1.2 - Objectives

Guidance in this section is intended for all stakeholders in the design and safe operation of a ship, including ship and equipment designers, ship builders, surveyors, ship operators/owners/managers, equipment manufacturers and suppliers, ship's personnel and marine terminal personnel.

It establishes the principles covering all aspects of the mooring system, from initial ship design and mooring equipment arrangements (including fixtures and fittings and associated ship structural strength), to the factors influencing the selection of mooring lines and their safe handling, maintenance and retirement.

Further guidance is provided on procedures for the safe operation and maintenance of the mooring system by ship's personnel, including the operational considerations and mooring management at the interface of the ship with the marine terminals that it visits.

This section also provides guidance on the requirements for the mooring system that are to be included in the ship's management system through a functioning Mooring System Management Plan (MSMP). An MSMP should cover all aspects of the mooring equipment, operation and maintenance (see section 1.9). These should be effectively managed from the ship's initial design through to end life.

1.3 - Forces acting on the ship

The moorings of a ship must resist the forces due to some, or possibly all, of the following factors:

- Wind.
- Current.
- Tides.
- Interaction from other ships.
- Waves/swell/seiche.
- Ice.
- Changes in draught, trim or list.

This section deals mainly with the development of a mooring system to resist standard environmental criteria (defined in section three) involving wind, current and tidal forces on a ship at a berth. If the mooring system is designed to accommodate maximum wind and current forces, reserve strength may be sufficient to resist other moderate forces that may arise. However, if significant surge, waves or ice conditions exist at a terminal, considerable additional loads can be developed in the ship's moorings. These forces are difficult to analyse except through model testing, field measurements or dynamic computer programs.

In planning for mooring at a terminal, consideration should be given to potential scenarios where the standard environmental criteria could be exceeded and deciding on what appropriate measures will need to be implemented to avoid causing injury to personnel, damage to the environment or to assets.

Forces on the moorings due to changes in ship elevation, from either tidal fluctuations or loading or discharging operations, must be addressed by diligent mooring line management.

1.3.1 Wind and current drag forces

The procedures for calculating wind and current drag forces are covered in appendix A. Calculations carried out on a range of ship sizes have shown that the wind and current drag coefficients are not significantly dependent on ship size. Consequently, the ship drag coefficients in appendix A may be used for bridge-aft ships with similar geometry, down to 16,000 DWT.

Figure 1.2 demonstrates how the resultant wind force on a ship varies with wind velocity and direction. For simplicity, wind forces acting on a ship can be broken down into two components: a longitudinal force acting parallel to the longitudinal axis of the ship and a transverse force acting perpendicular to the longitudinal axis. The transverse force generally produces a yawing moment.

Wind force on the ship also varies with the exposed area of the ship. Since a head wind only strikes a small portion of the total exposed area of the ship, the longitudinal force is relatively small. A beam wind, on the other hand, exerts a very large transverse force on the exposed side area of the ship. For a given wind velocity the maximum transverse wind force on a VLCC is about five times as great as the maximum longitudinal wind force. For a 50 knot wind on a ballasted 250,000 DWT tanker, the maximum transverse forces are about 300 tonnes (2,943kN), whereas the ahead longitudinal forces are about 60 tonnes (589kN).

Mean Draught (Metres)	**Astern** (Tonnes)	**Ahead** (Tonnes)	**Transverse** (Tonnes)
6	47.8	68	303
7	47.2	66.7	283
8	46.7	65.3	263
9	46.1	63.9	244

Table 1.1: *Maximum longitudinal and transverse wind forces on a 250,000 DWT tanker, 5m trim, 50 knot wind*

If the wind is from any quartering direction between the beam and ahead (or astern), it will exert both a transverse and longitudinal force since it is acting on both the bow (or stern) and the side of the ship. For any given wind velocity, both the transverse and longitudinal force components of a quartering wind will be smaller than the corresponding forces caused by the same wind acting abeam or head on.

