Common Structural Rules for Bulk Carriers, January 2006

Background Document

CHAPTER 4 – DESIGN LOADS

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.
- The content of the TB is not to be considered as requirements.
- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.
- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

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SECTION 1 – GENERAL

1 GENERAL

1.1

1.1.1

1.1.1.a The design loads in these rules use the equivalent design wave (design regular wave) method described in Section 4.

1.1.1.b The equivalent design wave method is used for setting design loads including hull girder loads and normal components of lateral pressure on plate members in waves and in still water.

1.1.2

1.1.2.a The loads mentioned below are considered as lateral loads in still water.

(1) External hydrostatic pressure
(2) Static pressure due to cargo, ballast and fixed equipment
(3) Self weight of hull and outfitting items
(4) Set pressures of safety valves (if set)

1.1.2.b The loads mentioned below are considered as lateral loads in waves.

(1) Wave pressure
(2) Dynamic pressure due to inertia of cargo, ballast, fixed equipment
(3) Inertia due to hull and outfitting items
(4) Dynamic pressure due to slamming of bow flare and bow bottom
(5) Dynamic pressure due to green waves

1.1.3

1.1.3.a Still water vertical shear force and still water vertical bending moment, vertical wave shear force and vertical wave bending moment, horizontal wave bending moment and wave torsional moment are considered as hull girder loads.

1.1.4

1.1.4.a Stresses due to wave induced lateral loads and wave induced hull girder loads are combined using load combination factors (LCFs) in 8 load cases each specified in Section 4, 2.2 for the 4 equivalent design waves mentioned in Section 4, 1.2.

SECTION 2 – SHIP MOTIONS AND ACCELERATIONS

1 GENERAL

1.1

1.1.1

1.1.1.a Ship motions and accelerations are assumed to vary periodically. The amplitude of ship motions and accelerations calculated from the formulae in this section is assumed as half the amplitude from the peak to the trough. The value corresponding to an exceedance probability level of 10^{-8} corresponds to the maximum ship motion and acceleration that the ship is expected to experience in its lifetime.

1.1.1.b The symbols and the acceleration parameter a_0, the roll angle θ, the pitch angle φ indicated in 2., and other simplified formulae for loads due to waves specified in other sections of this chapter are multiplied by the exceedance probability level factor f_p, and the value for the strength assessment corresponding to the 10^{-8} level (such as yield, buckling, ultimate strength) is taken as 1.0, and the value for the strength assessment (fatigue strength) corresponding to the 10^{-4} level is taken as 0.5.

1.1.2

1.1.2.a As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, justified on the basis of the ship's characteristics and intended service.

1.1.2.b Generally, the estimated values of ship motions and accelerations by direct load calculation and model tank tests correspond to exceedance probability levels of 10^{-8} or 10^{-4}. Wave spectra and long-term wave scatter diagrams used for short-term and long-term predictions are generally the standard items mentioned below.

(a) Long-term wave scatter diagram: North Atlantic Ocean wave environment (IACS Rec. 34).
(b) Wave spectra: Piersion-Moskowitz type
(c) Wave directionality function: $\cos^2$

2 SHIP ABSOLUTE MOTIONS AND ACCELERATIONS

The simplified formulae for ship absolute motions and accelerations indicated here are basically the ones developed by the IACS WD-SL (IACS Wave Data and Sea Loads) Working Group. The simplified formulae and the acceleration parameters given here are common to Part CSR-T.

2.1 Roll

2.1.1

2.1.1.a The roll period T_R is the natural period of roll. It is estimated using the radius of gyration of roll k_r and the metacentric height GM in the considered loading condition.

$$T_R = C\frac{2k_r}{\sqrt{GM}} \quad \text{(s)}$$

Here, the coefficient C converts the natural period of roll in the atmosphere to that in water considering added mass, and is taken as 1.1.

