MOORING ANALYSIS

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Mooring analysis is the process of ensuring a vessel, or any floating body, remains in position, under applied environmental conditions, safely and securely. Mooring lines are connected to an anchor system which can either be a series of installed/ laid anchors, or the lines can be connected to bollards which can be found positioned along quaysides and harbour berths. There a number of different types of offshore moorings leg types such as catenary, taut leg, tension leg and single point articulated moorings (SPMs). For most heavy lift operations, inshore, moorings will be either to shore side bollards or relaid anchors on the sea/river bed.

Offshore moorings

The most common offshore mooring spread is a catenary spread, where the body is moored using line and anchor systems – usually drag embedment anchors. These are put in position by lowering to the seabed, and then having a horizontal tension applied tot he line with "drags" the anchor along the sea bed. As this happens the anchor flukes cause the anchor to embed itself into the sea bed and as it does so, the resining focus increase to the point that the vessel can no Lanier move it. At this point the anchor is said to have "set".

Catenary spreads rely on the line length being greater than the water depth, this "grounded length" ensures that the anchor does not experience any uplift (vertical forces) and is subject to only horizontal loading. The long line lengths provide substantial added weight to the system, contributing to restoring forces required to counteract the response of the vessel due to environmental conditions and can also add to the holding capacity of an anchor system due to the friction between the bottom chain and the seabed.

The mooring analysis for such a spread will state vessel offset limits, which the spread must not allow the body to exceed. These offset limits are usually specified in terms of maximum surge, sway and yaw parameters defining the maximum amount the vessel can move during maximum storm conditions in either its longitudinal, transverse and rotation (about its vertical axis) directions.Although the catenary lines appear slack, the sheer weight of them will ensure the body remains within the desired offset envelope based on set limits. They do this by applying a restoring force on a vessel which increases the further a vessel moves from its original position. An example of this being of semi-submersible drill rigs; connected to the wellhead via a "riser" – increased vessel offsets will induce excessive bending and tensile stresses in the riser, which risks damaging the infrastructure.

Although catenary spreads are widely used, they are limited in their application, due to water depth restrictions. There are accepted industry limits as to how deep a catenary can be installed. These systems become impractical to install in deeper waters; however, the main issue is that the weight of the lines becomes too significant, with the buoyancy capacity of the vessel unable to counteract this. For this reason, many modern deepwater catenary systems employ elements of synthetic moorings which are either neutrally or slightly buoyant.

Taut leg

Taut leg mooring is a solution employed in deep to ultra-deep-water locations and, unlike catenary spreads, relies on vertically laid anchors – e.g. suction piles. The lines in a taut leg spread do not contact the seabed and are usually made of polymer or fibre lines so as to reduce line weight. The lines will be set in such a way that the spread creates an angle between the line and seabed, this produces a vertical and horizontal component at the anchor.

Tension leg

Tension leg moorings are very similar to taut leg moorings in that the lines do not come in contact with the seabed and they are employed in deep water locations. In these systems, the load component at the anchor is entirely vertical. This is achieved by laying the spread to produce 90 degree angles between the waterline and seabed – also eliminating almost all vertical movement at the platform. Although the platform is fixed against vertical displacement, wave motion can still affect the displacement in the horizontal plane.

Single point mooring (SPM)

Single point mooring is when a floating buoy or jetty is moored offshore and is primarily used by tankers to unload petroleum or other products to save the vessel going into port, or if the port does not have the unloading infrastructure required for such an operation. SPM is a simple system and is named as such due to the requirement for only one point of contact between the vessel and the buoy/ jetty

There are a number of key considerations which must be made,for the required analysis, such as;

- Where is the vessel to be moored?
- Sea states such as wave conditions, tidal behaviour, current velocity, water depth
- Expected wind conditions – velocity and direction
- Vessel particulars and motion data

Another consideration is how long the vessel is expected to remain on location, determining to which limits the analysis is run and could dictate the number/type of moorings required. Typically, winter moorings will be more substantial than those used in the summer months.

Industry standards and codes must be considered. These will outline the operational and environmental limits, desired safety factors and any preparatory instructions as to how the analysis must be run. It is at the engineer's discretion whether or not the analysis passes, a decision can be made to work within the limits of the codes, or allow for tolerances. Institutions such as DNV and API both outline such features, however, limits and factors of safety differ from code to code, therefore, a client will usually specify to which code the analysis should be run.

Inshore moorings:

Lay-By moorings follow the same principles and methodology as those for offshore moorings, however, inshore moorings predominately rely on bollards instead of physical "anchors" to provide the holding capacity. The bollards are in fixed locations on the quayside; therefore, the flexibility of these systems is more limited. Figure 8 shows a standard spread, where lines 1 and 8 (outboard lines) are angled close to perpendicular to the quayside to restrict transverse/sway motion, away from the quay. Lines 2-7 (spring lines) are angled parallel to the quayside, restricting longitudinal/surge motion forward and aft along the quayside.

By having these angles as such we can ensure that we utilise as much of the tensile properties of the mooring lines as possible.

There are a range of mooring analysis options and the two most common in heavy lift projects are Quasi-static and Dynamic.

