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OCIMF MEG-4 and Mooring Design of your vessels – Part I

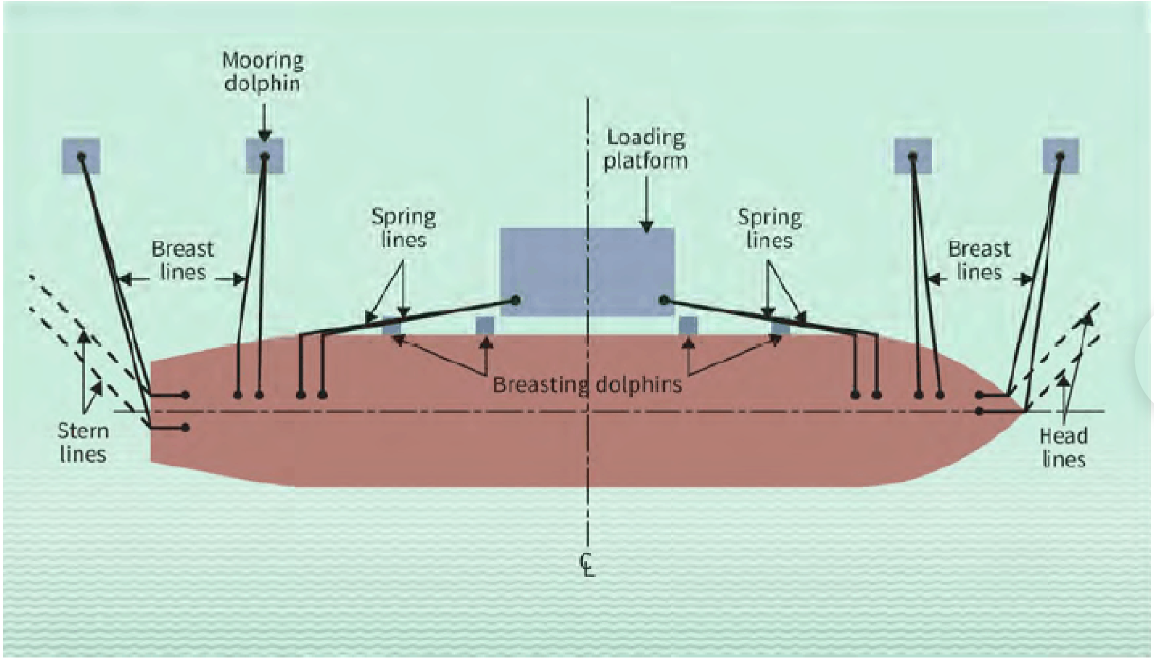
by Team TheNavalArch | Oct 12, 2019 | Marine Operations, Mooring | 1 comment

Part 1 – Environment and Environmental forces

The OCIMF (Oil Companies International Marine Forum) has come out with the latest edition of mooring Equipment Guidelines (MEG) – Rev 4. This revision incorporates significant changes and updates over the MEG-3, the third Edition. The changes include, besides other additions, a guidance on documentation of mooring equipment (Mooring System Management Plan), addition of a section on human

Mooring in the context of MEG-4 means mooring to a fixed structure like a berth, jetty, terminal or another ship.

Mooring Forces and Mooring Design



The design of mooring at berth can be broken down into a certain number of steps by thinking in very basic terms.

The problem at hand is – we are given a vessel, and we need to moor it to a berth. The first question which pops is why at all we need to berth the vessel? Why can't we just leave it floating? Well, if we leave it floating, it is subject to environmental elements of wind, current, waves, tides etc. These will make it drift, with the possibility of hitting another vessel in the vicinity.

The next thought that comes is: what's the best way to secure it to a berth? The simplest solution we can imagine is using ropes to tie it to strong and fixed structures on the berth. A ship needs equipment like bollards, fairleads and winches which can help secure the rope from ship to the mooring equipment on the berth.

So, how do we go about selecting the right sized rope? What about the bollards, fairleads and winches on the vessel? How big should they be? It is natural to expect that a bigger ship will require bigger sized

In simplest terms, mooring involves tying the vessel to a berth using ropes so that the vessel stays in place and is not carried away by the environment. The environment may comprise wind, current, tides, waves, ice, swell etc. which the berth is subject to.

