Establishment of a methodology for determination of the strength condition of fixed offshore jacket structures in deepwater, based on probabilistic model and reliability theory, and its application in Vietnamese sea conditions

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Abstract

Exploitation of oil and gas fields in deepwater is an increasing tendency worldwide; this requires the installation of production platforms with high safety in the most unfavorable conditions. This has encouraged new approaches to description of the environmental conditions by statistical modelling, then establishment of appropriate methods for structural analysis and design of deepwater platforms, from fixed jacket to anchored floating platforms.

In the framework of this paper, the authors present the methodology for expressing the strength condition by a probabilistic model for estimate of the safety based on reliability theory, in order to analyse fixed platform jacket structure in deepwater aimed to be applicable in Vietnamese sea conditions from 200 - 400m depth. The paper content is developed from authors' research results in the National research Project KC.09.15/06-10.

1. Introduction

1.1. Overview of the development of fixed offshore jacket platforms in deepwater

The increasing demands of oil and gas exploitation in deepwater from 1,000 - 3,000m has created the strong motivation to push technical and technological improvement in the aim to design and install various offshore platform types in deepwater capable of being operated safely in more severe natural conditions, and furthermore to ensure product cost acceptable in comparison with that exploited in shallow fields.

The evolution of oil and gas exploration and exploitation at greater water depth has been increasing day by day, especially in the first decade of the 21st century, as presented in Fig.1.

There is a tendency of developing various offshore platform types in water depths over 1,000ft (328m), in which there are 7 fixed steel platforms installed in deepest water worldwide, as given in Fig.2 and Table 1 [1].

1.2. Characteristics of deepwater jacket structure design

The design of jacket structures in a deepwater has some differences from structures in shallow water, such as situated far offshore, environmental conditions and jacket structure configurations. The main characteristics of jacket structure design in deepwater are presented below [2]:

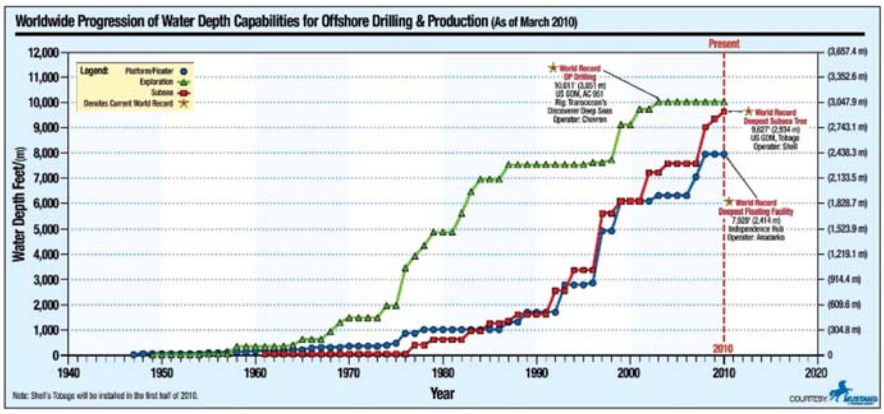


Fig.1. *The worldwide progression of water depth capabilities for drilling and production (as of March 2010) [1]*

- Basic frequency of jacket structure increases rapidly with water depth, resulting from the larger dynamic effect of the wave loads.

- The dynamic effect may be increased if the wave length is too larger than the distance between the legs of the jacket structure.

- In calculating internal forces of jacket elements it is necessary to take into account the axial bending effect of pipe elements subject to great axial forces (that leads to increase the element stress), and the vortex effect from current and wave passing through pipe elements (that creates periodic dynamic stresses resulting in the increase of the stress values in structural elements and maybe also local fatigue failure).

- Deepwater structures require the use of modern models and analytical methods giving high exactitude, this ensures safe operation of the offshore structures. This requires the use of the probability model for describing environmental conditions and to analyse strength as well as fatigue of jacket structure by reliability theory methods [4, 5].

The establishment of a methodology for expressing the strength condition of jacket structure based on the reliability as mentioned in the point 4 is the main content of the presentation below.

1.3. Some main problems of the methodology

- Description of random wave action on the jacket;

- Random dynamics of the jacket structure;

- Expressing structural strength condition by the probabilistic model and reliability theory.

2. Random wave loads

In each sea state, the motion of random surface waves is considered as a zero-mean stationary stochastic process, and described by surface wave spectra, $S_{\eta\eta}(\omega)$, typically, they are Pierson-Moskowitz (P-M) wave spectrum, JONSWAP spectrum. Hence, the velocity and acceleration spectrum can be determined. The distribution function of wave height then may be defined based on the wave spectrum bandwidth, either narrow or broad band or any other band type.

