Requirements for

Masts and Rigging Arrangements on Sailing Yachts

ABS

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REQUIREMENTS FOR

MASTS AND RIGGING ARRANGEMENTS ON SAILING YACHTS
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American Bureau of Shipping
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Foreword

This document provides classification requirements for the design and construction of masts and rigging systems of sailing or motor sailing yachts classed to the requirements of the ABS *Rules for Building and Classing Yachts*.

This document is to be used in conjunction with ABS *Rules for Building and Classing Yachts*.

This document becomes effective on the first day of the month of publication.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

REQUIREMENTS FOR

MASTS AND RIGGING ARRANGEMENTS ON SAILING YACHTS

CONTENTS

SECTION 1
General

1 Application

This document provides classification requirements for the design and construction of masts and rigging systems of new construction monohull sailing or motor sailing yachts classed to the requirements of the ABS *Rules for Building and Classing Yachts* and assigned the ABS Class Notation ✠ **A1 Yachting Service** or ✠ **A1 Commercial Yachting Service** or ✠ **A1 Passenger Yachting Service**.

This document applies to metal structures (masts, booms, and spreaders built in steel or aluminum alloy).

Structures built in composite materials (FRP or carbon fiber) are subject to special consideration with all supporting documents and calculations submitted to ABS for review. The submitted documents and calculations are to include, but not limited to, the items listed in the following:

- Detailed plans listed in Subsection 1/4.
- Allowable limits (global and local allowable stresses and buckling verification)
- Materials mechanical properties
- Building process description and quality controls
- Proposed materials test methods (during construction and after construction)

This document is to be used in conjunction with ABS *Rules for Building and Classing Yachts*.

2 Terms and Definitions

The following definitions of terms apply throughout this document.

Babystay. Removable stay attached below the headstay, leading forward from the main mast to a fitting point on deck, used to control mast bend and stabilize. See Section 1, Figure 3.

Backstay. Stay leading aft from the upper part of a mast to the deck or stern. See Section 1, Figure 3.

Boom. Horizontal structure connected to the mast, supporting the lower part of the sail.

Chainplate. Structural connection between standing rigging and hull supporting structures.

Clew. Lower corner of a sail where the leech and foot connect (located on the boom for main/mizzen sail). See Section 1, Figure 2.

Deck Stepped Mast. A mast with a hinged constrained base.

Diagonals. Shrouds attached from the side face of the mast to the tip of the spreaders or the deck chain plate They are numbered bottom to top D1, D2, … DN, with D1 being the one attached to the deck chain plate. See Section 1, Figure 5.

Downwind. Sailing in the same direction as the wind is blowing.

Foresail. Sail on forestay (inner head or outer stay).

Foot (of a sail). Bottom edge of a sail above deck. See Section 1, Figure 2.

Luff (of a sail). Forward edge of a sail coincident with the headstay or mast on which it is furled. See Section 1, Figure 2.

Forestay. Stay leading forward from the main mast to a fitting point on deck. See Section 1, Figure 3.

Genoa. Foresail used for upwind sailing conditions. See Section 1, Figure 1.

Gooseneck. Boom attachment point to the mast aft face. See Section 1, Figure 4.

Halyard. Rope used for raising and lowering a sail. See Section 1, Figure 4.

Head. Top Corner of a sail where the luff and leech connect. See Section 1, Figure 2.

Headboard. Attachment point on a sail between the head and the halyard.

Headstay. Stay leading forward from the head of the main mast. See Section 1, Figure 3.

Heel Angle. A steady angle of heel created by an external force.

Innerstay/Inner-Forestay. Innermost stay leading forward from the main mast. See Section 1, Figure 3.

Jib/Blade. Foresail set on the inner-forestay used for upwind sailing conditions. See Section 1, Figure 1.

Keel Stepped Mast. Mast with fixed constrained base between a weathertight collar on the deck and baseplate on the keel.

Ketch. Sailing yacht equipped with two masts (main and mizzen).

Leech. The trailing aft (or back) edge of a fore-and-aft sail. See Section 1, Figure 2.

Main Mast. Vertical structure supporting the mainsail. In yachts with two or more masts, it is the foremost mast.

Mainsail. Sail hoisted on the main mast. See Section 1, Figure 1.

Main/Mizzen Sheet. Sheet attached to the boom (with pulley or fixed points). See Section 1, Figure 4.

Mast Panel. Portion of a mast between spreader fitting points. gooseneck or mast base. They are numbered from bottom to top , starting with Panel 0 for the one between the base of the mast and the gooseneck. See Section 1, Figure 5.

Mizzen Mast. In yachts with two or more masts, it is the mast located aft of the main mast.

Mizzensail. Sail hoisted on the mizzen mast.

MPS/Gennaker. Asymmetric spinnaker used for downwind sailing conditions. See Section 1, Figure 1.

Reacher. Foresail used in reaching conditions or light wind upwind conditions. See Section 1, Figure 1.

Reaching. Sailing with the wind coming across the vessel.

Reef (of a Sail). Reduced sail to fraction of its full area.

Runner/Checkstay. Element of rigging attached below the backstay, leading from the aft face of the mast, and used to control mast bend and counteract the inner-forestay. See Section 1, Figure 3.

Running Rigging. Rigging elements used for hoisting, lowering, shaping, and controlling the sails and mast shape.

Sheet. A line (rope, cable, or chain) attached to the clew and used to control a sail.

Shrouds. Elements of standing rigging which hold the mast up from side-to-side.

Spinnaker. Fore sail used for downwind sailing conditions.

Spinnaker Pole. A spar used to help to support the spinnaker.

Spreader. Struts attached to the sides of the mast to hold the shrouds away from the mast. See Section 1, Figure 5.

Standing Rigging. Fixed rods and lines elements that support the mast.

Staysail. Foresail attached to inner-forestay used in upwind sailing conditions. See Section 1, Figure 1.

Tack (of a sail). Lower corner of a sail where the luff and foot connect. See Section 1, Figure 2.

Upwind. Sailing towards the direction from which the wind is blowing.

Verticals. Shrouds fitted between the tips of the spreaders or between the spreaders and the deck chainplate. They are numbered from bottom to top V1, V2, … VN, with V1 being the one attached to the deck chain plate. See Section 1, Figure 5.

