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Review Article

Review of academic studies for offshore structures

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Abstract:

Offshore structures are structures constructed on the seabed or on the water surface in the open seas, generally designed for the purpose of oil and natural gas extraction, energy production and other seabed-related works. The oil obtained from offshore structures met 9% of the world's energy consumption in 1988. It is known that this value reached 24% in 2000. Today, this figure has increased even more. It is estimated that offshore construction technology will advance further as time progresses in the world. The reasons for this can be listed as the increasing trend in the world's energy demand, the decrease in energy reserves on land and the discovery of undiscovered oil fields and new energy sources in the open seas. Within the scope of this study, studies on offshore structures were examined.

1. Introduction

Until the 1950s, when offshore technology was mentioned, shipbuilding and fishing technology were the first things that came to mind. However, today, offshore oil and natural gas exploration and, in parallel, the extraction of these natural resources from the bottom of the oceans have become much more important. The economic benefits provided by underwater oil and natural gas production are extremely important. In particular, the need for the design and manufacture of previously unused tools and equipment for drilling for oil and natural gas, their extraction, and the processing and transportation of the extracted raw materials has emerged. New technologies have also been needed to meet these requirements. Example images of offshore structures are shared below in Figure 1.

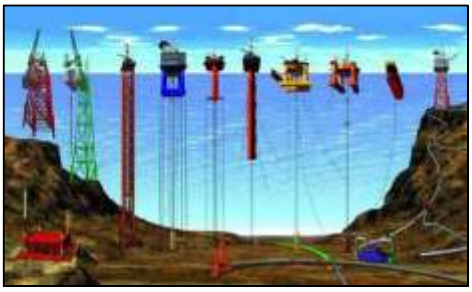

Figure 1. *Offshore structures [1].*

2. Other Academic Studies

Horr and Safi [2] focused on the dynamic analysis of offshore platforms using the Timoshenko pipe element technique in their study. The effects of shear force and the behavior of rotational vibration elements in the mathematical modeling of pipe structures constitute the main important issues. The aim of the study can be stated as the application of the finite element method (FEM) in offshore structures. The finite element method and the Timoshenko pipe element theory were compared in the dynamic analysis of offshore structures. Numerical examples were also made using two different analytical models in the study.

Newman and Lee [3] used the boundary element method in the analysis of offshore structures in their study. The boundary element method has a wide range of use. In the study, wave loads and other hydrodynamic effects were calculated by the boundary element method. Calculating wave loads and their reactions plays an important role in offshore structure design. The results obtained using high-order and low-order techniques were compared.

Bonillier, Chakrabarti and Christiansen [4] tried to show that wind effect is an important design parameter in floating offshore structures with the help of simulations and experiments. In the study, it was tried to show that the wind spectrum is broad-band. In the experimental study, a background model was created to examine the effect of different winds.

Zheng and Liaw [5] studied the response spectrum estimation of offshore structures using Price's theorem approach. In the study, the response spectrum was investigated using Price's theorem based on Fourier series instead of Volterra series method. Since the main source of dynamic responses in offshore structures is wave forces, these were emphasized. In the study, two approaches were compared and it was seen that the frequency values of VSFD method were lower than the frequency values calculated in PTFT method.

Moses and Stahl [6] studied the calibration development of mixed steel offshore structures in ISO standards. The study was supported by American Petroleum Institute (API) and the developments in the construction of offshore structures were examined. The study focused on the effects of loads and their response factors on design. ISO-LRFD calibration criteria based on API studies were discussed.

Schulz and Kallinderis [7] studied the numerical estimation of hydrodynamic loads and the effect of vortex vibration on offshore structures. The numerical representation of hydrodynamic loads in offshore structures was emphasized. The effects of incompressible fluids are among the difficulties encountered in offshore science. The effects of incompressible fluids on structures and flexible structures have been investigated. In the study, an elevated offshore structure model was made and in this model, frequency, resulting dynamic responses and numerical values were examined.

Heredia-Zovani and Montes-Iturrizaga [8] studied the Bayesian modeling of the probability distribution of fatigue damages in pipe elements. Fatigue-related damages are one of the most important issues for such structures. In offshore structures, this fatigue generally occurs due to wave loads. During the life of the structure, these damages accumulate and cause cracks and deformations in the structure. For this purpose, the probability distribution of fracture and cracking mechanics parameters in pipe elements of offshore structures with the help of the Bayesian model was emphasized.

Bea [9] examined the performance shape evaluation factors in the reliability analysis of offshore structures in his study. The relationship between qualitative evaluation and qualitative probability that is intended to be explained in the study, and these analyzes are used in the safety calculations of offshore structures. A numerical method has been developed to make safety calculations during design. There are certain steps in this method. This method is called SMAS (Safety Management Assessment System).

Sweetman [10] has studied how to make practical air gap calculations in offshore structures. Two new methods have been developed for the desired air gap. Calculations were made with these two methods on a sample model and the values obtained were discussed.