To know how many and how big ropes and what size equipment are needed, we should have an estimate of how much environmental forces the vessel is subject to. Once we know the forces, we can go about tying ropes in such a way that these are able to resist the forces.

Hence, the steps to designing a mooring system can be:

- **Step 1**: Get the environmental data for the berth – wind, wave, current, tide etc.
- **Step 2**: Calculate, based on the size and geometry of the vessel, the total environmental forces on the vessel
- **Step 3**: Design a mooring system comprising ropes and equipment adequate for resisting the environmental forces obtained in Step 2. This includes designing the mooring pattern and selecting the right equipment.

In this article we'll look into Steps 1 and 2, while the Step 3 will be dealt with in Part 2.

Step 1 – Environmental data

The application of environmental data depends on the purpose which we're using it. If we're designing the mooring equipment of a specific berth or terminal, then the environment experienced at that specific berth is important. This is obtained from Metocean data for the specific berth location.

However, things are different if we're designing the mooring equipment for a ship (which is what this article talks about). A ship may visit multiple berths over its lifetime, and each berth may be subject to different environments. Does that mean that we gather the environmental data of each berth the ship is expected to visit over its lifetime, and then take the worst-case environment? Such an exercise will be extremely cumbersome.

used for the mooring design. However, these are applicable only for vessels with DWT 16000 MT and above. The criteria are shown below:

60 knot wind (defined below) from any direction simultaneously with:

3 knots current at 0 degrees or 180 degrees

or

2 knots current at 10 degrees or 170 degrees

or

0.75 knots from the direction of maximum beam loading

Loading Conditions and tidal variations

The ship may be loaded to different drafts, which leads to different windage and current areas. For example, when the vessel is ballasted, it has a higher windage area and so the wind forces are expected to be higher compared to other loading conditions with higher draft. Similarly, fully loaded condition with fetch higher current forces compared to other loading conditions.

For the purpose of mooring design, it is generally recommended to investigate two extreme conditions:

- Fully loaded condition at lowest astronomical tide (LAT)
- Ballasted condition at highest astronomical tide (HAT)

Water Depth to Draft Ratio

The ratio of Water Depth (WD) to Draft (T) is a critical parameter affecting the current forces on a vessel. OCIMF recommends the following values to be used for the WD/T ratio:

- For tankers, WD/T to be taken as 1.05 when loaded and 3.0 when in ballast condition
- For a gas carrier the WD/T should be taken as 1.05 for all conditions

Since the wind of 60 knots can be from any direction, simultaneously with current from either head/following seas or beam seas, we need to investigate all cases while varying the direction of current from 0 to 360 deg, and also varying the loading condition (ballast/loaded). To simplify, we can create cases by considering wind and current to be collinear (along the same direction), and investigate the cases listed below:

The cases are listed below:

Case	Environment				Loading Condition
	Wind Speed	Wind Direction	Current Speed	Current Direction	
Case 1	60 knots	0	3 kn	0	Ballast
Case 2	60 knots	180	3 kn	180	Ballast
Case 3	60 knots	10	2 kn	10	Ballast
Case 4	60 knots	170	2 kn	170	Ballast
Case 5	60 knots	90	0.75 kn	90	Ballast
Case 6	60 knots	0	3 kn	0	Loaded
Case 7	60 knots	180	3 kn	180	Loaded
Case 8	60 knots	10	2 kn	10	Loaded
Case 9	60 knots	170	2 kn	170	Loaded
Case 10	60 knots	90	0.75 kn	90	Loaded

Now that we have defined the environmental conditions – wind and current, which also included the loading conditions and water depth to draft ratio, we can move on to the next step: calculation of environmental forces.