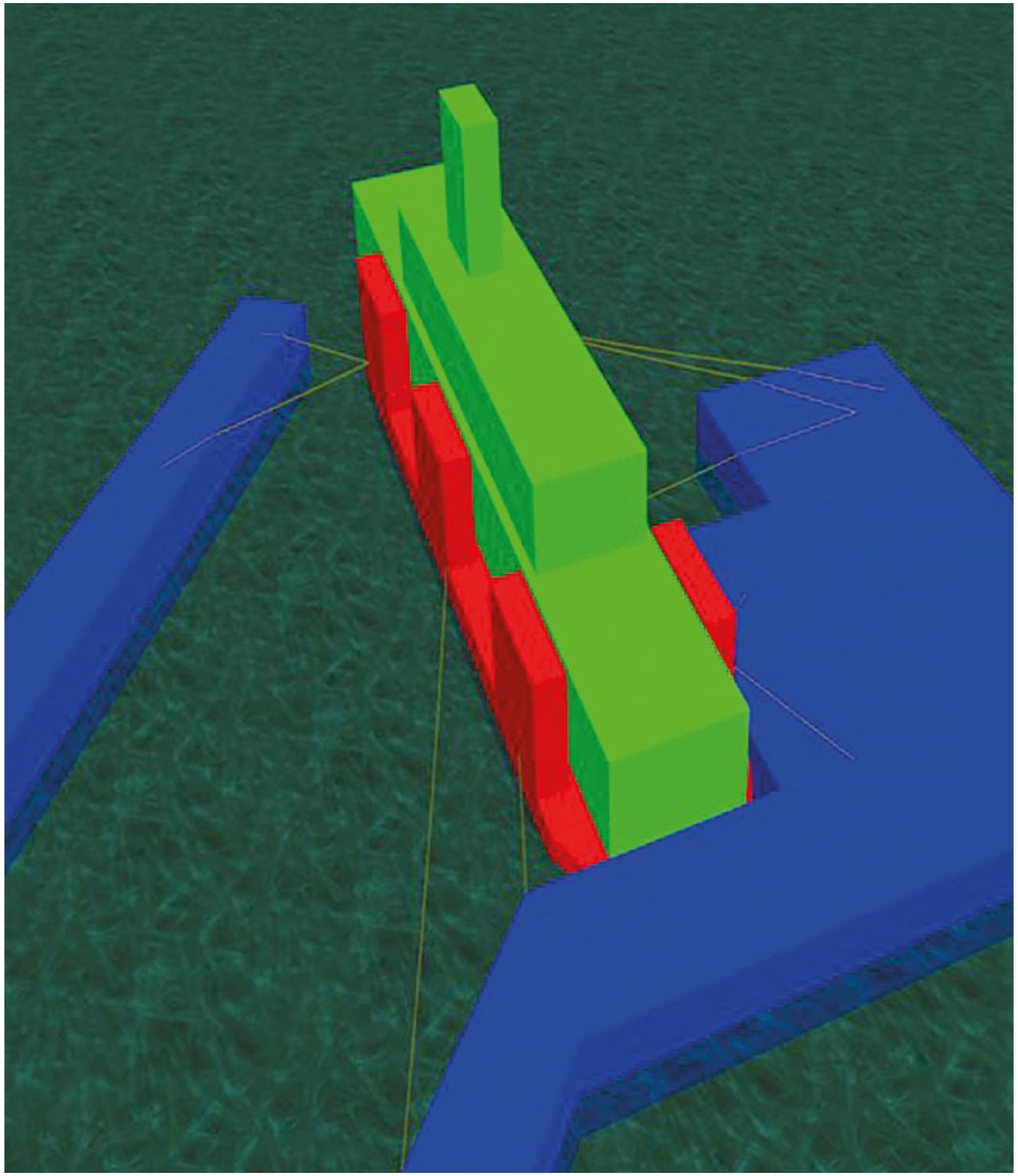

fig. 08/ complex Orcaflex mooring analysis

fig. 09/ pipelay vessel moored to bespoke mooring bouys

Quasi-Static

In Quasi-Static analysis, averages are taken for the environmental forces and vessel offsets, and low and wave frequency responses in the horizontal plane are combined, giving the maximum instantaneous offset. The wave frequency response is established when the effects of the mooring system are significant – mooring line tensions are then calculated statically for the determined maximum offset location. However, Quasi-Static analysis will begin to underestimate line tensions as water depth increases – as such, codes of practice will counteract this by implementing higher factors of safety. In deep water applications Quasi-Static is not considered a conservative approach.

Dynamic

Dynamic analysis takes into account line dynamics caused by inertia forces on mooring lines due to vessel motions and hydrodynamic effects on the lines. Dynamic analysis is generally accepted to be more accurate in comparison to Quasi-Static.

As the engineer, it is our responsibility to ensure that the mooring spread is optimised while operating within the boundaries set out. We must consider variables such as different line types, materials and attachments, anchor locations, subsea assets etc. In doing so we can ensure that the spread is not only cost effective but as suitable for purpose as practically possible. This process has been made far easier with the use of computer programs which allow the user to simulate and analyse various mooring spreads and environmental data accurately and quickly.

One of the most popular programs is Orcaflex by Orcina. Orcaflex allows the user to input all of the above parameters and allows basic structures to be modelled to simulate the real life scenario – Orcaflex utilises a Finite Element (FEA) method of analysis and can account for line elements with and without bending stiffness., and will allow static or dynamic analysis, to generate results and motion simulated outputs.The FE method in mooring analysis divides a loaded model or body into discrete (or finite) elements in much the same way as it would for a structural model. This network of elements are then assembled into a series of equations that are solved simultaneously to determine the overall deflection and tensions or beddings stresses for lines that can accommodate them. These results are then reported as tensions and stresses along the length of the mooring line as well as restraining forces and vessel movements in a report format. It also then allows the user to remove selected lines and rerun the analysis to model various damage scenarios.

By combining all of the mentioned environmental factors, load cases and industry standards, we can provide accurate, optimised and thoroughly analysed mooring arrangements to ensure that vessels, whether they be inshore or offshore, are steadfast and safe.