

Estimating the Fatigue Life of a Fixed Metal Platform with a different Approach

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ARTICLE INFO

Article History:

Received : 22 OCT 2024

Accepted : 17 SEP 2025

Keywords:

Fatigue, Jacket, concentration, S-N curves, ABAQUS Aqua

ABSTRACT

Offshore platforms are among the important structures in the energy industry and play a significant role in the economies of countries. One of the most important factors in the sudden failure, as well as the reduction of the strength of the offshore platforms, in the long run, is the fatigue phenomenon in connections and members of the structure. Acceptable consistency in comparison to each other. The present study reviews the conventional methods of fatigue analysis of marine structures and seeks to introduce an effective way to estimate the fatigue life. Since the natural period of is an important factor for analysing of structures, it has also been investigated. Even though the recommendation of the regulations in all of states, is the use of the spectral method in fatigue analysis, but this method, despite its high accuracy, requires more time and cost compared to the deterministic analysis.

1. Introduction

The offshore area is considered as one of the most important areas in the oil and gas industry for all countries worldwide. Such both countries that exploit the energy reservoirs and the consumer countries are inextricably intertwined with this industry. The technology of monitoring and drilling and the design and construction of structures in the seas and oceans are among the most important sectors of the offshore oil industry, which provides the possibility of access to more resources. The design and analysis of marine platforms is one of the most complicated engineering tasks with respect to the complexities that exist in determining the loadings applied to platforms in marine environments, which indeed definitely no precise standard schema has yet been provided for the design of these structures, and continuously with the advancement of related sciences and engineering tools, we are witnessing changes and updates to various regulations in this field. Since the sea environment is a fully dynamic environment and the loadings caused by waves, winds, and subsurface currents are permanent dynamic loads that are applied to the structure and cause fatigue and frailty in various components especially in the structural connections, the design of the structures for this phenomenon has become necessary and in recent decades has attracted

the attention of the researchers in this industry. Fatigue is one of the most important topics that is of particular importance in the design of all structures exposed to continuous cyclic loads. Fixed platforms of template type are also among these dynamic (dynamic behavior) structures.

Because of the nature of most marine environmental loads are repetitive and cyclical, the structures which placed into those are subject to cyclic loading. Waves, winds and earthquakes with a hydrodynamic condition, are the main loads that will be applied to the structure [1]. In the present study, different methods of fatigue analysis have been studied and compared to finally introduce a useful and low cost method. In the mid-nineteenth century, researchers turned their attention to the phenomenon of fatigue in materials. Meanwhile Mr. Wohler's studies led to (S-N)¹ curves [2]. The S-N curves are widely used to estimating of fatigue life [3].

1.1 Some of the Previous Researches

The topic of fatigue in engineering sciences is one of the topics with a short history so that It has not been fully analyzed and understood to this day. Generally, the knowledge of the stability of engineering structures against the massive loadings due to

¹ stress-cycle curves

earthquakes or floods is of particular importance in the civil engineering sector. What differentiates the phenomenon of fatigue and loadings applied to the structure from the phenomena such as earthquakes is that a phenomenon such as an earthquake, quite tangibly affects the structure, but the loads that lead to a fracture in the structure due to fatigue are applied to the structure subtly and with stresses or strains less than the breaking point in the long run and in a continuous and cyclic form. The tragedy of an oil platform in the North Sea, 123 crew members were killed Alexander L.Kielland, Norwegian oil platform. One of the main members connected to the pantons overaly failed and detached from the structuer and led it to compelletly collapse (Almar-Naess, 1985)as shown in Fig 1.



Figure 1: oil platform in the North Sea called Alexander
The sedco135 semi-submersible drilling rig, which started its activity in the Gulf of Mexico in 1965, suffered failure due to fatigue in one of its braces after two years in 1967.

One of the most widely used offshore structures is the fixed platform of template type or jacket, which is a steel structure with braces and a deck, and with bases fixed by numerous piles to the seabed. Fatigue cracks are the main cause of the breakdown in fixed platforms of template type (Stacey, 2007). Also, in studies carried out previously, the determination of fatigue damage due to ocean waves was developed using mathematical expressions (Nolte, K. G., and Hansford, J. E.,1976). This study clarified the relationship between the wave height and the range and distribution of the stress with respect to the interaction between the range of the stress and the number of cycles for the occurrence of failure and the probability of the event of the dispersion of wave heights.

