NR667 DT R01 DECEMBER 2024

PARAMETRIC ROLL ASSESSMENT

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RULE NOTE

BUREAU VERITAS

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RULES, RULE NOTES AND GUIDANCE NOTES

NR667 DT R01 December 2024 takes precedence over previous revision.

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NR667

PARAMETRIC ROLL ASSESSMENT

December 2024

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Section 1 Parametric Roll Assessment

1 General

1.1 Application

1.1.1 This Rules Note defines the methodology and requirements to assess the parametric roll resonance based on hydrodynamic computations for ships assigned the additional class notation **PaRoll1** or **PaRoll2**, as defined in [1.2].

1.2 Additional class notation PaRoll1 and PaRoll2

1.2.1 The additional class notation **PaRoll1** or **PaRoll2** may be assigned only to new or existing container ships complying with:

- the requirements of this Rule Note
- the requirements of NR467, Pt F, Ch 12, Sec 5 for the assignment of the additional class notations **LASHING** or **LASHING-RSSA( )**.

Note 1: NR467 Rules for the classification of steel ships.

1.2.2 Except for special cases stated in [1.2.3], the additional class notation **PaRoll1** or **PaRoll2** may only be assigned, in accordance with NR467, Pt A, Ch 1 Sec 2, to container ships for which operational guidances have been developed in compliance with this Rule Note:

- The additional class notation **PaRoll1** is assigned to ships without any anti-rolling devices or to ships using only bilge keels as anti-rolling devices.
- The additional class notation **PaRoll2** is assigned to ships using anti-rolling devices such as anti-roll tank, stabilizer fins or any anti-rolling devices different from bilge keels.

1.2.3 The assignment of additional class notations **PaRoll1** or **PaRoll2** is not relevant for a ship for which all loading conditions defined in [2.1] comply with the following condition:

$$\left(\frac{\delta GM}{GM_C} \leq R_{PR}\right)$$

where:

δ_{GM} : Amplitude of variation of metacentric height, in m, calculated in accordance with [1.2.3]

GM_C : Corrected metacentric height, in m, of the loading condition under consideration in calm water

R_{PR} : Coefficient as defined in Tab 1.

Table 1 : Value of R_{PR}

If the ship has a sharp bilge:	$R_{PR} = 1,87$
If $C_m > 0,96$:	$R_{PR} = 0,17 + 0,425\left(\frac{100A_K}{L \cdot B}\right)$
If $0,94 < C_m < 0,96$:	$R_{PR} = 0,17 + (10,625 \cdot C_m - 9,775) \cdot \left(\frac{100A_K}{L \cdot B}\right)$
If $C_m < 0,94$:	$R_{PR} = 0,17 + 0,2125\left(\frac{100A_K}{L \cdot B}\right)$
Note 1: C_M : Coefficient equal to: $C_M = \frac{A_m}{B \cdot d_{full}}$ where d_{full} is defined in [1.2.4] A_m : Area, in m², of the underwater midship section of the fully loaded condition A_K : Total overall projected area, in m², of the bilge keels L : Rule length, in m, as defined in NR467, Pt B, Ch 1, Sec 2 B : Moulded breadth, in m, as defined in NR467, Pt B, Ch 1, Sec 2	

1.2.4 The amplitude of variation of metacentric height δGM, in m, is to be determined according to the following formula:

$$\delta GM = \frac{I_H - I_L}{2V}$$

where:

I_H : Moment of inertia, in m^4, of the waterplane at the draught d_H

I_L : Moment of inertia, in m^4, of the waterplane at the draught d_L

V : Volume, in m^3, of displacement of the loading condition under consideration

$d_H = d_{LC} + \delta d_H$

$d_L = d_{LC} - \delta d_L$

d_{LC} : Draught amidships corresponding to the loading condition under consideration

$$\delta d_H = Min\left(D - d_{LC}, \frac{L \cdot S_W}{2}\right)$$

$$\delta d_L = Min\left(d_{LC} - 0,25\, d_{full}, \frac{L \cdot S_W}{2}\right)$$

D : Moulded depth, in m, as defined in NR467, Pt B, Ch 1, Sec 3

L : Rule length, in m, as defined in NR467, Pt B, Ch 1, Sec 3

$S_W = 0,0167$

d_{full} : Draught, in m, corresponding to the fully loaded departure condition.

1.3 Documentation and data to be submitted

1.3.1 The documentation and data to be submitted for the assignment of the notation **PaRoll1** or **PaRoll2** are defined in [1.3.2]and [1.3.3]. A summary is provided in Tab 2.

1.3.2 The following documentation and data are to be submitted to the Society for information:

- ship lines, by submitting a CAD model, or offset table
- necessary loading conditions as required in Article [2] including:
  - the displacement
  - the draught at forward and aft perpendicular
  - the three coordinates of center of gravity
  - the radius of gyration.
- maximum service speed of the ship
- roll decay or/and forced roll test results, from CFD or/and model tests are to be provided for:
  - several loading conditions so that the roll damping can accurately be estimated for all loading conditions described in [2.1]
  - several ship speeds so that the roll damping can accurately be estimated for all ship speeds specified in [3.2.3]
- the description of the anti-rolling devices used as described in [3.2.6].

1.3.3 The following documentation is to be submitted to the Society for approval:

- Set of polar plots corresponding to the results of calculations as specified in [4.1]
- Set of polar plots corresponding to various operating loading conditions, and obtained by means of interpolations as specified in [4.3.3].

