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Offshore petroleum rigs/platforms: An overview of analysis, design, construction and installation

Osamah Sarhan[1*], Mahdy Raslan[1]

[1]*Civil Engineering Department, Near East University, Nicosia, Mersin 10, Turkey*

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A B S T R A C T

Jacket platforms are one of the most important and regularly used types of offshore structures for oil and gas extraction that have a big impact on the economy of the countries. In this paper, all aspects including design, analysis, construction and installing of the jacket type offshore structure, are summarized and classified. This type of structure is one of the specified platforms for shallow water, and for long term service, it also has the ability to carry large deck loads. This paper aims to present general guidance about the planning, design and construction of offshore jacket (template) platforms. Jacket platforms are fixed type platforms which are attached to the seabed using piles which provide stability against the wind, wave and current loads. Also, this type of offshore platform has a high initial and maintenance cost because of its exposure to corrosion, and cannot be reused after the end of its service period. Jacket platforms are most suitable for shallow water having no better alternative while it has the cost disadvantage for deep water.

1. INTRODUCTION

Offshore structures play a significant role in the economy of many countries, as offshore structures are mainly drilling platformers which used to extract oil and gas from the bottom of the seabed. This study gives an overview of the offshore jacket platform's characteristics, and investigate the stage of its design, construction and installation. "Jacket type platforms are one of the most important and common types of offshore structures, and it plays an important role in drilling and exploring the oil" (Zhang et al., 2012).

Fixed platforms mainly are used in the Persian Gulf, Caspian Sea, North Sea, Gulf of Mexico, and Alaska (Nouban, 2016). Where the water is shallow, the use of this type of platform is more compatible and economical to the use in depths generally ranging between 10 m to 200 m (Xiaojie et al., 2019). Also, Sadeghi (2008) gives a detailed guide for the design and construction of offshore platforms while focusing on the jacket type platforms.

1.1. Types of offshore structures

1.1.1. Fixed platforms

This type of platform is attached and fixed to the seabed and have a very limited movement, whereas stability is one of its main advantages (Nouban, 2016). Also, there are many types of fixed platforms. For example, there are tower platforms and gravity platforms, in addition to jacket platforms. However, those platforms cannot be used in the deep water level because of the high risks, from the resulting deep-sea currents which made it uneconomical choice. The other types of fixed platforms like tension leg platforms can be used in deep water level up to 1500 m (Sadeghi & Tozan, 2018).

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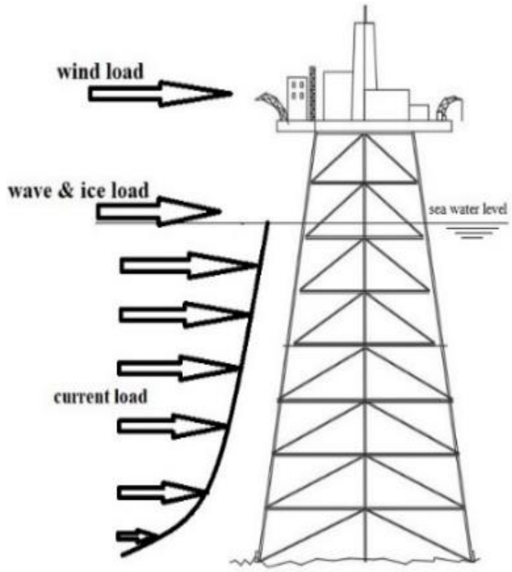

Fig. 1. Jacket type of offshore platform

1.1.2. Moveable platforms

This type of platforms can change its location and move from one place to another. This category includes other types of platforms like Jack-up, Semi-submersible platform and floating drilling ship.

1.1.3. Floating production system (FPS)

Floating production system is a kind of movable platform. This type of platform requires dynamic positioning. The system stabilizes and ensures its location directly above the drilling site using electronic motors and sensors that sense the waves and currents' directions. It then pushes the platform in opposite directions. Also, this type of platform can be used in shallow water between 70 - 250 m, plus has many advantages like low cost and reusability.