Note the sign convention used in this section is aligned with the sign convention used by the scientific community, such as research establishments and designers, where a force from directly astern is considered to be from 0 degrees and the compass angles proceed in an anti-clockwise direction. This convention is also adopted in appendix A when discussing wind and current forces. (This is different to the normal interpretation used by mariners, whereby force from directly ahead is considered to be from 0 degrees and the compass angles proceed in a clockwise direction).

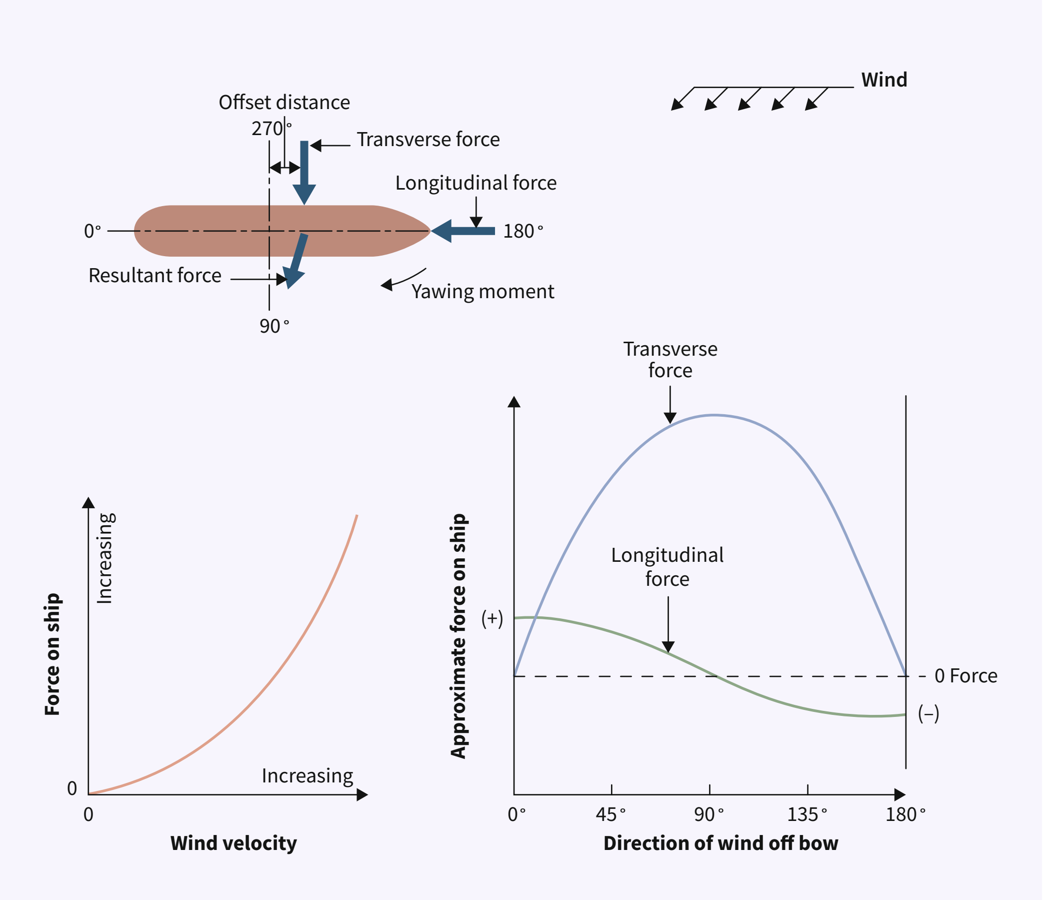

Figure 1.2: *Wind forces on a ship*

With the exception of wind that is dead ahead or astern or directly abeam, the resultant wind force does not have the same angular direction as the wind. For example, for a 250,000 DWT tanker, a wind 45 degrees off the bow leads to a resultant wind force of about 80 degrees off the bow. In this case, the point of application of the force is forward of the transverse centreline, producing a yawing moment on the ship.