FIGURE 1
Types of Sails

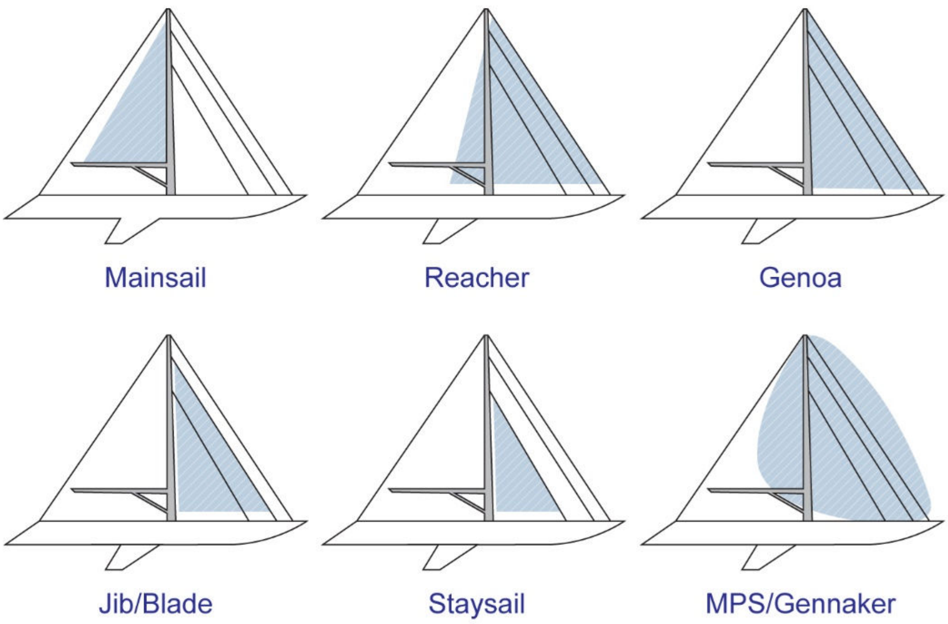


FIGURE 2
Parts of a Sail

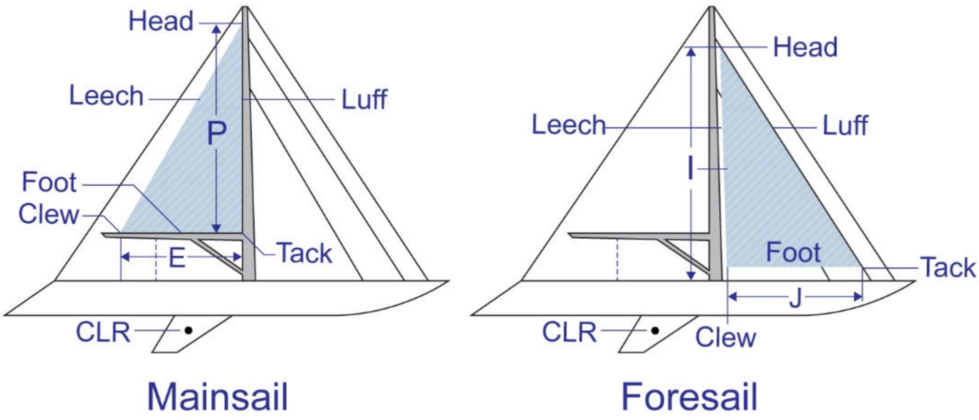


FIGURE 3
Stays

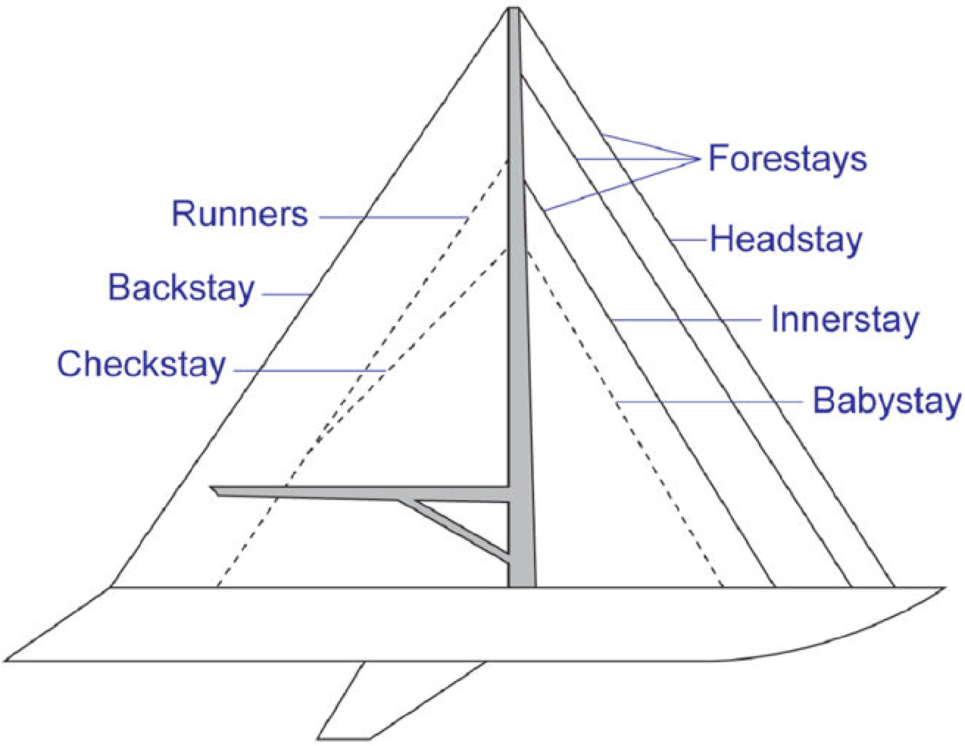


FIGURE 4
Running Rigging

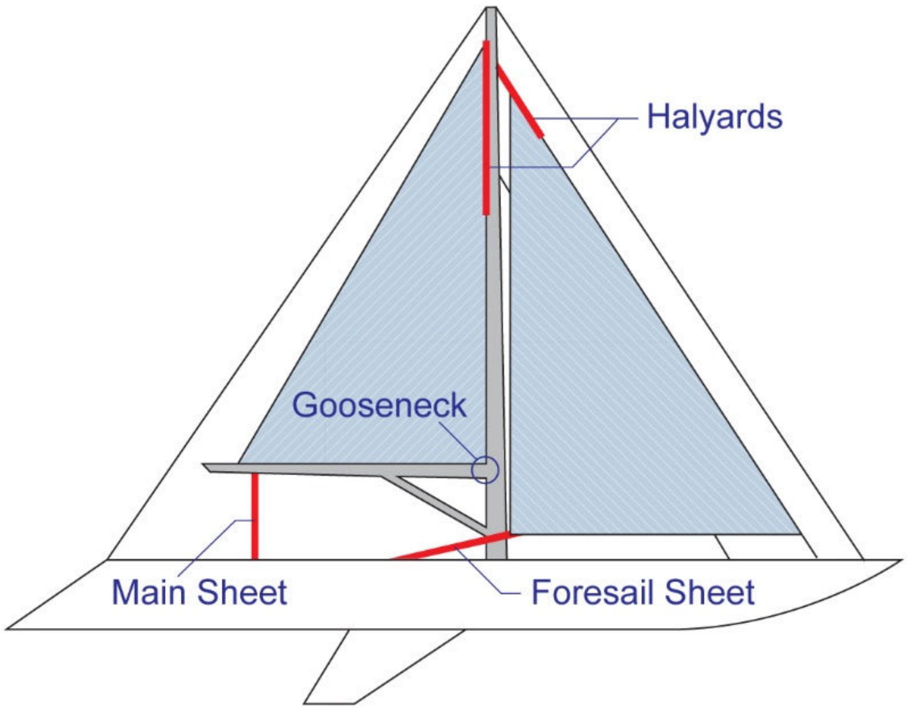
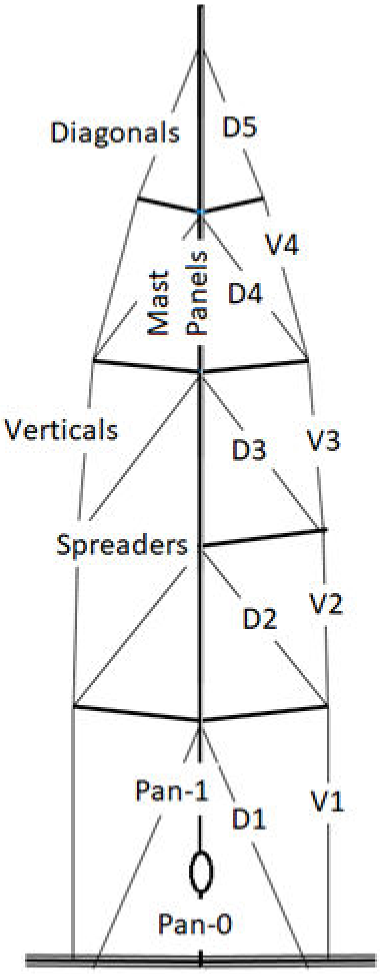


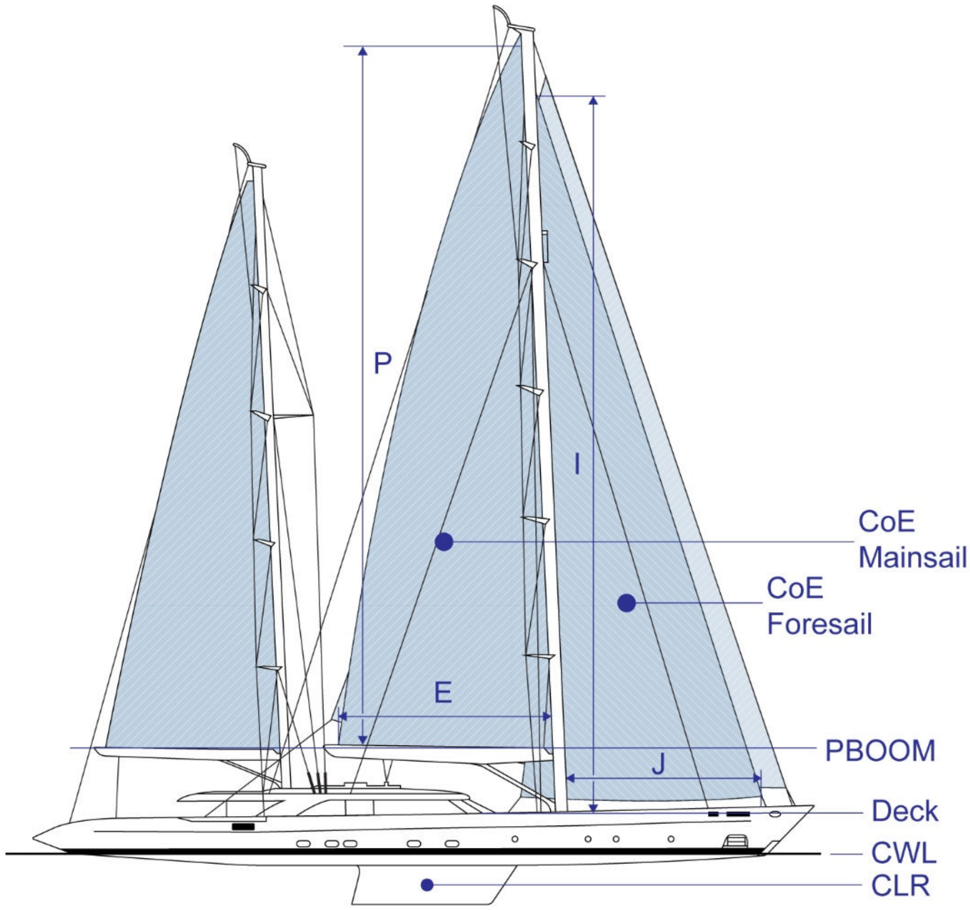
FIGURE 5
Standing Rigging



3 Symbols

CLR	Center of lateral resistance, or the point on which the resultant of the lateral hydrodynamic forces of the hull is applied.
E	Length of the boom or sail foot (when sail is not reefed), in m. See Section 1, Figure 6.
P	Length of the sail luff (length of the mast from gooseneck to sail head), in m. See Section 1, Figure 6.
J	Length from the mast fore face to the tack point of the foresail, in m. See Section 1, Figure 6.
I	Length from the foresail head to the deck, in m. See Section 1, Figure 6.
CLR-CWL	Distance between the center of lateral resistance and the waterline, in m. See Section 1, Figure 6.
CWL-DECK	Distance between the waterline and the deck, in m. See Section 1, Figure 6.
PBOOM-CWL	Distance between the sail foot and the waterline, in m. See Section 1, Figure 6.
CoE	Center of Effort for each sail. See Section 1, Figure 6.

FIGURE 6
Symbols



4 Documents and Information to be Submitted

4.1 Documents to be Submitted for Approval

- *Masts, Booms, Vangs, Solid Stays and Spreaders* – Materials, dimensions, scantlings, and construction and welding details
- *Solid Stays, Standing and Running Rigging* – Data sheets showing materials, dimensions, safe working loads, and breaking strength

4.2 Documents to be Submitted for Review

i) Sail Plan and Sailing Conditions. The plan is to include the loads induced by running riggings, stays and any other mechanical means (winches, hydraulic cylinders). The plan is also to include means for reefing/shortening sails and separate specific storm sails.

ii) Masts stepping procedure and diagram showing the mast and rigging pre-loads. Loads on lifting points are also to be included.

iii) Mast and rigging maintenance manual. As a minimum the manual is to include:

- Diagram showing the highly loaded components and strength points including attachment with solid/wire stays and connections with maneuvering/tensioning equipment (winches and hydraulic cylinders).

- For the highly loaded components and main strength points, the intervals and the locations for non-destructive tests, and testing method. Mast and rigging specific diagrams are to be included.
- Items that need to be replaced together with relevant time intervals.
- Maximum time intervals between masts disassembly.
- Procedures for masts disconnection, dismounting, and reassembling.
- Surveys/NDT to be carried out on disassembled mast and rigging. Mast and rigging specific diagrams are to be included.
- Any other manufacturer recommendations are also to be included.

4.3 Documents to be Submitted for Information

Designer calculations including verification of masts, booms, spreaders, and standing and running rigging in accordance with the requirements of this document are to be submitted for information.

5 Alternatives

More sophisticated methods of analysis may be acceptable, provided the results are determined by ABS to be not less effective than the requirements of this document.

SECTION 2
Materials

1 General Requirements

1.1 General

Materials are to be suitable for the intended service conditions. They are to be of good quality, free of injurious defects, and are to exhibit satisfactory formability and weldability characteristics.

All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of Part 2, Chapter 4 and Appendix 2-5-A1 of the ABS *Rules for Materials and Welding (Part 2)*.

Where dissimilar materials (such as aluminum and steel, stainless steel and carbon steel, or copper/nickel and carbon steel) are used in combination and exposed to water or weather, proper insulation is to be provided to avoid galvanic corrosion.

1.2 Material Certification

Materials of main structural members of masts and rigging are to be furnished with certificates issued by the mill or the material manufacturer, indicating, as a minimum and as applicable, the material specification, grade, process of manufacture, heat treatment details, and mechanical and chemical properties.

Standing and running rigging is to be provided with manufacturer certification including breaking strength.

SECTION 3
Loading Conditions

1 General

The strength assessment of the masts and rigging design is to be based on the most severe sailing configurations and the vessel in full load conditions.

The following load cases represent possible sailing configurations.

Load cases with mizzen mast sails are not to be considered for a single mast configuration.

The load cases indicated in Subsection 3/2 are always to be considered by the designer for the sizing of the masts and rigging.

The designer is responsible for identifying additional load cases that may result in more severe sailing configurations.

The maximum heeling angle set for each load condition is to be specified by the designer and is not to be exceeded. Therefore, a heel angle monitoring system is to be installed on board to alert the crew when the various design angles of each load condition are about to be exceeded.

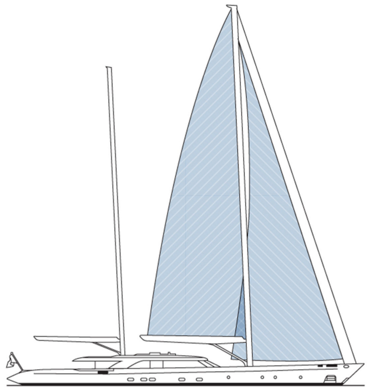
A minimum heeling angle of 25 degrees is to be considered.

Maximum heeling angles for each sailing condition are to be included in the sailing conditions tables (see 1/4.2).

2 Loading Conditions

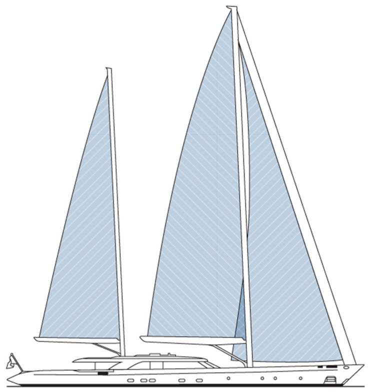
2.1 Load Case 1

- Full Main Sail + Foresail (Genoa or Jib)
- Upwind at 100% of maximum heeling angle.