Table 2 : Documentation and data to be submitted

No.	A/I **(1)**	Item
1	A	Polar plots (see [1.3.3])
2	I	Ships lines
3	I	Loading conditions
4	I	Maximum service speed of the ship
5	I	Roll decay and/or forced roll test results
6	I	Description of the anti-rolling devices
(1) A: to be submitted for approval; I: to be submitted for information		

2 Loading conditions

2.1 Loading conditions for simulations

2.1.1 The roll period, in s, is the most important parameter that drives both synchronous and parametric roll. The loading conditions to be considered for application of the requirements of [1.2.2] and Article [3] are to cover the entire range of roll period from $T_{\theta min}$ to $T_{\theta max}$, where:

$T_{\theta max}$: Maximum roll period from the stability booklet

$T_{\theta min}$: Minimum roll period from the stability booklet.

The roll period T_θ is to be assessed as defined in NR467, Pt B, Ch 5, Sec 3, [2.1.1]:

$$T_\theta = \frac{2,3\pi k_r}{\sqrt{g \cdot GM}}$$

where:

g : Gravity acceleration, taken equal to 9,81 m/s^2

GM : Metacentric height, in m

k_r : Roll radius of gyration, in m. In absence of data about k_r in the stability booklet, the roll period may be assessed using both k_r = 0,35 B and k_r = 0,40 B in order to have the largest range of roll period.

2.1.2 The roll period is to be incremented from $T_{\theta min}$ and up to $T_{\theta max}$ according to the following formula:

$$T_{\theta_{i+1}} = \frac{1}{\frac{1}{T_{\theta i}} - \Delta f}$$

where:

$T_{\theta i}$: Roll period of step i with the first step being $T_{\theta min}$ as defined in [2.1.1]

Δf : Increment factor not to be taken greater than 0,015 s^{-1}.

2.1.3 Each roll period ($T_{\theta i}$), in this range is to be associated to a draught d_i. The draught d_i associated to each $T_{\theta i}$ may be obtained using the following formula:

$$d_i = \frac{1}{T_{\theta i}^2} \frac{d_{T\theta max} - d_{T\theta min}}{\left(\frac{1}{T_{\theta max}^2} - \frac{1}{T_{\theta min}^2}\right)} + \frac{d_{T\theta min} T_{\theta min}^2 - d_{T\theta max} T_{\theta max}^2}{T_{\theta min}^2 - T_{\theta max}^2}$$

where:

$d_{T\theta min}$: Draught from stability booklet associated to $T_{\theta min}$

$d_{T\theta max}$: Draught from stability booklet associated to $T_{\theta max}$

If duly justified, a different roll period-draught curve may be considered.

2.1.4 Each roll period in the range defined in [2.1.1] is to be associated a roll radius of gyration k_r. If there is no information about the roll radius of gyration for the loading condition used in calculations, the roll radius of gyration is to be considered as a constant and the value set to the one defined in NR467, Pt B, Ch 5, Sec 3, Tab 4 (k_r = 0,35B, with B being the ship's breath).

3 Roll motion assessment

3.1 General

3.1.1 Ship motion simulations are to be computed using a non-linear time domain hydrodynamic code as described in App 1 and are to include the following three degrees of freedom: heave, roll and pitch.

3.1.2 The Froude-Krylov forces are to be calculated by applying the pressure of the undisturbed incoming wave to the hull on every wet panel at any time step.

3.2 Ship operational profile

3.2.1 Sea states

Ship motion simulations are to be computed using all the sea states below the 25 years contour of the wave scatter diagram for North Atlantic from IACS Recommendation No. 34, Rev. 2. This contour is given in Tab 3.

The sea states are to be modelled by a Jonswap spectrum with gamma = 1,5 and a “cos n” spreading function with n = 3, as defined in IACS Recommendation No. 34, Rev. 2.

Table 3 : 25 years contour of the wave scatter diagram for North Atlantic from IACS Recommendation No. 34, Rev. 2

Mean wave period T_{0m1}, s	5,0	5,5	6,0	6,5	7,0	7,5	8,0	8,5	9,0	9,5	10,0	10,5	11,0	11,5
Peak wave period T_p, s	5,73	6,30	6,88	7,45	8,02	8,60	9,17	9,74	10,32	10,89	11,46	12,04	12,61	13,18
Significant wave height H_s, m	1,79	2,45	3,10	3,75	4,40	5,05	5,71	6,38	7,05	7,72	8,39	9,09	9,75	10,45

Mean wave period T_{0m1}, s	12,0	12,5	13,0	13,5	14,0	14,5	15,0	15,5	16,0	16,5	17,0	17,5	18,0	
Peak wave period T_p, s	13,76	14,33	14,90	15,47	16,05	16,62	17,19	17,77	18,34	18,91	19,49	20,06	20,63	
Significant wave height H_s, m	11,09	11,72	12,31	12,83	13,26	13,54	13,64	13,48	12,88	11,69	10,03	8,18	4,56	

3.2.2 Wave heading

Numerical simulations are to be carried out for the range of wave directions from 0 degrees (following seas) to 180 degrees (head seas) with a recommended maximum increment of 15 degrees.

3.2.3 Speed profile

Numerical simulations are to be carried out for the entire range of service speed, starting from 5 knots, with a recommended maximum increment of 5 knots.

3.2.4 Loading conditions

The ship motion analysis is to be carried out for each of the loading conditions specified in [2.1].