Degree Off Stern	Force Direction	5 x Draught or More (Tonnes)	3 x Draught (Tonnes)	1.10 x Draught (Tonnes)	1.02 x Draught (Tonnes)
90	Longitudinal	8	9	20	37
	Lateral	221	427	788	1,171
150	Longitudinal	-10	1	142	-55
	Lateral	80	141	632	377
170	Longitudinal	-12	-6	-12	11
	Lateral	0	26	212	205

Table 1.2: *Example of the effect of under keel clearance versus draught (assuming 2 knot current)*

Current forces on the ship must also be considered when evaluating a mooring arrangement. In general, the variability of current forces on a ship due to current velocity and direction follows a pattern similar to that for wind forces. Current forces are further complicated by the significant effect of under keel clearance. Table 1.2 shows the impact on force due to reduced under keel clearance. The majority of terminals are orientated more or less parallel to the current, thereby minimising current forces. Nevertheless, even a current with a small angle (such as 5 degrees) off the ship's longitudinal axis can create a large transverse force and must be taken into consideration.

1.4 - Mooring system design principles

Once the forces acting on the ship have been calculated (using the standard environmental criteria), the ship designer, ship builder (if known at time of design/build) and the ship owner will need to decide what individual components of the mooring system to use to withstand these forces.

These components will comprise:

- Mooring equipment and arrangements.
- Mooring equipment strength.
- Mooring pattern.

While components will be discussed separately below, they are interlinked and must be considered jointly during the design phase of the ship. This will ensure the ship can both moor safely and achieve the design capacity to meet or exceed the requirements of the standard environmental criteria as defined in section 3.2.

1.4.1 Mooring equipment and arrangements

Early in the ship design process the selection and location of mooring equipment and their arrangement on the deck of the ship must be determined to ensure that the ship can moor safely alongside berths and meet the standard environmental criteria.

Areas that should be considered when designing mooring equipment and arrangements are outlined throughout this publication and take full account of the safety and exposure of personnel during mooring operations. They include:

- The need for sufficient deck space and equipment to enable effective oversight and supervision of operations, adequate lighting and avoidance of impairments that degrade communications capability, such as from machinery noise.
- The number, location and size of deck winches, mooring lines, bollards and fairleads to provide an effective, balanced mooring pattern.
- Industry requirements including applicable IMO regulations, recognised industry standards (e.g. IACS, ISO) and associated industry guidance and recommendations as they apply to mooring and towing equipment.
- The application of human factors in the design to ensure crews are not exposed to avoidable risks during mooring operations.

If a ship operator requests enhanced flexibility with ship mooring, which may be outside a standard mooring arrangement, the following may also be considered:

- Residual capacity to ensure the ship can berth, or remain berthed, in the event of unscheduled occurrences such as winches being out of service.
- Lines unable to be deployed from optimal locations due to incompatibility with berth facilities.
- Equipment redundancy, including critical equipment and spares.
- Other influencing factors, such as locations with peculiar environmental operating parameters, e.g.:
    - Exposed locations.
    - Operating envelope limits of loading arms at berth.
    - Extraordinary strong tide, current or other phenomena (tidal bore).

1.4.2 Mooring equipment strength

In considering the design of the mooring equipment and arrangements in section 1.4.1, this publication also establishes principles for equipment strength, many of which are interrelated and should also be taken into consideration. These include:

- System design will establish, from standard environmental criteria, the effective ship design MBL for each mooring line in the standard mooring pattern.
- System design will ensure that the mooring fittings and machinery, and the structure to which they are attached, do not suffer structural damage or failure before the mooring line; i.e. the SWL of fittings should be at least equal to or exceed the ship design MBL.
- Loads to which mooring lines are exposed do not exceed the stated WLL.

The relationship between SWL, WLL and ship design MBL of loose and permanent equipment is explored in figures 1.3 and 1.4.

All values are percentage values of the ship design MBL.