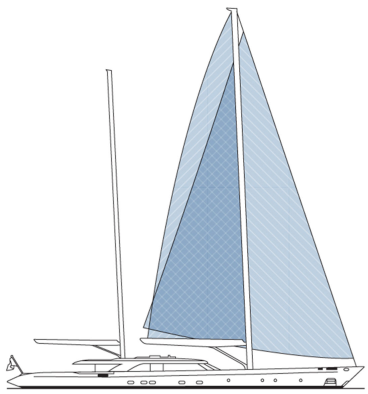
2.2 Load Case 2

- Full Main Sail + Mizzen Sail + Foresail (Genoa or Jib)
- Upwind at 100% of maximum heeling angle



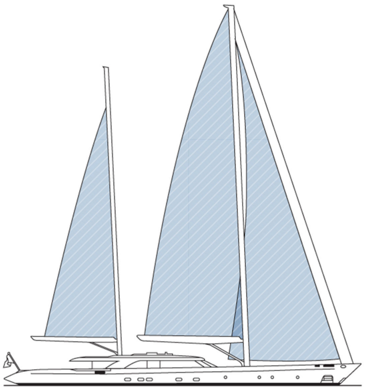
2.3 Load Case 3

- Full Main Sail + Reacher
- Reaching/Downwind at 70% of maximum heeling angle



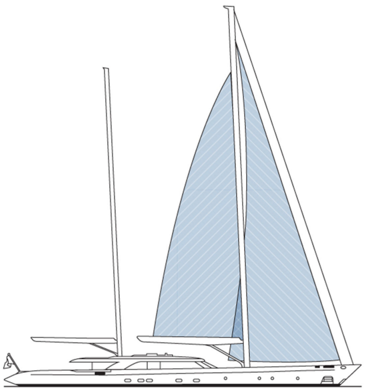
2.4 Load Case 4

- Full Main Sail + 1 Reef Mizzen Sail + Foresail
- Upwind at 100% of maximum heeling angle



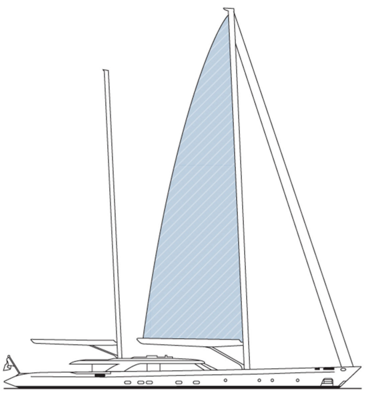
2.5 Load Case 5

- 1 Reef Main Sail + Foresail
- Upwind at 80% of maximum heeling angle



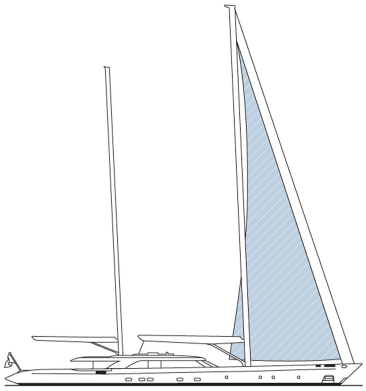
2.6 Load Case 6

- Main Sail Only
- Upwind at 60% of maximum heeling angle



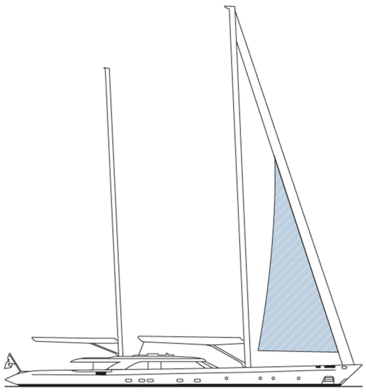
2.7 Load Case 7

- Fore Sail Only (Jib or Genoa)
- Upwind at 50% of maximum heeling angle



2.8 Load Case 8

- Staysail Only
- Upwind at 50% of maximum heeling angle



3 Loads Calculation

3.1 Center of Effort and Pressure Distribution

The pressure distribution and associated position of the CoE is normally provided by the designer through a trapezoidal distribution as indicated in Section 3, Figure 1c.

If this information is not available, the following load distributions are to be considered. A linear distribution is to be considered for reaching sailing conditions (See Section 3, Figure 1a):

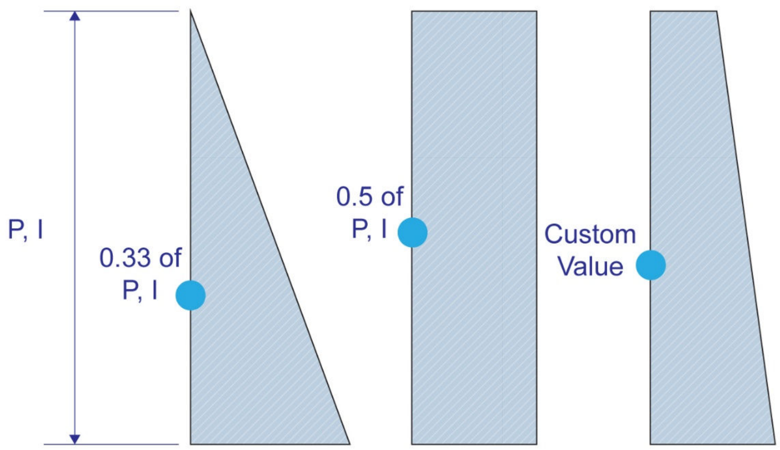
- Mainsail/Mizzensail = CoE located at 0.33P above the sail foot/boom
- Foresail = CoE located at 0.33I above the sail foot/deck

A uniform distribution is to be considered for upwind sailing conditions (See Section 3, Figure 1b):

- Mainsail/Mizzensail = CoE located at 0.5P above the sail foot/boom
- Foresail = CoE located at 0.5I above the sail foot/deck

For MPS and Spinnaker Sail, a CoE located at 0.5I is to be used.

FIGURE 1
Center of Effort and Pressure Distribution



3.2 Lateral Force on Each Sail

The total lateral force, $Flat_i$, in N, on each sail is given by the following equation:

$$Flat_i = \frac{1}{2} \cdot \rho \cdot AWS^2 \cdot A_i \cdot rf_i \cdot CL_{sail}$$

where

ρ	=	air density at sea level (1.29 kg/m^3)
AWS	=	apparent wind speed, in m/s
A_i	=	area of each sail, in m^2
rf_i	=	reef fraction for each sail based on total sail area from 0 to 1
CL_{sail}	=	lateral force coefficient of each sail as indicated in Section 3, Table 1

TABLE 1
Lateral Force Coefficient for Sails

Type of Sail	*Lateral Force Coefficient (CLSail)*
Main Sail	1.0
Mizzen Sail	0.9
Genoa/Jib/Blade/Staysail	1.1
Reacher	1.2
Spinnaker/MPS/Gennaker	1.2

The apparent wind speed AWS in m/s is to be calculated with the following equation:

$$AWS = \sqrt{\frac{2 \cdot RMtot}{\rho \cdot \sum_1^{nSAIL} A_i \cdot rf_i \cdot CL_{sail} \cdot CoECLR_i}}$$

where

$RMtot$ = total righting moment of the vessel at the heeling angle under consideration, in N-m

$CoECLR_i$ = distance, in m, between the center of pressure of each sail and hull center of lateral resistance (see Section 1, Figure 6)

ρ, A_i, rf_i and CL_{sail} are defined above.

3.3 Lateral Forces on Masts

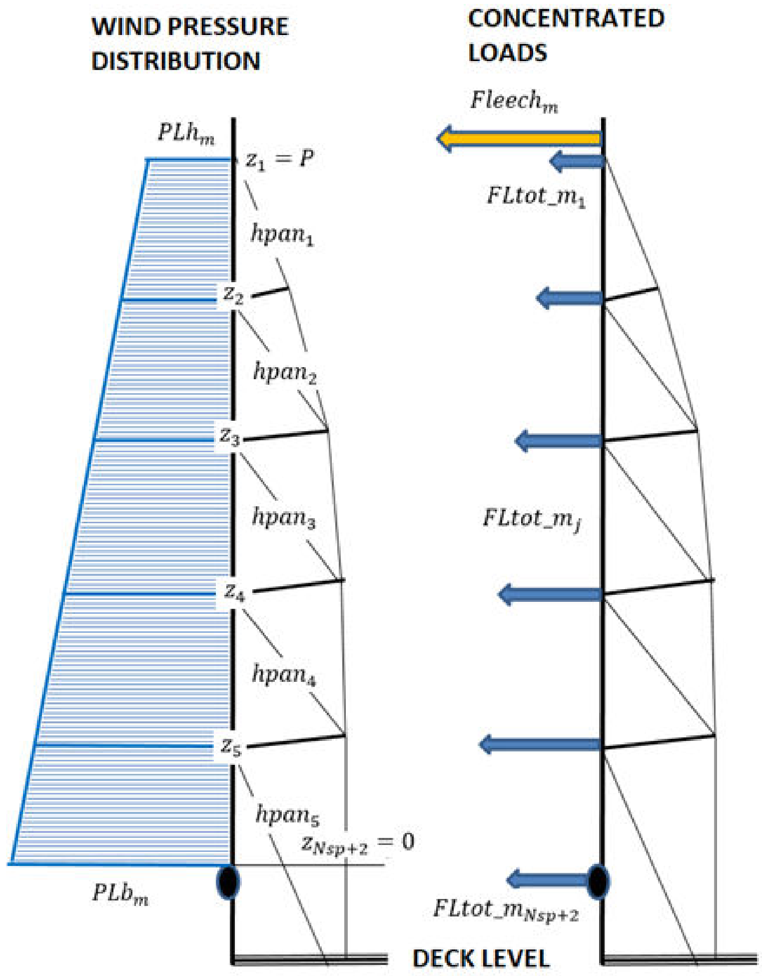
3.3.1 Lateral Load from Main and Mizzen Sails

The following calculation procedure is to be used to calculate the concentrated forces to be applied to the mast at the points indicated in Section 3, Figure 2.

The lateral load of the mainsail and mizzensail is transferred by the sail membrane along the mast and by the sail leech to the masthead and boom clew point.

The shape of the pressure distribution of the two contributions (membrane and leech) is a sum of a constant and a linear distribution to match the vertical location of the sail center of effort.

FIGURE 2
Calculation of Concentrated Loads



The lateral/side membrane load, $Fmem_m$, in N, transferred by the sail leech directly to the mast is calculated with the following formula:

$$Fmem_m = \left(\frac{PLb_m + PLh_m}{2}\right) \cdot P$$

where

PLh_m	=	linear force, in N/m, at the sail head (see Section 2, Figure 2)
	=	$2 \cdot K \cdot \frac{Flat_m}{P} \cdot \left(\frac{3 \cdot CoEb_m}{P} - 1\right)$ in N/m
PLb_m	=	linear force, in N/m, at the foot/boom (see Section 2, Figure 2)
	=	$2 \cdot K \cdot \frac{Flat_m}{P} \cdot \left(2 - \frac{3 \cdot CoEb_m}{P}\right)$ in N/m
P	=	length of the sail luff (length of the mast from gooseneck to sail head), in m. See Section 1, Figure 6

The lateral/side concentrated load, $Fleech_m$, in N, transferred by the sail leech to the headboard point of the mast is calculated with the following formula:

$$Fleech_m = Flat_m \cdot (1 - K) \cdot \frac{CoEb_m}{P}$$

The lateral/side concentrated load, $Fclew_m$, in N, transferred by the sail leech to the boom clew point of the boom is calculated with the following formula ($Fclew_m$ is applied to the boom clew and not to the mast directly):

$$Fclew_m = Flat_m \cdot (1 - K) - Fleech_m$$

where

$Flat_m$	=	total lateral force, in N, on the m sail calculated in accordance with 3/3.2
$CoEb_m$	=	distance between the Center of Effort and the boom line, in m
K	=	fraction of the lateral load transferred to the mast by the sail membrane. This fraction is normally provided by the designer. If this data is not available, a value of 0.35 may be considered.
P	=	length of sail luff (length of the mast from the gooseneck to the sail head) in m (see Section 1, Figure 6)

The lateral/side membrane load, $FLtot\_m_j$, in N, is to be distributed on each spreader as indicated in the following formula:m

$$FLtot\_m_j = \frac{FLc\_m_{j-1} + FLc\_m_j}{2} + \frac{2 \cdot FLtr\_m_{j-1} + FLtr\_m_j}{3}$$

where

j	=	$1, 2 \ldots . Nsp + 1$, where Nsp is the total number of spreaders
FLc_m_j	=	$plm_j \cdot hpan_j$ concentrated load, in N, due to constant part of the load distribution

$FLtr\_m_j$	=	$\left(plm_{j+1} - plm_j\right) \cdot \frac{hpan_j}{2}$ concentrated load, in N, due to linear part of the load distribution
plm_j	=	$PLh_m + \frac{(PLb_m - PLh_m)}{P} \cdot hm_j$ load per unit length along the mast, in N/m
$hpan_j$	=	length, in m, of mast panel $(j = 1, 2 . . . . Nsp + 1)$
P	=	length of the sail luff (length of the mast from gooseneck to sail head), in m. See Section 1, Figure 6
hm_j	=	$P - z_j$ distance, in m, between the headboard and load points $(j = 1, 2 . . . . Nsp + 2)$
z_j	=	distance, in m, of load points above the boom $\left(z_1 = P, z_{Nsp+2} = 0\right)$

PLb_m and PLh_m are defined above.

The lateral load, $FLtot\_m_1$, in N, to be applied at the headboard of a sail is:

$$FLtot\_m_1 = \frac{FLc\_m_1}{2} + \frac{FLtr\_m_1}{3}$$

FLc_m_1 and $FLtr\_m_1$ are defined above.

