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EXTENDED ABSTRACT

Reliability Analysis Based Safety Factors for Designing the Tubular Members of Horizontal Braces in Offshore Jacket Structures

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1. Introduction

In the present paper, the reliability of tubular members used in the horizontal braces of an offshore jacket structure against the failure induced by the presence of stresses higher than the allowable values is evaluated. In order to define the failure criteria, equations proposed by the 21th edition of API RP 2A-WSD (2007) for the design of tubular members under the combined axial pressure and bending are used. In this study, internal forces of the tubular members and the parameters involved in the member strength are considered as random variables and the probability distribution functions governing these forces including the axial compressive force and in-plane and out-of-plane bending moments are derived for a typical jacket-type platform installed in the Persian Gulf. For the modeling of environmental loads, information available on the sea states in the South Pars region has been used and the results of three different methods of reliability analysis including MVFOSM, HL-RF, and MCS are compared. Finally, based on the results of reliability analysis, a set of equations are proposed for the determination of suitable safety factors for designing the tubular members in horizontal braces of a jacket structure as a function of target reliability index and target failure probability.

2. Development of the limit-state function

Based on the 21st edition of API RP 2A-WSD (2007), following equation should be used to check the static strength of a tubular member subjected to the combination of compressive force and flexural moment:

$$\frac{f_a}{F_a}+\frac{\sqrt{f_{bx}^2+f_{by}^2}}{F_b}\leq 1.0 \tag{1}$$

in which, f_a and f_b are nominal axial and bending stresses, respectively; and F_a and F_b are corresponding allowable stresses.

The limit-state function (g) for the reliability analysis of the tubular member was then developed based on Eq. (1) as follows:

$$g=1-\frac{f_a}{F_a}-\frac{\sqrt{f_{bx}^2+f_{by}^2}}{F_b} \tag{2}$$

Since in working stress design (WSD) method, allowable stresses are defined as a function of yield stress (F_y), Eq. (2) can be rewritten as follows in order to take the loading and strength uncertainties into account:

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$$g = 1 - \frac{f_a}{R_1 F_y} - \frac{\sqrt{f_{bx}^2 + f_{by}^2}}{R_2 F_y} \quad (3)$$

in which, R_1 and R_2 are usage factors defined as F_a/F_y and F_b/F_y, respectively. Safety factors for compressive force and bending moment are thus $1/R_1$ and $1/R_2$, respectively.

3. Proposing reliability-based safety factors

In API RP 2A-WSD (2007), R_1 and R_2 are calculated based on deterministic inputs. Hence, the safety factors are fixed values. In the present research, the usage factors are formulated as a function of the reliability index (β) and the probability of failure (P_f). Consequently, the safety factors can be calculated as a function of target level of safety.

After performing a large number of reliability analyses using *Rt* software (Mahsuli and Haukaas, 2013), on the data extracted from FE analyses performed by SAP2000 on a typical jacket structure, values of the reliability index (β) and the probability of failure (P_f) were calculated considering the loading and strength uncertainties. Afterwards, a set of nonlinear regression analyses was performed to develop the design equations as follows:

$$\beta = 1.8851R_1^2 - 5.4147R_1 + 8.1072 \quad (4)$$

$$R_1 = 0.087\beta^2 - 1.2804\beta + 5.0218 \quad (5)$$

$$P_f = 0.000003R_1^{10.418} \quad (6)$$

$$R_1 = 3.3857P_f^{0.096} \quad (7)$$

$$\beta = -1.4365R_2^2 + 0.6296R_2 + 5.505 \quad (8)$$

$$R_2 = -0.5274\beta^2 + 4.7658\beta - 9.7909 \quad (9)$$

$$P_f = 0.0000006R_2^{4.9082} \quad (10)$$

$$R_2 = 17.859P_f^{0.2013} \quad (11)$$

Values obtained for the coefficient of determination are 0.99 for Eqs. (4)-(9) and 0.98 for Eqs. (10) and (11) indicating the quite acceptable accuracy of the fit.

4. Conclusions

In the present research, based on the results of reliability analysis, a set of equations was proposed for the determination of suitable safety factors for designing the tubular members in horizontal braces of a jacket structure as a function of target reliability index and target failure probability.

5. References

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