Ships						Lines				Lines				Shore/Terminal				
Ship Mooring System Component	Double Bollard, Closed Chock, Pedestal Fairlead	Single Bollard, Recessed Bitt	Winch Foundation	Winch Drum, Shafts, Bearings	Winch Brake	Mooring Line Type/ Component	Wire	Synthetic		HMSF	Polyamide (Nylon)	Synthetic Tail	Joining Shackle	Shore Mooring Point Type	Single Hook/Bollard	2 Hook Mooring Point	3 Hook Mooring Point	4 Hook Mooring Point
Operational brake render					60	Shackle SWL (synthetic)							50	EU - Mooring structure SWL, extreme loads benign locn	100	120	180	240
Max design brake render (ISO-Holding load)					80	Shackle SWL (wire)							55	EU - Mooring structure SWL, extreme loads exposed locn	100	150	230	310
Safe Working Load (SWL)	100	100	100	100	100	Working Load Limit (WLL)	55	50		50	50			EU - Mooring structure SWL, accidental load condition	118	210	280	350
Ship design MBL	100	100	100	100	100	Ship design MBL	100	100		100	100	100	100	Max ship design MBL	100	100	100	100
Max rated pull				33		Replace	75	75		75	75	75		US - Mooring structure SWL	118	160	220	280
Design Basis Load (DBL)	200	100	100	100	100	Line Design Break Force (LDBF)	100	100		100	100	125		Hooks	1	2	3	4
Specified Minimum Yield Stress (SMYS)	250	125	118	111	118	LDBF (Max)	105	105		105	105	130						

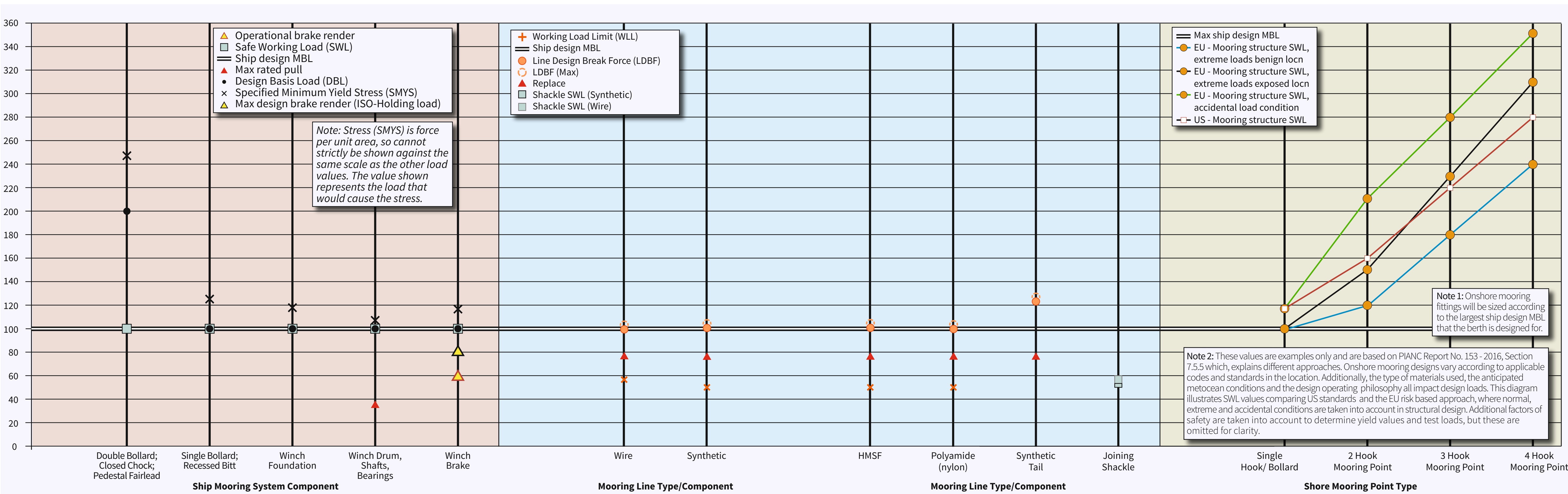

Figure 1.3: *Relative percentage values of mooring system components based on ship design MBL*