2.1.1.b The values of radius of gyration of roll k_r, and the metacentric height GM, are basically the values used in the Loading Manual corresponding to the considered loading condition. If these values have not been derived during the initial design stage, then the values shown in Table 1, Section 2, Chapter 4 may be used.

2.2 Pitch

2.2.1

2.2.1.a The pitch period T_P, is the wave period (or wavelength λ) at which the pitch motion response function RAO becomes maximum. Pitching motion generally becomes maximum in the head sea condition.

2.2.1.b The regular wavelength λ at which the pitch motion response function becomes maximum is practically the same as the regular wavelength λ_H at which the vertical wave bending moment at the midship part of the hull specified in Section 4 becomes maximum. Therefore, the same equation given below is used.

$$\lambda = 0.6\left(1+\frac{T_{LC}}{T_S}\right)L = \frac{g}{2\pi}T_P^2 \quad \text{(m)}$$

Here, T_S is the scantling draft (m), while T_{LC} is the draft (m) at midship in the considered loading condition.

2.3 Heave

2.3.1

2.3.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

2.4 Sway

2.4.1

2.4.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

2.5 Surge

2.5.1

2.5.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3 SHIP RELATIVE ACCELERATIONS

3.1 General

3.1.1

3.1.1.a To estimate the dynamic pressures due to inertial forces such as those of cargo and ballast, the accelerations in the *X* (ship's length direction), *Y* (ship's breadth direction) and *Z* (ship’s depth direction) directions at an arbitrary position of the hull (such as at the center of a cargo hold or a tank) should be used.

3.1.1.b These accelerations consist of accelerations of roll and pitch motions described in 2., angular acceleration components that arise because of these motions, and accelerations due to heave, sway, and surge.

3.2 Accelerations

3.2.1

3.2.1.a The values of the longitudinal acceleration (a_X), the transverse acceleration (a_Y) and the vertical acceleration (a_Z) at any point can be estimated from the formula below from the absolute values (corresponding to the exceedance probability level) of the ship motion and acceleration components described in 3.1, and the load combination factors described in 2.2 of Section 4, for each loading case of each equivalent design wave.

$$a_X = C_{XG} g \sin\Phi + C_{XS} a_{surge} + C_{XP} a_{pitch\,x}$$
$$a_Y = C_{YG} g \sin\theta + C_{YS} a_{sway} + C_{YR} a_{roll\,y}$$
$$a_Z = C_{ZH} a_{heave} + C_{ZR} a_{roll\,z} + C_{ZP} a_{pitch\,z}$$

Here, C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR} and C_{ZP} are load combination factors for each loading case of each equivalent design wave specified in Section 4, Table 3.

SECTION 3 – HULL GIRDER LOADS

1 GENERAL

1.1 Sign conventions of bending moments and shear forces

1.1.1

1.1.1.a For strength analysis and strength assessment, shear forces and bending moments in still water and in waves acting on the hull as specified in this section must be considered. The magnitude of the shear forces and bending moments specified in this section are given as absolute values. The sign conventions of shear forces and bending moments shall be according to the load combination factors of Table 3 of Section 4, Chapter 4 of the Rules.

2 STILL WATER LOADS

2.1 General

2.1.1

2.1.1.a Generally, still water shear forces and bending moments used in strength analysis or strength assessment are used according to each planned loading condition.

2.1.1.b When studies related to hull girder strength in still water (Chapter 5 of Part CSR-B) are performed, the maximum value of still water shear force and vertical bending moment in various intermediate conditions during voyage are used for each loading condition.

2.1.2 Partially filled ballast tanks in ballast loading conditions

2.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.1.3 Partially filled ballast tanks in cargo loading conditions

2.1.3.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.2 Still water bending moment

2.2.1

2.2.1.a For the design hogging still water vertical bending moment ($M_{SW,H}$) and sagging vertical bending moment ($M_{SW,S}$) at any transverse section of the hull, the maximum values at the relevant transverse sections in the hogging and sagging conditions at the loading condition described in 2.1.1 are used. The designer can also specify a larger still water vertical bending moment and use the same.