1.2. Classification and comparison of different types of platforms

Table 1. Movable platforms

	Jack-up	**Semisubmersible**	**Floating production system**
Waterdepth	Shallow depending on the length of its legs	Deep up to 1800 m	70 - 250 m
Application	Drilling for oil and gas	Drilling for oil and gas	Drilling, collecting and transporting oil and gas
Cost	Low cost because it can be moved and used in many locations		

Table 2. Fixed platforms

	Jacket	**Spar**	**Tension-leg**	**Gravity**
Waterdepth	Shallow (19-200 m)	Very deep	Deep up to 1500 m	Shallow up to 30 m
Application	Oil and gas production & wind turbine	Oil production	Oil and gas production	Oil production and wind turbine
Area	California, Nigeria, Gulf of Mexico, Persian Gulf	The Gulf of Mexico, Malaysia and Norway	The North Sea, Gulf of Mexico	North Sea
Price	Increase exponentially with the depth	The change in depth does not have a big effect on the costs	The change in depth does not have a big effect on the costs	Very high costs increasing with the depth
Reusability	Non-reusable	Reusable	Reusable	Non-reusable

2. JACKET PLATFORM

Jacket platform is a kind of offshore structure, made of lots of steel cylindrical members with different diameter arranged in an oblique condition relative to the seabed (Zhang et al., 2006). Table 1 summarizes the advantage and the disadvantage of the jacket platform.

Table 3. Advantage and disadvantage of the jacket platform

Advantages	**Disadvantages**
Stability due to piles foundation	Uneconomical for deep water
Support large deck loads	Cost increases dramatically with the increase of waterdepth
Long term production	Not reusable
Constriction is done on the land	Subjected to corrosion
	High maintenance and initial costs

2.1. Prices

The weight of the steel and concrete offshore structure increases exponentially with the waterdepth, and this results in a high increase in costs (Reddy & Swamidas, 2014) as Fig. 2 shows the relationship between the waterdepth and the installation cost, where with the advancement of technology over the years, the amount and steal used in jacket platforms was decreasing through the optimization studies like the study of Xiaojie et al. (2019). The Jacket platform installation costs continue to increase exponentially with the increase in waterdepth.

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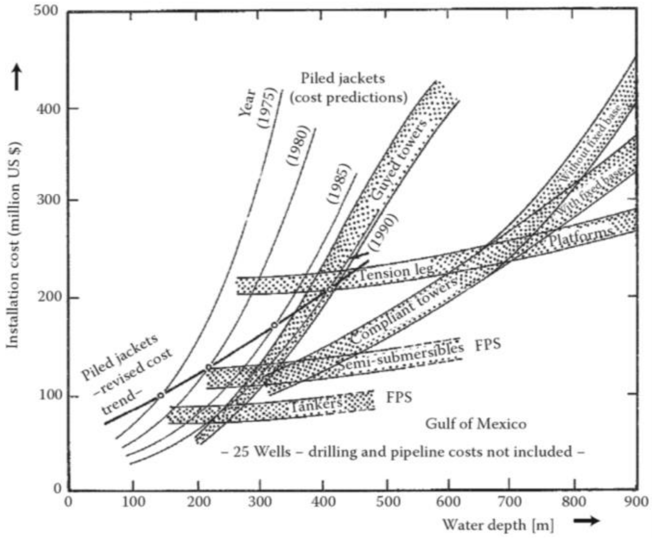

Fig. 2. The relative installation cost of various offshore structure (Günther et al., 1992)

2.2. Planning

A lot of factors must be taken into consideration when planning to construct a jacket platform like the location of the project, where selecting the best site holds great importance and affect the project in many aspects. Besides, the environmental conditions must be considered when planning the project, for example, the waterdepth, seismic conditions, wind directions, ice loads, current and weather. Also, "design, calculate, construct, and install coastal, port, marine, and offshore structures, environmental data are needed, in particular wave and wind data." (Sadeghi, 2007). It is difficult to start and construct the project in seasons that have bad weather like storms. However, the site location can be limited to the location of the oil and gas fields, so it is important to consider that in planning.

