cause that led to different problems in the Gulf of Mexico, North Sea, Caspian as well as Canada Sea (Fattakhova & Barakhnina, 2020). Table 1 gives the details of some major incidents in the history of offshore oil and gas field.

Table 1. Some major incidents in the history of offshore oil and gas field

No.	Place	Year	Causes
1	Gulf of Mexico	2010	The main causes in the 2010 accident were oil slippage, explosion and fire. In this situation, the platform sank in the water body, and 11 people died.
		2013	Gas flow, explosion and fire. This situation occurred due to unsuccessful operation of staff trying to put an anti-blowout; 44 people were removed from the site.
		2015	A fire occurred to the platform after an explosion. 300 persons were removed from the site, 16 injured and 4 died.
2	North Sea	1988	An explosion and fire led to platform destruction. 164 persons died due to this issue.
		2008	Slippage of oil. In this case, oil got to the water body instead of the intended way.
		2012	Gas leakage leading to safety issues for personnel as well as the impact on the environment.
3	Caspian Sea	2014	An explosion from the platform followed by fire. The cause of this explosion is not yet well known, and 12 people died in water.
4	Canada Sea	1982	The accident occurred in 1982 as a result of platform's flooding during a storm. 84 people died. The main cause of this accident was the lack of knowledge in many aspects of safety from the crew.

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5. RESULTS AND DISCUSSIONS

There are two main ways to classify the offshore platforms, based on the movement availability and water depth condition. It is important to specify that platforms mentioned in this paper are the most popular these days since each one of them has its own attributes which make it suitable for the condition which it is used for (Sadeghi & Dilek, 2019).

Figs. 1 and 2 give a comparison of different types of platforms with respect to water depth.

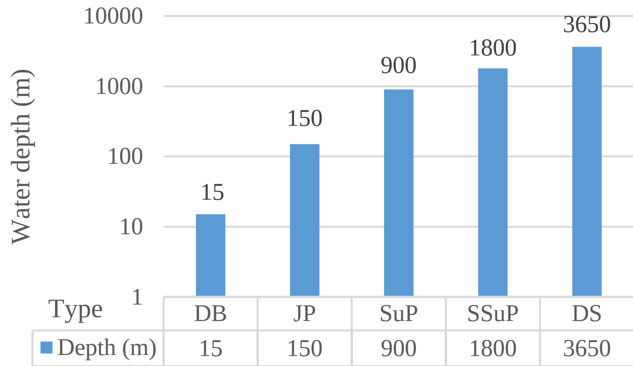

Fig. 1. Movable platforms versus water depth

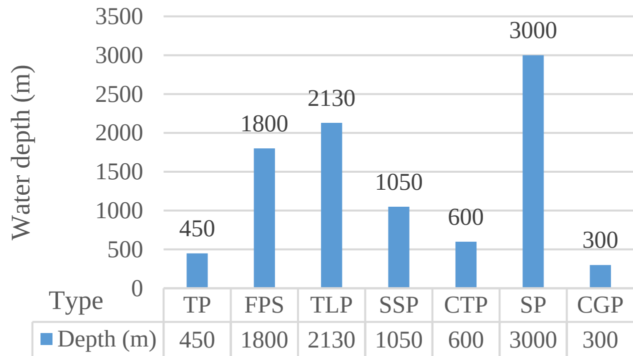

Fig. 2. Fixed platforms versus water depth

It has been found that an incident or accident may result from one event or a combination of two or more events. For instance, an accident from a fire may result from a combination of a blowout, explosion and fire.

Christou and Konstantinidou (2012) specify that events may be caused in one hand by human errors such as design error, unsafe procedures, war and other considerations. On the other hand, it may be caused by equipment failure such as failure of equipment due to weather, malfunctioning of safety systems, earthquake, structural failure due to foundation settlement. As per Fattakhova and Barakhnina (2020), it has been found that event causing accidents arises due to the impossibility in solving technical issues. The main reasons for this impossibility are bad conditions of climate such as storm, difficulties in performing soil investigation at the bottom of the water body especially when the temperature is extremely low followed by ice or when it is extremely high. Finally, the impossibility may arise when the site restricts surveyors to reach to some areas for preliminary survey.

From lessons learned, it may be noted that a good selection of materials for the fabrication of components is vital. Care should be taken to avoid any structural issue, corrosion as well as mechanical problems. Components shall be fabricated, keeping in mind the minimization of inspection and maintenance. Sadeghi (2001) specified that API RP-2A, ASTM, AISC and API 5L grade 52 codes give the required properties of materials to be utilized as per the situation at the site. Transportation, as well as load out of components, shall be well studied including 20^{o} roll angle for a rolling period of 10s; the pitch of 12.5^{o} with a pitch period of 10s and 0.2g as heave acceleration. Natural hazards shall be taken into account during preliminary studies by the emergency team. This point is important since it permits to protect the platform as well as people working at the site. Keeping in mind the number of people that may perish during an accident in offshore facilities, a plan on how to evacuate them is necessary when a major incident is likely to happen (Necci et al., 2019; Burkett, 2011).

6. CONCLUSIONS

This study gives the reader a wide understanding of main platforms' classifications which is followed worldwide and accidents that may occur in this field. Different classifications have been given, and the selection of a platform depends mainly on the water condition, environmental report, geotechnical report, and the way of extracting the oil and gas from the seabed level. Additionally, different types of events that cause accidents have been given. A good preliminary study is of great importance in order to know the water condition. Environmental records of at least 100 years have to be available in order to design a platform that may resist any environmental as well as weathering issue.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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