The scientific debates taken place indicated that the most important issues related to the fatigue in offshore metalstructures were calculations related to the determination of fatigue stress and fatigue life (Almar-Naess, A., 1985). In the topic related to the stress concentration factor (SCF) in connections, simplifications, and reviewing previous research studies in the area of stress concentration and fatigue mechanics in tubular connections, failure analysis and reliability analysis in the connections were performed

(Dover, WD and Madhava Rao, AG, 1996). (Etube et al., 1999) presented a model of the response of a steel jack-up platform for fatigue calculations. By analyzing a mathematical model to achieve the transfer function of the dynamic response of a conventional jack-up platform, they found that a complex interaction between the structure and the soil at the base of the platform could be modeled satisfactorily using spring and solid foundation. (Ramachandra Mutthy et al., 1994) and (Gandhi et al., 2000a) and (Gandhi et al., 2000b) performed studies on fatigue phenomena on hardened tubular metal connections and the effects of corrosion and fatigue behavior. (Vugts, J. H., 2005) discussed the study of the fatigue failure and the impact of the incoming wave on the structure. This scholar conducted his studies on a symmetrical circular structure (a vertical cylinder) and presented the results in numerical. Form based on a spectral analysis, (Shangfeng et al., 2007) performed fatigue calculations on a metal template platform located in the South China Sea. (They carried this out) by examining the transfer function of the stresses of a connection, which was the first systematic method for providing assistance and preliminary instruction for (obtaining) the dynamic response of the structure, and (emphasized the fact) that a proper choice of frequency and bandwidth has a significant effect on the structural response. A metal template platform located in the Bohai Gulf, which has also a conically shaped structure as an icebreaker, was optimized by (Li et al., 2008), and the results indicated that the fatigue life of the platform can be increased, and also the weight of the platform can be reduced. (Marco et al., 2007) presented an effective nonlinear dynamic approach for calculating the fatigue failure due to waves in offshore structures, and they also identified its industrial applications for increasing the fatigue life. In this study, due to the symmetry of the connection members, only one half of the member was analyzed.

(Khalafi et al., 2014) conducted a study on a metal template platform and studied the fatigue life of its connections. They also carried out studies to determine the minimum safety factor for each connection and they presented all their results in the form of diagrams and tables. Among the important results of this research we can mention the following that: the impact of sea currents on the fatigue life of the connections under study is about 10% and can be neglected, and also predictably the connections are considerably under the influence of the waves in the wave splash zone and are sensitive to breakdown and failure. This research also confirmed that the simplified fatigue analysis method could have negative effects on the accuracy of fatigue calculations. This is particularly the case for platforms that the impact of dynamic specifications is significant

in them and the abovementioned method does not take into account the natural period of the structure.

2. Hydrodynamic Forces and affects of the Waves

During the splash of sea waves to the structures exposed to water, forces are applied to the structures that are caused by the acceleration and velocity of water droplets, determining these forces depends on such factors as the state of the sea and the type of the structure itself. With regard to the type of the structure being floating or fixed, and/or bulky or with a small surface, different situations arise in determining the forces. The environments forces applied to the platforms include wind, marine currents, waves, ice, earthquake, hydrostatic variations, as well as the effect of floating forces on the members due to variations on the surface as the impact of tides (API). The share of the wind force is less than 40% of the hydrodynamic forces (DNV), which in the analysis of fatigue in the jacket structure its effects are neglected because the wind force is applied to the upper levels of the platform and outside the water.

In general, the status of a marine environment is summarized in its waves; including the waves with certain height and periods, and the waves caused by wind or tectonic movements of the seabed or tsunami and other factors that are involved in the status of the sea. In this research, because of the small diameter of the members of the structure compared to the wavelength, the Morrison equation, and Airy linear wave theory were used.

2.1 Fatigue in Offshore Platforms

The wave loading is the major force applied to the marine platforms. The wave loading, due to being cyclic, causes fatigue in members and structural connections. The structural connections have a high sensitivity to fatigue failure due to the concentration of stress and welding defects in these areas.

3. Materials and Methods

3.1 Fatigue Analysis Methods

There is two common methods for fatigue life analysis in offshore structures, deterministic and spectral. Due to the API-RP 2A and some released researchs, connection areas are subject to stress concentration phenomena and these areas are so important for stability of structures. Hence, it's necessary to evaluation of fatigue analysis on the connections that are subject to cyclic stresses. The APA regulation recommend that the spectral analysis is accurate at all. Of course, for structures that their natural period is less than 3 and maximum height to 122 m for water depth about 100m, and in lack of the precise analysis for any justifiable reason, the API recommends a simplified procedure according to the part of C.5.2 [3].

3.1.1 Deterministic Method

For the deterministic analysis, we need to select a number of waves with specific properties (height and period) from wave scatter diagram. The wave selection method is according to the highest rate of repetition of the wave in the wave scatter diagram. These selected waves categorized with each other and then applied separately to the structure. Nominal stresses in the Structure include members and connections by applying the appropriate stress concentration factor (SCF) for every separate element is converted to the hotspot stress. After finding the hotspot stress range and according to the occurrences of each wave and using S-N curves and Palmgren-Miner law (equation 5) separately for each selected wave, the fatigue damage index is obtained for selected waves. Eventually, overall fatigue damage and useful life of the platform is obtained from sum of each wave's damage on the structure. In general, this approach based on the time domain theory with using separate waves and sum of their effects on the structure. According to the DNV recommendation, the hotspot stresses calculate at least on 8 points of around of each connection (at every 45 degrees).