2.3. Analysis and design

There is a lot of required analysis for the Jacket type offshore platform where the main required analyses are listed below. Where the analysis, design recommendations and guidance can be found in design codes like AISC.

- In-place analysis
- Earthquake analysis
- Fatigue analysis
- Impact analysis
- Temporary analysis
- Load-out analysis
- Transportation analysis
- Appurtenances analysis
- Lift or Launch analysis
- Upending analysis
- Up-righting analysis
- Un-piled stability analysis
- Pile and conductor pipe drivability analysis
- Cathodic protection analysis
- Transportation analysis
- Installation analysis

2.3.1. Pile foundations design

Offshore type jacket platform is fixed to the seabed using long piles, with a minimum of 3 piles. The pile's depth depends on the soil type and the location of the offshore structure. However, the inclination of the piles has a big effect on the stability of the platform as the inclination is one of the main factors affecting the pile's behaviour where it was found that the optimal degree of inclination is about 5 degrees, and the by increasing it the instability of the soil surrounding it start to grow significantly in a wild scale (Aminfar et al., 2016).

2.4. Loads considered in the design

The offshore structure faces extreme marine environmental conditions in the sea with different types of unusual loads that land-structures do not face it. Therefore, it is a challenging task to analyse and design where the offshore structures can face a combination of wind, current and wave loads in addition to its self-white and live load at the same time. For that its crucial to have a very good and reliable design with high safety factors for a long service life period. As in this section, we will discuss the load's types that the jacket type offshore structure is exposed too.

2.4.1. Dead and live load

The dead load considered in design is the self-weight of the jacket platform and all permanent loads on top of it like the drilling rigs, oil and gas reservoirs and other excavation equipment. While as the live loads are the workers who stay on top of it.

2.4.2. Wind force

The wind force is one of the loads taken under consideration in the design as it may play a critical point and affect the structural stability where it is very critical in the marine environment.

2.4.3. Wave impact

Wave is one of the environmental conditions considered in analysis and design, and there are many methods used to get the waves data like using devices, simulation models and data collected from remote sensing by satellites. Additionally, many equations can be used in the analysis of waves like Brettschneider equations and spectrum wave to predict the characteristics of waves (Sadeghi, 2007) as spectral height and peak spectral period. These characteristics can be used with waterdepth data to determine the condition of waterdepths: shallow, transitional, or deep, and to determine the appropriate wave theory.

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2.4.4. Current Load

Marine currents have the most influence and are the dominate load considered in the design, as most of the structure is located under the sea. This results in the push and drag force. Moreover, one of the common phenomena is the wave-current interaction, where the current has a big effect on the generation of waves and their direction (Zeng et al., 2019).

2.4.5. Earthquakes

The earthquake analysis of offshore structures has a significant difference from the onshore structures, and "the procedure must be modified to consider the fluid-structure and the soil-pile interaction effects" (Smith, 1996). Jacket offshore structures are directly attached and fixed to the seabed by piles, as the response of offshore platforms is completely dependent on the foundation (Asgarian & Agheshlui, 2009). Therefore, earthquake design is essential for the jacket platform. In contrast, the earthquake analysis is based on the historical records of the site and the location of it. Earthquake analysis is very important and must be considered with the effects of other loads because the maximum displacement of the load combination is more than the displacement of earthquake load alone (Bargi et al., 2011).

2.5. Materials used in the design

The main martial used to make jacket platforms is steel. Different grades of steel can be chosen (according to the design code) representing the main body and the foundation. Steel is used in a very high amount which increases the costs dramatically. The steel materials with the limitations are specified in the American Petroleum Institute (API). Additionally, other materials are used for corrosion protection like magnesium, aluminium and zinc.

2.6. Construction and fabrication

The fabrication and composition of the jacket platform are done onshore before transporting it to the site for installation. The main body is made of different diameter of cylindrical beams and column which are welded together. Also, bracings system is used to increase the stability and against earthquake as well as dampers.