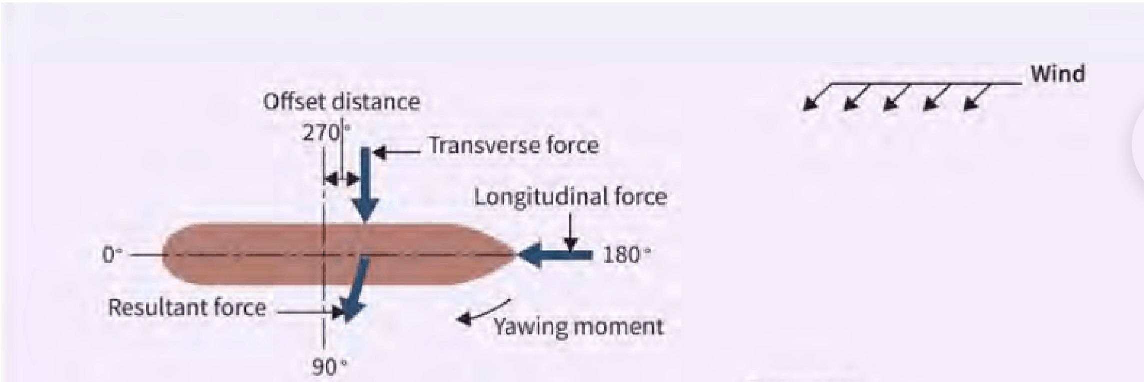
Step 2 – Environmental forces

At a berth, generally it is only wind and current forces which significantly impact the design of moorings.

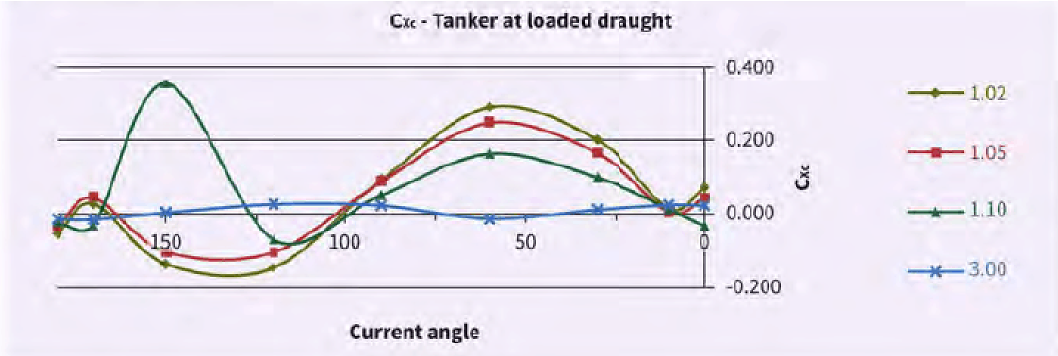
The environmental forces on the vessel can be calculated using the force coefficients provided in Appendix A of OCIMF MEG-4. These tables provide the coefficients for Wind and Current forces depending on the vessel heading, loading condition (ballasted/loaded) and also the Water Depth to Draft ratio. At this stage, and for the purpose of this article, waves and other factors which are 'dynamic' in nature

- Surge force or longitudinal force – wind and current forces faced by the fore or aft of the vessel
- Sway force or transverse force – wind and current forces faced by the beam of the vessel
- Yaw moment – wind and current yaw moment which makes the vessel turn about its vertical axis

The force coefficients provided in MEG-4 follow a specific sign-convention as per the figure below:



The coefficients can be obtained from the charts and tables provided in Appendix A of OCIMF MEG-4.