The lateral loads, $FLtot\_m_{Nsp+2}$, in N, to be applied at the boom point:

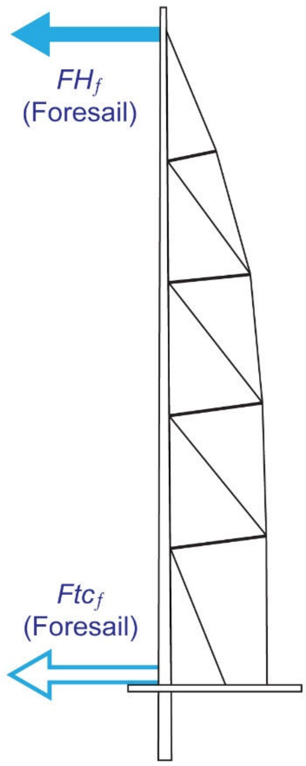
$$FLtot\_m_{Nsp+2} = \frac{FLc\_m_{Nsp+1}}{2} + \frac{2 \cdot FLtr\_m_{Nsp+1}}{3}$$

Where FLc_m_{Nsp+1} and $FLtr\_m_{Nsp+1}$ are FLc_m_j and $FLtr\_m_j$ calculated for $j = Nsp + 1$.

3.3.2 Lateral Load from Fore Sails

The following calculation procedure is to be used to calculate the lateral concentrated forces from fore sail: FH_f applied to the mast, Ftc_f applied to deck. (See Section 3, Figure 3).

FIGURE 3
Fore Sail Concentrated Loads



The load, FH_f, in N, applied on the fitting point on the mast is to be calculated as follows:

$FH_f = Flat_f \cdot CoEf / I_f$

where

$Flat_f$	=	total lateral force, in N (see 3/3.2)
$CoEf$	=	Center of Effort above the sail foot/deck, in m (see 3/3.1)
I_f	=	length from foresail head to deck, in m (see Section 1, Figure 6)

The load, Ftc_f, in N, applied on tack and clew points on deck:

$Ftc_f = Flat_f - FH_f$

$Flat_f$ and FH_f are defined above.

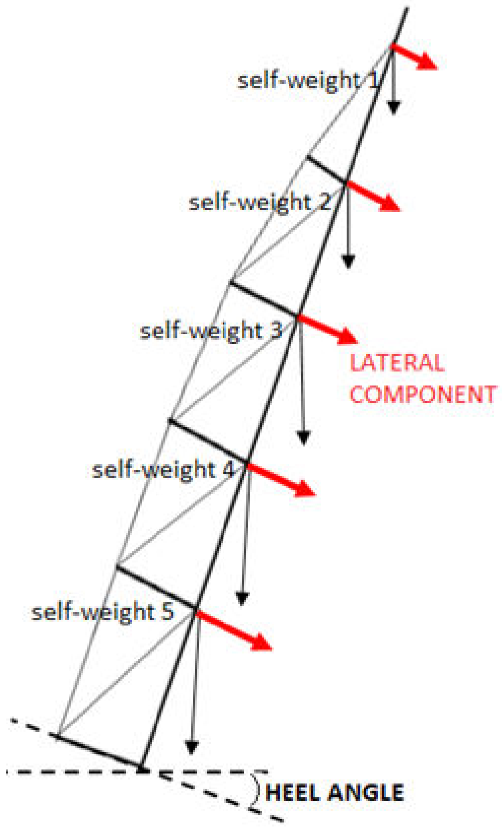
3.3.3 Lateral Load from Self Weight

In addition to the aerodynamic loads, it is necessary to consider the loads induced by the self-weight of the mast and rigging. These loads have an important role in defining the stresses on the mast and rigging since their lateral components have significant values when sailing at high design heeling angles.

The various contributions to the lateral load generated by the self-weight of the mast panel, spreaders, shrouds, boom, and stays are to be applied to the same nodes of the structure where aerodynamic loads are also applied.

The various concentrated loads are to be calculated through equilibrium considerations knowing the center of gravity of each element. See Section 3, Figure 4.

FIGURE 4
Mast Self Weight

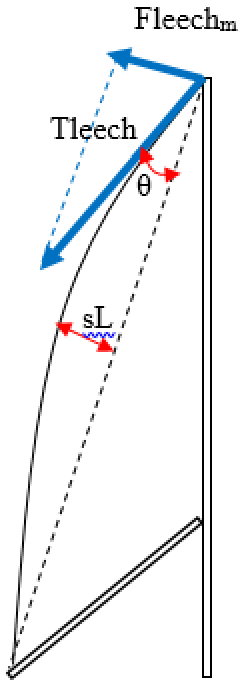


3.4 Vertical Forces on Masts

3.4.1 Vertical Load from Main/Mizzen Sail Halyard

The following formula is to be used for the calculation of the vertical load, F_{Halym}, in N, induced by the main/mizzen sail's halyard on the mast structure. See Section 3, Figures 5 and 6.

FIGURE 5
Vertical Forces on Masts Induced by Main/Mizzen Sails



$$F_{Halym} = 1.05 \cdot Tleech$$

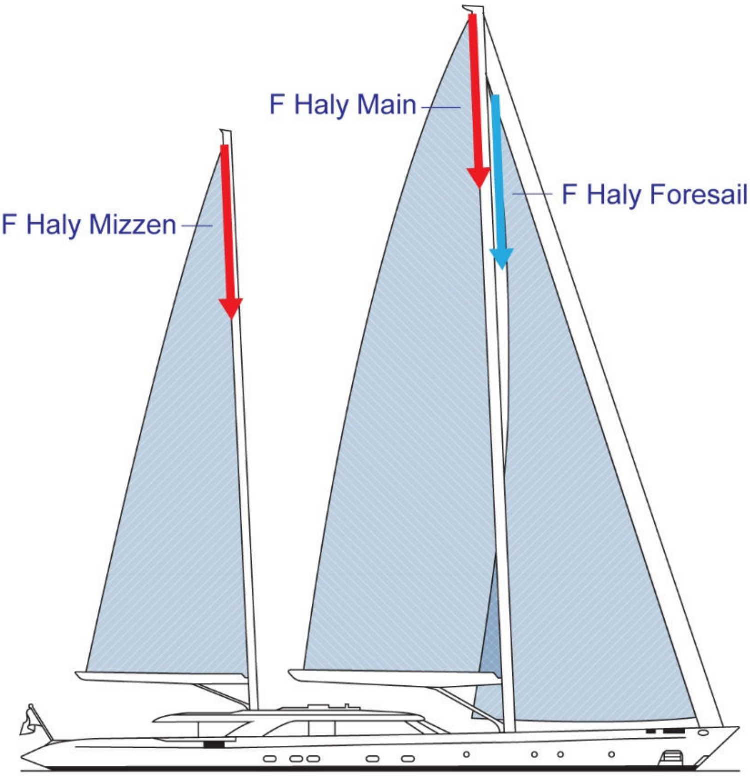
where

$Tleech$	=	Leech tension load, in $N = Gf \cdot \frac{Fleech_m}{\sin(\theta)}$
$Fleech$	=	lateral/side concentrated load, in N, transferred by the sail leech to the headboard point of the mast (see 3/3.3.1)
Gf	=	gust factor. This fraction is normally provided by the designer. If this data is not available, Gf = 2.0 is to be considered.
θ	=	angle of leech deflection = $\arctan\left(\frac{Lleech}{2 \cdot k}\right)$
$Lleech$	=	leech length, in m
k	=	leech deformation parameter = $\frac{Lleech^2/4 - (s \cdot Lleech)^2}{2 \cdot s \cdot Lleech}$
s	=	sag fraction. This fraction is normally provided by the designer. If this data is not available, the following values are to be considered:
	=	0.055 (5.5% of leech length) for upwind conditions
	=	0.2 (20% of leech length) for downwind conditions

3.4.2 Vertical Load from Fore Sails Halyard

The following formula is to be used for the calculation of the vertical load, F_{HalyF}, in N, induced by the foresail's halyard on the mast structure. See Section 3, Figure 6.

FIGURE 6
Vertical Forces on Masts Induced by Fore Sails



$$F_{HalyF} = \frac{Flat_F}{8 \cdot s}$$

where

$Flat_F$	=	sail lateral force, in N (see 3/3.2)
s	=	sag fraction. This fraction is normally provided by the designer. If this data is not available, the following values are to be considered:
	=	0.045 (4.5% of leech length) for genoa/jib/blade
	=	0.05 (5% of leech length) for reacher
	=	0.06 (6% of leech length) for MPS/gennaker

3.4.3 Pretension Loads

Pre-tensioning procedures which will reach at least the following pre-load values are to be applied:

- *Verticals*. Pretension load at least 22% of breaking load of each vertical
- *Diagonal D1*. Pretension load at least 18% of breaking load of D1
- *Other Diagonals*. Pretension load at least 12% of breaking load for each diagonal

Commentary:

Pre-tensioning should avoid slack leeward cap shrouds with an appropriate reserve, when sailing at heeling angles at or below the maximum design value.

As far as the vertical chain is concerned, if it is desired to maintain greater loads on the leeward part when sailing at maximum design heel angle, it will be necessary to give a greater pretension during the first preload phase (verticals only) with a consequent increase in the cable sections of the verticals.

Diagonals, on the other hand, can reach the slack condition without creating instability of the mast. However, the designer can decide to give a higher pre-tensioning load to avoid slack diagonals even in conditions of maximum heeling angle.

End of Commentary

3.5 Boom Loads

3.5.1 Boom Thrust

The boom forward thrust, $Tboom$, is due to the longitudinal component of the leech load at the clew point. This force is applied directly to the gooseneck of the mast. See Section 3, Figure 7.

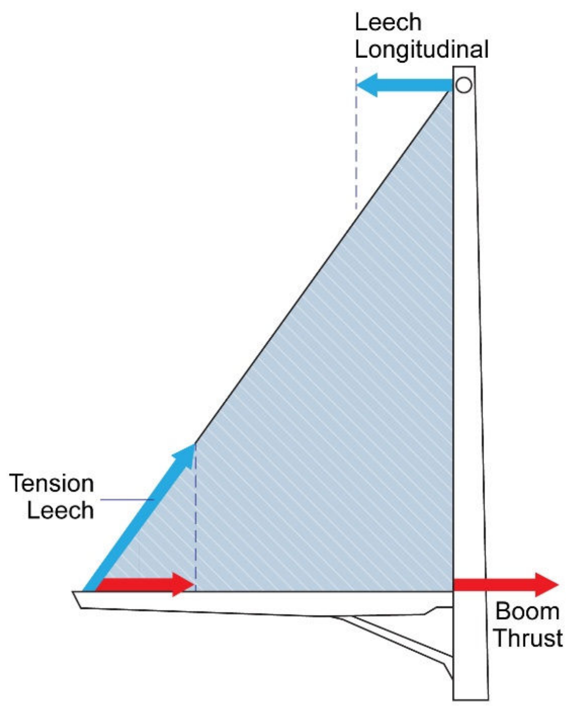
$$Tboom = \cos\left(\operatorname{atan}\left(\frac{P}{E}\right)\right) \cdot Tleech$$

where

$Tleech$	=	leech tension load, in N (see 3/3.4.1)
E	=	length of the boom or sail foot (when sail not reefed), in m (see Section 1, Figure 6)
P	=	length of sail luff (length of mast from gooseneck to sail head), in m (see Section 1, Figure 6)

The same load is to be applied to the masthead in the opposite direction.

FIGURE 7
Boom Loads



3.5.2 Boom Outhaul

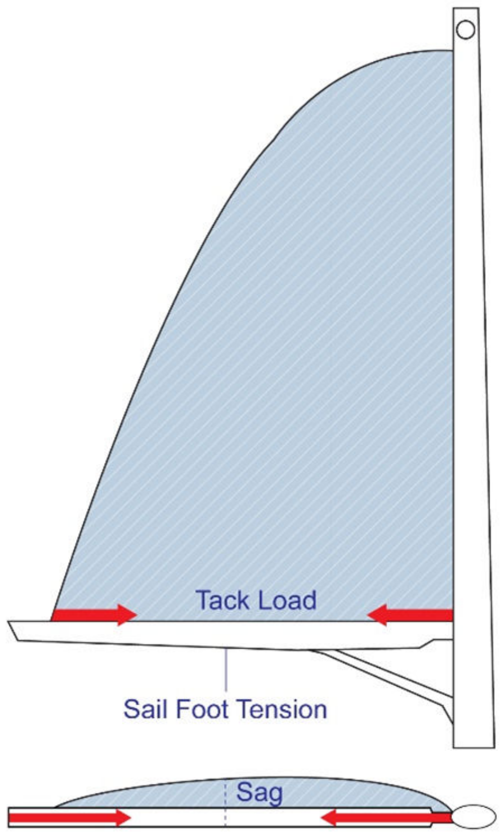
The boom outhaul, $F_{outhaul}$, is the sum of the boom thrust and the tension due to the sag of the foot of the sail (called tack load). This load is used for boom sizing and is not applied to the masts, See Section 3, Figure 8.

$$F_{outhaul} = F_{Tack} + T_{boom}$$

where

T_{boom}	=	See 3/3.5.1
F_{Tack}	=	$\frac{0.3 \cdot Flat}{8 \cdot s}$, in N
$Flat$	=	lateral force on the sail, in N (see 3/3.2)
s	=	sag fraction. This fraction is normally provided by the designer. If this data is not available, a value of 0.05 is to be considered (5% length)

FIGURE 8
Boom Outhaul



3.6 Main/Mizzen Sheet Loads and Vang Loads

3.6.1 Mainsheet Load

The mainsheet load is the reaction to the vertical component of the leech tension. See Section 3, Figure 9.

