Fatigue life prediction on jacket leg structure subjected to axial and wave loads

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Abstract. Fixed jacket platform is an offshore structure consists of many elements such as leg and braces. Both legs and braces play an important role to support the structure from internal and external loads like structure itself and wave loads. Especially for jacket leg, the deck load is distributed to all jacket leg to support deck structure. Besides, jacket leg also resists wave loads in horizontal direction. Due to the axial load caused by deck and horizontal load caused by wave, these loads act periodically on jacket leg. Therefore, the analysis of fatigue life to jacket leg should be performed for structural design. The present study focuses on fatigue life prediction on jacket leg under axial and wave load. The numerical method is conducted to analyze fatigue life on jacket leg. It is found that the fatigue life due to axial and wave loads are 185 and 108 years, respectively.

1. Introduction
Fatigue life of offshore platform like jacket or floating structure is influenced not only by axial load caused by deck but also wave loads which act as cyclic load during in offshore or voyage. Fatigue life is defined by a cyclic stress with load having unlimited number. Fatigue strength is the maximum strength where load acts to structure without failure for definite load. Fatigue life is depended some factors such as material characteristic, crack, structural geometry and so on. Damage caused by fatigue on jacket leg of offshore structure dominantly caused by deck and wave loads. Stress caused by these loads generally fluctuative and change randomly. Therefore, fatigue life of offshore platform especially on jacket leg under cyclic loading must be analyzed for the structural failure.

The offshore structures like fixed jacket or floating structures should be evaluated for fatigue life due to the load of the structure itself and environmental loads. Yang [1] conducted the seismic collapse performance of jacket offshore platforms with a time-variant zonal corrosion model. Eldin [2] conducted the sensitivity analysis on the seismic life-cycle cost of a fixed-steel offshore platform structure. The sensitivity analysis was performed using different methods such as tornado diagram analysis, first-order second moment, and Latin hypercube sampling. Guede [3] presented a method for risk assessment and inspection plan development as part of the risk-based structural integrity management of the offshore jacket platform. Muis Alie [4] analyze the effect of symmetrical and unsymmetrical configuration shapes on buckling and fatigue strength analysis of the fixed offshore platform. Two models of the fixed offshore structure were taken to be analyzed with the same dimension but different configuration shapes. The numerical calculation was performed to investigate the buckling and fatigue strength of both structures. Hezjararibi [5] performed the nonlinear response of jacket-type platforms against extreme waves that were examined utilizing sensitivity analyses. Muis
Alie [6] discussed the configuration effect of fixed offshore structure with symmetrical and unsymmetrical shape toward buckling failure. Two kinds of the offshore structure were analyzed. The numerical analysis was adopted to calculate buckling failure under axial and lateral load. Khalifa [7] assessed the fatigue life for single-side welded tubular joints of the fixed platform. The analysis procedure was presented for numerical fatigue assessment methods based on S-N curve approach for the American Petroleum Institute standard utilizing the simplified method and the spectral (stochastic) method. The effects of the current, the jacket natural period, and the jacket stability on fatigue life assessment have been investigated.

The objective of the present study is to predict the fatigue life of jacket leg of an offshore structure subjected to axial and wave loads. The numerical method is conducted to analyze the fatigue life of the jacket leg.

2. Methodology

The fixed jacket structure in this study has four legs. The structure is fixed at the sea bottom, as shown in figure 1. The section properties between jacket leg and brace are different, but the material properties are constant. The structure is subjected to constant axial and wave loads, and those are applied at jacket leg.

![Figure 1. Fixed jacket structure](image)

The axial load is applied on the jacket leg structure as shown in figure 2, and it is calculated by using the following formula,

\[ \sigma = \frac{F}{A} \]  \hspace{1cm} (1)

where \( F \) and \( A \) are the axial force and cross sectional area, respectively. The stress-strain relationship related to element under tension or compression is also represented by the following formula,

\[ \sigma = E \varepsilon \]  \hspace{1cm} (2)
The young’s modulus $E$ and strain $\varepsilon$ are expressed by the relationship form the Hooke’s law. The equation (2) can be modified to obtain the strain as,

$$\varepsilon = \frac{\sigma}{E} \quad (3)$$

![Figure 2. Axial load on jacket leg](image2)

![Figure 3. Wave load direction](image3)
The number of cycle can be determined using the following equation,

$$ N = 2 \times 10^6 \left( \frac{\Delta_{\sigma}}{\Delta_{\sigma_{ref}}} \right)^m $$

where $\Delta_{\sigma} = \sigma_{\text{max}} - \sigma_{\text{min}}$, $\Delta_{\sigma_{ref}}$ are the stress range and stress range on cycle, respectively. The value of $m$ is taken 4.38 based on the S-N curve. Design of fatigue life may be approached using the following equation,

$$ T_{\sigma} = \Delta_{\sigma_0} N \frac{T_s}{3} $$

where $\Delta_{\sigma_0}$, $N$ and $T_s$ are value of structural failure, number of cycles and periodic of structural response.

3. Results and discussion
The offshore structures may occur failure under cyclic loading. The cyclic loads such as wave always act on structure periodically. Therefore, this may the structure becomes critical leads to failure. Therefore, the failure phenomenon and fatigue life of the structure must be evaluated. This is very important to predict fatigue life especially on the tubular joint of jacket leg. Table 1 shows the comparison of fatigue life on jacket leg of fixed structure. According to table 1, it is found that the fatigue life on the jacket leg under axial load (structure) is larger than wave load. This is caused by the installation and all equipment act on the deck structure is larger than wave load. It is found that the wave load act on the jacket leg is smaller, in other word the cross-section where the wave load acts on jacket leg is different with cross-section where the axial load act on the jacket leg in vertical direction.

| Load cases              | Fatigue life (years) |
|-------------------------|----------------------|
| Axial load (structure)  | 185                  |
| Wave load               | 108                  |

4. Conclusion
The prediction of fatigue life of jacket leg on fixed offshore structure has been conducted using numerical method. The stress product from numerical method used as a basis to determine fatigue life for two different load cases. It is found that the fatigue life under axial load is 185 years. While for wave load, fatigue life of jacket leg is 108 years. The parameters like stress range and number of cycles have significant influence to fatigue life.

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