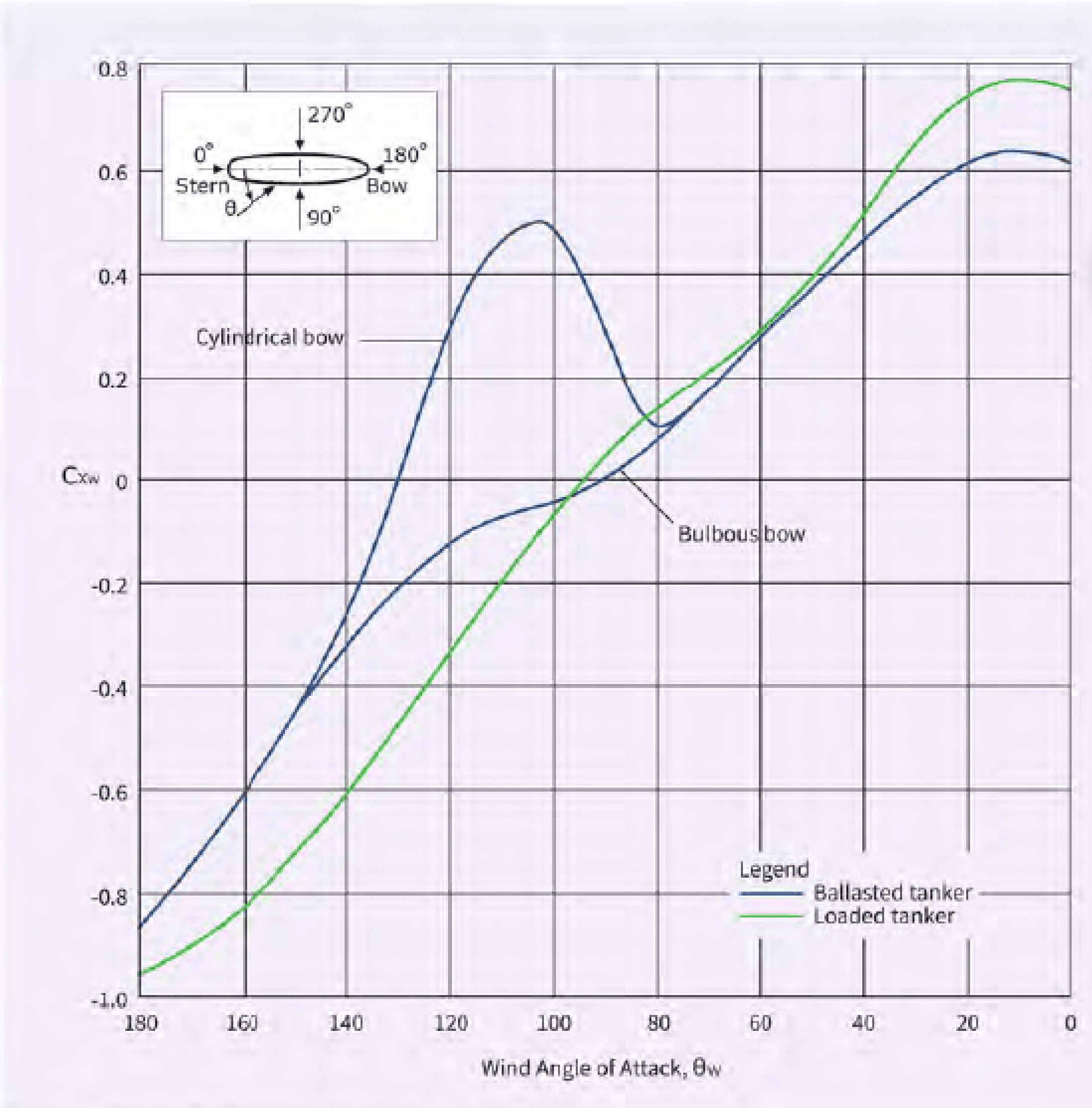


Figure A3: *Longitudinal wind drag force coefficient (C_{Xw})*

Next, we calculate, for all cases listed in Step 1, the environmental forces of wind and current (forces and moments).

The forces are obtained from the coefficients by using the standard formulae:

$$F_{XW} = \frac{1}{2} C_{XW} \rho_W V_W^2 A_T \qquad F_{XC} = \frac{1}{2} C_{XC} \rho_C V_C^2 L_{BP} T$$

$$F_{YW} = \frac{1}{2} C_{YW} \rho_W V_W^2 A_L \qquad F_{YC} = \frac{1}{2} C_{YC} \rho_C V_C^2 L_{BP} T$$

$$M_{XYW} = \frac{1}{2} C_{XYW} \rho_W V_W^2 A_L L_{BP} \qquad M_{XYC} = \frac{1}{2} C_{XYC} \rho_C V_C^2 A_L L_{BP}^2 T$$

Once we have the environmental forces, the next step is to design/select the mooring equipment based on the forces obtained.

