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Abstract

Leadline Maritime carries out computational mooring assessments in both terminal engineering and offshore engineering assessments. Various standards can be adopted, the most common being OCIMF and DNV. Typically OCIMF is used in terminal engineering (which can be supplemented by British Standards) while DNV Position Mooring (OS-E301) is used in Offshore Engineering services. Their implementation is slightly different. DNV follows a load and resistance design approach that takes safety factors on both the load and resistance into account and specifies different safety factors based on a consequence class and mooring situation (permanent or mobile). OCIMF does not at the moment of writing consider the mooring situation and consequence class in too much detail. The aim of this article is to compare results using the standard OCIMF guidelines and DNV Position Mooring Standard. Although DNV is more of an offshore standard, it is well applicable for floating units with position mooring systems consisting of chain links, steel wire ropes, synthetic fibre ropes and a combination of these components when moored at a quayside. In this example, line tensions will be evaluated in two limit states according to both design approach.

1. Mooring model

1.1. Setup

In this example a tanker type vessel is moored next to a quay wall by using 18 nylon double braided mooring lines on 8 bollards as shown in Figure 1-1. The manifold eccentricity is 12.65m and lines are pretensioned with 10t. The Working Load Limit (WLL) is 50% of the MBL. Wind is modelled in 22.5° sectors, using 1/10 year^{-1} wind speeds per sector (API spectrum). Both intact and single line failure (where each individual line is removed in a separate analysis) is considered.

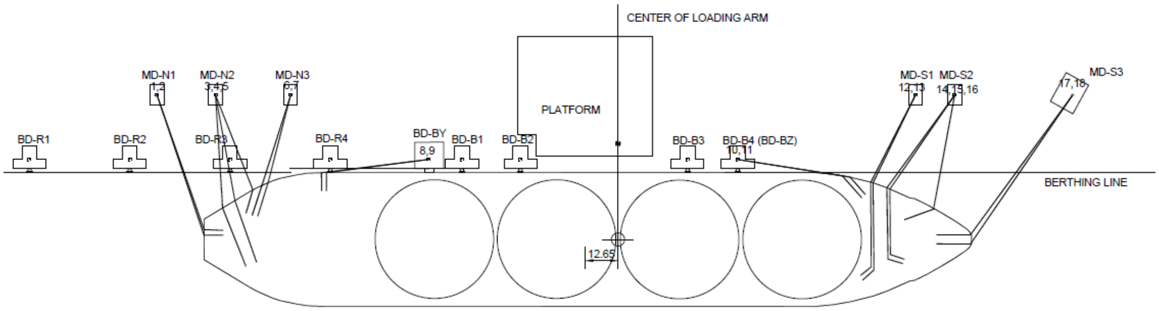

Figure 1-1: moored vessel setup

1.2. Design methodology

The mooring system shall be analyzed according to design criteria formulated in terms of three limit state equations.

- Ultimate Limit State. Used to ensure that the individual mooring lines have adequate strength to withstand the load effects imposed by extreme environmental actions.
- Accidental Limit State. Used to ensure that the mooring system has adequate capacity to withstand the failure of one mooring line (or thruster).
- Fatigue Limit State. Used to ensure that the individual mooring lines have adequate capacity to withstand cyclic loading. This limit state is disregarded further in this analysis (typically steel components are susceptible to fatigue).

Each limit state is formulated as a design equation or inequality in the form:

The limit state is formulated as a design equation in the form:

$$S_{mbs} - S_{char}\gamma \geq 0 \qquad \text{\{Eq. 1\}}$$

Where:

- S_{mbs} : design capacity.
- S_{char}: characteristic load effect.
- γ: partial safety factor on load-effect.