The wave load spectral density function is used for analysis of structure subjected to random wave action. A typical structure is presented below to illustrate the method of determining wave load spectral function acting on the structure.

The random wave load acting on unit length of vertical fixed column, circle cross-section (A) with diameter D, is determined based on Morison's equation of linear form [2]:

$$F(t) = \frac{1}{2}\rho D C_D \sqrt{\frac{8}{\pi}}.\sigma_{vx} v_x + \rho C_I A a_x \qquad (1)$$

Where: ρ: Sea water density; C_D and C_I - drag and inertial coefficients;

v_x and a_x: Horizontal velocity and acceleration of water particle, as stationary random processes with their spectral densities Sv_xv_x and Sa_xa_x;

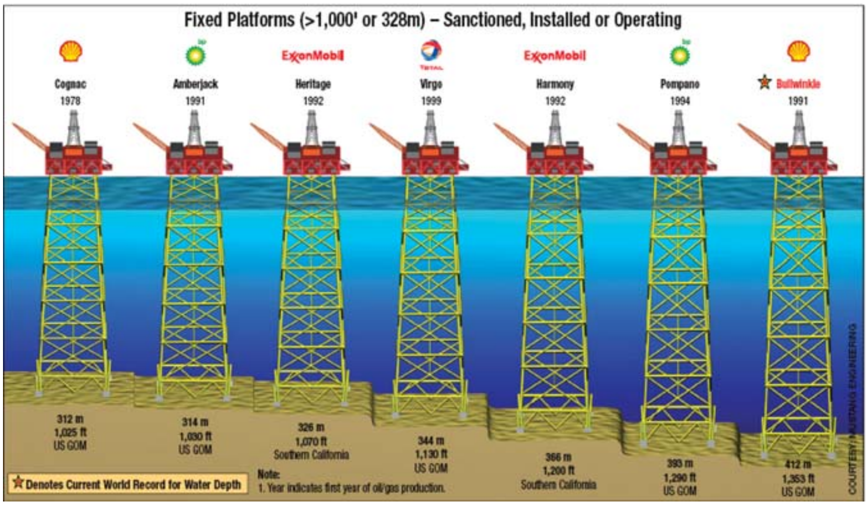


Fig.2. *The seven deepest water worldwide fixed platforms*

Table 1. *Fixed platforms in the deepest water worldwide*

No	Platform name	Year	Water depth (m)	Sea zone	Operator
1	Cognac	1978	312	GOM	Shell
2	Amberjack	1991	314	GOM	BP
3	Heritage	1992	326	South. Cali.	ExxonMobil
4	Virgo	1999	344	GOM	Total-Fina-Elf
5	Harmony	1992	366	South. Cali.	ExxonMobil
6	Pompano	1994	393	GOM	BP
7	Bullvinkle (*)	1991	412	GOM	Shell

(*) Maximum water depth at present time

σ_{v_x}: Standard deviation of random process v_x, determined by the variance of velocity v_x as follows:

$$\mathrm{Var}\,(v_x) = \sigma_{V_X}^2 = \int_0^\infty S_{V_X V_X}(\omega)d\omega$$

From (1), we obtain the wave load spectrum:

$$S_{FF}(\omega) = \frac{2(\rho D\ C_D \sigma_{v_x})^2}{\pi} S_{v_x v_x}(\omega) + (\rho C_I A)^2 S_{a_x a_x}(\omega) \qquad (2)$$

The expression (2) can be written by the new form below, taking into account the relationship between $S_{a_x a_x}(\omega)$, $S_{v_x v_x}(\omega)$ and $S_{\eta\eta}(\omega)$:

$$S_{FF}(\omega) = \left[\frac{2(\rho D C_D \sigma_{V_X})^2}{\pi} + (\rho C_I A)^2 \omega^2\right]\left(\omega \frac{\mathrm{ch}(ky)}{\mathrm{sh}(kd)}\right)^2 S_{\eta\eta}(\omega) \qquad (3)$$

Where $S_{\eta\eta}(\omega)$ is surface wave spectrum.

In the general case, the wave load acting on the diagonal elements with the circle cross-section of jacket structure, taking into account the structural displacement, Morison's equation (1) is written by the vector form, depending on the relative velocity vector of water particles (v) and structure, and on the relative acceleration vector of water particles (a) and structure, where $C_I = 1 + C_m$, C_m is added coefficient, and the relative acceleration calculated only with the term corresponding to C_m [16].