Mooring equipment can be the following:

- Mooring lines and shackles
- Bollards
- Fairleads
- Winches

Each mooring equipment is specified by its Safe Working Load (SWL), which is what we need to determine.

OCIMF provides a simple approach to calculating the SWL once environmental forces are calculated.

OCIMF proposes calculation of a parameter called the 'Ship's Design MBL'.

In Part 2, we'll look into what is Ship's Design MBL, and also how the mooring pattern for the vessel can be designed.

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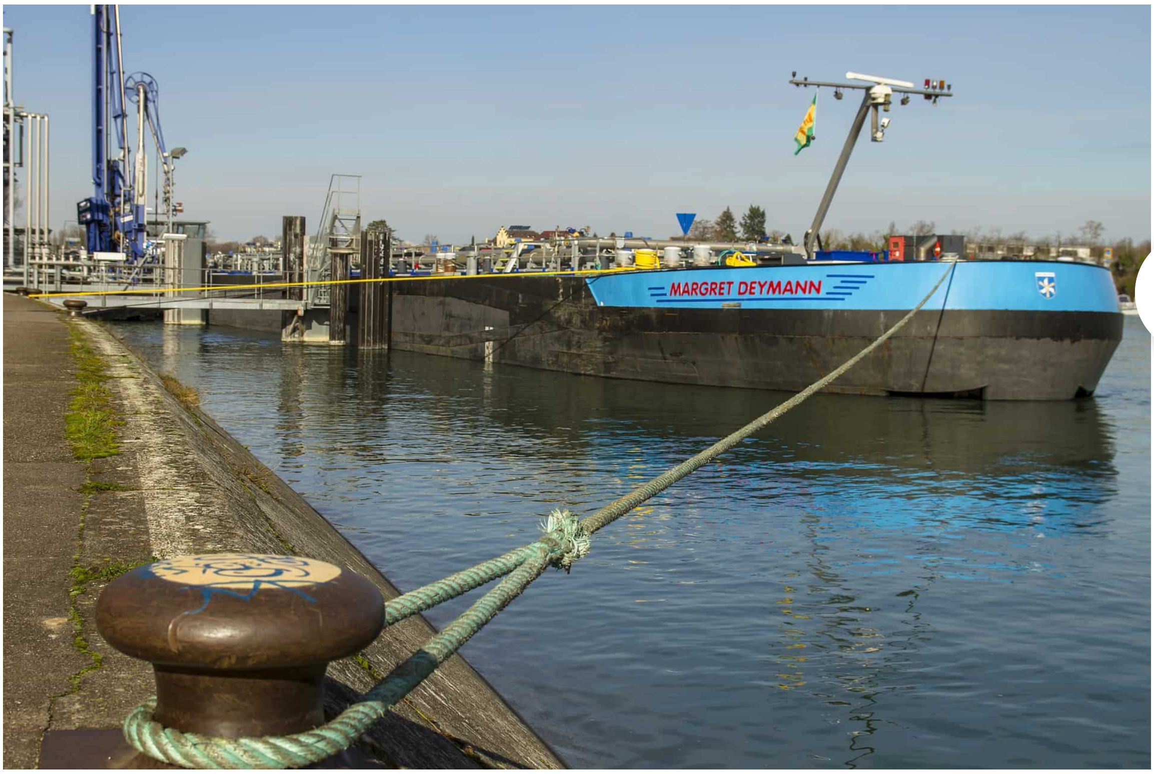
Calculating a Ship's Design MBL using OCIMF MEG-4