2.7. Loud out, transportation and launching

Jacket platforms are usually manufactured onshore in a fabrication yard where it is usually slipped onto a cargo barge then transported to the installation site to be launched. A lot of consideration should be taken during design to avoid any uncontrolled motions during the launching process. The launching and upending of the platform are very critical parts of the project because it involves 40% of the total cost (Omdehghiasi et al., 2018).

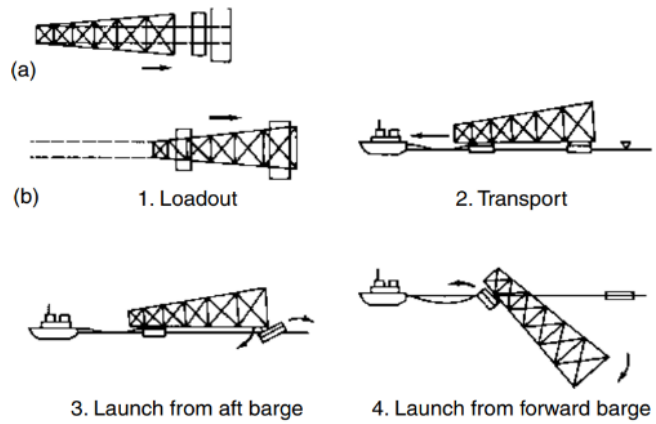

Fig. 3. Jacket platform insulation process (Gerwick, 2007)

2.8. Installation

The insulation process exposes the structure to a different type of loads that should be considered in the design. The structural sections should resist different types of launching, upending, up-righting and other installation stresses. The first step of the process is to place the mud-mat steel plates on the seabed which designed to help in fixing the pile's angle, which will be hammered into the soil. The piles are divided into several sections, where the first will be hammered into the soil then the main body will be installed on it. The other sections will be welded together and hammered consecutively. In short "It consists of positioning and levelling the platform on the site and assembling the various components into a stable structure in accordance with the design drawings and specifications (Muyiwa & Sadeghi, 2007).

2.9. Corrosion protection

Durability is an essential issue in the offshore environment. Like every steel structure, jacket platform is exposed to corrosion which can further increase more in the marine environment due to the availability of factors like high humidity and sea salt that increase the electric conductivity of the seawater. Therefore, it is essential to use some corrosion resistance methods like cathodic protection by covering the steel surface by other metals like magnesium, aluminium or zinc. Those anodic metals will work as an alternative source of conductors and sacrifice themselves instead of the active part of the steel. However, in this method, the anode metal needs to be checked and maintained regularly.

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3. CONCLUSIONS

In this paper, all aspects related to the construction of the jacket type offshore platform are summarized. It includes planning, analysing, designing, fabricating and integrating, transportation and insulation of the platform. Jacket platforms are wildly used in several applications like sea wind turbines, oil and gas, etc. However, our paper focuses on the drilling rigs for oil and gas platforms. It can be concluded that Jacket platforms have no better alternative in shallow water, having mare benefits and lower costs, while, in deep water is the opposite.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

REFERENCES

[1] Aminfar, A., Ahmadi, H., & Aminfar, M. H. (2016). Parametric study on the effects of pile inclination angle on the response of batter piles in offshore jacket platforms. *Journal of Marine Science and Application, 15*(2), 193-200. https://doi.org/10.1007/s11804-016-1355-9

[2] Asgarian, B., & Agheshlui, H. (2009). Reliability-based earthquake design of jacket-type offshore platforms considering pile-soil-structure interaction. *American Journal of Applied Sciences, 6*(4), 631-637. https://doi.org/10.3844/ajas.2009.631.637

[3] Asgarian, B., & Shokrgozar, H. R. (2013). A new bracing system for improvement of seismic performance of steel jacket type offshore platforms with float-over-deck. *Petroleum Science, 10*(3), 373-384. https://doi.org/10.1007/s12182-013-0285-2

[4] Bargi, K., Hosseini, S. R., Tadayon, M. H., & Sharifian, H. (2011). Seismic response of a typical fixed jacket-type offshore platform (SPD1) under sea waves. *Open Journal of Marine Science, 01*(02), 36-42. https://doi.org/10.4236/ojms.2011.12004

[5] Günther, C., Lehmann, E., & Carsten, Ö. (1992). Offshore structures. Conceptual design and hydromechanics. London: Springer-Verlag, Vol. I, 1992, 135.