2.2.2

2.2.2.a These formulae are based on IACS UR S7 that specifies the minimum hull girder section modulus and the IACS UR S11 that specifies the hull girder wave bending moment and the permissible hull girder stress.

2.3 Still water shear force

2.3.1

2.3.1.a The design still water shear force Q_{SW} at any hull transverse section is the maximum positive value or the maximum negative value of still water shear force at that transverse section in the loading condition described in 2.1.1. The designer can also prescribe a larger still water shear force and use the same.

2.4 Still water bending moment and still water shear force in flooded condition

2.4.1

2.4.1.a The still water shear force in flooded condition $Q_{SW,F}$ and the still water vertical bending moment $M_{SW,F}$ (hogging condition and sagging condition) are determined considering the scenario that in each case the cargo hold is independently flooded up to the water line in the final equilibrium condition during the hull strength assessment (hull girder ultimate strength assessment of Section, 2, Chapter 5, for instance) in the flooded condition.

2.4.2

2.4.2.a The permeability to calculate the mass of flooded water is specified according to the flooded cargo hold and the type of cargo carried.

2.4.3

2.4.3.a The effects of flooding on the still water vertical bending moment and the still water shear force need to be studied and quantified during the hull girder strength assessment.

3 WAVE LOADS

3.1 Vertical wave bending moments

3.1.1 Intact condition

3.1.1.a The vertical wave bending moment at a hull transverse section in the intact condition is determined after considering the non-linear phenomena, which are asymmetric in the hogging and sagging conditions due to waves. The vertical wave bending moment at the exceedance probability level of 10^{-8} corresponds to the maximum value of 25 years (design life). The vertical wave bending moment in the intact condition and the wave shear force in the intact condition specified in 3.2.1 are based on IACS UR S11.

3.1.2 Flooded condition

3.1.2.a For the vertical wave bending moment in the damaged condition, 0.8 times ($\{\log(10^8/25)\}/\log 10^8 \approx 0.8$) the maximum vertical wave bending moment in 1 year (vertical wave bending moment in intact condition) is used.

3.1.3 Harbour conditions

3.1.3.a The vertical bending moment acting on the hull induced by waves and in the condition at port is considered to be small compared to the normal voyage condition offshore, and thus the value of 0.4 times the vertical wave bending moment in the intact condition is used.

3.2 Vertical wave shear force

3.2.1 Intact condition

3.2.1.a The formula in IACS UR S11 is used for the vertical wave shear force that acts on a hull transverse section in the intact condition. Similar to the vertical bending moment, the vertical wave shear force at the exceedance probability level of 10^{-8} corresponds to the maximum value of 25 years (design life).

3.2.2 Flooded condition

3.2.2.a The maximum wave shear force (0.8 times the wave shear force in the intact condition) in one year is used as the shear force in the damaged condition because of the reasons mentioned in 3.1.2.

3.2.3 Harbour conditions

3.2.3.a The value of 0.4 times the vertical wave shear force in the intact condition is used as the vertical wave shear force in port because of the reasons mentioned in 3.1.3.

3.3 Horizontal wave bending moment

3.3.1

3.3.1.a In addition to the vertical wave bending moment and the vertical wave shear force that were considered in the assessment of local strength and direct structural analysis, the horizontal wave bending moment acting on the hull transverse section induced by waves must also be considered.

3.4 Wave torsional moment

3.4.1

3.4.1.a The wave torsional moment specified in this sub-section is used only in the fatigue strength assessment of structural members at the hatch corners specified in Section 5, Chapter 8 of the Rules, and therefore, the value corresponding to the exceedance probability level of 10^{-4} (f_p=0.5 in the formula used) is used. This formula is based on the wave torsional moment of GL Rules.

