The ultimate strength analysis of jacket leg under deck load

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Abstract. Jacket platform is one of the offshore structure where the pile is fixed at the bottom sea level. Jacket leg has a significant influence on local and global structural strength under axial and lateral loads. Jacket leg is one of the most important elements for the fixed offshore structure. On the other hand, the jacket leg is also very critical to resist not only axial compression but also lateral pressure. The objective of the present study is to analyze the ultimate strength of a jacket leg under deck load. The numerical calculation is used to analyze jacket leg due to deck load. It is assumed that the support condition is fixed at bottom sea level. The result obtained by numerical analysis is therefore presented in this study. It found that the jacket leg obtained by numerical analysis can withstand the axial compression load.

1. Introduction

Fixed jacket offshore platform consists of many elements such as braces and piles. Braces and piles have played a significant role to withstand axial and lateral loads in vertical and horizontal directions. Mainly, pile gives significant influence for local and global deformation when axial compression and lateral pressure take place. In this case, wave load acts in horizontal direction asymmetrically distributed to pile. This is caused by the water particle velocity at the bottom and surface is different from one another so that the asymmetrical distribution load on the pile may occur. Therefore, the asymmetrical load distribution must be taken into account.

Fixed jacket offshore structure has been analyzed by some researchers. Yang [1] conducted the seismic collapse performance of jacket offshore platforms with time-variant zonal corrosion model. Guede [2] presented a method for risk assessment and inspection plan development as part of the risk-based structural integrity management of offshore jacket platform. Muis Alie [3] 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 analyze the buckling and fatigue strength of both structures. Eldin [4] conducted the sensitivity analysis on 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. Muis Alie [5] discussed the configuration effect of fixed offshore structure with symmetrical and unsymmetrical shape toward buckling failure. Two kinds of offshore structure were analyzed. The numerical analysis was adopted to calculate buckling failure under axial and lateral load. Hezarjaribi [6] performed the nonlinear response of jacket-type platforms against extreme waves was examined utilizing sensitivity analyses.
In this study, pile deflection due to asymmetrically distributed loads is analyzed. The numerical calculation is used to analyze pile deflection due to asymmetrically distributed loads. In this case, large deflection analysis is separated into two asymmetrically loading conditions: trapezoidal and triangular with different end supports. The result obtained by numerical analysis is therefore compared with the analytical solution using direct integration. It is found that the pile deflection obtained by numerical analysis is almost identical with direct integration.

2. Analytical formulation

It is well known that the jacket offshore structure consists of some decks such as helideck, production, drilling, and accommodation where all decks have their self-weight. Besides, there is also equipment that must be calculated to ensure that the structure is safe based on the structural function and requirement. All the loads are distributed not only to the element braces but also to the jacket legs of the structure. The accumulation of the loads then transferred and divided to the jacket legs represented by an axial load. Therefore, the axial load must be calculated and determined by 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 is also represented by the following relationship,

$$\sigma = E \varepsilon$$ \hspace{1cm} (2)

The young’s modulus $E$ and strain $\varepsilon$ are expressed by the relationship from the Hooke's law. The equation (2) can be modified to obtain the strain as,

$$\varepsilon = \frac{\sigma}{E}$$  \hspace{1cm} (3)

Due to the axial stress acting on the jacket leg, so that the jacket leg may buckle or deform in a vertical direction. The deformation or deflection of this behavior can be determined by the following formula,

$$\delta = \frac{5wL^4}{384EI}$$  \hspace{1cm} (4)

The allowable deflection for floor and roof are $\delta_{allowable} = \frac{L}{360}$ and $\delta_{allowable} = \frac{L}{240}$, respectively.

3. Results and discussion

The offshore jacket structure is modeled by using the Finite Element Method. The jacket structure is assumed to be fixed at bottom sea level. The configuration shape of the jacket structure mostly used brace diagonal to withstand not only axial compression load but also horizontal load, particularly wave load acting on the model. The structural geometry of the jacket offshore is shown in table 1, and the finite element model of the jacket structure is shown in figure 1 as follow,

| Material properties          | 210000 |
|------------------------------|--------|
| Young’s modulus (N/mm²)      | 210000 |
| Shear modulus (N/mm²)        | 81000  |
| Yield strength (N/mm²)       | 295    |
| Tensile strength (N/mm²)     | 450    |

Table 1. Material properties
The material properties are constant for brace element, diagonal, and jacket legs.

Figure 1. Finite Element Model of the jacket structure
Figure 2. Deformation due to axial load

Figure 2 shows the deformation due to the axial load. The structural components at the top of the structure deform denoted by yellow color. The maximum stress also located at the top, as shown in figure 2. According to figure 3 that the jacket structure has normal deformation caused by the normal load and there is no significant influence by the normal load.

Figure 3. Deformation due to normal load

Figure 4. Deformation due to incremental load
Figures 4 describes the deformation under incremental load. Unlike figure 3, figure 4 shows the deformation becomes larger when the incremental of the load is added. The local deformation caused by the incremental load takes place. It is found that some elements around the top part, namely diagonal braces, horizontal braces, and jacket legs deform due to this load.

4. Conclusion
The analysis of jacket legs of the fixed offshore structure has been done using finite element analysis. The result obtained by finite element analysis shows that the structure deforms around the top part caused by the incremental load. Even though the axial compression load is added, the working stress of each element is still under the allowable stress.

References
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