3. Random dynamics problem of the jacket structures

3.1. Problem of single-degree-of-freedom structure

The governing equation of single-degree-of-freedom problem is given by [2]:

$$M\ddot{u} + C\dot{u} + Ku = F(t) \qquad (4)$$

Where: M, C and K: Mass, damping coefficient and stiffness of structure;

F(t): Random acting on the structure;

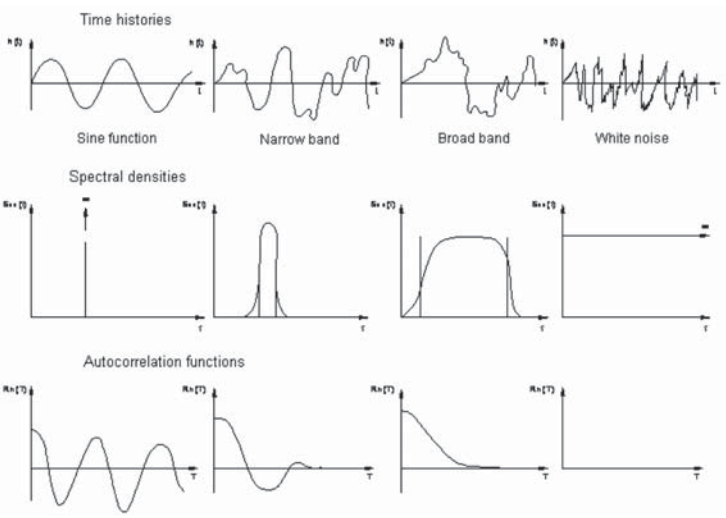


Fig. 3. *The relationship between stationary random h(t), correlation function, and spectral density function for various spectral bandwidths*

u (t): Displacement, ie. Structural response.

Let $R_{FF}(\tau)$ be the autocorrelation function of stationary random process F(t), and using the Fourier transformation for $R_{FF}(\tau)$, we obtain:

$$R_{FF}(\tau) = \int_{-\infty}^{\infty} S_{FF}(\omega)\, e^{i\omega t}\, d\omega \qquad (5)$$

Where: $S_{FF}(\omega)$: Spectral density of random process F(t), can be considered as Fourier image of the autocorrelation function $R_{FF}(\tau)$, given by:

$$S_{FF}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} R_{FF}(\tau)\, e^{-i\omega t}\, d\tau \qquad (6)$$

The pair of Eq. (5) and (6) is called Khintchine-Wiener expression; it plays the important role in the methodology of random dynamics problems. The relationship (6) allows transferring the original problem with the autocorrelation of time variable (t) to the new problem with the spectral density of the frequency variable (ω). This new problem can be favourably solved. The forms of this transformation are expressed in Fig. 3.

Using once again the Khintchine - Wiener expressions for random process u(t), [in taking into account of the linear system (4), u(t) is also a stationary random process], we obtain:

$$R_{uu}(\tau) = \int_{-\infty}^{\infty} S_{uu}(\omega)\, e^{i\omega\tau}\, d\omega \qquad (7)$$

and $$S_{uu}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} R_{uu}(\omega)\, e^{-i\omega\tau}\, d\omega \qquad (8)$$

Solving the problem (4) based on the spectral theory, one gets the important result which permits determination of the structural response spectrum density function, $S_{uu}(\omega)$ [2]:

$$S_{uu}(\omega) = |H(i\omega)|^2\ S_{FF}(\omega) \qquad (9)$$

Where:

H(iω) - Transfer function of the SDOF structure subjected to stationary random loads: it is the complex function as follows

$$H(i\omega) = \frac{1}{(K - M\omega^2) + iC\omega} \qquad (10)$$

|H(iω)|: Module of the transfer function determined by

$$|H(i\omega)| = \frac{1}{\left[(K - M\omega^2)^2 + (C\omega)^2\right]^{1/2}} \qquad (11)$$

Either: $$|H(i\omega)| = \frac{1}{K}\frac{1}{\left[(1-\Omega^2)^2 + (2\xi\Omega)^2\right]^{1/2}} \qquad (12)$$

Or:

$$\left|H(i\omega)\right| = \frac{1}{M}\frac{1}{\left[\left(\omega_1^2-\omega^2\right)^2+\left(2\varepsilon\omega\right)^2\right]^{1/2}} \quad (13)$$

Where: $\Omega = \frac{\omega}{\omega_1}$; $\omega_1 = (K/M)^{1/2}$: Natural angular frequency of structure;

$C = 2\varepsilon M$; $\xi = \frac{C}{2\sqrt{KM}}$: Damping ratio.

