**2.019, Spring 2011**

# Guidance for Part III Design: Mooring System Design

General:

- You may consider only the head sea situation with wind, current, and waves all coming from the same direction (say, along the negative x-direction).

- 100-year survival environment:

  - Wind speed – 40 m/s
  - Current – 1.5 m/s
  - Wave – JONSWAP spectrum with $H_{1/3}$ =12 m, $T_p$ =14 s, $\gamma$= 3 ~5 (just be consistent with your other parts of design)

- You may assume 10% ~ 20% critical damping for slowly-varying response of the FPSO (the damping includes effects from mooring damping, viscous damping on the hull due to current and wind, and wave drift damping from nonlinear effect)

- You need to examine the maximum tension for one cable only (which is the most dangerous one) for both intact and damaged cases

(a) Under the head sea condition, (i) determine steady wind, current, and wave drift loads on the FPSO; (ii) determine slowly-varying wave loads on the FPSO; and (iii) determine wave-frequency motions of the FPSO

(i) Steady loads: estimate ship surface area on wind and current, use simple empirical formula to compute the steady wind and current loads. Use the formula to compute steady wave force :

$$\bar{F}_x = \sum_{j=1}^{N} \left( \frac{\bar{F}_1(\omega_j)}{\zeta_a^2} \right) A_j^2$$

$\bar{F}_1(\omega_j)/\zeta_a^2$ is the wave draft force transfer function outputted from seakeeping computation in head sea. $A_j = \sqrt{2S(\omega_j)\Delta\omega_j}$ amplitude of the wave component with frequency $\omega_j$.

is the wave

(ii) Slowly-varying force: use Newman's approximation to compute slowly-varying wave force on the FPSO:

$$S_F(\mu) = 8 \int_0^{\infty} S(\omega)S(\omega+\mu) \left[ \frac{\bar{F}_1\left(\omega+\frac{\mu}{2}\right)}{\zeta_a^2} \right]^2 \mathrm{d}\omega \qquad (1)$$

Note that you only need to compute $S_F(\mu_n)$ $\mu_n$ being the natural frequency of slowly varying surge motion.

with

(iii) You should have the solution from the Part II design.

(b) Develop a preliminary design of the mooring system

Suggest to use 12 identical lines. (a) Divide 12 lines into three groups, which are separated by 120º in the horizontal plane, or (b) divide 12 lines into four groups, which separated by 90º in the horizontal plane. The property of the line is suggested in the table below:

| Segment | Type | Length m | Diameter[(1)] mm | Wt. in water kg/m | Wt. in air kg/m | EA[(2)] tonne |
|---|---|---|---|---|---|---|
| 1 (at fairlead) | Studless Chain | 60 | 132 | 303.2 | 349.0 | 164474 |
| 2 | Jacket SS Wire | 2500 | 144 | 60.0 | 77.0 | 137931 |
| 3 (at anchor) | Studless Chain | 250 | 132 | 303.2 | 349.0 | 164474 |

(1) For chain diameter is nominal bar diameter, for Spiral Strand diameter includes jacket
(2) EA is effective stiffness.

Note that:

- You could change the length and property of each line segment if you prefer.
- In your analysis, you can align one group of line in the surge direction, and compute the maximum tension of a cable in this group.

## (c) Compute load-excursion relations

Use software RISER-SIM to compute load-excursion relations.

- Choose 10 to 20 positions for x in the range of -100m to 100m, and compute (i) horizontal (in surge direction), vertical, and total tension force of a single cable (in each group); and (ii) total horizontal tension force (in surge direction) and vertical force of the mooring system.
- Plot each load-excursion relation.

## (d) Compute: (i) steady tension in the cable and steady horizontal displacement of the FPSO; (ii) wave-frequency tension in the cable; (iii) estimate (surge) natural frequency of the FPSO; and (iv) slowly-varying tension in the cable and slowly-varying displacement of the FPSO

- From the obtained load-excursion relations, determine spring constants of the mooring system and each single line. Use these spring constants to compute (i), (ii), (iii), and (iv).

## Estimate of Slowly-Varying Motion

Spectrum of slowly-varying motion:

$$S_x(\omega) = \frac{S_{F^{sv}}(\omega)}{[c-\omega^2(m+M_a)]^2+b^2\omega^2}$$

Variance:

$$\begin{aligned}
\sigma_x &= \int_0^\infty S_x(\omega)\mathrm{d}\omega \\
&= \int_0^\infty \frac{S_{F^{sv}}(\omega)}{[c-\omega^2(m+M_a)]^2+b^2\omega^2}\mathrm{d}\omega \\
&\approx S_{F^{sv}}(\omega_n)\int_0^\infty \frac{\mathrm{d}\omega}{[c-\omega^2(m+M_a)]^2+b^2\omega^2} \\
&= \frac{\pi}{2cb}S_{F^{sv}}(\omega_n)
\end{aligned}$$

Source of c: mooring lines

Source of b: (i) related to hull from — friction, flow separation, current/wind, **wave drift damping**

(ii) mooring lines

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