by tna_ivsadmin | Feb 1, 2020 | Marine Operations, Mooring | 4 comments

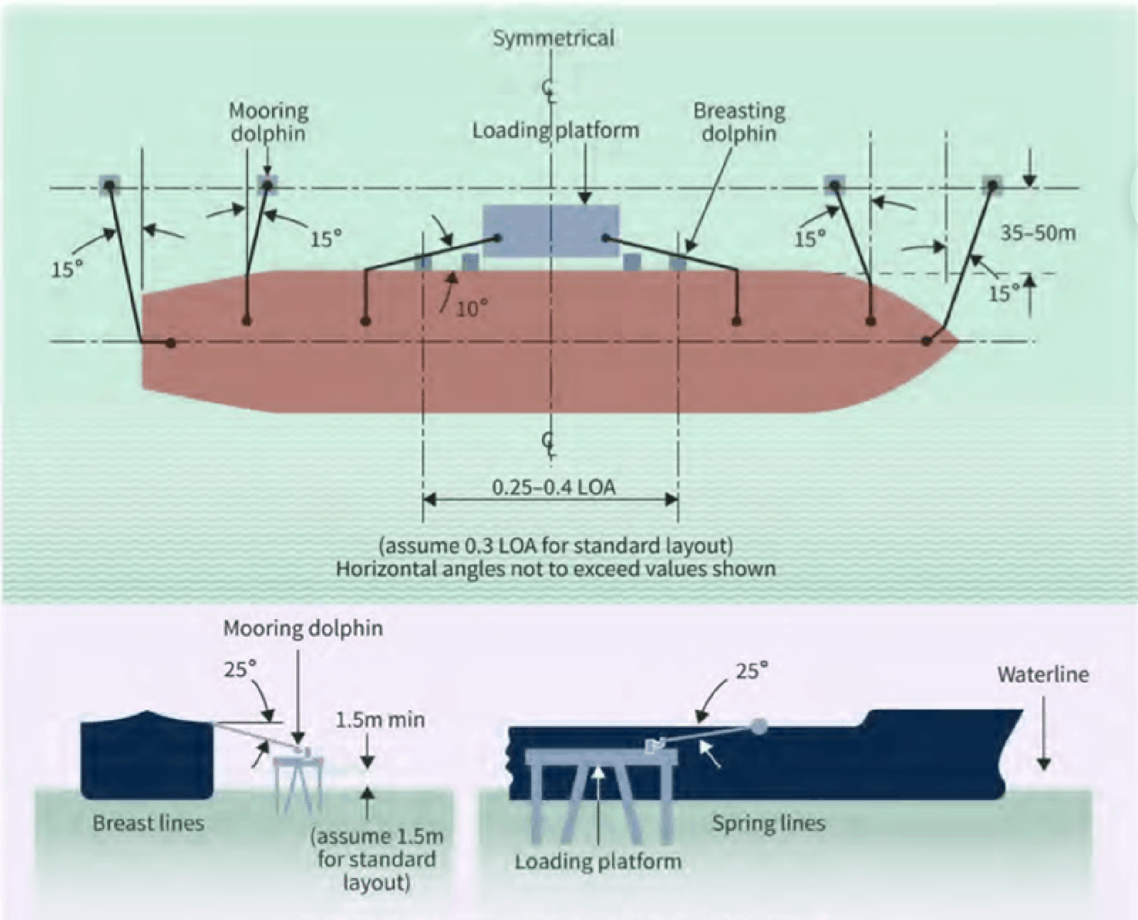


In **Part 1 of this article**, we saw a step by step guide to calculate the Environmental forces on a vessel based on "Standard" environmental criteria defined in Section 3 of OCIMF Mooring Equipment Guidelines Fourth Edition (MEG-4) in order to determine the ship's design MBL which in turn can be used to size the various components of the vessel's mooring system, like bollards, fairleads and winches. Various parameters like loading conditions, tidal variations, WD/T ratio etc. were discussed and calculation of wind and current forces on the vessel based on coefficients was presented.

In Part 2 of the article we will look into how to

Mooring Pattern

The vessel mooring pattern is to be designed to effectively counter the environmental forces from any direction. This means that the lines should be able to cope horizontal as well as transverse loads. The mooring pattern should therefore have lines along longitudinal direction to prevent motion in forward and aft directions and also in the transverse direction to prevent motion away from the berth. The longitudinal lines are knows as spring lines and the transverse lines are known as breast lines. The pattern also depends on the provisions at the terminal and it should be chosen, as much as possible, to keep the spring lines parallel and breast lines perpendicular to the ship length.



Mooring Pattern (Source: OCIMF MEG-4)

MEG4 provides the below guidelines for a generic mooring line layout.