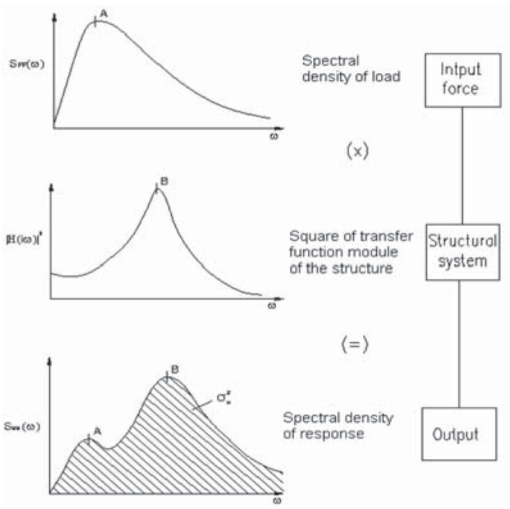
Hence, square of the transfer function is evaluated by:

$$\left|H(i\omega)\right|^2 = \frac{1}{K^2}\frac{1}{\left[\left(1-\Omega^2\right)^2+\left(2\xi\Omega\right)^2\right]} \quad (14)$$

From (9) one can conclude: The spectral density of output (response of the structure) equals the product of spectral density of input (load) and square of the transfer function module (Fig. 4).

The variance of structural response can be determined by formula:

$$\sigma_u^2 = R_{uu}(0) = \int_0^\infty S_{uu}(\omega)\,d\omega = \int_0^\infty \left|H(i\omega)\right|^2 S_{FF}(\omega)d\omega \quad (15)$$



(a)
(b)
(c)

Fig.4. *Relationship between load spectrum density and response spectrum density, by Eq.(9)*

The transfer function H(iω) still has meaning as a Response-Amplitude Operator (RAO), which can be used in Eq.(9) giving new form [2]:

$$S_{uu}(\omega) = [RAO]^2 S_{\eta\eta}(\omega) \quad (16)$$

3.2. Problem of multi-degree-of-freedom structure

The governing equation of the multi-degree-of-freedom (MDOF) problem for the jacket structure is performed as the principle of finite element method, and has the form developed from the SDOF problem:

$$M\ddot{U} + C\dot{U} + KU = F(t) \quad (17)$$

Where:

M: Mass matrix of structure, including added mass;

C: Matrix of structural and hydrodynamic damping coefficient;

K: Stiffness matrix of structure;

F(t): Vector of random wave loads, calculated using the linearised Morison's equation with absolutely rigid structure model;

U, $\dot{U}$ and $\ddot{U}$: Vectors of displacement, velocity and acceleration at structural nodes.

Using the mode superposition method as in the deterministic dynamics problem, the procedure of solving the random dynamics problem (17) in the frequency domain is given as follows:

1) Establisment of modal matrix: ϕ (n x n).

2) Change of variable from *U(t) to Y(t)* basing on ϕ:

$$U(t) = \phi\, Y(t) \quad (18)$$

The meaning of Eq.(18) is to express the structural response U(t) by modes of structure ϕ.

3) Establishment of dynamic equations with variable *Y(t)*: Substituting (18) in Eq.(17), then product at left of all terms and ϕ^T, one gets

$$\phi^T M\phi\ddot{Y} + \phi^T C\phi\dot{Y} + \phi^T K\phi Y = \phi^T\ F(t) \quad (19)$$

Note that the damping matrix C is often recognised as depending on M and K with the form [2]:

$$C = \gamma_1 M + \gamma_2 K \quad (20)$$

Where: γ_1 and γ_2 are damping constants.

For offshore structures the damping matrix, including hydrodynamic damping, can be received by [2]:

$$C = \gamma_1 M = 2\varepsilon M; \quad \varepsilon \approx (0{,}05 \div 0{,}1)\,\omega_1$$

Owing to the perpendicularity of modes, Eq. (19) can be transferred to new form:

$$M'\ddot{Y} + C'\dot{Y} + K'Y = F'(t) \quad (21)$$

Where:

$M' = \phi^T M\,\phi$: Generalised mass matrix, diagonal matrix;

$$M' = \begin{bmatrix} M_1' & 0 & . & . & 0 \\ 0 & M_2' & . & . & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & . & . & M_n' \end{bmatrix};$$

$C' = \phi^T C \phi$: Generalised damping matrix, diagonal matrix;

$K' = \phi^T K \phi$: Generalised stiffness matrix, also diagonal matrix;

$$C' = \begin{bmatrix} C'_1 & 0 & . & . & 0 \\ 0 & C'_2 & . & . & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & . & . & C'_n \end{bmatrix}; K' = \begin{bmatrix} k'_{11} & 0 & . & . & 0 \\ 0 & k'_{22} & . & . & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & . & . & k'_{nn} \end{bmatrix};$$

F′(t): Generalised random load vector (n x l);

Y(t): Generalised random displacement vector (n x l).