3.1.2 Spectral method

Contrary to the deterministic method, spectral approach use wave spectrum instead of the separate waves. The dynamic response of structure is one of the main principles of this method. Therefore, the effects of the all of waves participate in the calculation of the fatigue life of structure.

The waves are modeled and instead of applying each wave separately (with specific features) to the structure, the wave spectrum is used for it and then by a transfer function is converted to the hotspot stress spectrum on the circumferential points of the connection. This method is in frequency domain analysis that is assumed for a certain period, the force is proportional to the wave height. Therefore, to create a transfer function the nonlinear term of drag force in the Morrison equation should be linear by a proposed way of the regulation such as using of steepness of the continuous wave. In the dynamic analysis in deep waters under the influence of large storm waves, the dominant wave force consists of the drag force that is nonlinear, therefore, for a proper's response, these structures should be dynamically analyzed in the time domain [4].

The hotspot stress range (HSSR) is the same as the stress on the toe of a connection. The stress concentration factor (SCF) introduced as follows in Eq.(1):

$$SCF = \frac{HSSR \text{ at the Location}}{\text{Range of Nominal brace stress}} \quad (1)$$

The (HSSR) is calculated at the 8 points around the joints. The API regulation proposes the Eftymiou equations for non reinforced tubular joints and Lloyd equations for reinforced tubular joints. The regulation recommends minimum values of stress concentration for all of tubular joint parts (main and subsidiary members) the value 2, for the intrnally reinforced joints the value of 2.5, for the extrrnally reinforced joints the value of 6.

Most of joints are used in offshore structures are the multi-planner joints. Therefor we need to compute separatly SCF for each joint. The Maximum value will used in the final calculations for each joint. Geometric parameters of a tubular joint can be seen in the figure below at Figure 2.

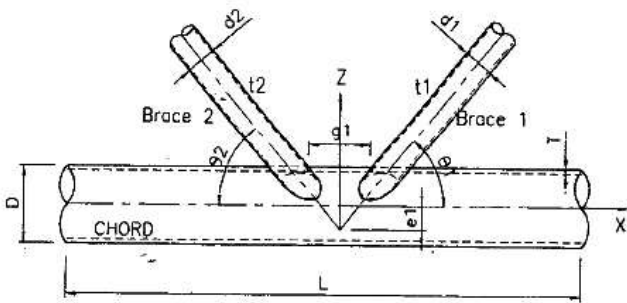


Figure (2): Geometric Parameters of Tubular Connection (DNV) [5]

Where is, D: diameter of main member, t: sub_member tickness , T: main member tickness
 L: length of the members
 Θ: angle between the two members
 g: distance between two braces at the toe of the weld

The 8 peripheral spots of a joint for calculating of hotspot stress are displayed in figure 3. Axial load (N), in-plane bending moment (IPB), out of plane bending moment (OPB) can be seen in the figure 3, a and b.

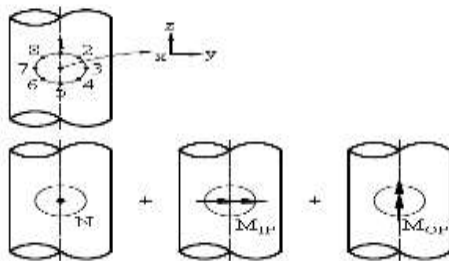


Figure (3): Forces Applied to a joint (DNV) [5], (a).

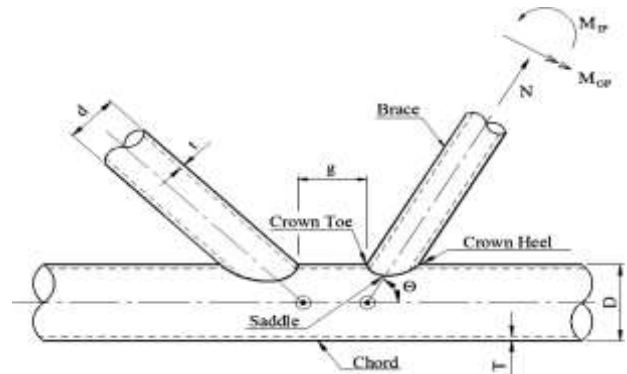


Figure (3): Forces Applied to a joint (DNV) [5], (b).

The DNV regulation proposes the following equation Eq.(2), for calculating hotspot stress and then used in the S-N curves [5].

$$HSSR = DAF \left(\frac{F_{ax}}{A} SCF_{axi} + \frac{F_{ipb}}{Z} SCF_{ipb} \sin\theta_i + \frac{F_{opb}}{Z} SCF_{OPB} \cos\theta_i \right) \quad (2)$$

Where in Eq.(2) DAF: dynamic magnification coefficient, Z: modulle of the cross-section, SCF_{ipb}: SCF of in-plane bending moment, SCF_{OPB}: SCF of out of plane bending moment, θ: angle between spots.

