Marine Fenders and Mooring Systems

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Abstract

Marine fendering systems are necessary to absorb the energy of the moving ship as it berths at the wharf and thus protect the supporting wharf structure from damage. Mooring systems hold the vessel securely at the berth. If a ship undergoes excessive movements on its mooring lines, the fenders are required to prevent damage to both the ship and the wharf. Damage to the fendering system and the supporting wharf can occur when they are overloaded due to excessive ship impacts caused by berthing accidents or when ships larger than the system design capacity berth at the wharf. They can also suffer damage due to vessels which undergo excessive movement on their mooring lines or due to direct mechanical damage caused by protrusions from the vessel's hull. Modern fender units utilise sophisticated shapes and rubber compounds which enable the units to efficiently absorb relatively large amounts of energy. This is where modern fenders differ significantly from older fender designs.

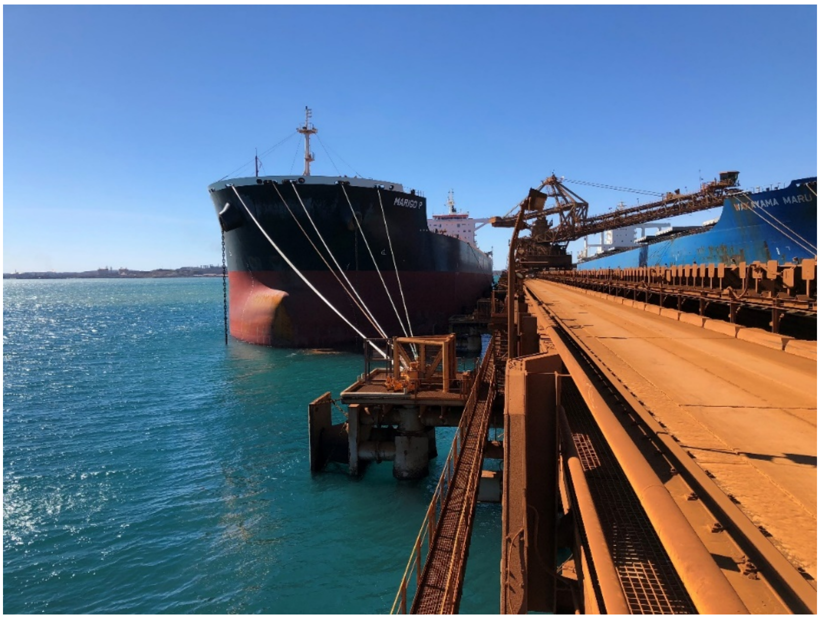

Figure 1: Moored Ship

When selecting a fendering and mooring system, several factors need to be considered. These include the size and tonnage range of the ships using the facility, the tidal range, and whether the facility is for unloading full ships or loading empty ships. For an exposed berth, the range of sea conditions must also be considered. At exposed berths, the effects of waves, currents and winds can cause a moored ship to undergo movements on its mooring lines, and the fendering system has to be designed to be compatible with the arrangement of lines, bollards, quick release hooks and support structures which form the mooring system. Fendering and mooring systems represent a significant capital expenditure and their continued performance can be critical in determining the safety, whole of life costs, and production capacity of a marine facility.

1. Fender Selection

Fenders protect the berthing structure against ship impact. Theories have been developed to calculate the expected berthing energy, resulting from the mass and berthing velocity/angle of the ship. The berthing energy normally governs the fender design and depends mainly on:

- The mass of the ship;
- The berthing velocity of the ship;
- The berthing angle, usually not more than 10 degrees; and
- The eccentricity of the ship towards the first point of contact with the berth which would ideally be at a quarter of the total ship's length, but can vary.

Vessel approach and manoeuvring, berthing criteria, impact energy calculations and fender selection procedures are described in PIANC WG Report 33 Guidelines for the Design of Fender Systems, 2002 [5]. British Standard BS 6349 [6] also contains detailed design procedures for the design for berthing of vessels at quay structures.

The installation level of the fender will be governed by the smallest ships so the freeboard at lowest water should still be able to have proper and adequate contact with the fender. The main function of frames in front of the fenders is to distribute the fender reaction force over the hull of the ship to achieve a hull pressure of around 20 tonnes per square metre. They have a low friction surface to avoid rubbing forces in longitudinal as well as vertical directions, due to the movements of the ship.