4) Independent SDOF equation system:

Expanding the differential matrix equation (21) we receive n independent differential equations, in which each equation has the typical form of the SDOFs dynamics equation as follows:

$$M'_j \ddot{Y}_j + C'_j \dot{Y}_j + K'_{jj} Y_j = F'_{j(t)} \quad (22)$$

Where:

$$F'_j(t) = \phi_{j1} F_1(t) + \phi_{j2} F_2(t) + ... + \phi_{jn} F_n(t); j = \overline{1, n} \quad (23)$$

With F_k (k = 1, n) is the k[th] order element of random load vector.

5) Define the spectral densities of generalised loads: $F'_j(t)$, (j = 1-n): basing on the random process theory one gets the following expression with full form of spectral density of $F'_j(t)$:

$$S_{F'_j F'_k}(\omega) = \sum_{r=1}^{n} \sum_{s=1}^{n} \phi_{jr}(\omega) \phi_{ks}(\omega) S_{F_r F_s}(\omega); \left(j = \overline{1, n}; k = \overline{1, n}\right) \quad (24)$$

If neglecting the correlation between wave loads F_r and F_s $(r \neq s)$, ie. $S_{F_r F_s} \approx 0$, then Eq.(24) has the new simple form:

$$S_{F'_j F'_k}(\omega) = \sum_{r=1}^{n} \phi_{jr}(\omega) \phi_{kr}(\omega) S_{F_r F_r}(\omega); \left(j = \overline{1, n}; k = \overline{1, n}\right) \quad (25)$$

For the case j = k, from (25) we have:

$$S_{F'_j F'_j}(\omega) = \sum_{r=1}^{n} \phi_{jr}^2(\omega) S_{F_r F_r}(\omega) \quad (26)$$

6) Determine the transfer function in generalised coordinate system

The complex transfer function of generalised coordinate j (j = 1, n) for the SDOF system equation (22):

$$H_j(i\omega) = \frac{1}{K'_{jj} - M'_j \omega^2 + i C'_j \omega} \quad (27)$$

Hence, the module of transfer function (27) has form:

$$|H_j(\omega)| = \frac{1}{\sqrt{\left(K'_{jj} - M'_j \omega^2\right)^2 + \left(C'_j \omega\right)^2}} \quad (28)$$

These densities can be easily defined by the same way as for the SDOF system problem:

$$S_{Y_j Y_k}(\omega) = H_j^*(i\omega) H_k(i\omega) S_{F'_j F'_k}(\omega) \quad (29)$$

j = (1, n); k = (1, n)

Where:

$H_j^*(i\omega)$: Complex conjugate of the function $H_j(i\omega)$ (27);

$S_{F'_j F'_k}(\omega)$: Cross spectral density of two generalised loads (24).

7) Determine response spectral densities of the n-DOF system

The relationship between response $U_j(t)$ and generalised coordinates $Y_1(t)$, $Y_2(t)$, ...,$Y_n(t)$ is given from matrix (18) by the general formula below:

$$U_j t = \phi_{j1} Y_1 t + \phi_{j2} Y_2(t) + ... + \phi_{jn} Y_n(t); \; j = \overline{1, n} \quad (30)$$

Hence, one obtains the displacement spectral densities of n-DOF structure of the original problem (17) with the full form:

$$S_{u_j u_j}(\omega) = \sum_{r=1}^{n} \sum_{s=1}^{n} \phi_{jr}(\omega) \phi_{js} \omega S_{Y_r Y_s}(\omega); \; \left(j = \overline{1, n}\right) \quad (31)$$

Considering as $S_{Y_j Y_j}(\omega) = S^*_{Y_r Y_s}(\omega)$, so Eq.(31) has new form :

$$S_{u_j u_j}(\omega) = \sum_{r=1}^{n} \phi^2_{jr}(\omega) S_{Y_r Y_r}(\omega) + 2 \sum_{r=2}^{n} \sum_{s=1}^{r-1} \phi_{jr}(\omega) \phi_{js}(\omega) \operatorname{Re}\left\{S_{Y_r Y_r}(\omega)\right\}; \left(j = \overline{1, n}\right) \quad (32)$$

Where: Re{*}: Real part of the complex function (29).