- Breast mooring lines should be at an angle less than 15^{o} to the perpendicular axis of the ship.

Static Equilibrium

A vessel subject to environmental forces/moments will move in the forward or transverse directions or rotate about the vertical axis i.e. the vessel will have surge, sway or yaw respectively. The vessel motion will change the relative distance of the fairlead from the shore anchor point, changing the length of the mooring lines. The lines, generally speaking, behave like a spring and the force exerted is proportional to the change in length of the line. This characteristic of the lines can be found from the data sheet of the line from the manufacturer. The change in length of the lines increases the tensions in the lines and the combined load exerted by all the lines then balances the total environmental loading. This condition of the vessel where the environmental loading is balanced by the mooring lines is known as static equilibrium.

Ship design MBL calculation

A simple spring formulation can be applied to evaluate the translations/rotations of the vessel in static equilibrium under the effect of the calculated environmental loads. Once a mooring system for the vessel at the berth has been chosen, for given position of the vessel the change in length of each mooring line with respect to its initial (un-stretched) length can be calculated using a simple spring formulation $F = k\,\delta L$ where F is the line tension, k is the stiffness of the line and δL is the change in line length. Tension in each line can be aggregated to get the net loading on the vessel.

Hence we can calculate the translation/rotation of the vessel that will result in unit force/moment on the vessel by the mooring lines. Let's call this the inverse stiffness k'. If k' is displacement produced by unit force on the vessel, the total displacement X produced by the net environmental loading F can be calculated as $X = F\,k'$. The new position for the ship can be used to re-calculate the net mooring loads on the vessel and compared to the environmental forces and the whole process can be repeated until static equilibrium is achieved. The total length of the mooring line from winch to bollard should be used in the calculations. Also the stiffness of the lines change with use and the calculations should use the stiffness of used lines instead of new lines. The above can be summarized in below steps,

1. Calculate total environmental forces/moments on the vessel in surge, sway and yaw directions. E.g. F_x is the net environmental force in the surge direction
2. Determine the inverse stiffness of the mooring system in terms of amount of surge/sway/yaw per unit force/moment. E.g. k' m/N is the stiffness of the vessel in surge direction.