SECTION 4 – LOAD CASES

1 GENERAL

1.1 Application

1.1.1

1.1.1.a The load cases described in this section are used in strength analysis and strength assessment. That is, the load cases are used in local strength analysis for structural scantlings (plate members, stiffeners, primary supporting members) specified in Chapter 6 of Part CSR-B, direct strength analysis of structural members (primary supporting members) specified in Chapter 7, and fatigue assessment of structural details specified in Chapter 8.

1.1.2

1.1.2.a For local strength analysis and direct strength analysis, the 8 load cases (H1，H2，F1，F2，R1，R2，P1 and P2) corresponding to four equivalent design waves (design regular waves) specified in 1.2 are considered.

1.2 Equivalent design wave

1.2.1

1.2.1.a The design conditions shown below in the development of design loads are considered as basic conditions of CSR.

Operating sea area: North Atlantic Ocean (wave data: IACS Rec. No.34）

Design life: Minimum 25 years (exceedance probability: Q=10^{-8} level)

The technical background described below is mainly for bulk carriers (BC) but it also includes a part of the results of study on double hull oil tankers.

1.2.1.b The load components in 1 to 4 below are selected as dominant load components for structural strength in the Rules.

1. Vertical wave bending moment (head sea)
2. Vertical wave bending moment (following sea)
3. Roll
4. Have pressure at waterline

1.2.1.c The short-term sea states set for the dominant load conditions of 1 to 4 are proposed as design sea states. Here, the design sea states are defined as the short-term sea states that generate the stress values equivalent to the long-term prediction values of stresses for structural members of the ship (exceedance probability $Q=10^{-8}$, All Headings) .

Short-term sea state according to 1: Design sea state H

Short-term sea state according to 2: Design sea state F

Short-term sea state according to 3: Design sea state R

Short-term sea state according to 4: Design sea state P

Here, the design sea state H is the short-term sea state at which the vertical acceleration due to the combination of pitching and heaving, and the vertical bending moment generally become maximum The design sea state F is the short-term sea state similar to the design sea state H, but at which the vertical acceleration becomes minimum (that is, inertial force due to acceleration becomes minimum). Also, the design sea state *R* is the short-term sea state at which the transverse acceleration due to roll and the hydrodynamic pressure having asymmetric distribution generally become maximum. Furthermore, the design sea state P is the short-term sea state at which the hydrodynamic pressure at the waterline of the weather side and the vertical acceleration due to heave generally become maximum.

2 LOAD CASES

2.1 General

2.1.1

2.1.1.a Two load cases exist for each equivalent design wave. That is, the cases are the wave trough case (H1 or F1) and the wave crest case (H2 or F2) corresponding to the equivalent design waves H and F, the weather side (port) Down case (R1 or P1) and the weather side (port) Up case (R2 or P2) corresponding to the equivalent design waves R and P.

2.1.1.b Moreover, if the hull structure or the cargo loading is not symmetric with respect to the hull center line, in addition to the beam sea load cases (R1, R2, P1 and P2) mentioned above, additional four load cases must also be assessed for strength.

2.2 Load combination factors

2.2.1

2.2.1.a Load combination factor (LCF) is specified by using the response function of load component (RAO) and dominant load components for each WDW (H, F, R and P).

2.2.2

2.2.2.a In addition to considering hull girder loads in waves corresponding to load combination cases mentioned in 2.1, the still water bending moment mentioned in 2.2 of Section 3 also needs to be considered in the structural analysis.

2.2.3

2.2.3.a In addition to the external pressure specified in Section 5, static pressures or static forces due to loading (including ballast) including deck loading, or inertial pressures or inertial forces acting on loading (including ballast) induced by accelerations should be considered for the internal loads used in structural analysis.

SECTION 5 – EXTERNAL PRESSURES

1 EXTERNAL PRESSURES ON SIDE SHELL AND BOTTOM

1.1 General

1.1.1

1.1.1.a External pressure used for strength assessment and structural analysis is the total pressure (p) equal to the sum of the hydrostatic pressure (p_S) at the position of the member being examined and the wave pressure (p_W).