In practical analysis and design with acceptable exactitude, the terms of cross spectral densities between generalised coordinates in Eq.(32) are often neglected, so one has the new shorter form:

$$S_{u_j u_j}(\omega) = \sum_{r=1}^{n} \phi^2_{jr}(\omega) S_{Y_r Y_r}(\omega) \quad (33)$$

The variance of jacket structure response (ie. square of the displacement standard deviation) is determined based on the spectral density function (33) as follows:

$$\sigma_{u_j}^2 = \int_0^\infty S_{u_j u_j}(\omega) d\omega = \int_0^\infty \sum_{r=1}^{n} \phi_{jr}^2(\omega) S_{Y_r Y_r}(\omega) d\omega = \sum_{r=1}^{\infty} \int_0^\infty \phi_{jr}^2(\omega) S_{Y_r Y_r}(\omega) d\omega \quad (34)$$

3.3. Evaluate the spectral densities of internal forces and stress of the jacket structure

The main purpose of random dynamics problem of the jacket structure (17) is already performed, that is to determine the structural joint spectral density by either (32) or (33).

However, in order to realize the strength problems of structures by the reliability theory, as presented below, it is necessary to determine the spectra of internal forces, then stresses at jacket structural typical positions.

The total force vector (F_T) acting on all structural jacket joints depended on their displacements U(t) with the algebraic relationship, is determined from Eq. (17):

$$F_T(t) = K.U(t) = F(t) - [M\ddot{U} + C\dot{U}] \quad (35)$$

We can find then the internal forces and stresses with algebraic relationship also of the total loads $F_T(t)$.

The calculation procedure can be realized by starting from the structural spectrum by (31) or (32), $S_{u_i u_j}(\omega)$, for obtaining the total force spectrum, $S_{F_T F_T}(\omega)$, then internal force spectrum and finally one sets the maximum stress (σ_m) spectrum of all typical structural points necessary for the strength checking, $S_{\sigma_m \sigma_m}(\omega)$.

From spectrum $S_{\sigma_m \sigma_m}(\omega)$, the standard deviation of maximum stress is given by

$$\sigma_{\sigma_m \sigma_m}(\omega) = \left[\int_0^\infty S_{\sigma_m \sigma_m}(\omega) d\omega \right]^{1/2} \quad (36)$$

This standard deviation is main parameter of the distribution function of random maximum stress at points under consideration, used later for the structural reliability assessment in strength checking.

4. Strength checking of jacket structure in deepwater zone

4.1. Strength checking of jacket structures by probability model basing on reliability

The structural reliability in strength condition at typically dangerous positions of the jacket structure is given under the probability form as follows [4], [5]:

$$P = \text{Prob}(R \geq S) = \text{Prob}(Z = R - S \geq 0) \quad (37)$$

Where:

R = Strength of material, with its probabilistic density function (PDF), f_R;

S = Random maximum stress of checking point, with its PDF, f_S;

P = Reliability in strength condition at checking point.

From reliability (37), one can receive the failure probability at the point under consideration:

$$P_f = 1 - P = \text{Prob}(Z = R - S < 0) \quad (38)$$

The safety condition by structural reliability is expressed by:

$$P = \text{Prob}(Z = R - S \geq 0) \geq [P] \quad (39)$$

or

$$P_f = 1 - P < [P_f] \quad (40)$$

Where:

[P]: Permissible (or acceptable) reliability;

[P_f]: Permissible (or acceptable) reliability of failure.

From Eq. (37) and (38) we see that *Z = R - S* is the safety zone of strength condition, also the random variable with its PDF, f_Z.

Fig. 5 is the diagram of PDF of three random variables R, S and Z = R - S, and failure probability described by the shaded area of the f_Z curve.

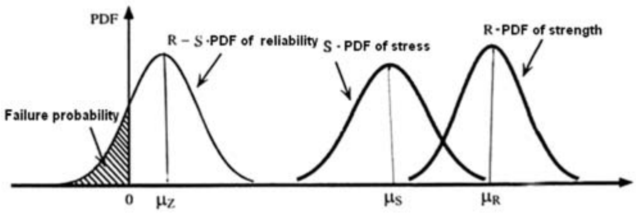


Fig.5. *PDF diagram of the random variables R, S and Z = R – S*

Note that in Eq. (37) the maximum stress, S, at the strength checking point, is the total stress consisting of two components, in which only the second one (S_2) is random variable:

$$S = S_1 + S_2 \quad (41)$$

Where:

S_1: Stress at the point under consideration due to deterministic loads, with constant value;

S_2: Maximum stress, σ_{max}, of zero-mean random process, σ(t), due to random waves.