Rubber fenders are available in different rubber qualities. By selecting a softer, but larger-sized fender, the fender reaction force can be reduced. Consequently, by selecting a more efficient fender, savings can be made in the costs of the dolphin structure resulting in a more economical structure.

The most common type of fender achieves the maximum reaction early in the deflection range, then exhibits a buckling action with a fairly constant reaction until it reaches the end of its range at which stage the reaction increases rapidly. It is therefore important to size the fender within the working range. Figure 2 below shows a typical deflection versus reaction and deflection versus energy absorption curve for a buckling action fender.

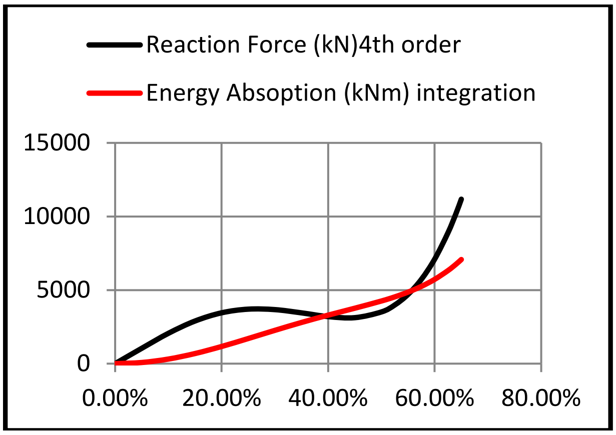

Figure 2: Fender Curves

The design approach velocity values provided in the PIANC fender design guidelines WG33 2002 [5] are based on data obtained by Brolsma, et al, in 1977. While this is the most relevant data available to date, it has a number of limitations. It is recommended that lower limits of 0.1m/sec for protected harbours and 0.15m/sec and offshore berths should be used. For the determination of the appropriate fender size and loads applied to the supporting structure, a factor should be applied to the berthing energy to account for abnormal berthing. This factor should be based on risk assessment for the particular circumstances and consequences of damage with an expected range of 1.5 for low risk situations and 2.0 for higher risk situations.

a. Cell Fenders

These consist of large rubber cylinders, placed perpendicular on the quay face, combined with a large front panel. Although smaller units are available, their normal range is from 1,000mm to 3,000mm, with energy absorption from 20 tonne-metre to maximum 400 tonne-metre each.

Figure 3: Cell Fender

b. Cone Fenders

They are similar to cell fenders but the rubber cylinder is tapered. The cone shape gives a better performance during angled berthing. The largest size is 2,000mm in height, which can have energy absorption between 300 and 500 tonne-metre depending on the rubber grade.

Figure 4: Cone Fender

2. Mooring Lines

The proper mooring of a ship not only requires the ship to stay at berth, but also to maintain position, within certain limits. For terminals that have separate mooring dolphins, the mooring quick release hooks will ideally be more than 35 metres away from the side of the ship. This will require access walkways (catwalks) or alternatively line boats to access the mooring points.

- Stern and head lines are the mooring lines at front and stern, to be placed as far away as possible, preferably at least 45 degree angles to the quay line.
- Aft and forward breast lines come from the same location on the ship but are approximately perpendicular to the quay.
- Spring lines come from the ship at approximately quarter length and run nearly parallel to the quay.

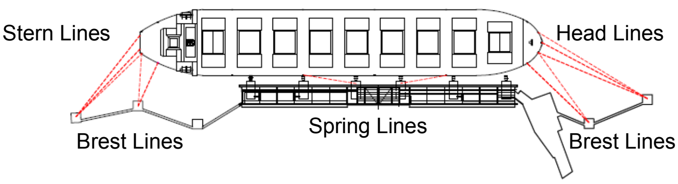

Figure 5: Ship with Mooring Lines

As the ship size increases larger, stronger and more lines are employed. The number of lines is dictated by the number of available mooring winches on the ship, although some additional lines can be run to ship's bitts where the port conditions dictate. There is no universal standard that specifies the number, type and size of lines or limitations of mooring in harbours. However, there are international guidelines and useful references such as Mooring Equipment Guidelines 4th Edition (MEG4), OCIMF, 2018 [4].