6. Several iterations of steps 2-5 may be required until static equilibrium is achieved.

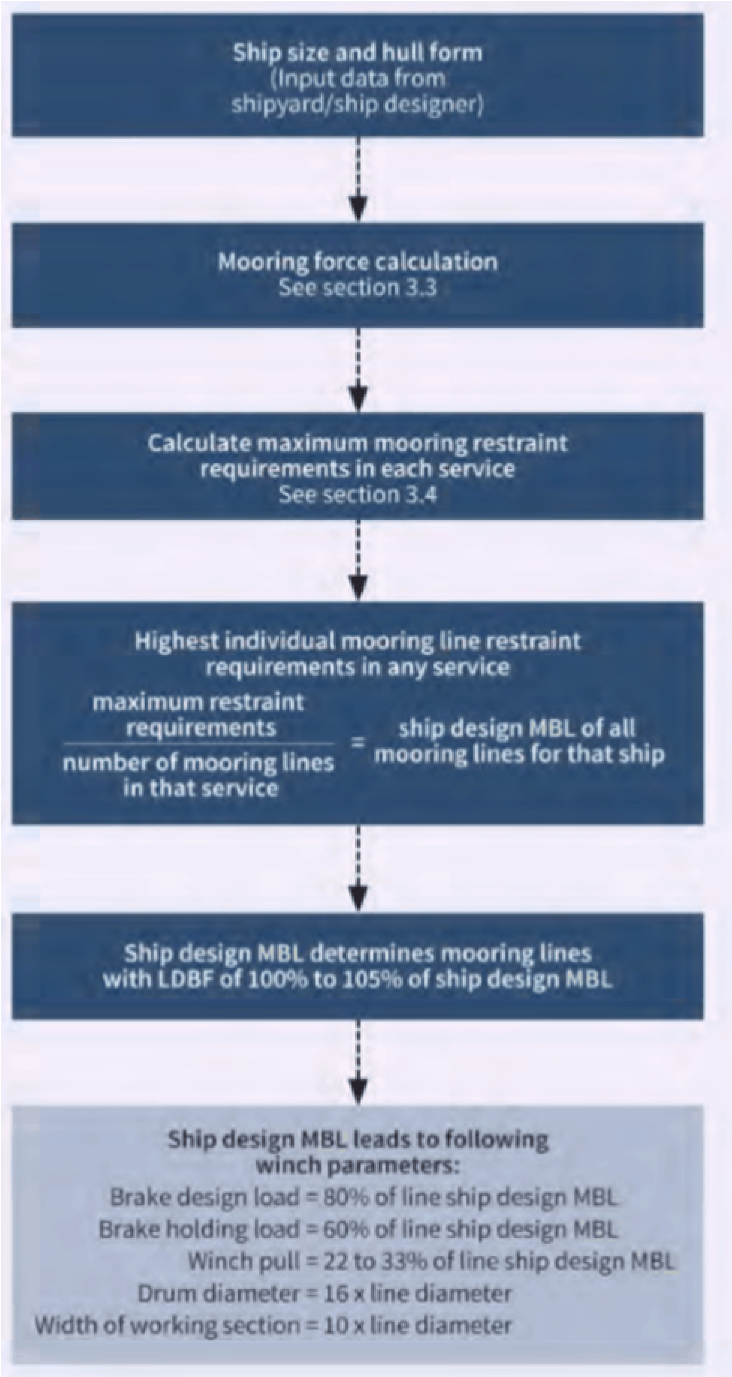
Once static equilibrium is achieved, maximum mooring restraint force can be determined and used in the flowchart below, provided by MEG4, to calculate the ship design Minimum Breaking Load i.e. Ship design MBL. With the vessel in static equilibrium, the tensions in each mooring line can be determined. Since there are several components in the mooring pattern that support multiple mooring lines, the total loading on such component can be used to calculate the Ship design MBL as

$$\text{Ship design MBL} = \frac{\text{Total mooring load}}{\text{number of lines}}$$

The ship design MBL is the MBL of a new, dry mooring line for which a ships mooring system is designed and that meets the mooring restraint requirements as defined in MEG4, section 3. All other components of a ship's mooring system are based on this ship design MBL, with defined tolerances.

It must be noted that static analysis may only be suitable for benign environment as we are assuming the lines as simple springs. In other cases dynamic analysis for the vessel motions and line tensions should be performed.

The steps above are also lined out in OCIF MEG-4, and shown in the figure below.



Ship's Design MBL Calculation Steps (Source: OCIMF MEG-4)

In Part 3, we will further look into using this Ship design MBL for line selection and to determine D/d ratio (bend dia/rope dia) of mooring line and other parameters.

Do check out some products relevant to OCIMF MEG-4 below. The product for calculation of Ship's Design MBL is in progress and shall be out soon!

OCIMF Environment Forces Calculator – Gas Carrier (updated to MEG4)

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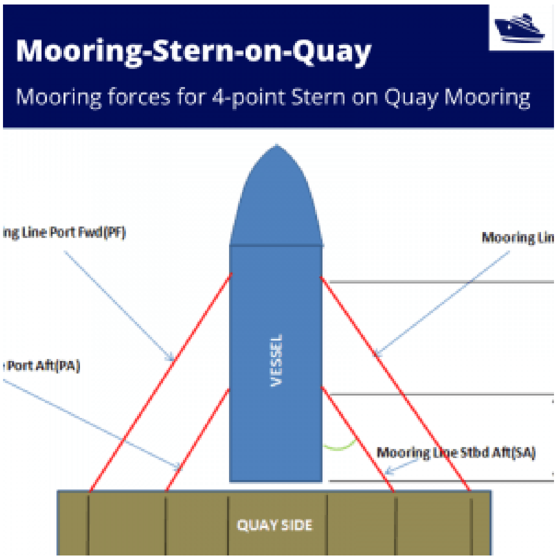

Mooring Forces Calculator (Stern on Quay, 4-Point Mooring)

$99.00

Mooring Forces Calculator (Port or Stbd on Quay)

$99.00