The distribution function of random process of stress S_2, is determined based on the bandwidth of its spectrum, $S_{\sigma_m \sigma_m}(\omega)$ either narrow or broad as well as any band. The distribution function of total maximum stress S in Eq. (41), f_S, can be given based on the distribution function of random stress S_2. From the distribution functions f_S, and f_R (of material strength), we obtain the distribution function Z = R - S, so called f_Z, (Fig. 5).

The structural reliability is still expressed by the reliability index as follows:

$$\beta = \frac{\mu_Z}{\sigma_Z} = \frac{\mu_R - \mu_S}{\sqrt{\sigma_R^2 - \sigma_S^2}}; \qquad (42)$$

and the structural safety is still estimated by its reliability index with the expression:

$$\beta \geq [\beta] \qquad (43)$$

Where:

μ_R, μ_S and μ_Z: Mean value of random variables R, S and Z, with μ_S = S1 [see Eq. (41)];

σ_R, σ_S and σ_Z: Standard deviation of random variables R, S and Z;

[β]: Permissible (or acceptable) reliability.

4.2. Safety checking of structures by the deterministic model based on maximum probability value

If there is not now regulation in design standards using the reliability theory for structural strength checking, one can transfer the reliability model to the deterministic model based on probabilistic theory for obtaining the approximate maximum stress value of random variable max σ(t).

In the case of narrow band spectral density of stress, σ(t), of the checking point, $S_{\sigma\sigma}(\omega)$, the random variable max σ(t) has Rayleigh distribution function, and the approximate maximum stress value in N stress cycles of the extreme sea state is approximately evaluated by the following formula [2]:

$$\sigma_{max} = \sqrt{M_o} \cdot \sqrt{2\ln(N)}; \qquad (44)$$

Where:

$$M_o = \int_0^\infty S_{\sigma\sigma}(\omega).d\omega; \; N = \frac{T^*}{T_Z} = \frac{T^*}{2\pi}\sqrt{\frac{M_2}{M_o}};$$

with: $S_{\sigma\sigma}(\omega)$: Spectral density of the stress random process σ(t);

T^* (sec): Duration of the extreme sea state, normally used with 3 or 6hrs for a storm;

$T_Z = 2\pi.\sqrt{\frac{M_o}{M_2}}$ (sec): Mean zero-upcrossing period of random process σ(t), depending on the k^{th}-order spectral moments, M_k, eg. M_0 for k = 0, M_2 for k = 2.

5. Application to deepwater condition in Nam Con Son basin

In our country today, the fields are being exploited in up to just 150m water depth. In the future, the strategy objective of the Petrovietnam Group is to exploit oil and gas fields in deepwater zones of over 200m depth on the Vietnam continental shelf [10], [11].

In the previous research by the same authors on choosing the appropriate solution for jacket structure in 200m deepwater conditions at the Nam Con Son basin based on the deterministic wave load model, research results were presented in a paper in the Petrovietnam Journal Vol. 6/2010 [18].

The research methology application of this paper is realized for a concrete jacket structure in deepwater zone of Vietnam sea. In order to compare favorably between the „rough" models for deterministic wave and the more exact model for random wave, the same jacket structure installed in the same natural environmental conditions in the Nam Con Son basin is used.

5.1. Geometric shape of the fixed jacket structure installed in deepwater zone of Nam Con Son basin

The jacket structure configuration in 200m water depth of Nam Con Son basin as the same one presented in

Table 2. *Overall configuration of the jacket structure*

Parameter	Jacket of 200m depth	Parameter	Jacket of 200m depth
Top Dimension	22 x 48m	Slope	I = 1/10
Number of wells	16	Largest distance between two diaphragms	30m
Number of Risers	4	Smallest distance between two diaphragms	20m

Table 3. *Preliminary selection of jacket members, piles, and construction method*

Main parameters	Jacket of 200m depth	Main parameters	Jacket of 200m depth
Legs	From ϕ 3000 x 4 to ϕ1067 x 25.4	Brace system	K and X form braces
Braces	From ϕ 813 x 20.6 (at bottom) to ϕ 508 x 15.9 (jacket top)	Construction method	Load out by skidding to barge, transportation to the sea site installation by launching
Pile diameter	ϕ 1219	Piling solution	Vertical skirt piles connected by under-water welding

the published paper [18], has main parameters given in Table 2, Table 3 and Fig. 6.