- *Vertical Load on Mainsheet, in N:*

$Fv_{msheet} = Tleech_{vert} \cdot \frac{E}{Xsheet}$

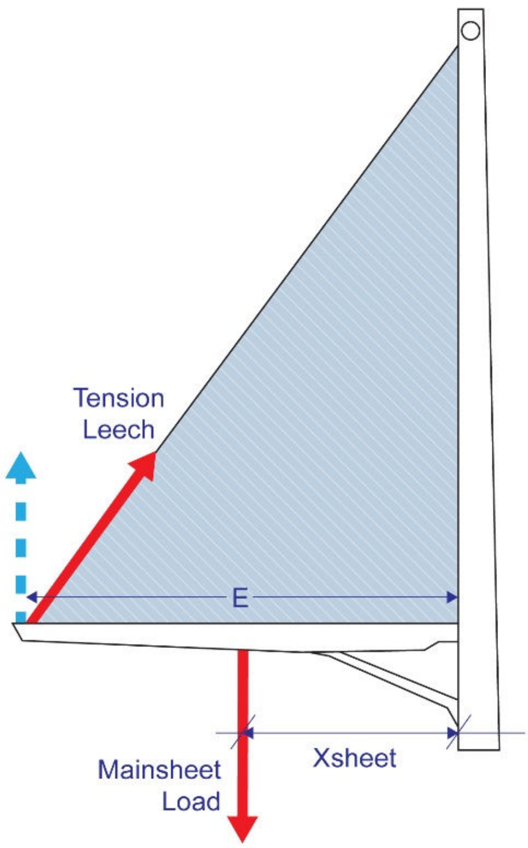
- *Horizontal Load on Mainsheet, in N:*

  $Fh_{msheet} = Fclew_m \cdot \frac{E}{Xsheet}$

where

$Tleech_{vert}$	=	$Tleech \cdot \sin\left(\arctan\left(\frac{P}{E}\right)\right)$
$Tleech$	=	leech tension load, in N (see 3/3.4.1)
$Fclew_m$	=	lateral/side concentrated load transferred by the sail leech to the boom clew point of the boom, in N (see 3/3.3.1)
$Xsheet$	=	See Section 3, Figure 9
E	=	length of the boom or sail foot (when sail not reefed) in m (see Section 1, Figure 6)
P	=	length of sail luff (length of the mast from the gooseneck to the sail head) in m (see Section 1, Figure 6)

FIGURE 9
Main/Mizzen Sheet Loads



For downwind conditions, horizontal load is to be also verified in accordance with 3/3.6.2. The maximum value is to be considered in the strength assessment.

3.6.2 Mainsheet Horizontal Load in Downwind Conditions

In downwind conditions, the mainsheet reacts to lateral loading applied at the clew point.

Unless different information is provided by the designer, an apparent wind speed of 30 knots is to be considered.

- Downwind force on mainsail $Fsail_{DW} = \frac{1}{2} \cdot \rho \cdot V^{2} \cdot Asail$
- Lateral force on mainsheet $Fhdw_{sheet} = 0.3 \cdot Fsail_{DW} \cdot \frac{E}{Xsheet}$

where

ρ	=	air density at sea level (1.29 kg/m^3)
V	=	15.4 m/s, apparent wind speed, in m/s (30 knots) unless different information is provided by the designer
$Asail$	=	sail area in m^2
E	=	length of the boom or sail foot, in m. See Subsection 1/3.
$Xsheet$	=	distance, in m, between the mainsheet and the mast. See Section 3, Figure 9.

3.6.3 Vang Load

The vang can be used both during upwind and downwind sailing conditions. Therefore, it is necessary to calculate the leech tension values for both cases. In the case of upwind, unless differently advised by the designer, it can be considered that the vang contributes 50% to the balance of leech tension. For the downwind case, a mainsail sag increased to a value equal to 0.20 of P is to be used.

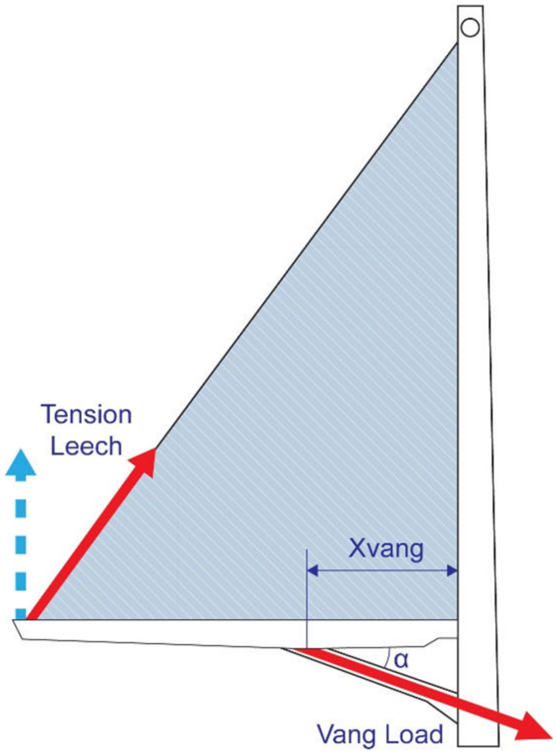
The relief valve load can be used if it is lower than the calculated design load.

- $Fvang_{downwind} = \sin\left(\arctan\left(\frac{P}{E}\right)\right) \cdot Tleech_{downwind} \cdot \frac{E}{Xvang \cdot sin(\alpha)}$
- $Fvang_{upwind} = 0.5 \cdot \sin\left(\arctan\left(\frac{P}{E}\right)\right) \cdot Tleech_{upwind} \cdot \frac{E}{Xvang \cdot sin(\alpha)}$

For P, E, and $Tleech$, see 3/3.6.1.

For $Xvang$ and α, see Section 3, Figure 10.

FIGURE 10
Vang Loads



3.7 Headstay/Forestay Tension Load

Unless differently indicated by the designer, the forestay tension load, H_{stay}, in N, is calculated from the same catenary formula used for calculating mainsail and foresail leech tension. See Section 3, Figure 11.

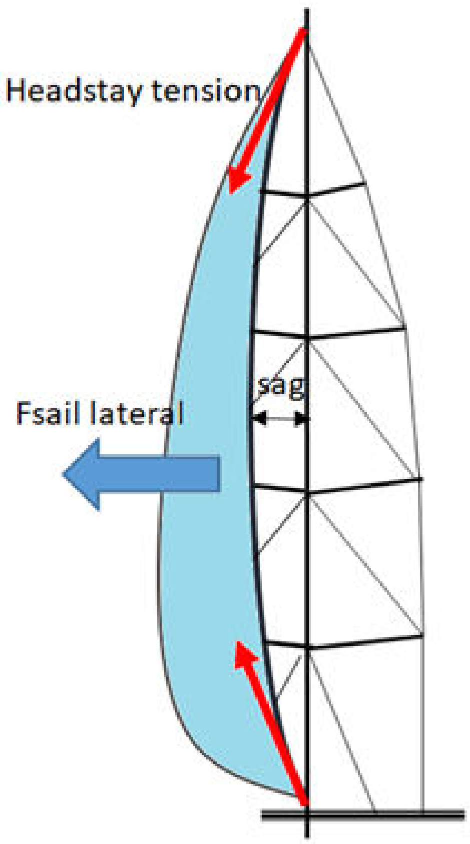
$$Hstay = \frac{Fsail_{lat}}{8 \cdot s}$$

where

$Fsail_{lat}$	=	sail lateral force, in N.
s	=	sag fraction. This fraction is normally provided by the designer. If this data is not available, the following values are to be considered:

- Genoa/Jib = 0.018 (1.8% of the length)
- Reacher = 0.023 (2.3% of the length)
- Staysail = 0.025 (2.5% of the length)

FIGURE 11
Headstay/Forestay Tension Load



3.8 Additional Loads on Spreaders

In addition to the compressive load on the spreaders, the following loads are to be considered.

3.8.1 Mast Bend Load

The prebend given during the setting of the mast transfers a load to the spreaders on the horizontal plane directed towards the stern.

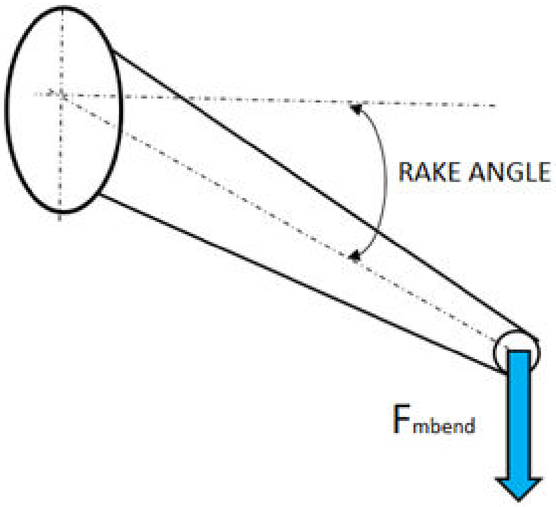
The bending moment, M_{mbend}, in N-m, induced by this load at the root of the spreader is to be determined as follows. See Section 3, Figure 12.

$$M_{mbend} = \cos(\alpha_{rake}) \cdot F_{mbend} \cdot L$$

where

F_{mbend}	=	$1.25 \cdot \mathrm{V1}_{wl} \cdot K_{bend}$
K_{bend}	=	$0.00385 + \frac{0.00165}{20} \cdot \alpha_{rake}$
$\mathrm{V1}_{wl}$	=	max working load, in N, on vertical V1 for all sailing conditions (see Subsection 3/2)
L	=	length of spreader, in m
α_{rake}	=	spreader rake angle, in degrees, for K_{bend} calculation

FIGURE 12
Spreader Bend Load



3.8.2 Tip Cup Offset Load

A bending moment is usually generated near the tip cup of the spreader.

Due to the misalignment of the connected shrouds, this can vary depending on the tip cup manufacturer and must therefore be evaluated by the designer.

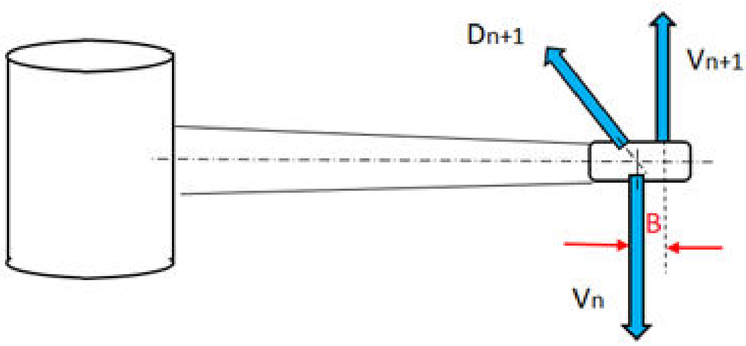
If no information is provided by the designer, the following formula is to be used. See Section 3, Figure 13.

$M_{tipcup} = 2.5 \cdot B \cdot \mathrm{V}(n + 1_{wl})$

where

B	=	tip cup offset $= 0.6 \cdot \varnothing_{(\mathrm{V}n+1)}$
$\mathrm{V}(n + 1_{wl})$	=	maximum working load, in N on upper vertical for all sailing conditions (see Subsection 3/2)
$\Phi(\mathrm{V}n + 1)$	=	diameter of Vertical $\mathrm{V}(n + 1)$

FIGURE 13
Spreader Tip Cup Offset Load



3.8.3 Electronics and Rigger Load

Bending moments induced by weights of electronic devices placed at half the length of the spreader and the weight of a person (rigger) are to be considered as well.