3.1.3 Stress-cycle Diagrams

The API regulation offer the following diagram according to Eq.(3), for x and x' modes, Figure 4.

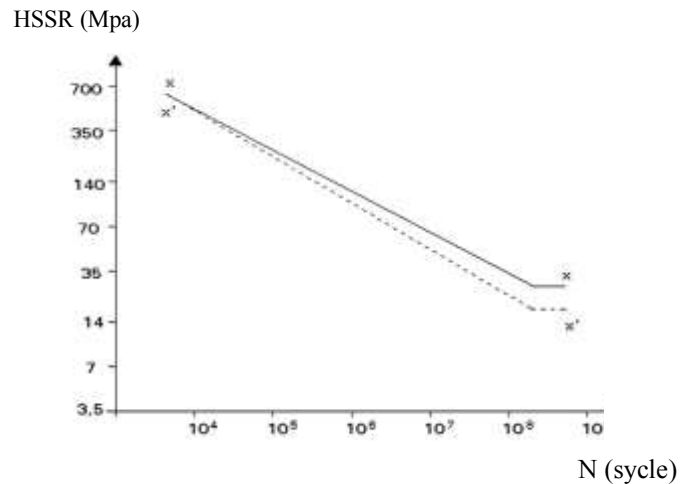


Figure (4) - S-N Curves in the API [3]

$$N(s) = 2 \times 10^6 \times \left(\frac{\Delta\sigma}{\Delta\sigma_{ref}} \right)^{-m} \quad (3)$$

Where in Eq.(3), N(s): Number of cycles allowed, Δσ: the current stress , Δσ_{ref}: experimental standard stress and m: diagram slope, according the following table:

Table (1) - Characteristic values of the equation of the S-N curves

Application	$\Delta\sigma_{ref}$ in two million cycles mpa	m	curve
Two sides with flat weld profile and control with x-ray	100	4/38	X
Susceptible weld with rugged sides	79	3/74	X'

The X is for the situation that the weld of joint is controlled and the thickness of subsidiary member is less than 25 mm.the following Eq.(4), can be used for modification of thickness effects.

$$S = S_o \left(\frac{t_{ref}}{t}\right)^{0.25} \tag{4}$$

S_o : allowed stress obtained from S-N Curves, S: allowed stress, t: thickness of the subsidiary member t_{ref} :16 mm for X' curve and 25 mm for X.

About unchecked welded joints, X' one is used. However, it must comply with the standard AWS profile and it is used where the subsidiary tubular joint is less than 16 mm. to modification of thickness effects, the equation 4 can also used [3].

3.2 fatigue life estimating methods

3.2.1 Palmgren–Miner theory

Several methods have been investigated by scientists in relation to the estimation of the ultimate lifetime of structures and components. However, Miner' rule is still one of the most widely used lifetime estimation equation. Although it is worth mentioning that Miner's rule has been scientifically criticized many times over the course of the period that it was published and used up until to this date. Not taking into account the loading history can be mentioned as one of the flaws of the Miner's rule, which has a tangible impact on the results of the lifetime estimates. This cumulative rule proceeds to determine the "cycles until failure" from the stress-cycle curve for the various sea states and the stresses caused by it. According to the number of waves under study, with the accumulation of the damages resulted from each wave, the total damage is obtained. In the process, the impact of the previous wave on the structure is not considered, and it is based on the assumption that each wave crashes into an intact and healthy structure. Despite the fact that the structure has been attacked before confronting the next wave and has taken impacts from the previous wave. Despite this fact, Miner's rule is still one of the most widely used theories of lifetime estimation in the above cycle, due to the ease of use, and because it is an empirical rule and is also consistent with the stress-cycle curve and provides acceptable solutions. The procedure of this method has been shown summarily in Figure 7. The mathematical equation of this theory, along with the

introduction of its parameters, have been described in the previous sections where it was necessary, and for the sake of brevity, only the general Eq.(5), is given here[8].

$$D = \sum \frac{n_i}{N_i} \leq 1 \tag{5}$$

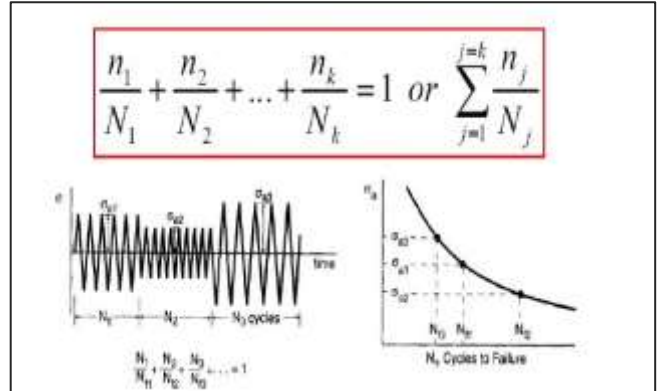


Figure (5) - The general process of Palmgren-Miner

The Palmgren-Miner cumulative method is generally used in the estimation of fatigue life, but because in the calculations it does not take into consideration the history of stresses, it has some deficiencies, therefore, we can achieve a more accurate and realistic estimate by correcting these deficiencies. In the proposed method, by taking into account the impacts of the loading, it has been attempted to obtain a more accurate estimate of the structural lifetime. There are three main steps in this method that we will deal with them:

- Reviewing the history of stress
- Using the entire range of S-N curves
- Using the sequential method

The stress history is obtained by structural analysis during various states of the wave phase for nodes in the structure. The conversion of the partial range of curve to the full range is based on the curve modeling technique that was performed by Kohout and Vechet. A general overview of this curve conversion is presented in Figure 6.

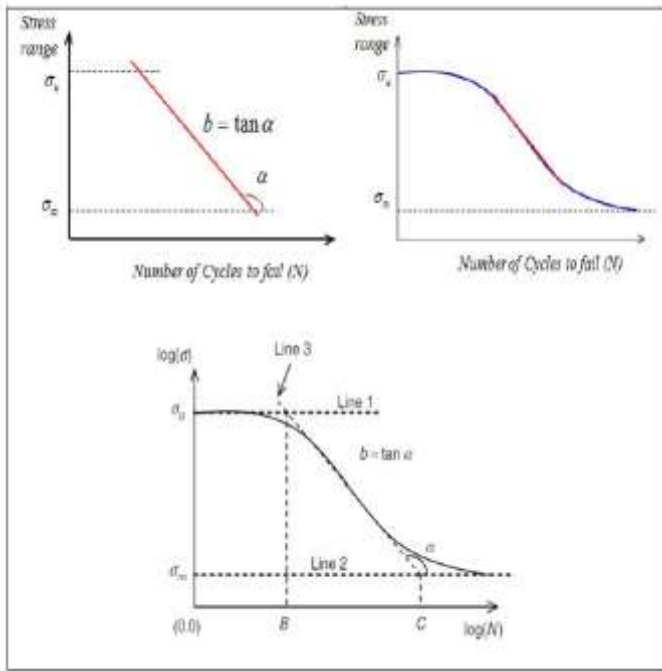


Figure (6) – The display of the general steps of the expansion of Wöhler curve

As can be seen, the graph is given in the logarithmic form, which it has also been given similar to this in all regulations. In Figure (6), line number 1 crosses the equivalent point of the final stress of σ_u , and line number 2 crosses the equivalent point of the compressive strength of σ_∞ . The infinite compressive strength is, in fact, a stress at which it can acceptably be said that a structure with infinite cycles of this stress does not still reach the failure. Also, line 3 shows the tangent line in the range that is used in the regulations for the calculable range of limited cycles of the stress. Also, points B and C represent the range of the tangent line 3 on the horizontal axis with lines 1 and 2, and also “a” is the Basquin index. The full range of the S-N curve is presented by the two models of Basquin and Kohout, which can be presented by equations (6)-A and (6)-B:

$$\sigma = \sigma_\infty \left(\frac{N+B}{N+C} \right)^b \quad (6)-A$$

$$\sigma = aN^b \quad (6)-B$$

Where b is the slope of the tangent line.

In the regulations, these curves are usually provided with two slopes, which are generally considered to be 3 and 5. The limit of the compressive strength is considered to be 1 MPa. The curves used for connections and tubular members are known as T-Curves. In Figure 7, the final curve is displayed. It should be noted that the basic equation of the S-N curves is obtained from the logarithmic equation in the general form of:

$$\log N = \log a - m \log \Delta \sigma \quad (7)$$

where in Eq.(7), m: negative slope of S-N curve, N:estimated cycle rate of the curve for the stress range, log a: parameter of the horizontal logarithmic axis N.

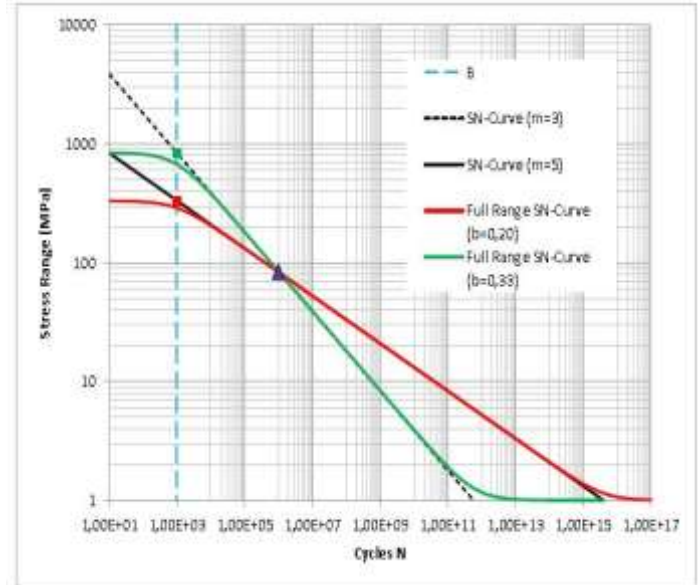


Figure (7) - The general range of the curve known as T-CURVE

In Fig. 9, the curves related to slopes 3 and 5 can be seen. The red curve with a slope of 0.2 and the green curve with a slope of 0.33 have been given, which these curves can be extracted from equation (14). With regard to the ranges covered by the curves, the curve with a slope of 0.2 is suitable for this research. because the stresses in the research are in the high-cycle range.