1.1.1.b The wave pressure may be a negative pressure as explained in 1.3, 1.4, and 1.5. However, the total pressure (p) is not to be taken as a negative value.

1.1.1.c The maximum value from the simplified formulae specified in 1.3, 1.4, and 1.5 is assigned a value equivalent to the maximum value of wave pressure (long-term prediction value corresponding to the exceedance probability level of 10^{-8}).

1.2 Hydrostatic pressure

1.2.1

1.2.1.a The hydrostatic pressure equivalent to static pressure in various loading conditions to be studied in still water is considered.

1.3 Hydrodynamic pressures for load cases H1, H2, F1 and F2

1.3.1

1.3.1.a The distribution of wave pressure corresponding to 4 load cases (H1, H2, F1, and F2) is the distribution in equivalent design waves H and F at which vertical wave bending becomes maximum. The wave pressure is obtained by multiplying the response function RAO of wave pressure in equivalent design wave at which the vertical wave bending moment at midship specified in Section 4 becomes maximum, by the regular wave height of equivalent design wave of the corresponding dominant load component.

1.3.1.b The wavelength at which the amplitude of the wave pressure at the centerline of midship generated in head seas becomes maximum is practically the same as the wavelength when the vertical wave bending moment becomes maximum. When the wave pressure at the centerline of midship becomes maximum, the wave pressure at another location in the same cross section also becomes nearly maximum, and the phase is almost the same.

1.3.1.c The nonlinear influence coefficient of 0.9 is considered based on the results of model tank tests for the wave pressure for load cases H1, H2, F1, and F2 at the exceedance probability level of 10^{-8}.

1.4 Hydrodynamic pressures for load cases R1 and R2

1.4.1

1.4.1.a The distribution of wave pressure for load cases R1 and R2 is the distribution in equivalent design wave R at which the rolling ship motion becomes maximum.

1.4.1.b The distribution of wave pressure comprises the fluctuating part of the hydrostatic pressure from the roll angle (asymmetric component; first term of the formula specified in 1.4.1, Sec. 5, Ch. 4 of the Rules) and the fluctuating part due to heave (asymmetric part; 2nd term of the formula above).

1.4.1.c A nonlinear influence coefficient of 0.8 is considered for the wave pressure for load cases R1 and R2 at the exceedance probability level of 10^{-8}.

1.5 Hydrodynamic pressure for load cases P1 and P2

1.5.1

1.5.1.a The distribution of wave pressure for load cases P1 and P2 is the distribution of equivalent design wave P at which the wave pressure at midship becomes maximum.

1.5.1.b A nonlinear influence coefficient of 0.65 is considered for the wave pressure for load cases P1 and P2 at the exceedance probability level of 10^{-8}.

1.6 Correction to hydrodynamic pressures

1.6.1

1.6.1.a When the wave pressure at the waterline becomes positive (load cases H1, H2, F2, R1, R2 and P1), the wave pressure at the waterline is converted to head of sea water and the wave pressure above the waterline is assumed to occur linearly (inclination of 45 degrees) up to the converted water head position.

1.6.1.b When the wave pressure at the waterline becomes negative (load cases H1, H2, F1, R1, R2 and P2), the wave pressure below the waterline is taken as the sum of the wave pressure and the hydrostatic pressure that does not become negative.

2 EXTERNAL PRESSURES ON EXPOSED DECKS

2.1 General

2.1.1

2.1.1.a The pressures specified in 2.2 and 2.3 must be considered regardless of the existence of water breakers installed on the exposed deck.

2.2 Load cases H1, H2, F1 and F2

2.2.1

2.2.1.a The external pressure p_D, at any point on the exposed deck for load cases H1, H2, F1 and F2 in head seas and following seas is estimated by the pressure (p_W) acting on the exposed deck specified in the LL Convention (or IACS UR S21) and the pressure coefficient φ for the exposed deck (φ, coefficient depending on height of deck which becomes smaller as the height of deck increases).