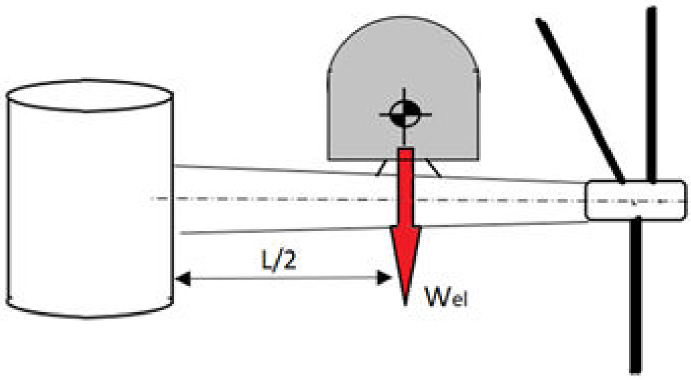
If no information is provided by the designer, a value of 1000 N is to be considered as total weight. See Section 3, Figure 14.

$$M_{el} = W_{el} \cdot \frac{L}{2} \cdot K_{el}$$

where

L	=	length of spreader, in m
W_{el}	=	1000 N weight of electronics and rigger
K_{el}	=	dynamic factor = 3

FIGURE 14
Spreader Electronics and Rigger Load

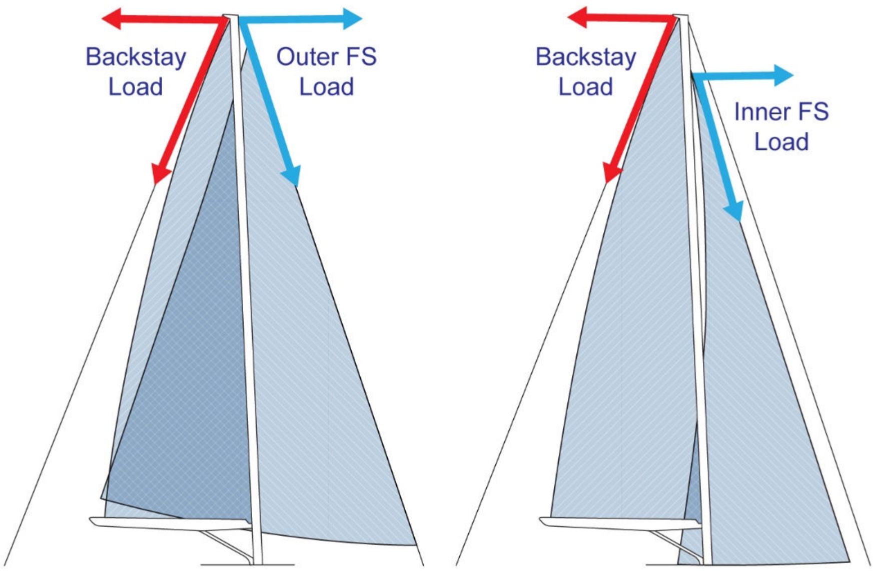


3.9 Loads on Running and Standing Rigging

3.9.1 Backstay Loads

The loads on the backstay are to be calculated considering the backstay in opposition to each stay with the most loaded sail for each load case considered. In the calculation, the equilibrium of moments about the mast base is to be satisfied. See Section 3, Figure 15. If there is a sweepback angle of the spreaders, it is also possible to consider the contribution of the cap shrouds.

FIGURE 15
Loads due to Running and Standing Rigging



3.9.2 Runners, Checkstay, Babystay Loads

Loads on runners can be evaluated by looking at the windward runner opposing the inner-forestay with loaded sail in load cases where this is meant to be used. Also in this case, the equilibrium of moments about the mast base is to be satisfied in the calculation. If there is no intermediate stay loaded with a sail, the runners are used only to stabilize the mast (often together with the use of a babystay) or to give the mast the desired bend. In this case, it is up to the designer and the crew to decide how much preload to give to the runner and/or babystay. The maximum load of the runners and babystays is often obtained during motoring navigation in severe sea conditions due to the angular accelerations induced on the rigging by the yacht's motion. This type of load can only be calculated accurately using a finite element model.

3.9.3 Standing Rigging Loads

The loads on the standing rigging are to be evaluated by the designer including the longitudinal elements (backstay, runner, checkstay, babystay) and supporting calculations are to be submitted for review. Pre-tension loads for each rigging element are to be considered.

SECTION 4

Allowable Limits

1 General

The loads are to be calculated in accordance with Section 3. Stresses resulting from the calculations are to be verified with the allowable limits reported in the following paragraphs.

As an alternative, independent calculations developed by the designer may be considered.

A complete Finite Element Model of the mast and rigging structures is to be submitted. Methodology and software used are to be specified. When a Finite Element Calculation is used for the strength assessment of masts and rigging structures, the following allowable limits are to be considered:

- The designer is to demonstrate that the stresses for the strength members subjected to the combined loads provided in Section 3 do not exceed the allowable stresses in accordance with Section 3-1-3 of the ABS *Rules for Building and Classing Yachts*.
- Strength members subjected to axial compression or combined loads, such as axial compression and bending moment, are also to be assessed in accordance with the ABS *Requirements for Buckling and Ultimate Strength Assessment for Offshore Structures*.

2 Mast Structures

The area and inertia of the mast structures are normally provided by the designer.

A simplified method to calculate the offered area and inertia of a typical elliptical mast section is provided in Appendix 1.

2.1 Global Buckling Strength

2.1.1 Mast Panels Other Than Panel 0 and Panel 1

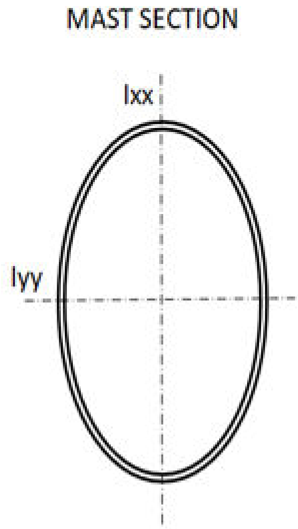
The minimum required inertia, in mm^4, for each mast panel (see Section 4, Figure 1) is to be calculated as follows:

- *Minimum Lateral Inertia*

$$Ixx_{min} = \frac{h^2 \cdot N_{pan}}{E \cdot \pi^2} \cdot SF_{mast}$$

- *Minimum Longitudinal Inertia*

$$Iyy_{min} = \frac{h^2 \cdot N_{pan}}{E \cdot \pi^2} \cdot SF_{mast} \cdot \frac{H_{Caps}}{h}$$



where

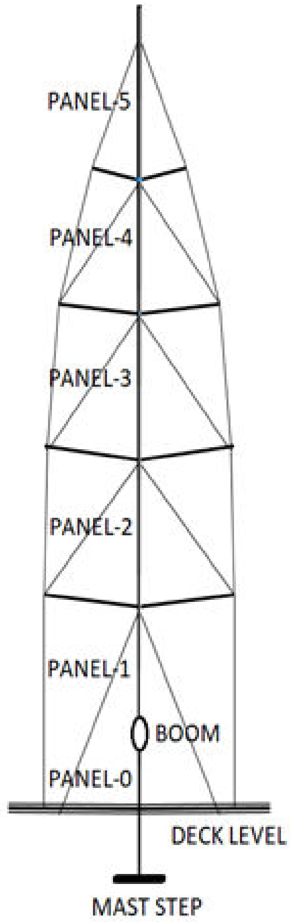
h	=	length of mast panel, in mm
H_{Caps}	=	height of cap shrouds from deck level, in m
N_{pan}	=	compression force on mast panel, in N, obtained from direct calculations (see Subsection 4/1)
E	=	Young's modulus of mast material, in N/mm^2
SF_{mast}	=	2.5 Safety Factor

Commentary:

N_{pan} is the normal compressive force acting on each panel and is to be calculated through a grillage/FE calculation by the application of all the loads specified in Section 3.

End of Commentary

FIGURE 1
Mast Panels



2.1.2 Mast Panel 0 and Panel 1

Panel 0 and Panel 1 are to be considered as a single panel called Panel 0/1 with a length equal to the sum of the two.

For keel stepped masts, a length equal to 0.7 times the sum of the two is to be considered.

2.2 Local Buckling Strength

2.2.1 Mast Panels Other Than Panel 0

The maximum working compressive axial stress, in N/mm^2, on each mast panel is to be not greater than the allowable local buckling stress, in N/mm^2, calculated with the following formula:

- σw_m – working compressive axial stress for mast panel:

  $$\sigma w_m = \frac{N_{pan}}{A} \cdot C_{bend}$$

- σc_m – allowable local buckling stress for mast panel:

  $$\sigma c_m = \frac{1}{SFmast} \cdot \left(0.5 \cdot \frac{E}{\sqrt{3 \cdot \left(1 - \upsilon^2\right)}} \cdot \frac{\mathrm{tm_{min}}}{Rm} \right)$$

where

N_{pan} = compression force on mast panel, in N, obtained from direct calculations (see Subsection 4/1 and Commentary in 4/2.1.1)

A = area of elliptical section, in mm^2

C_{bend} = bending moment coefficient = 1.1

E = Young's modulus of mast material, in N/mm^2

υ = Poisson's ratio of mast material

$tm_{\min}$ = minimum wall thickness of mast section, in mm

SF_{mast} = Safety Factor for local buckling = 2

Rm = $\frac{am^2}{2 \cdot bm}$

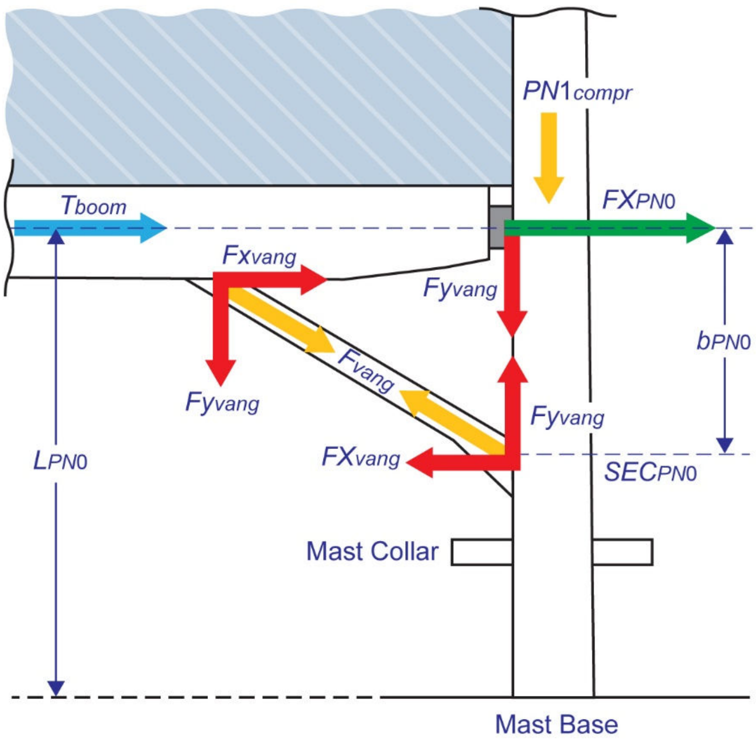
am = longer dimension (length) of the mast section, in mm.

bm = shorter dimension (width) of the mast section, in mm.

2.2.2 Mast Panel 0

Panel 0, the section of mast that extends from the base to the attachment of the boom (gooseneck), is subject to additional loads on top of the calculated compression of Panel 1. In particular on Panel 0, large shear loads are caused by the vang and the boom, which consequently generate large bending moments. Panel 0 is therefore to be verified taking into consideration the stresses induced by these concentrated loads. See Section 4, Figure 2.