3.2.5 Roll damping

The data to be used for roll damping calibration may be:

- roll decay, and/or
- forced roll test, and/or
- CFD computations.

If the wave component of roll damping is already included in the calculation of radiation forces, measures are to be taken to avoid including these effects more than once.

The roll damping is essentially non-linear and may be modelled by a linear and quadratic coefficients.

3.2.6 Anti-rolling devices

When a ship is equipped with anti-rolling devices, the following information is to be provided to the Society according to the type of anti-rolling devices:

- if the anti-rolling devices are bilge keels, their geometry, size and position along the ship are to be provided
- if anti-rolling devices are anti-roll tank (ART), the geometry and the operational guidance of the ART (filling levels according to the loading conditions and the wave period) are to be provided. In addition, the loss of stability due to the reduction of metacentric height is to be taken into account
- if other anti-rolling devices are used, the full description of the system including the geometry, installation and operation of these devices is to be provided.

3.2.7 Reduction of number of simulations

For a given loading condition, wave period, wave heading and ship speed, it is possible to reduce the number of simulations by considering that:

- if for a given wave height (H_s), the roll angle assessed as defined in [3.3.3] is smaller than 5 degrees, it may be considered that roll angle for all wave height smaller than H_s are also smaller than 5 degrees
- if for a given wave height (H_s), the roll angle assessed as defined in [3.3.3] is greater than the threshold defined in Article [4], it may be considered that the roll angle for wave height higher than H_s, the ship will experience roll angle greater than the threshold.

3.3 Computation of maximum roll angle

3.3.1 For each combination of loading condition, wave height, wave period, wave heading, and ship speed, simulations are to be repeated at least 20 times with the same spectrum but with different sets of initial phase angles.

3.3.2 The duration of each calculation is to be at least 1 hour; therefore the total time for each combination of loading condition, wave height, wave period, wave heading, and ship speed is at least 20 hours.

3.3.3 The maximum roll angle θ_{sh} as defined in [4.2.1] corresponds to one-hour maximum roll angle with a probability of exceedance of 0,5.

4 Operational guidance

4.1 Polar plot

4.1.1 The final results are a set of operational guidance presented as polar plots. In the polar plot, as shown for example in App 2, Fig 5 to App 2, Fig 8, the radial direction represents the ship speed from 5 knots to the maximum service speed and the rotational direction corresponds to the wave encounter angle.

4.1.2 Polar plots are to be represented according to the roll angle for each specific combination of significant wave height, wave period, and loading condition. The polar plots are to be coloured according to the roll angle. Areas where the criterion defined in [4.2.1] is not fulfilled are to be clearly defined (e.g. hatched).

4.1.3 As an alternative to [4.1.2] polar plots may represent the Lashing Utilization Factor (LUF). For a given loading condition, LUF is to be calculated according to the following procedure:

a) Step 1:

1) The following load components acting on the lashing system and containers are to be calculated in accordance with NR467, Pt F, Ch 12, Sec 5:
   - loads acting on containers
   - loads acting on container corners
   - loads acting on lashing equipment.
2) These load components are to be calculated for all container stacks and roll angles between 5 degrees and 30 degrees, with an increment not greater than 5 degrees.
3) The individual utilization factor, defined as the ratio between the load calculated in item a) and the permissible load defined in NR467, Pt F, Ch 12, Sec 5 [6.2] to [6.4], is to be calculated for each load component and all roll angles defined in a).
4) For each roll angle, LUF_{θ} is to be taken as the greatest individual utilization factor calculated in item 3) for all container stacks.

b) Step 2:

For each sea state (H_S, T_{0m1}) and combination of wave heading and speed, LUF is to be calculated by means of linear interpolation of LUF_{θ} for the roll angles computed in [3.3] which are to be multiplied by γ_{PR} as defined in [4.2.1].

In this case the polar plots are to be coloured according to the LUF. Areas where the criterion defined in [4.2.2] is not fulfilled are to be clearly defined (e.g.: hatched).

4.1.4 Alternative ways to display the operational guidance may be accepted, provided that all necessary information is included.

4.2 Criteria

4.2.1 When the polar plots are defined according to [4.1.2], it is to be checked that the maximum roll angle for any combination of loading condition, wave height, wave period, wave heading, and ship speed, is in compliance with the following criterion:

$$\theta_{sh} < \frac{\theta_{Lash}}{\gamma_{PR}}$$

where:

θ_{sh} : Maximum roll angle computed in [3.3]

θ_{Lash} : As defined in NR467, Pt F, Ch12, Sec 5, [4.3.5]

γ_{PR} : Short-term to long-term conversion factor taken equal to 1,6

Note 1: For ships assigned the additional class notation **LI-LASHING**, the angle θ_{Lash} may be defined by the Interested Party in order to extend the area of the polar plot complying with the criterion given in [4.2.1]. In this case, θ_{Lash} is not to be taken less than $f_{ART} \cdot \theta$ where f_{ART} and θ are defined in NR467, Pt F, Ch 12, Sec 5, [4.3.5].

4.2.2 When the polar plots are defined according to [4.1.3], it is to be checked that the maximum utilization factor LUF for any combination of loading condition, wave height, wave period, wave heading and ship speed, is in compliance with the following criterion:

$LUF \leq 1$

where:

LUF : Lashing Utilization Factor as defined in [4.1.3].