2.3 Load cases R1, R2, P1, and P2

2.3.1

2.3.1.a The external pressure p_D at any point on the exposed deck for load cases R1, R2, P1 and P2 in beam seas is estimated using the wave pressure at the side shell position on the exposed deck described in 1.4, 1.5, and 1.6 (the larger of the values from the port side and the starboard side is taken), the pressure coefficient (φ) at the exposed deck and the considered position z.

2.4 Loads carried on exposed deck

2.4.1 Pressure due to distributed load

2.4.1.a When the exposed deck is loaded with distributed cargo load (such as lumber, etc.), the static and dynamic loads due to such cargo should be considered.

2.4.2 Concentrated forces due to unit load

2.4.2.a When unit load is carried on the exposed deck (such as outfitting items), the static and dynamic forces due to this unit load must be considered.

3 EXTERNAL PRESSURES ON SUPERSTRUCTURES AND DECKHOUSES

3.1 Exposed decks

3.1.1

3.1.1.a External pressures on exposed deck specified in 2also apply to the exposed decks of superstructure and deckhouses. However, the external pressures and those specified in 3.2, 3.3, and 3.4 apply only to the scantling requirements of members specified in Section 4, Chapter 9.

3.2 Exposed wheel house tops

3.2.1

3.2.1.a The pressure p acting on the tops of exposed wheelhouse is taken as 2.5 kN/m^2 and greater.

3.3 Sides of superstructures

3.3.1

3.3.1.a The pressure acting on the sides of superstructure is estimated according to the longitudinal position and height of the location in the superstructure.

3.4 Superstructure end bulkheads and deckhouse walls

3.4.1

3.4.1.a The pressure acting on the superstructure bulkheads and deckhouse walls is calculated according to the longitudinal position and height on the bulkhead (wall).

4 PRESSURE IN BOW AREA

4.1 Bow flare area pressure

4.1.1

4.1.1.a This calculation formula has been corrected to attain consistency with GL Rules calculation formula that assumes the sea conditions in CSR.

This slamming pressure is applicable only to the scantling requirements of members specified in 4., Section 1, Chapter 9.

4.2 Design bottom slamming pressure

4.2.1

4.2.1.a This slamming pressure is applicable only to the scantling requirements of specified members. This calculation formula has been corrected to attain consistency with the GL Rules calculation formula that assumes the sea conditions in CSR.

4.2.2

4.2.2.a To limit the slamming loads at acceptable level, the smallest design ballast draught at forward perpendicular should only be undercut in cases where bottom slamming is not expected.

5 EXTERNAL PRESSURES ON HATCH COVERS

5.1 General

5.1.1

5.1.1.a When cargo is loaded on hatch covers, the static and dynamic loads due to the loaded cargo are specified in 2.5 according to the type of cargo.

5.2 Wave pressure

5.2.1

5.2.1.a The wave pressure on hatch covers is basically estimated by calculating the pressure acting on the exposed deck specified in 2.2.1 (according to the regulations of the LL Convention or IACS UR S21). This wave pressure is applicable only to scantling requirements of members of hatch covers specified in 4., Section 5, Chapter 9.

SECTION 6 – INTERNAL PRESSURES AND FORCES

1 LATERAL PRESSURE DUE TO DRY BULK CARGO

1.1 Dry bulk cargo upper surface

1.1.1

1.1.1.a When cargo of small density (ρ_C) is carried and the shape of the surface of the cargo reaches the upper end of the hatch coaming, the upper surface of the bulk cargo should be taken ignoring the topside tanks, based on practicality and safety and taking into account the friction effects between the cargo and the wall surfaces.

1.1.1.b The height of surface contour of loaded cargo (h_C, vertical distance from the inner bottom plating to the assumed bulk cargo upper surface) is determined assuming loaded condition with width equal to the width between side shell plating or longitudinal bulkheads surrounding the cargo in the cargo hold considering an equivalent volume of cargo.