3.2.2 Sequential Law

The basis of this rule is based on the assumption that: If the physical state of damage is the same, then fatigue life estimation should depend on the load condition only [9]. The procedure of this method is that first, by definition, the initial damage index D_i at the level one of the stress of σ_i , which is obtained from the curve by reading the corresponding (N_i) and according to Eq.(17), is obtained. Then, this damage is transferred to the next level of the stress $\sigma_{(i+1)}$. This process continues until the value of the equivalent stress reaches to the final stress and the damage index approaches to one millimeter. During this process, the cycle values of each stress range are also involved, which are taken into account as n_i in the equations. The value of the remaining cycle for the failure in

each step is obtained from the subtraction of $N_i - n_i$, which again for this cycle the equivalent stress is obtained from the curve as well. The curve in Figure 8, clearly illustrates this procedure. The parametric equations of this procedure are given below.

$$D_i = \frac{\sigma_{(i)eq} - \sigma_i}{\sigma_u - \sigma_i} \quad (8)$$

$$D_i = \frac{\sigma_{(i)eq} - \sigma_i}{\sigma_u - \sigma_i} = \frac{\sigma_{(i+1)eq} - \sigma_{i+1}}{\sigma_u - \sigma_{i+1}} \quad (9)$$

Where is the equivalent stress of the remaining cycle of $\sigma_{(i+1)eq}$ of the level i that is transferred to the next level and results in the permitted cycle of $N_{(i+1)R}$, and this same trend continues.

$$\sigma_{(i+1)eq} = D_i(\sigma_u - \sigma_{i+1}) + \sigma_{i+1} \quad (10)$$

$$N_{(i+1)R} = \hat{N}_{(i+1)R} - n_{i+1} \quad (11)$$

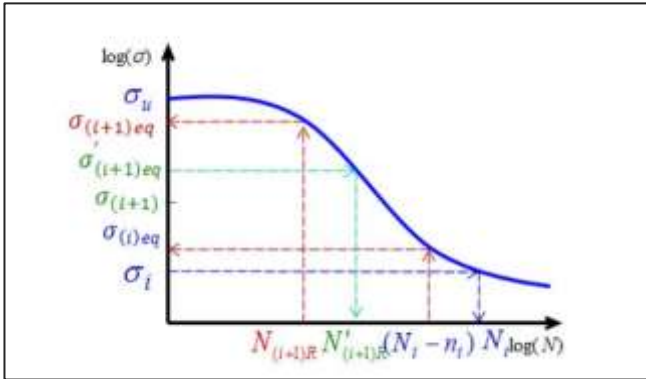


Figure (8) – The functional procedure in sequential law method in S-N curve[9]

The verification of this theory has been done with the aid of the studies of the scientists active in this field. These studies have been performed experimentally and numerically, which the results of these studies can be seen in the form of diagrams. These studies have been performed with different slopes that are in the form of a comparison with Palmgren-Miner law and the experimental results have been plotted as some diagrams. These studies have been carried out based on the full range (extended) curves of S-N curves. In the experiments performed, 45c and 16Mn steels, and also the values of B and C, and compressive strength limit, and a specific slope in the selected equation, that is based on equation 6, have been used. These graphs can be seen in Figures 9 and 10. From the general analysis of these diagrams, it can be seen that in determining the fatigue life, the "sequential law" has performed much better and more precise than Palmgren-Miner law. This can be found out from the results obtained from the sequential law being close to the experimental results given in the diagrams.