4.3 Operation

4.3.1 Operational guidance is to be provided on board as easily accessible and understandable information in graphical form, which clearly indicates operational conditions (combination of loading conditions, ship speeds and ship course) that is to be avoided for a given sea state. Automatic alert systems may be used for cases when operational conditions are close to areas where those conditions are to be avoided.

4.3.2 For a given sea state specified by significant wave height and wave period, operational conditions to be avoided are derived from the pre-defined databases of roll angle computed as specified in [3.3], and stored as functions of the ship forward speed and ship heading with respect to the mean wave direction, using as input the actual significant wave height, mean wave period, mean wave direction and ship course.

4.3.3 In the case where the actual operational conditions (significant wave height, wave period and roll period) are not in the pre-defined databases, linear interpolation from the closest calculation points can be accepted.

4.3.4 When retrieving wave period from weather nowcast / forecast, T_p (peak period) and T_{0m1} (energy period) are to be preferred over T_z (mean up-crossing period).

Consistency with the available polars is to be ensured (i.e. if the database seastates are parametrized in T_p, the wave period from the forecast is to be T_p, or converted to T_p assuming Jonswap spectrum with $\gamma = 1,5$).

4.3.5 The ship master is to ensure that the ship satisfies the operational guidance at any time during the voyage, considering the available weather forecasts. It remains the responsibility of the ship master to adjust speed and heading in order to limit as far as practicable the risk of parametric roll.

Appendix 1 Methodology for Short Term Hydrodynamic Calculations for Ship Motions Response

1 General

1.1 Introduction

1.1.1 The present Appendix describes methods and tools to be used for the direct calculation of the hydrodynamic response of ships.

1.1.2 The following information, model and method are needed to determine the extreme ship motions corresponding to a given exposure time:

- a description of the operating conditions during the exposure time, including the wave environment (see Article [2]) and the ship operational profile
- a hydrodynamic model of the ship, which is able to compute the ship response on any type of wave conditions (see Article [3])
- a method to derive extreme responses from the results of the hydrodynamic computations.

2 Wave environment

2.1 General

2.1.1 In order to properly describe the sea-states that the ship will face over a voyage, the short term description of waves is defined in NI638, Sec 2, [2.2]. Note that the short term description of waves is used to define one specific wave condition over a short duration (usually 3 hours) where the sea-state is considered as stationary.

3 Ship hydrodynamic model

3.1 General

3.1.1 An acceptable evaluation of the motion response of a ship in waves requires a proper hydrodynamic model, describing the interaction between the ship and the waves. Several levels of assumption can be chosen for the hydrodynamic model, depending on which physical behaviour is expected to be reproduced.

3.2 Hydrodynamic loads

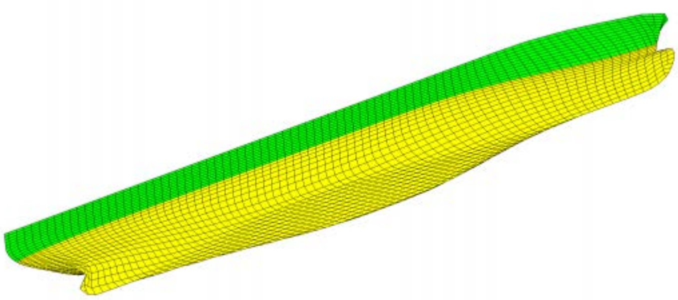
3.2.1 For parametric roll assessment the weakly non-linear loads model described in [3.2.2] is mandatory.

3.2.2 Weakly non-linear

The minimum non-linearities that are to be included are based on the so called Froude-Krylov approximation. The pressure of the undisturbed incoming waves is applied to the hull on every wet panel. The mesh used to integrate the pressure loading has to include the parts above and below the mean waterline as shown in Fig 1. The non-linear hydrostatic restoring forces are also included by taking into account the real position of the ship in the integration of the hydrodynamic pressure.

The motion equation is solved using a time domain seakeeping code. The radiation forces are included through the memory functions, whereas the diffraction forces remain linear. The outputs of a non-linear hydrodynamic computation are time traces. Ship motions are directly computed by the seakeeping code.

Figure 1 : Typical hydrodynamic mesh for non-linear seakeeping calculations



3.3 General modelling considerations

3.3.1 Mass properties

For all loading conditions the following mass properties are to be verified according to the values given in the trim and stability booklet:

- displacement
- radii of gyration
- location of center of gravity.

3.3.2 Hydrostatic balance

For each loading condition, the computed values of displacement and trim are to be checked and compared to those of the trim and stability booklet. The following tolerances are considered acceptable:

- 2% of the displacement
- 0,1 degree of the trim.

It is also worth checking the following hydrostatic properties:

- location of the center of buoyancy
- transverse metacentric height (GMt).

3.3.3 Roll damping

Additional damping forces are to be added to the motion equation in order to take into account the viscous damping and damping due to bilge keels, rudders and other existing appendages. This additional damping is to be added to the wave damping computed by the hydrodynamic program. This damping may be based on experimental data obtained by roll decay test, or forced roll test performed by a company recognized by the Society (typically a member of the International Towing Tank Conference). This damping may also be based on Computational Fluid Dynamic computations obtained by means of a validated tool. This damping is essentially non-linear and may be modelled by a linear and quadratic damping coefficient.

Appendix 2 Example of Application of Parametric Roll Calculations

1 General

1.1 Objective

1.1.1 This Appendix presents an example of application of parametric roll calculations. It aims at giving a typical illustration of the methodologies described in Sec 1.