FIGURE 2
Loads on Mast Panel 0



The actual stresses, in N/mm^2, at the section SEC_{PN0} are to be calculated as follows:

- *Total Compressive Stress:*

  $$\sigma_{PN0} = \frac{Fy_{PN0}}{A_{PN0}} + \frac{Fx_{PN0} \cdot b_{PN0} \cdot am}{2 \cdot Iyy_{PN0}}$$

- *Shear Stress:*

  $$\tau_{PN0} = \frac{Fx_{PN0}}{A_{PN0}}$$

- *Von Mises Stress:*

  $$\sigma vm_{PN0} = \sqrt{{\sigma_{PN0}}^2 + 3 \cdot {\tau_{PN0}}^2}$$

where

Fx_{PN0}	=	total forward load = $T_{boom} + Fx_{vang}$, in N
Fy_{PN0}	=	total compressive load = $PN1_{comp} + Fy_{vang}$, in N
A_{PN0}	=	area of mast panel 0 (see SEC_{PN0} in Section 4, Figure 2), in mm^2
b_{PN0}	=	bending moment arm at SEC_{PN0}, in mm
am	=	longer dimension (length) of the mast section,in mm
$PN1_{comp}$	=	Panel 1 compression, in N, obtained from direct calculations (see Subsection 4/1 and Commentary in 4/2.1.1)
T_{boom}	=	boom thrust in N, see 3/3.5.1
F_{vang}	=	vang pulling load = $Fvang_{upwind/downwind}$, in N, see 3/3.6.3
Fx_{vang}	=	vang load horizontal component, in N, see 3/3.6.3
Fy_{vang}	=	vang load vertical component, in N, see 3/3.6.3
Iyy_{PN0}	=	longitudinal inertia of Panel 0, in mm^4

The total compressive stress, σ_{PN0}, in N/mm^2, is not to be greater than the allowable local buckling stress, in N/mm^2, for Panel 0, σc_{mP0}, as given below:

$$\sigma c_{mP0} = \frac{1}{SFmP0} \cdot \left(0.5 \cdot \frac{E}{\sqrt{3 \cdot (1 - \upsilon^2)}} \cdot \frac{tmP0_{\min}}{Rm} \right)$$

where

$tmP0_{\min}$	=	minimum wall thickness of Panel 0 mast section, in mm
$SFmP0$	=	Safety Factor for local buckling for Panel 0 = 2
υ	=	Poisson's ratio of mast material
Rm	=	$\frac{am^2}{2 \cdot bm}$
am	=	longer dimension (length) of the mast section at Panel 0, in mm.
bm	=	shorter dimension (width) of the mast section at Panel 0, in mm.

2.3 Local Strength

2.3.1 Mast Panels Other Than Panel 0

The maximum working compressive axial stress, σw_m, in N/mm^2, on each mast panel calculated in accordance with 4/2.2.1 is to be not greater than the maximum allowable stress, in N/mm^2, calculated with the following formula:

$$\sigma w_m \leq \sigma ult_m / SFmu$$

where

σult_m = ultimate strength of the mast material, in N/mm^2

$SFmu$ = Safety Factor for ultimate strength = 3

2.3.2 Mast Panel 0

The maximum working Von Mises stress, σvm_{PN0}, in N/mm^2, calculated in accordance with 4/2.2.2 is to be not greater than the maximum allowable stress, in N/mm^2, calculated with the following formula:

$$\sigma vm_{PN0} \leq \sigma ult_m / SFmuP0$$

where

σult_m = ultimate strength of the Panel 0 mast material, in N/mm^2

$SFmuP0$ = Safety Factor for ultimate strength = 2

3 Spreaders Structure

The area and inertia of the spreaders structure are normally provided by the designer.

A simplified method to calculate the offered area and inertia of a typical elliptical spreader section is provided in Appendix 2.

3.1 Buckling Strength

3.1.1 Global Buckling Strength

The offered lateral and fore-and-aft inertia, in mm^4, are not to be less than the following:

- *Minimum Lateral Inertia*

$$Ixxspr_{min} = \frac{L_{spr}^2 \cdot N_{spr}}{E_{spr} \cdot \pi^2} \cdot SF_{spr} + \frac{Mx_{spr} \cdot bs}{4 \cdot 0.8 \cdot \sigma ult_s} \cdot \left(1 + \sqrt{1 + \frac{8 \cdot N_{spr} \cdot 0.8 \cdot \sigma ult_s \cdot L_{spr}^2}{Mx_{spr} \cdot bs \cdot E_{spr} \cdot \pi^2}}\right)$$

- *Minimum Fore-and-Aft Inertia*

$$Iyyspr_{min} = \frac{4 \cdot L_{spr}^2 \cdot N_{spr}}{E_{spr} \cdot \pi^2} \cdot SF_{spr} + \frac{My_{spr} \cdot as}{4 \cdot 0.8 \cdot \sigma ult_s} \cdot \left(1 + \sqrt{1 + \frac{32 \cdot N_{spr} \cdot 0.8 \cdot \sigma ult_s \cdot L_{spr}^2}{My_{spr} \cdot as \cdot E_{spr} \cdot \pi^2}}\right)$$

where

N_{spr} = compression force on spreader, in N, obtained from direct calculations (see Subsection 4/1)

as = longer dimension (length) of the spreader section, in mm.

bs = shorter dimension (width) of the spreader section, in mm

L_{spr}	=	length of spreader, *in mm*
Mx_{spr}, My_{spr}	=	lateral and fore-aft bending moments due to the additional loads on spreaders (see 3/3.8).
E_{spr}	=	Young's modulus of spreader material, in N/mm^2
σult_s	=	ultimate strength of spreader material, in N/mm^2
$SFspr$	=	Buckling Safety Factor = 3.0

3.1.2 Local Buckling Strength

The maximum working compressive stress, in N/mm^2, on each spreader is to be not greater than the allowable local buckling stress, in N/mm^2, calculated with the following equations:

- σw_{spr} – working compressive axial stress for spreader panel:

  $$\sigma w_{spr} = \frac{N_{spr}}{A_{spr}}$$

- σ_{Mx} – axial stress on upper/lower side of spreader due to Mx_{spr}:

  $$\sigma_{Mx} = \frac{Mx_{spr} \cdot bs}{2 \cdot Ixxspr}$$

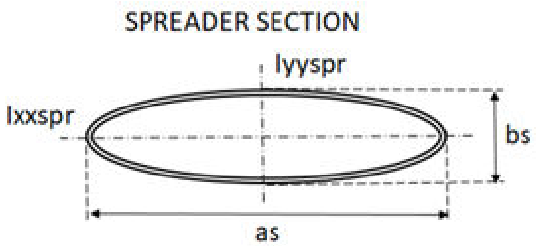
- σ_{My} – axial stress on fore/aft side of spreader due to My_{spr}:

  $$\sigma_{My} = \frac{My_{spr} \cdot as}{2 \cdot Iyyspr}$$

- Total compressive stress on upper side $\quad \sigma w_{up} = \sigma w_{spr} + \sigma_{Mx}$
- Total compressive stress on aft side $\quad \sigma w_{aft} = \sigma w_{spr} + \sigma_{My}$

where

A_{spr}	=	area of elliptical section, in mm^2



Mx_{spr}, My_{spr}	=	lateral and fore-aft bending moments due to the additional loads on spreaders (see 3/3.8).
$Ixxspr$	=	Lateral inertia of elliptical section, in mm^4
$Iyyspr$	=	Fore-aft inertia of elliptical section, in mm^4

N_{spr}, bs, as are defined in 4/3.1.1.

- σc_{up} – allowable local buckling stress for spreader on upper side

  $$\sigma c_{up} = \frac{1}{SFs} \cdot \left(0.5 \cdot \frac{E_{spr}}{\sqrt{3 \cdot \left(1 - \upsilon_{spr}^2\right)}} \cdot \frac{tsx}{Rs}\right)$$

- σc_{aft} – allowable local buckling stress for spreader on aft side

$$\sigma c_{craft} = \frac{1}{SFs} \cdot \left(0.5 \cdot \frac{E_{spr}}{\sqrt{3 \cdot \left(1 - \upsilon_{spr}^2\right)}} \cdot \frac{tsy}{Rs} \right)$$

where

$Rs = \frac{as^2}{2 \cdot bs}$

E_{spr}	=	Young's modulus of spreader material, in N/mm^2
υ_{spr}	=	Poisson's ratio of spreader material
L_{spr}	=	length of spreader, in mm
tsx, tsy	=	minimum wall thickness of spreader section, in mm
SFs	=	Buckling Safety Factor = 2.5

3.2 Local Strength

The maximum working compressive stress, in N/mm^2, on each spreader panel calculated in accordance with 4/3.1 is to be not greater than the maximum allowable stress, in N/mm^2, calculated with the following formula:

$\sigma w_s \leq \sigma ult_s / SFsu$

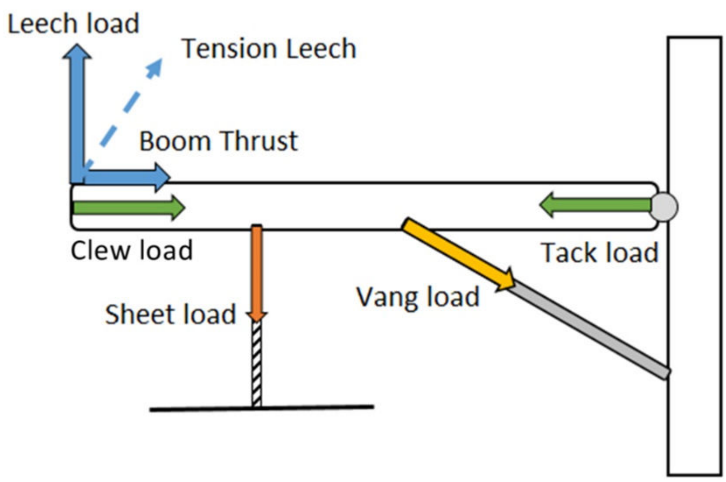
where

σw_s	=	$\max(\sigma w_{up}, \sigma w_{aft})$ (see 4/3.1)
σult_s	=	ultimate strength of the spreader material, in N/mm^2
$SFsu$	=	Safety Factor for ultimate strength = 3

4 Boom Structures

The boom is subject to compressive, shear, bending, and torque stresses deriving from the forces shown in Section 4, Figure 3.

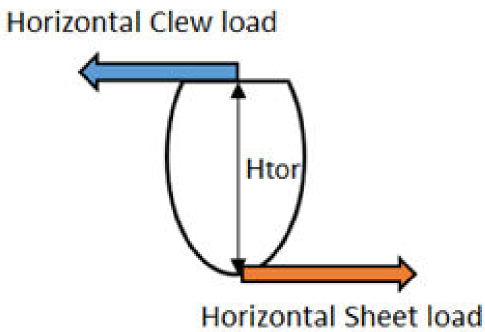
FIGURE 3
Loads on Boom Structure



The external aerodynamic loads are applied by the sail in the clew points and in the reef points, which vary according to the choices made by the sail designer and the use of the yacht in the various load conditions.

The torque applied to the boom (see Section 4, Figure 4) is produced by the combination of the lateral components of the leech load and the reaction of the mainsheet (see 3/3.5 for boom loads).

FIGURE 4
Boom Torque



The load combinations shown in Section 4, Table 1 are to be considered for boom verification.

Additional load cases can be proposed by the designer.

TABLE 1
Load Combinations for Boom Verification

	Sail Case	*Clew Load*		*Tack Load*	*Sheet Load*		*Vang Load* (2)	*Boom Thrust*
		Horiz.	*Vert.*	*Boom Axis*	*Horiz.*	*Vert.*	*Vang Axis*	*Boom Axis*
A	Upwind 100% R.M.	F_{clew}	$Tleech_{vert}$	F_{tack}	Fh_{msheet}	Fv_{msheet}	0	T_{boom}
B	Upwind 100% R.M.	F_{clew}	$Tleech_{vert}$	F_{tack}	Fh_{msheet}	React.(1)	$Fvang_{upwind}$	T_{boom}
C	Downwind 60% R.M.	F_{clew}	$Tleech_{vert}$	F_{tack}	$Fhdw_{sheet}$	0	$Fvang_{downwind}$	T_{boom}

For the definition of the loads, refer to:

F_{clew}	3/3.3.1
$Tleech_{vert}$, Fh_{msheet} and Fv_{msheet}	3/3.6.1
F_{tack}	3/3.5.2
Fh_{msheet}	3/3.6.1
$Fhdw_{sheet}$	3/3.6.2
$Fvang_{upwind}$ and $Fvang_{downwind}$	3/3.6.3
T_{boom}	3/3.5.1

Notes:

1 "React." means the support load that is obtained to balance condition B.

2 Use the relief valve load if it is less than the calculated design load

Load Cases A and B are also to be calculated for configurations with mainsail/mizzensail in reefed conditions (the clew load must be applied at the reef points) by scaling the righting moment (RM) or heel angle percentage, based on the sailing conditions adopted.

The structural analysis used for the boom design is to provide the stresses and deformations of the boom structure.