5.2. Main results of the strength problem

Some typical calculation results are presented below basing on the API standard (API - RP 2A WSD) [7], and using professional software SACS (specified for offshore structures by spectral method).

5.2.1. Natural frequencies and dynamic coefficient

Three first periods (s)	Dynamic coefficient
T1 = 2.7 (DY) T2 = 2.1 (DX) T3 = 1.5 (RZ)	1.14

5.2.2. Main results of the strength problem (in comparing with the deterministic model)

- Strength checking of some typical elements

- Strength checking of some typical joints

5.3. Conclusion

- The member at the bottom bay and top pile have highest ratio of used material; this is the appropriate distribution of internal forces in the jacket structure.

- The used material ratio in calculation by the random model is a little greater than by the deterministic model [18], noting that the random model gives the calculation results more exactly than the deterministic model;

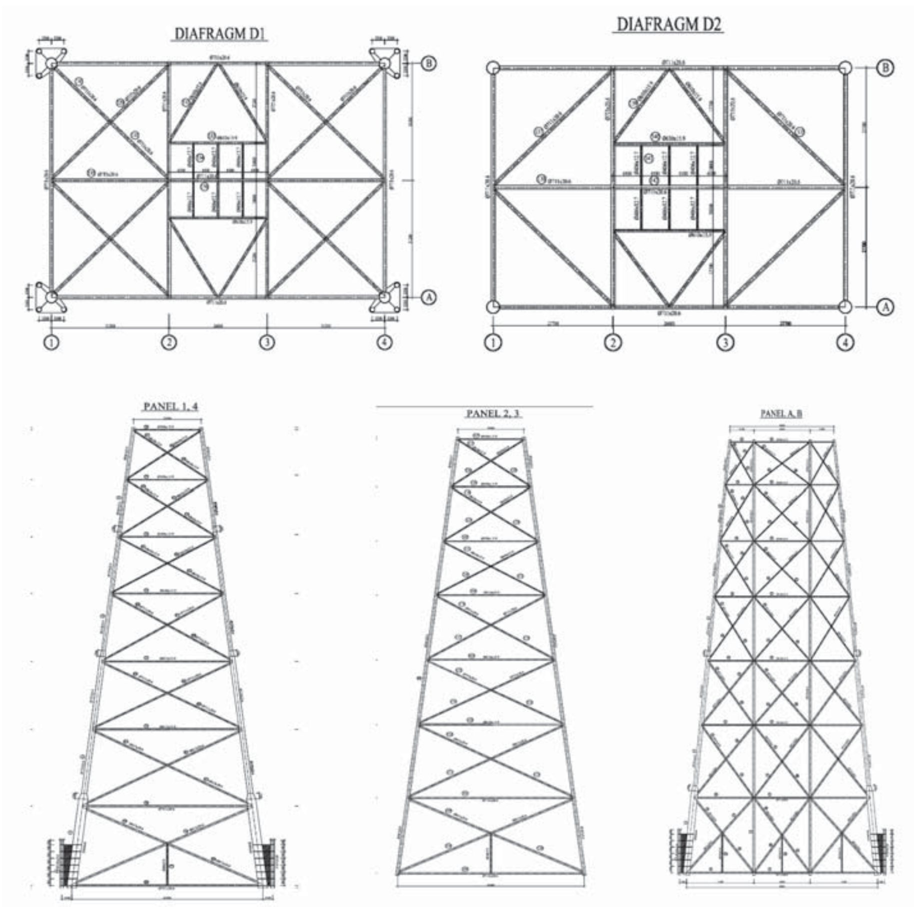


Fig.6. *Layout of the jacket structure chosen with 213m height, chosen for 200m water depth zones*

Element	Position	Used material ratio	
		Deterministic dynamic model	Ramdom dynamic model
469 - 293	Bottom bay braces	0.96	1.02
195 - 295	Pile	1.05	1.07

Joint	Location	Used material ratio	
		Deterministic dynamic model	Ramdomdynamic model
62	Second bay (from seabed) Face x = -13m	0.96	1.03
63	Second bay (from seabed) Face x = 13	0.97	1.05

- The used material ratio of some members and joints has values of 1,05 and 1,07; this means that their behaviour is exploited in maximum and permisible also by current API standard.

- Almost jacket members have the used material ratio values less than 1.0, except the element 195 - 295 with value of 1.05, but it is acceptable for API standard.

- The jacket structure configuration above chosen with 200m water depth in specified sea zone satisfied entirely technique condition (strength safety of structure) as well as economic condition (saving material volume as using in maximum the permissible used material ratio values).

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