1.2 Sample ship

1.2.1 The ship used in this application is a container ship assigned the additional class notation **LASHING**. The lines of this ship are presented in Fig 1, and the details of the ship are given in Tab 1.

Figure 1 : Lines of sample containership

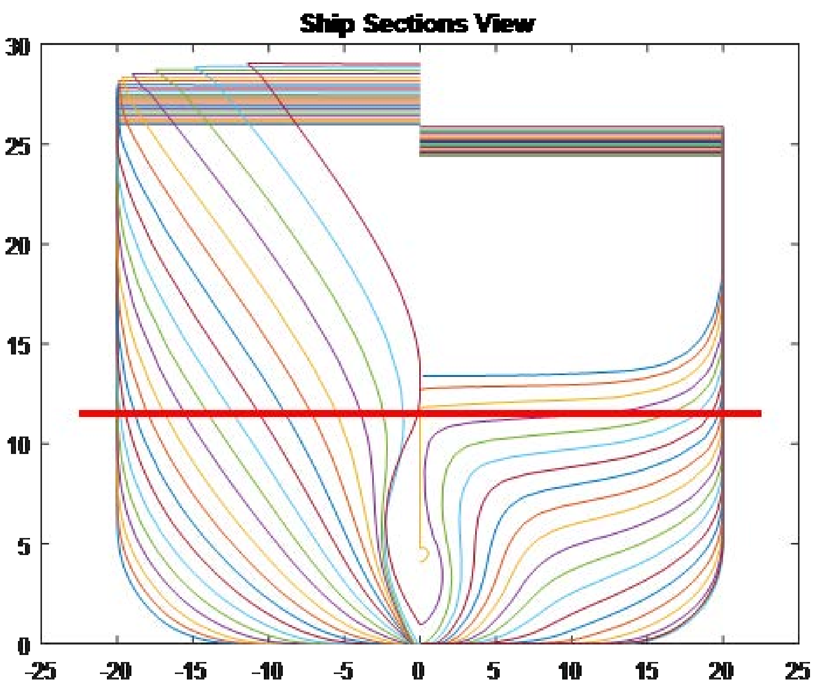


Table 1 : Characteristics of the sample container ship

Description		Unit	Value
L	Ship length	m	359,5
B	Breadth	m	48,8
d	Draught	m	13,93
T_θ	Natural roll period	s	23,7
GM_C	Corrected metacentric height in calm water	m	3,17
L_{bk}	Bilge keel length	m	92,7
B_{bk}	Bilge keel breadth	m	0,4
K_{xx}	Roll radius of gyration	m	0,375 x B

2 Roll motions computations

2.1 Preliminary check

2.1.1 The loading conditions have been selected using the procedure defined in Sec 1, [2.1].

Minimum and maximum roll periods ($T_{\theta,min}$ = 9,80 s, $T_{\theta,max}$ = 36,68 s) and their associated draughts ($d_{T\theta,min}$ = 6,68 m, $d_{T\theta,max}$ = 14,80 m) are taken from the trim and stability booklet.

The roll resonance periods are calculated using the formula of Sec 1, [2.1.1]. The roll periods of loading conditions $T_{\theta,i}$ are derived according to Sec 1, [2.1.2] and using an increment factor Δf taken equal to 0,015 sec^{-1}. Values of $T_{\theta,i}$ are given in Tab 2.

The draughts of the loadings conditions d_i which are used for the computations are derived by applying the formula given in Sec 1, [2.1.3]. Values of d_i are given in Tab 2.

Table 2 : Roll period versus draught

	i = 1 **(1)**	i = 2	i = 3	i = 4	i = 5	i = 6 **(1)**
Roll period $T_{\theta,i}$, according to Sec 1, [2.1.2]	9,80	11,48	13,87	17,50	23,71	36,68
Associated draught d_i, according to Sec 1, [2.1.3]	6,68	9,06	11,06	12,68	13,93	14,80
(1) Data extracted from the trim and stability booklet for i = 1 and i = 6						

The loading conditions for calculations according to Sec 1, [2.1] are represented on Fig 2 and Fig 3, where:

- In Fig 2 the line describes the assumed relationships between GM and draught.

Note 1: Operational data points correspond to loading conditions in operations, which are generally unknown at design stage.

- In Fig 3 the curve describes the assumed relationships between the roll periods and draught.

Note 2: Operational data points correspond to loading conditions in operations, which are generally unknown at design stage.

- The diamonds corresponds to the loading conditions for calculations according to Sec 1, [2.1].
- The crosses corresponds to the loading conditions taken from the trim and stability booklet.

Fig 4 represents loading conditions, which are not in compliance with the requirement defined in Sec 1, [1.2.3] (i.e. for which the variation in GM is above the threshold represented by a line in Fig 4). In this case, the additional class notation **PaRoll1** or **PaRoll2** may be assigned.