The minimum required safety factors are listed below:

- Minimum Safety Factor with respect to local buckling = 2
- Minimum Safety Factor with respect to global buckling = 3
- Minimum Safety Factor with respect to ultimate stress = 3

5 Running and Standing Rigging

5.1 Safety Factors for Standing Rigging

The rigging safety factors are defined as:

$$SF_{rig\ element} = \frac{Breaking\ Load_{rig\ elements}}{Max\ Working\ Load_{rig\ element}}$$

The maximum working load is to be calculated in accordance with 3/3.9.

The breaking loads of the various rigging elements are to be obtained from test certificates provided by the rigging manufacturer.

Minimum Safety Factors for standing rigging are listed in Section 4, Table 2.

TABLE 2
Standing Rigging Safety Factors

Rig Element	*Safety Factor*	
	Metallic Rigging	*Synthetic Rigging*
Vertical V1 to Caps	2.7	4
Diagonals	2.7	4
D1 only	2.7	4
Forestays	2.7	4
Backstay	3	4.5
Runners, Babystay, Checkstay	3	4.5

5.2 Safety Factors for Running Rigging

The rigging safety factors are defined as:

$$SF_{runnrig} = \frac{Breaking\ Load_{runnrig\ elements}}{Max\ Working\ Load_{runnrig\ element}}$$

The maximum working load is to be calculated in accordance with 3/3.9.

The breaking loads of the various rigging elements are to be obtained from test certificates provided by the rope manufacturer.

Minimum Safety Factors for running rigging are listed in Section 4, Table 3.

TABLE 3
Running Rigging Safety Factors

Running Rig	*Safety Factor*
Halyards of all sails	3
Boom sheet	3.5
Sheets of all sails	4

SECTION 5

Surveys During and After Construction

1 Surveys During Construction

For terms and definitions see Subsection 1/2.

All masts, spreaders, standing riggings and associated structures are to be surveyed during construction to the necessary extent to determine that the details, materials, welding, and workmanship have been carried out to the satisfaction of the attending ABS Surveyor and are in accordance with the approved drawings.

All material test certificates are to be collected and presented to the attending ABS Surveyor for review.

Nondestructive tests are to be carried out on the critical welds in accordance with the ABS *Guide for Nondestructive Inspection* or other recognized codes. The areas to be nondestructively inspected and methods of inspection are to be submitted together with the design plans.

For metallic structures, the minimum extent of NDT to be carried out is:

- 20% Volumetric NDT plus 100% Surface NDT of all complete joints penetration welds, where plate thickness is ≥ 8.0 mm (5/16 inch); and
- 10% Surface NDT of all fillet welds, where plate thickness is ≥ 8.0 mm (5/16 inch).

2 Installation and Sea Trials

A physical survey of the rig stepping procedure and verification of the preloads is to be carried out to the satisfaction of the attending ABS Surveyor to verify compliance with reviewed documentation.

Adequate means of reefing or shortening sail is to be provided and verified.

Vessels intended for unrestricted operations are either to be provided with separate storm sails or have specific sails designated and constructed to act as storm sails.

During sea trials, the attending ABS Surveyor is to verify the following as a minimum:

- Proper functioning of sails hoisting and lowering
- Proper functioning of reefing/shortening of sails in accordance with the sailing plan (see 1/4.2).
- Visual checks of captive winches including function tests by helm, local handheld, emergency panels (if fitted).
- Visual checks of the furlers, including function tests by helm, local handheld, emergency panels (if fitted).
- Visual checks of pulleys, pins, and tensioning equipment.
- Visual checks of halyard stand-up blocks, tracks for sails, cunningham system.

Sea trial testing is to be carried out at various configurations and sailing conditions to prove correct mounting of rigging and sails. Where the wind condition is considered impractical, the wind condition for sea trial testing may be reduced but is subject to approval by ABS.

3 Surveys After Construction

3.1 Annual Surveys

Annual Surveys are also to include reviewing records and history of rig maintenance measures against the specifications provided by the maintenance manual.

For yachts intended for unrestricted operation, availability of separate storm sails is to be confirmed.

At a minimum, at each Annual Survey, the following items are to be examined and/or verified to the satisfaction of the attending ABS Surveyor:

i) Masts and rigging are maintained in accordance with the ABS Engineering reviewed manufacturer's maintenance manual (see 1/4.2)

ii) Mast compression is correct using the jacking bar/tension gauges

iii) Fore-and-aft rigging is at its nominal tension in accordance with the reviewed stepping procedure and rigging pre-loads (see 1/4.2)

iv) Examination of mast and boom for cracks, damage, and worn sections/components paying particular attention at connection point of spreaders, diagonals, verticals, boom to mast and spinnaker pole and connections with hull supporting structures

v) Examination of all standing rigging for corrosion, cracks, loose connections and broken wires, damaged rigging and connections with hull supporting structures

vi) Examination of the turnbuckles and connecting screws

vii) Examination of all sheets, travelers, sheaves, cleats, and blocks along highly loaded bearing items as detailed in the manufacturer's maintenance manual

viii) All pins along highly loaded bearing items as detailed in the manufacturer's maintenance manual are not bent

ix) All bearings along highly loaded bearing items as detailed in the manufacturer's maintenance manual are not worn

x) All hydraulics are free of leaks

xi) All recesses housing rigging parts drain properly

xii) All lashings and splices for burned rope or compression damage

xiii) Covers intended to create weathertight protection to highly loaded members for damages

xiv) Functionality, cleaning and greasing of deck gears including winches and hydraulic cylinders

xv) All recesses housing deck gear drain properly

xvi) Mast grounding is to be verified. Confirm if any lighting strikes have occurred to the vessel since the previous annual or periodic survey, and that same was reported. In case of lightning strikes, the following is to be verified:

a) Verify the grounding cable insulation and lighting pole.

b) Electronic components necessary for navigation are to be verified in good working conditions (ECDIS, GMDSS, AIS, Speed-Log, Echosounder, Radar) by qualified service suppliers.

c) Anemometer

d) Antennas

e) Insulation of any electrical cable inside the mast

f) Navigation Lights

Commentary:

Due to the remote location of items to be verified, the Surveyor may request recognized RIT (Remote Inspection Technology) service supplier for close-up examination.

End of Commentary

3.2 Special Surveys

At each Special Survey, in addition to the Annual Survey requirements, the following items are to be verified to the satisfaction of the attending ABS Surveyor:

i) Clean and survey all masts and spreaders components, all sail maneuvering fittings, insulation of electric cables.

ii) NDT examination to be carried out on each standing rigging in accordance with the maintenance manual. Particular attention is to be given to the end connections as indicated in the specific diagrams of the maintenance manual (see 1/4.2iii))

iii) NDT the mast tube on strength points in accordance with the maintenance manual.

iv) NDT boom near attachment points (boom ends, vang and sheets attachment see Section 4, Figure 3)

v) Verify correct setting and relieving pressure of safety valves installed on hydraulic systems.

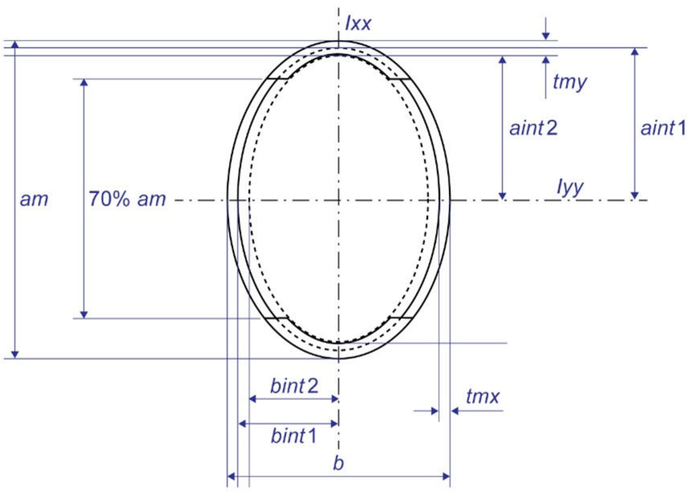
Masts are to be disassembled at intervals established by the mast manufacturer. Survey requirements in accordance with annual and special survey need to be complied with together with any additional recommendation included in the maintenance manual. See 1/4.2.

APPENDIX 1

Simplified Method to Calculate the Offered Inertia of a Typical Elliptical Mast Section

The following formulas can be used as a first estimate to evaluate the real inertias of a typical elliptical mast section with am/bm ratio of about 2 with different thicknesses between the side and the front.

Ixx – lateral inertia of elliptical section
Iyy – fore-and-aft inertia of elliptical section
A – area of elliptical section
tmx – mast section lateral thickness
tmy – mast section fore-and-aft thickness



$$Ixx = \frac{\pi}{4} \cdot \left[\left(b1^3 \cdot am1 - bint1^3 \cdot aint1\right) \cdot Kx_{long} + \left(b1^3 \cdot am1 - bint2^3 \cdot aint2\right) \cdot Kx_{tra}\right]$$

$$Iyy = \frac{\pi}{4} \cdot \left[\left(b1 \cdot am1^3 - bint1 \cdot aint1^3\right) \cdot Ky_{long} + \left(b1 \cdot am1^3 - bint2 \cdot aint2^3\right) \cdot Ky_{tra}\right]$$

$$A = \pi \cdot \left[(b1 \cdot am1 - bint1 \cdot aint1) \cdot A_{long} + (b1 \cdot am1 - bint2 \cdot aint2) \cdot A_{tra}\right]$$

$where \qquad b1 = b/2 \qquad am1 = am/2$

am/b	Kx_{long}	Kx_{tra}	$long$	Ky_{tra}	A_{long}	A_{tra}
2	0.891	0.109	0.297	0.703	0.651	0.349
2.5	0.874	0.126	0.27	0.733	0.638	0.363

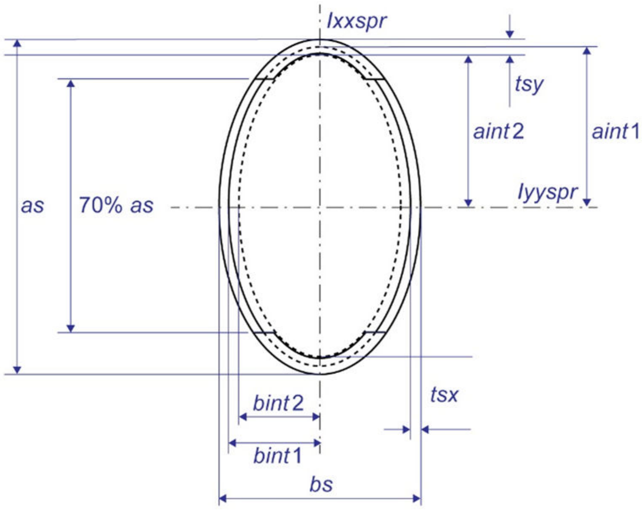
These coefficients were determined by calculating the contributions to the longitudinal and transversal inertia given by the two ellipses with thickness tmx and tmy.

APPENDIX 2

Simplified Method to Calculate the Offered Inertia of a Typical Elliptical Spreader Section

The following equations can be used as a first estimate the inertia of a typical elliptical section with am/bm ratio of about 3 with different thicknesses between the lateral and frontal parts.

$Ixxspr$ – lateral inertia of elliptical section
$Iyyspr$ – fore-and-aft inertia of elliptical section
$Aspr$ – area of elliptical section
tsx – spreader section lateral thickness
tsy – spreader section fore-and-aft thickness



$$Ixxspr = \frac{\pi}{4} \cdot \left[\left(bs1^3 \cdot as1 - bsint1^3 \cdot asint1\right) \cdot Kspx_{long} + \left(bs1^3 \cdot as1 - bsint2^3 \cdot asint2\right) \cdot Kspx_{tra}\right]$$

$$Iyyspr = \frac{\pi}{4} \cdot \left[\left(bs1 \cdot as1^3 - bsint1 \cdot asint1^3\right) \cdot Kspy_{long} + \left(bs1 \cdot as1^3 - bsint2 \cdot asint2^3\right) \cdot Kspy_{tra}\right]$$

$$Aspr = \pi \cdot \left[(bs1 \cdot as1 - bsint1 \cdot asint1) \cdot As_{long} + (bs1 \cdot as1 - bsint2 \cdot asint2) \cdot As_{tra}\right]$$

$$where \qquad bs1 = bs/2 \qquad as1 = as/2$$

as/b	$Kspx_{long}$	$Kspx_{tra}$	$Kspy_{long}$	$Kspy_{tra}$	As_{long}	As_{tra}
3	0.888	0.112	0.302	0.698	0.671	0.329

The coefficients have been determined by calculating the contributions to the longitudinal and transversal inertia given by the two ellipses with thicknesses tsx and tsy.