[6] Digre, K. A., & Zwerneman, F. (2012). Insights into using the 22nd edition of API RP 2A recommended practice for planning, designing and constructing fixed offshore platforms - working stress design. *Offshore Technology Conference*. https://doi.org/10.4043/23558-ms

[7] Gerwick, B. C. (2007). *Construction of marine and offshore structures* (3rd ed.), CRC Press.

[8] Muyiwa, O., & Sadeghi, K. (2007). Construction planning of an offshore petroleum platform. *GAU J. Soc. & Appl. Sci. 2*(4), 82-85.

[9] Nouban, F., French, R., & Sadeghi, K. (2016). General guidance for planning, design and construction of offshore platforms. *Academic research international. 7*(5), 37-44.

[10] Omdehghiasi, H., Mojtahedi, A., & Farajpour, I. (2018). A parametric stability analysis of the offshore jacket launch: a case study in the Persian Gulf. *Marine Systems & Ocean Technology, 13*(2-4), 87-102. https://doi.org/10.1007/s40868-018-0049-3

[11] Reddy, D. V., & Swamidas, A. S. J. (2014). *Essentials of offshore structures framed and gravity platforms. Boca Raton*: CRC Press.

[12] Sadeghi, K. (2007). A numerical simulation for predicting sea waves characteristics and downtime for marine and offshore structures installation operations. *GAU J. Soc. & Appl. Sci. 3*(5), 1-12.

[13] Sadeghi, K. (2008). Significant guidance for design and construction of marine and offshore structures. *GAU J. Soc. & Appl. Sci. 4*(7), 67-92.

[14] Sadeghi, K. & Tozan, H. (2018). Tension leg platforms: An overview of planning, design, construction and installation. *Academic Research International. 9*(2), 55-65.

[15] Smith, C. E. (1996). Response of a steel-jacket platform subject to measured seafloor seismic ground motions. *Offshore Technology Conference*. https://doi.org/10.4043/8110-MS

[16] Tabeshpour, M. R., & Fatemi, M. (2020). Optimum arrangement of braces in jacket platform based on strength and ductility. Marine Structures, *71*, 102734. https://doi.org/10.1016/j.marstruc.2020.102734

[17] Tian, X., Wang, Q., Liu, G., Liu, Y., Xie, Y., & Deng, W. (2019). Topology optimization design for offshore platform jacket structure. *Applied Ocean Research, 84*, 38-50. https://doi.org/10.1016/j.apor.2019.01.003

[18] Zeng, Y., Zhou, H., Huang, W., & Wen, B. (2019). Studying wave-current interaction by HF radar. *OCEANS 2019* - Marseille. https://doi.org/10.1109/OCEANSE.2019.8867053

[19] Zhang, B.-L., Hu, Y.-H., & Tang, G.-Y. (2012). Stabilization control for offshore steel jacket platforms with actuator time-delays. *Nonlinear Dynamics, 70*(2), 1593-1603. https://doi.org/10.1007/s11071-012-0559-z

[20] Zhang, G.-F., Ji, Z.-S., Li, T.-L., & Lin, Y. (2006). Calculation of wave and current loads on launching offshore jacket. *Journal of Marine Science and Application, 5*(4), 1-7. https://doi.org/10.1007/s11804-006-6025-x

[21] Zhao, Y., Dong, S., Jiang, F., & Soares, C. G. (2020). System reliability analysis of an offshore jacket

DOI: https://doi.org/10.47346/ijaesa.v2i1.58 ISSN: 2703-7266

platform. *Journal of Ocean University of China, 19*(1), 47-59. https://doi.org/10.1007/s11802-020-4181-2