Figure 2 : Example of loading conditions (LC) from a curve GM - Draft

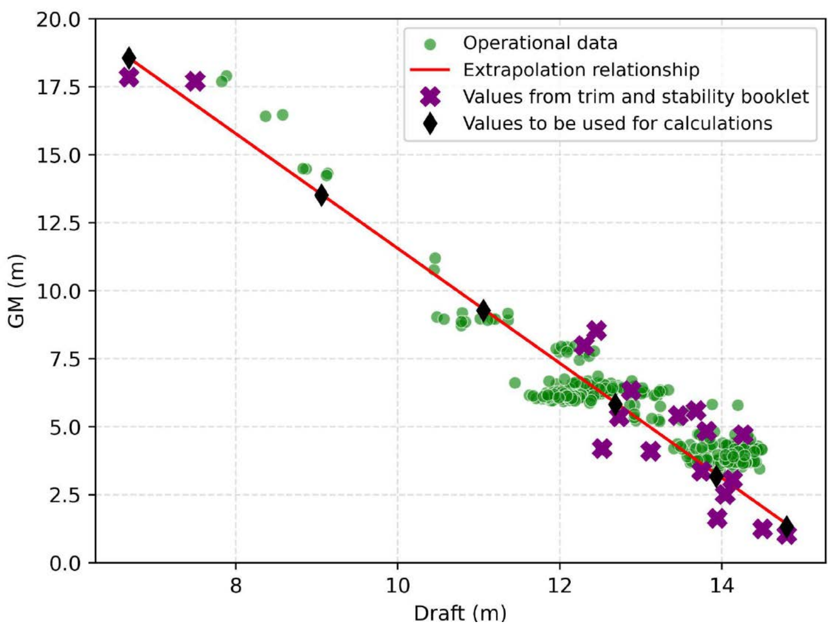


Figure 3 : Example of loading conditions derived from the procedure described in Sec 1, [2.1]

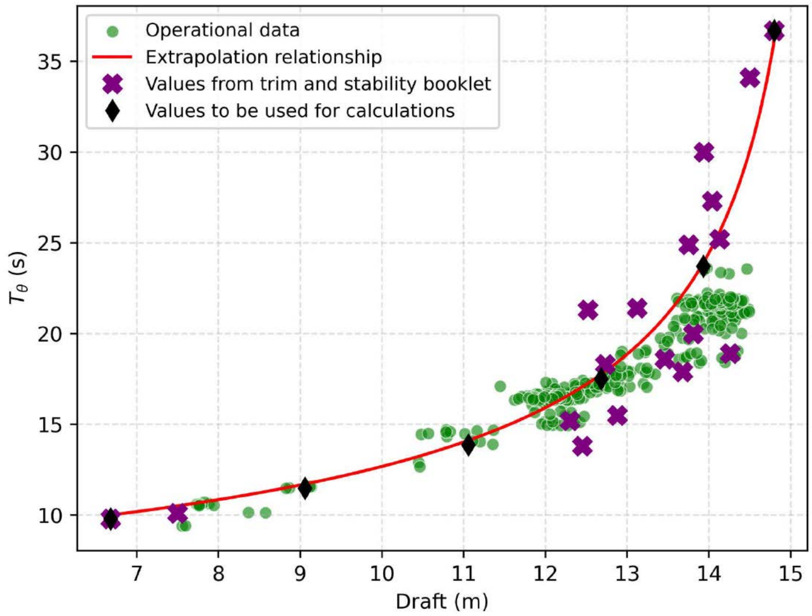
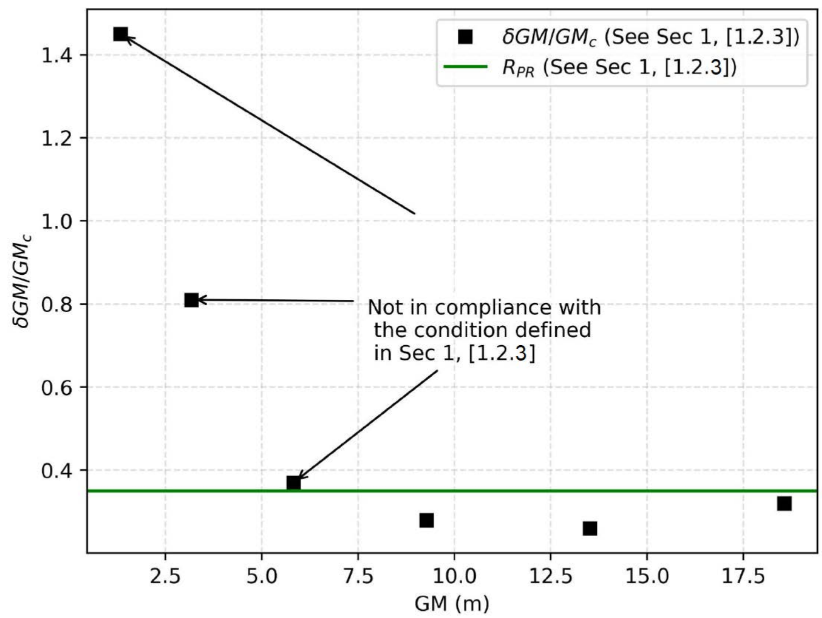


Figure 4 : Preliminary check results (see Sec 1, [1.2.3])



2.2 Roll assessment

2.2.1 Operational guidance in terms of polar plot can be derived according to Sec 1, [4.1] assuming that:

- the procedures described in Sec 1, [3] are followed
- the requirements defined in Sec 1, [4.2.1] are applied.

2.2.2 Four samples of polar plots are shown in Fig 5 to Fig 8. These polar plots are created from a series of numerical simulations considering speed and heading range as follows:

- for speed: from 5 to 25 knots in 5 knots increments
- for heading: from 0 degree (following seas) to 180 degrees (head seas) with 15 degrees increments.

Note 1: These polar plots have been produced using the non-linear time domain seakeeping software, HydroStar++.