Taiebat and Carter [11] focused on the subject of liquefaction analyses of offshore structure foundations with partial experimental methods in their studies. 3-dimensional liquefaction analyses were carried out for offshore structures in the study. Mohr-Coulomb model was used.

The structure behavior under periodic loads was investigated experimentally. Marine structure foundations are generally subjected to periodic loads, which can be an example of wave forces. These loads generally have high amplitudes in short periods. Tests were carried out under laboratory conditions under periodic loads on granular soil and the reactions of the foundations were investigated.

Suhardjo and Karem [12] studied the feedback-forward control of offshore platforms under random waves. In the study, the hydrodynamic drag force was calculated using the JONSWAP wave spectrum.

Ferrant, Le Touze and Pelletier [13] conducted a study on irregular wave diffraction of offshore structures. In the study, wave diffraction was modeled in the time domain with the help of numerical simulation. Two different methods were presented in the study on this subject. Being able to accurately predict the effects of hydrodynamic interaction is an important issue for the design and construction of offshore structures.

Ellermann [14] conducted a study on the nonlinear dynamics of offshore structures in random waves. Several different effects come to the fore in the dynamics of offshore structures and ships, some of which have nonlinear characteristics. In the study, ocean waves were defined with Pierson-Moskowitz and Jonswap wave spectra.

Yazdchi [15] conducted a study on the techniques for keeping offshore pipes and platforms afloat for dynamic analysis. In the study, an attempt was made to find the hydrostatic frequency band gap and while doing this, Gaussian and Pierson-Moskowitz wave models were used. Similar works reported in the literature[16-20].

Naess and Karlsen [21] have studied the calculation of high transition and extreme response levels caused by waves in offshore structures using numerical methods. The forces that occur due to current and horizontal ground motion and affect the platform legs have been tried to be calculated stochastically. Nichols [22] has studied the subject of structural strength control of offshore structures using environmental stimuli. In this study, the effect of environmental stimuli on the structure has been investigated and experimental models have been made to find the damages that may occur in offshore structures. Offshore structures have to withstand periodic wave forces, severe storms, sea earthquakes and corrosion effects caused by sea water. In this context, it has been carried out to control the structures from these aspects and to research new techniques to withstand these loads.

Grime and Langley [23] have focused on finding the most suitable transition values to define extreme movements in fixed offshore structures using estimation methods. The response of the structure to extreme movements acting on fixed floating offshore structures and their prediction is one of the most important issues in the offshore structure industry and their prediction is quite difficult. During the design of the structure, some values may not be known exactly. Experimental components and statistical methods are used for this prediction. In the study, these transition values were tried to be found using the Faltinsen and Lokenin approach.

Harland, Taylor and Vugts [24] studied the extreme forces on offshore structures and their variability. Extreme forces are very important in the design of offshore structures. These are generally the extreme forces that can occur in a century. The study focused on how to evaluate and interpret the variable design wave forces. Numerical applications were also carried out for this purpose.

Langen and Skjastad [25] studied the prediction and calculation of the dynamic behavior of offshore gravity platforms. The dynamic properties and dynamic behaviors of the Gullfaks C platform were investigated. The platform was dimensioned and numerical predictions were made in the study.

Naess and Pisano [26] studied the frequency domain of dynamic responses in offshore structures where friction forces are effective. Hydrodynamic friction forces that offshore structures are exposed to due to irregular waves are defined and stochastic approaches are used.

Hung, Cuong and Quan [27] studied the general reliability of offshore structures in Vietnamese sea conditions, combining ultimate and fatigue limit states. The study includes the effects of wave loads on jacket elements in Vietnamese sea conditions, reliability of steel jacket type structures due to fatigue loads, reliability of concrete gravity type structures due to fatigue loads, ensuring general structural reliability and a new approach for design.

Benjamin and Darell [28] studied wave group effects on offshore structures. Wave spectrum is used in many methods to calculate the dynamic response of offshore structures. Knowing the effect of the largest wave in wave groups is important in the design phase because it can cause damage to the structure. The dynamic effects of wave forces on offshore structures are investigated analytically in the study.

Yang, Li and Hu [29] have studied the location of damages in offshore structures using energy dissipation method. In the study, the location of damages seen in offshore structures has been examined and applicable two and three-dimensional truss structures have been presented.

Rudlin [30] has studied the control of fatigue cracks in offshore structures. As it is known, offshore structures are exposed to wave and wind loads that cause fatigue cracks. The growth rate of cracks depends on the history of the load, the environment, the design of the structure and elements. Therefore, it is emphasized in the study to control this periodically.

Mistree, Lyon and Shupe [31] have studied the subject of damage tolerance in the design of offshore structures. In the study, the damage tolerance of offshore structures has been discussed and a method has been tried to be developed on this subject. A model has been made on this subject in the study and numerical applications have been made on this model with the finite element method.

Hayward, Pearson and Stirling [32] have worked on a smart ultrasonic control system to detect flooding in offshore structures. The study was conducted on the control of flooding in offshore structures with the help of high-frequency sound waves. A sample model was made in the study and the obtained results were examined.