1.1.2

1.1.2.a When cargo of high density such as iron ore is loaded in the cargo hold, the upper surface of the cargo does not reach the position of the upper deck. To set the cargo pressure applied on the inner bottom plating on the safe side, the height of the shape of the surface of cargo (h_C) should be set assuming that the volume and mass (M) of the cargo remain unchanged, the upper surface of the cargo is considered as having a plane surface of width $B_H/2$ on the centerline (B_H is the mean width of the cargo hold), and the shape of the cargo has inclined parts with an angle equal to half the angle of repose ($\psi/2$) at sides.

1.2 Dry bulk cargo pressure in still water

1.2.1

1.2.1.a The static pressure due to grain cargo is estimated from the position of the location to be studied, the height of the shape of the surface of loaded cargo (h_C), and the coefficient K_C ($K_C = \cos^2\alpha + K_0 \sin^2\alpha$) which takes the coefficient of earth pressure at rest K_0, and the angle of the slant plate as parameters.

1.3 Inertial pressure due to dry bulk cargo

1.3.1

1.3.1.a The dynamic pressure due to inertial force of the grain cargo can be estimated by the position of the location to be studied, the height of the shape of the surface of loaded cargo (h_C), the coefficient K_C, and the longitudinal, transverse and vertical accelerations at the center of gravity of the cargo hold specified in 3., Section 2, Chapter 4, for the load cases (H1, H2, F1, F2, R1, R2, P1 and P2) specified in 2, Section 4, Chapter 4.

1.4 Shear load due to dry bulk cargo

1.4.1

1.4.1.a To consider a balance between the overall internal pressure or force (gravity and inertial force due to vertical acceleration) in the vertical direction of the FE structural model in direct structural analysis, shear load according to the calculation formula shown in 1.4.1 should be considered in addition to the static internal pressure and dynamic internal pressure according to the calculation formula shown in 1.2.1 and 1.3.1.

1.4.2

1.4.2.a Only inertial forces due to longitudinal and transverse accelerations exist in the longitudinal and transverse directions of the ship because of basically the same reasons as in 1.4.1, and therefore, shear load is applied on the inner bottom plating to consider the balance of overall forces (inertial force due to acceleration) in the longitudinal and transverse directions of the FE structural model. The shear load is considered only for direct structural analysis.

2 LATERAL PRESSURE DUE TO LIQUID

2.1 Pressure due to liquid in still water

2.1.1

2.1.1.a Pressure due to liquid in still water is calculated based on the head of liquid including the height of air pipe, in principle. The setting pressure is to be considered when a safety valve is provided. Also, the pressure due to liquid in still water is taken as 25 kN/m^2 or greater for assessment of local strength.

2.1.2

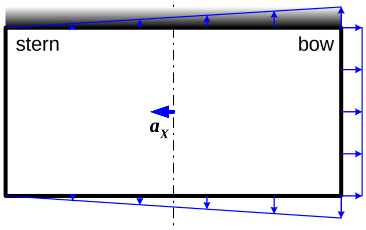
2.1.2.a If ballast water exchange is scheduled by the flow-through method, the pressure due to liquid in still water is taken as 25 kN/m^2 and greater for direct strength analysis specified in Chapter 7 and for local strength assessment. To generate a higher pressure by design of piping and pumps, high pressure needs to be considered.

2.2 Inertial pressure due to liquid

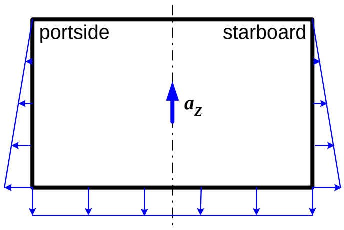
2.2.1

2.2.1.a The internal dynamic pressure due to liquid can be estimated for general load cases (H1, H2, F1, F2, R1, R2, P1 and P2) by multiplying the longitudinal, transverse and vertical accelerations at the centerline of cargo holds or tanks by the distance from the reference point to the assessment point.