The hatched region corresponds to combination of speed and heading for which the criterion given in Sec 1, [4.2.1] is not complied with.

The area with high speed in stern quartering waves corresponds to synchronous roll resonance, while regions with low speed in head seas correspond to parametric roll.

Figure 5 : Example of polar plot:

Hs = 5,71 m, T_{0m1} = 12,5s, GM = 3,17 m, T_θ = 23,7s

Left: θ_{LASH}/θ = 1,0   Right: θ_{LASH}/θ =1,2

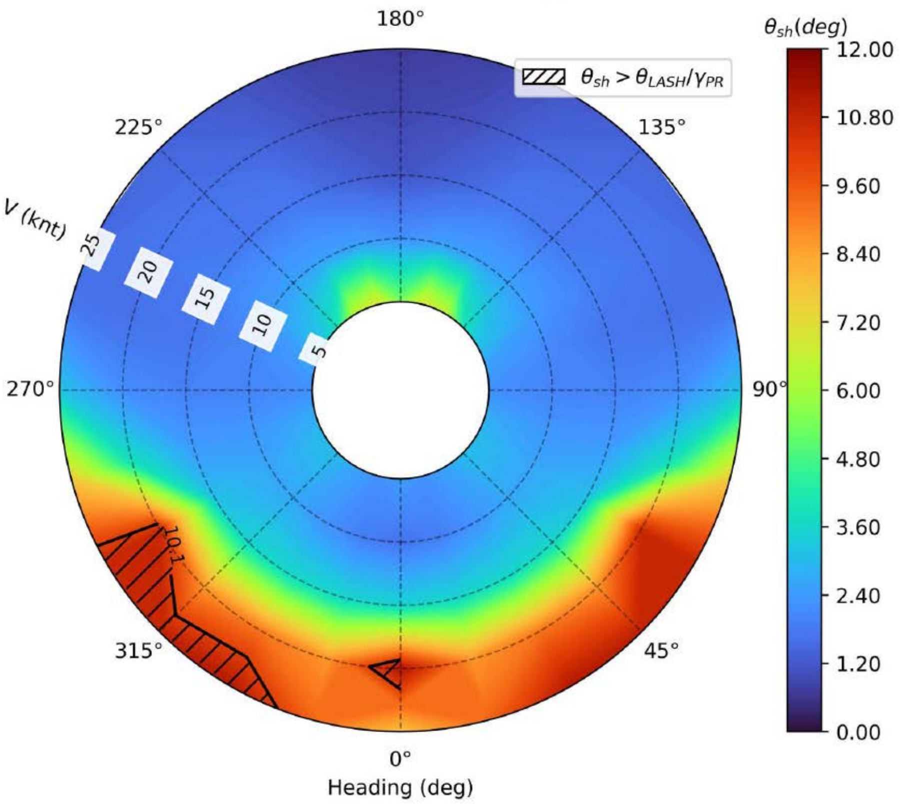


Figure 6 : Example of polar plot:

Hs = 8,39 m, T_{0m1} = 12,5s, GM = 3,17 m, T_θ = 23,7s

Left: θ_{LASH}/θ = 1,0   Right: θ_{LASH}/θ =1,2

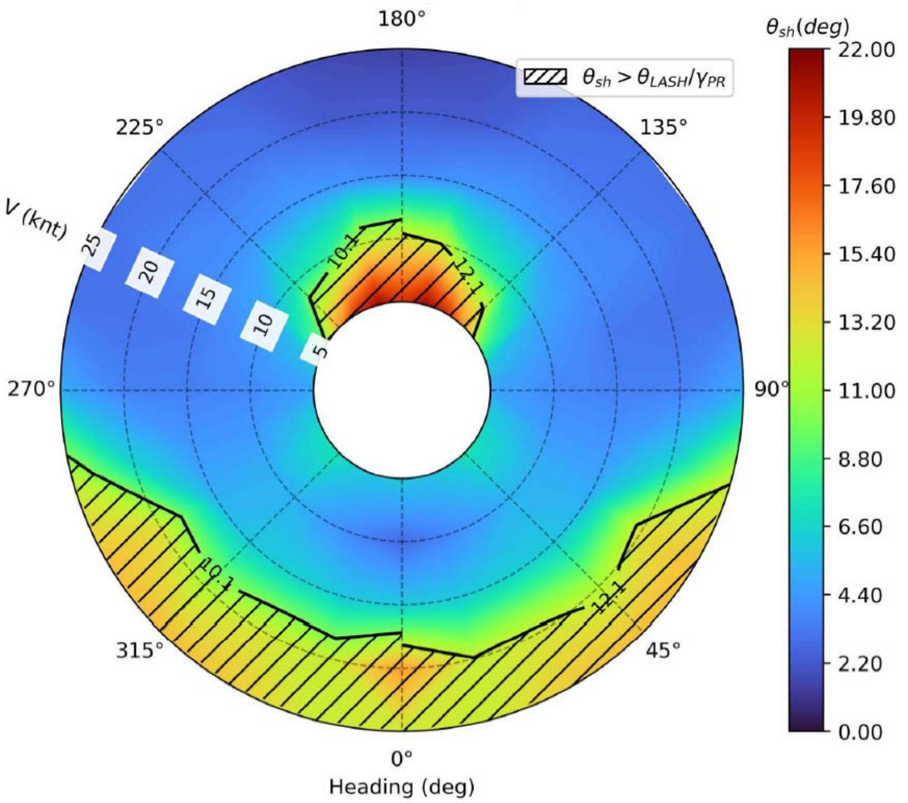


Figure 7 : Example of polar plot:

Hs = 11,09 m, T_{0m1} = 12,5s, GM = 3,17 m, T_θ = 23,7s

Left: θ_{LASH}/θ = 1,0   Right: θ_{LASH}/θ =1,2

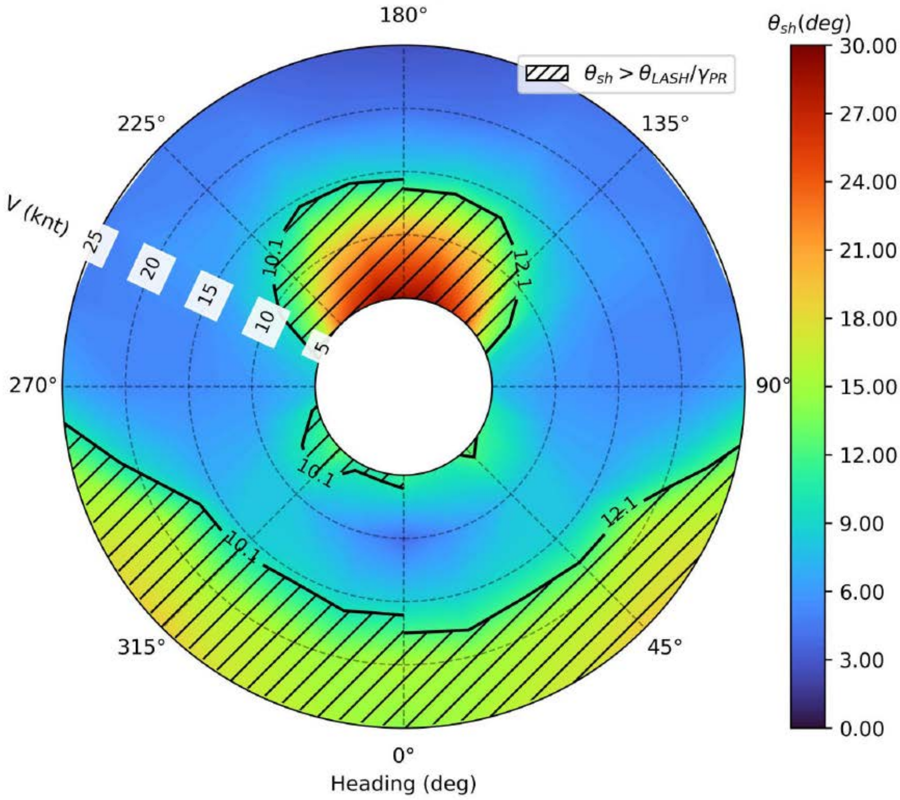
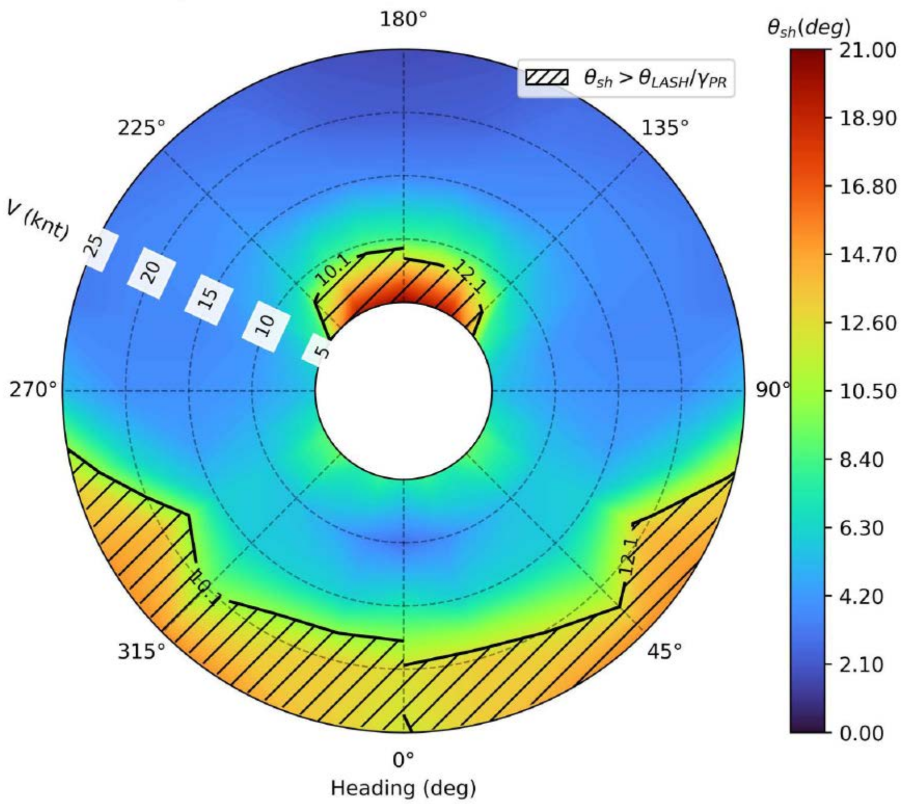


Figure 8 : Example of polar plot:

Hs = 8,39 m, T_{0m1} = 11,0s, GM = 3,17 m, T_θ = 23,7s

Left: θ_{LASH}/θ = 1,0   Right: θ_{LASH}/θ =1,2



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