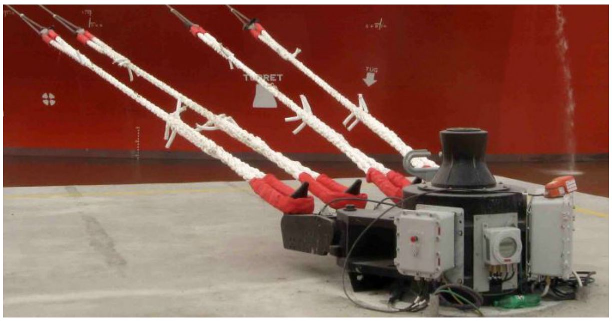

Figure 6: Quick Release Hook and Capstan Unit
(Courtesy Trelleborg Marine Systems)

Mooring line stiffness and stretch will generally fall into one of four categories:

- Stiff - Low Elongation less than 5% at 100% minimum breaking load (MBL) (steel wire, high modulus polyethylene (HMPE) and Aramid rope)
- Standard "A" - Moderate Elongation generally 10-20% at 100% MBL (most synthetic fibre ropes, used condition). Lower stretch standard ropes include polypropylene and composite fibre ropes.
- Standard "B" - Higher stretch standard ropes include polyester and some composite fibre ropes
- Flexible - High Elongation >20% at 100% MBL (polyamide "nylon" ropes, used condition)

3. Rope Guards

Mooring lines are heavy and carry large tension loads. They need to be handled with care to avoid entanglement, cuts, rope burns, entrapment of limbs, etc. Lines are made out of materials with high elasticity. This elasticity has advantages and disadvantages. The main advantage is that in high winds, currents or wave action, excess force can be spread among several lines. However, if a highly-stressed line does break or part, it causes a dangerous phenomenon called "snapback".

Because of the very high energies stored in the lines, line breaks are very dangerous when they snapback at failure. Every year around the world seamen and port workers are seriously injured or killed by these events. In situations where there may be a greater risk of line failure such as in an exposed offshore terminal, rope guards can be provided to protect mooring crews from snap back. The OCIMF guidelines provide some very clear diagrams of snap back danger areas that can be used to plan suitable barriers.

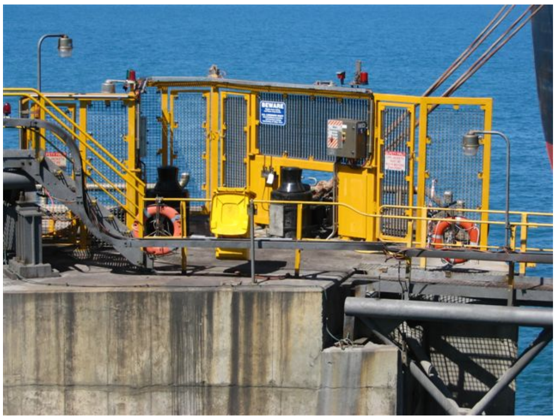

Figure 7: Rope Guard on Mooring Dolphin

4. Suction Moorings

Suction moorings consist of a series of powered articulated pads that attach to the side of the vessel hull using a vacuum pump to generate a suction load. The pads can be arranged in groups on each unit and multiple units are arranged along the length of the hull. Such systems can overcome the problem of mooring line angles being inefficient in terms of load path. The MoorMaster™ system uses vacuum pads instead of ropes to provide the mooring attachment. Hydraulic cylinders connected to the vacuum pads generate forces in the horizontal plane to control the horizontal motion of the moored ship. The MoorMaster™ system has been used successfully on container ships and ferries for a number of years and has recently been applied to bulk materials berths.

Figure 8: MoorMaster™ Unit on Container Berth

5. References

[1] De Bont, J. (October 2010). Calculations of the Motions of a Ship Moored with Moormaster™, PIANC, Magazine no 141.

[2] PIANC, 2018, WG184 Report, "Design Principles for Dry Bulk Marine Terminals (draft)"

[3] Morgan, R 2011, Bulk Materials Handling Berths, Engineers Australia, Coast and Ports 2011, Perth

[4] OCIMF, 2018, MEG4, Mooring Equipment Guidelines, 4th Edition

[5] PIANC, 2002, WG33, Guidelines for the Design of Fender Systems

[6] British Standards Institution, 2014 BS 6349, Maritime works series

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