1.3. Definitions

The general response analysis shall be performed by applying either a frequency domain or a time domain method. A time domain analysis is preferred in case non-linearities of wave and motion variables are involved. From the time domain analysis global maxima are obtained during a 3-hour simulation time. These global maxima are independent stochastic variables often modelled by a Gumbel distribution. The limit state is formulated as follows:

$$S_c - T_{pret}\gamma_{pret} - T_{c,env}\gamma_{env} \geq 0 \qquad \{\text{Eq. 2}\}$$

The above equation can also be written as a utilization factor:

$$u = \frac{T_{pret}\gamma_{pret} + T_{c,env}\gamma_{env}}{S_c} < 1 \qquad \{\text{Eq. 3}\}$$

Where:

- S_c: characteristic strength. In some cases, the characteristic strength can be reduced, for example in case of corrosion, or when steel wire rope goes over a fairlead. In this example, the characteristic strength is taken as the Minimum Breaking Load.
- T_{pret}: pretension value. This is the static tension due to environmental loading.
- γ_{pret}: safety factor on pretension.
- γ_{env} : safety factor on environmental tension.
- $T_{c,env}$: environmental tension. The environmental tension is calculated as the maximum dynamic (occurring in a 3-hour simulation) load minus the pretension load.

$$T_{c,env} = T_{MPM} - T_{pret} \qquad \{\text{Eq. 4}\}$$

- T_{MPM}: most probable maximum value, obtained from running multiple realizations (more information is described in Article 003).

1.4. Consequence classes

Two consequence classes are introduced in the ULS and ALS, being:

- Class 1, where mooring failure is unlikely to lead to unacceptable consequences such as loss of life, collision with an adjacent platform, uncontrolled outflow of oil/gas, capsize or sinking.
- Class 2, where mooring line failure may well lead to unacceptable consequences of these types.

1.5. Safety factors

The safety factors to consider in ULS and ALS for chain, steel wire ropes and synthetic fibre ropes in a time domain analysis are described in below table.

Table 1-1: Limit State safety factors

Limit State	Consequence Class	Type of Unit	γ_{pret}	γ_{env}
ULS	1	Permanent	1.2	1.45
	1	Mobile	1.2	1.35
	2	Permanent & Mobile	1.2	1.90
ALS	1	Permanent	1.0	1.10
	1	Mobile	1.0	1.05
	2	Permanent & Mobile	1.0	1.45

1.6. Evaluation of test case

For the design vessel the maximum lines loads for the considered wind conditions have been evaluated for both ULS (intact) and ALS (single line failure). The result is shown in Table 1-1. In the comparison, a representative utilization factor of 50% MBL (ULS) and 70%MBL (ALS) has been used to get an equivalent OCIMF utilization factor. Note: only line utilization is considered. Other factors such as manifold envelopes within the existing marine loading arm is not considered for the purpose of this article.

Table 1-2: results test case

Line number	Max Load in ULS	Max Load in ALS	Utilization factor ULS (DNV)	Utilization factor ULS (OCIMF)/ 50% WLL	Utilization factor ALS (DNV)	Utilization factor ALS (OCIMF) / 70% MBL
Line01	43.5	51.2	49%	56%	45%	47%
Line02	42.4	52.4	47%	54%	46%	48%
Line03	43.5	39.3	49%	56%	34%	36%
Line04	43.5	41.9	49%	56%	36%	38%
Line05	43.5	55.8	49%	56%	49%	51%
Line06	31.3	33.4	34%	40%	28%	31%
Line07	31.3	34.1	34%	40%	29%	31%
Line08	27.0	35.2	28%	35%	30%	32%
Line09	26.7	35.6	28%	34%	30%	33%
Line10	61.0	96.6	70%	78%	87%	88%
Line11	61.0	95.7	70%	78%	86%	88%

Line12	49.5	41.7	56%	63%	36%	38%
Line13	49.5	43.0	56%	63%	37%	39%
Line14	40.7	35.1	45%	52%	30%	32%
Line15	40.7	36.8	45%	52%	31%	34%
Line16	29.9	65.2	32%	38%	58%	60%
Line17	40.7	44.0	45%	52%	38%	40%
Line18	40.7	43.9	45%	52%	38%	40%

1.7. Conclusion

The following observations are drawn:

- OCIMF is the more conservative standard (with a maximum difference of 8% and 3% of the line utilization) of the two. This is because DNV considers a lower safety factor for the static part of the environmental loading. However, DNV can also consider a reduction of characteristic strength, for example when corrosion is applicable, or when steel wire goes over fairleads. This is not considered in this particular case.
- Both standards consider for this particular case the line utilization to be safe (<100%). In no condition one standard gives a safe result for operation while the other one gives an unsafe result.

Both standards are used in engineering assessments. There is no particular method we recommended over the other. Please contact us such that we can look into the project specifics and select the appropriate one for the management of your project.