Bekker and Komarova [33] have conducted a study on the reliability assessment of ice effects in offshore structures. The safety problem of gas and oil processing structures in frozen seas was emphasized. An external load is formed on offshore structures due to the drift of glaciers. Offshore structures established in environmental conditions that are not suitable for gas and oil processing and exploration carry great risks. These structures are exposed to many external loads such as wind, waves, ice, temperature changes and earthquakes. In cold weather conditions in northern regions and in frozen seas, ice loads play an important role in design. Ice masses were examined geometrically, kinematically, physically and mechanically in the study.

Ozakı and Hayashı [34] have worked on the earthquake design of offshore building structures. In the study, offshore structure functions, seismic properties of Japan were investigated.

Reddy and Cheema [35] studied the response of offshore structures to random ice forces. In the study, physical modeling was done and numerical application was carried out on it.

Abdelnour, Comfort, Pilkington and Wright [36] studied ice forces on offshore structures. In the study, modeling was done on an offshore structure and the effect of ice forces was compared with the real structure. The drilling structure in the Gulf of Canada was chosen as the real structure compared in the study.

Karadeniz [37] worked on an advanced software program for probability and fatigue safety analysis on offshore structures. In the study, SAPOS program was developed, which performs spectral, stochastic fatigue and fatigue reliability analysis using advanced methods. SAPOS program was designed for practical applications and it was stated that it can be used in further research. Inputs and outputs of the program were explained and input and output files for a tripod offshore platform were shown. The results obtained in the SAPOS program can be explained in a simple way. The wave forces in the SAPOS program are calculated according to the Morisons equation. In severe sea conditions, Pierson-Moskowitz and Jonswap spectra are used. The SAPOS program is written in Fortran 77 language.

Chen and Milburn [38] numerically investigated the effect of nonlinear wave interaction on the open sea structure. In the investigation, dynamic responses were made according to the Morisons equation. Waves were classified and comparisons were made between them. The obtained results were analyzed. Nonlinear waves were defined and the response of the structure to these waves was investigated.

Cornet and Timco [39] investigated the effect of ice loads on the Molikpaq structure. In 1986, the Molikpaq structure in the Beaufort Sea of Canada was exposed to ice loads during drilling, which revealed that the effect of ice loads should be investigated by the researchers. In the study, an elastic modeling of this structure under the effect of ice loads was made and the deformations caused by ice loads on the structure were investigated. In the study, graphs for general characteristics of ice loads are presented. Winterstein and Engebretsen [40] made a study on design load estimation and response of floating ocean structures. An example modeling was done and numerical values obtained from it were examined. In the studies, two types of structures were studied and comparisons were made between them.

Krunic and Winterstein [41] have studied the probabilistic modeling of extreme wave crests. The peak wave crest, the lowest wave crest and the average wave crest were taken into consideration. They have examined waves in different situations with the modeling they have done. They have suggested coefficients to calculate wave forces.

Williams, Thompson and Houlsby [42] have studied the nonlinear dynamic analysis of offshore jack-up platform elements. In the study, nonlinear dynamic analysis of jack-up structural elements under storm loads was carried out using the two-dimensional finite element method. The obtained values were examined and frequency diagrams were drawn.

Jha and Winterstein [43] have studied the prediction of nonlinear ocean waves and their comparison with the available information. In the study, hydrodynamic forces were examined with their basic principles. In the study, the relations related to wave effects were derived using the available data. Wave modeling was done in this way.

Özüdoğru [44] presented a study on aseismic geotechnical design of offshore structures. In his study, he stated the parameters that should be considered during the earthquake design of an offshore structure. For dynamic analysis, soil parameters and soil-structure-water system were examined.

Mestanzade and Yazıcı [45] examined the dynamic behavior of floating platforms (TLP). These structures are used for piling and oil extraction in offshore mines. In the study, dynamic studies were conducted on a sample structure and a model was created at 1/100 scale. Experiments were conducted on this model and the obtained experimental results were compared with theoretical values. As a result of the study, it was seen that the difference between the results obtained in the TLP model test and the theoretical results was 15%. From the dynamic test results, it was seen that when the tensile force in the ropes was small, the differences between the calculation and test results were small.

Zhao and Burdekin [46] examined the dynamic structural integrity of offshore structures in their studies. The elements and components of such structures are subjected to static and dynamic loads. This study focuses on two types of wave theories. These are Stokes and Gridded wave theories. They used ABAQUS software in their studies. They developed modeling techniques in this context.

3. Conclusions

Offshore platforms are complex engineering structures that can potentially be exposed to various risks. These risks can have serious consequences in terms of both the safety and health of workers and environmental factors.

The effects of high winds and storms, the effects of waves, the effects of accidents that will occur in the sea, the effects of natural disasters, etc. contain risks that may occur. For this reason; determining the requirements during design is very important. Design, verification, production and commissioning studies depend on the evaluation of engineers with extremely professional knowledge and experience. In addition, design verification studies with analysis in a computer environment are very important. The importance of examining different studies within the detailed structure above has also been revealed.

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- **Ethical approval:** The conducted research is not related to either human or animal use.
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