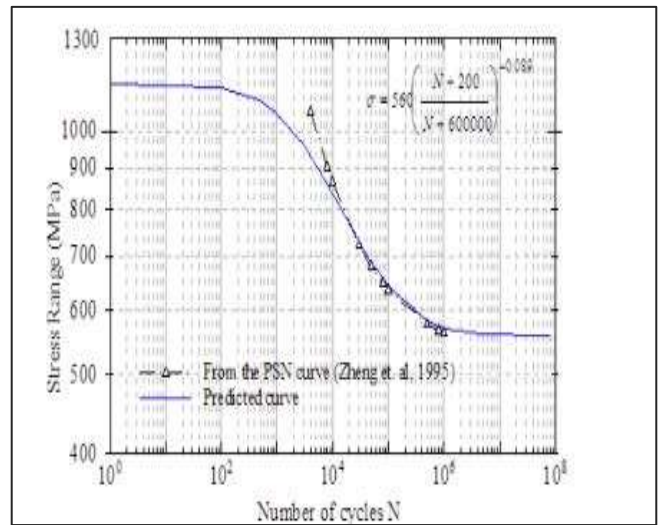
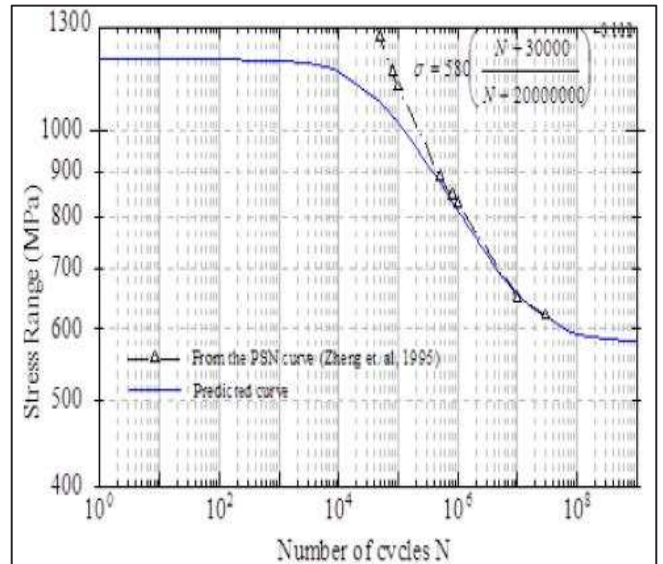


Figure (9) – The verification of sequential rule by experimental results (Zheng et al, 1995)

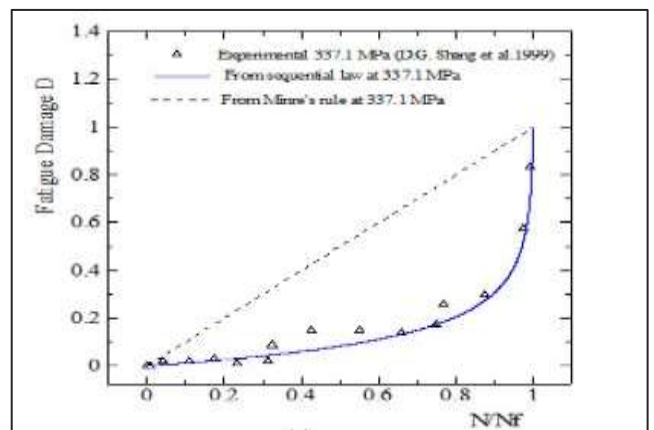


Figure (10), a – The comparison of sequential rule with experimental and Miner's rule results (Shang et al., 1999)

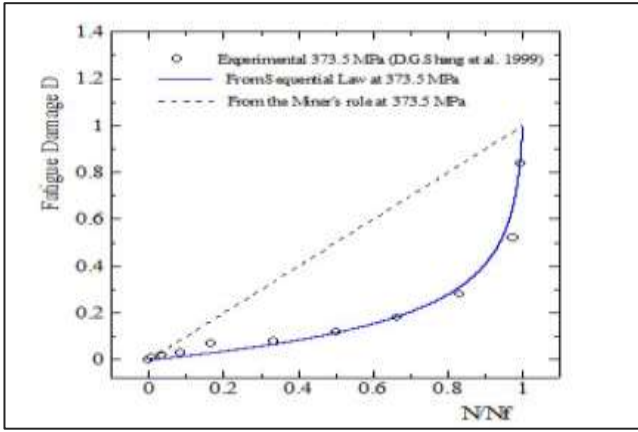


Figure (10), b – The comparison of sequential rule with experimental and Miner’s rule results (Shang et al., 1999)

3.3 The Studied Sample Case

The studied platform is one of the sample jackets located in the Persian Gulf that has been modeled by ABAQUS finite element software. Depending on the geometrical design parameters and the installed depth of the fixed offshore platforms and environmental and hydrodynamic condition in the Persian Gulf, a jacket platform is modeled similar to the SPD15 according to a plan of Iran Oil Company. The depth and overall height of the modeled platform are 66.6 and 73.85 meters, respectively. It is modeled in 3D and formed by the wire module of the Abaqus. The members of the modeled offshore structure provided by pipe profile and Beam elements (in 3D) with the ability to take into account the rotation, displacement and bending at the end of each element. The platform is meshed by B32 elements and fixed leg on the sea bottom. The natural period of this model is less than 3 seconds that makes it possible to use deterministic and static analysis in the modeling [10].

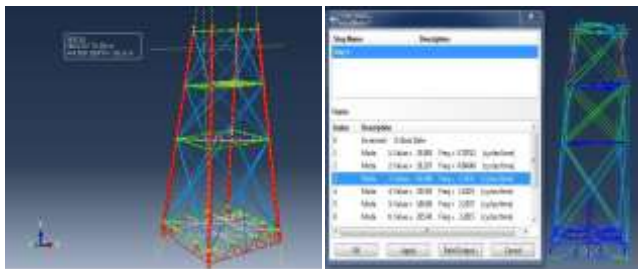


Figure 11 – The platform modeled by ABAQUS

In the software, applying the wave and current loading is done by Aqua coding where first, a wave with the specifications of a period of 11 seconds and a height of 12.2 meters is applied to the structure. In the fatigue analysis of the platform, the one-year dispersion table belonging to the Persian Gulf has been used, in such a way that, the waves with a higher number of incident events were selected and used (Table 2). In this research, according to the reports used in offshore engineering operations of the National Iranian Oil and Gas Company, the northwest

direction was selected as the direction of the dominant wave, and for the purpose of finding the direction of the dominant wave, the changes of the angle of the incident wave with the structure were neglected.

Table (2) – The dispersion of the selected waves.

	Height	Cycle range	Number of event
Wave 1	3/90	0/8 - 0/0	1613221
Wave 2	8/90	0/0 - 0/9	587321
Wave 3	8/30	1/0 - 1/8	179709

From the location of the structure, it can be deduced that the structure has been positioned directly against the dominant waves because the north of the platform is along the northwestern geographical direction of the earth. According to DNV and API regulations, in the platforms with natural frequencies less than 3 seconds, the dynamic magnification coefficient (DAF) can be neglected, because it does not have much effect in increasing the applied static stresses. And often in these cases, the value of 1 is used for this coefficient. The method of the calculation of this coefficient is given by Eq.(12).

$$(12) DAF = \frac{1}{\sqrt{\left[1 - \left(\frac{T_P}{T_W}\right)^2\right]^2 + \left[2\beta \frac{T_P}{T_W}\right]^2}}$$

Where in Eq.(12), T = Natural period of the structure, T_W = Period of the wave, β = Attenuation coefficient

The modeling done for the fatigue analysis has been assessed for a connection at the base of the platform, Figure 12. For the verification of the model, the platform has been analyzed without wave loadings and under the weight of the structure, and the inconsistency of the results indicates the operating of the loading in the software.

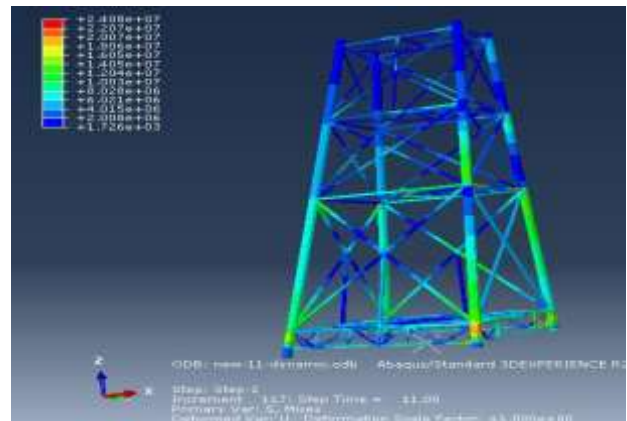


Figure (12): under loading platform

4. Discussion and Results

Since the analysis of marine offshore structures is of great importance with regard to the sea conditions and environmental loadings, determining the type of analysis and recognizing the importance of the conditions governing the environment has a significant role in the analysis of these structures. The quasi-static analysis is one of the most appropriate analyzes in jacket structures because the dynamic loads of the sea do not occur at a high speed and a short time like explosions. Nevertheless, pure static loads are not dominant in the sea either. Therefore, the quasi-static analysis is the most appropriate type of analysis in this type of structure. The API regulation requires a dynamic analysis at depths of more than 120 meters for all marine structures. In this research, with regard to the stress analysis performed, and taking into account the stress concentration coefficients and the use of stress-cycle diagrams for the selected type K connections, such results were obtained. According to the analyses obtained from dynamic, static, and quasi-static methods, the difference of about 33.1% in determining the maximum stress indicates the accuracy of the static and quasi-static analyses at depths below 100 meters and a natural period of less than 3 seconds, which confirms the regulations as well. Platform connections are one of the most sensitive structural points where stresses and concentration of stresses occur due to geometric imperfections and changes in cross-sections and welds. Therefore, in the present study, connections were observed as critical structural points that there is a need to analyze, study, and improve the performance of the structures in these points. Miner and sequential law are among the laws used for estimating the lifetime of these connections, which have been used in this research. The life of the present critical connection, which due to the depth of the area, is considered as an un-inspectable connection, was obtained to be selected about 37 and 33 years for the braces from the Miner and sequential laws, respectively. The difference of about 12% in the results indicates the importance of the methods used for estimating the lifetime of the structures.

Applying effects of the every wave on a structure and incorporating it on structure situation that is subject to next wave can be leads us to accurate estimate for structure fatigue life. Regarding these results, the sequential law has a significant degree of

accuracy in estimating fatigue life compared to the Miner law, which is also recommended for engineering tasks.

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