2.2.1.b Fig. 3.1(a) and (b) show the dynamic internal pressure distributions due to longitudinal and vertical accelerations respectively for load case H1. Also, Fig. 3.2 (a) and (b) show the dynamic internal pressure distributions due to transverse and vertical accelerations respectively in load cases R1 or P1. Furthermore, Fig. 3.2(c) shows the combined dynamic internal pressure distribution due to transverse and vertical accelerations.

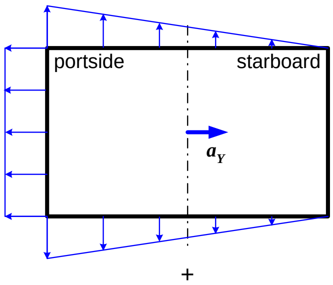


(a) Dynamic internal pressure distribution due to *a*

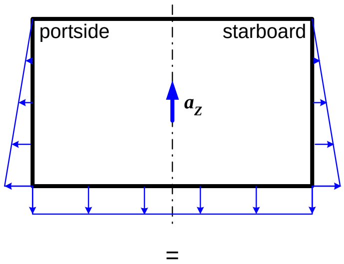


(b) Dynamic internal pressure distribution due to a_z

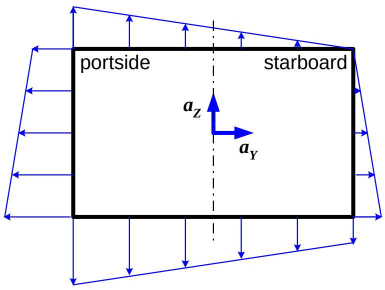
Fig. 3.1 Dynamic internal pressure distributions due to longitudinal and vertical accelerations for load case H1



(a) Dynamic internal pressure distribution due to a_Y



(b) Dynamic internal pressure distribution due to a_Z



(c) Dynamic internal pressure distribution due to the combination of accelerations $a_Y$and a_Z

Fig. 3.2 Dynamic internal pressure distribution due to transverse acceleration (a_Y), vertical acceleration (a_Z) and the combination of a_Y and a_Z in load case R1 or P1

3 LATERAL PRESSURES AND FORCES IN FLOODED CONDITION

3.1 Application

3.1.1

3.1.1.a Regulations for pressure in the general case are shown in 3.2, those for the special case of corrugated transverse bulkhead are shown in 3.3 and those for the special case of double bottom are shown in 3.4 in the flooded condition, according to the members studied.

3.2 General

3.2.1

3.2.1.a Structural members corresponding to the general case are plate members that form the boundaries of compartments in which liquid is not carried except inner bottom plating and side shell. The pressure applied on these plate members can be estimated from the formula specified in 3.2.1, Section 6, Chapter 4.

3.3 Transverse vertically corrugated watertight bulkheads

3.3.1 Application

3.3.1.a The regulation is in accordance with the regulation of IACS UR S18. For each cargo hold, the flooded condition is considered independently.

3.3.2 General

3.3.2.a The regulation is in accordance with the regulation of IACS UR S18.

3.3.3 Flooding level

3.3.3.a The regulation is in accordance with the regulation of IACS UR S18.

3.3.4 Pressures and forces on a corrugation in non-flooded bulk cargo loaded holds

3.3.4.a The regulation is in accordance with the regulation of IACS UR S18.

3.3.5 Pressures and forces on a corrugation in flooded bulk cargo loaded holds

3.3.5.a The regulation is in accordance with the regulation of IACS UR S18.

3.3.6 Pressures and forces on a corrugation in flooded empty holds

3.3.6.a The regulation is in accordance with the regulation of IACS UR S18.

3.3.7 Resultant pressure and forces

3.3.7.a The regulation is in accordance with the regulation of IACS UR S18.

3.4 Double bottom

3.4.1 Application

3.4.1.a The regulation is based on the regulation of IACS UR S20. For each cargo hold, the flooded condition is considered independently.

3.4.2 General

3.4.2.a The regulation is based on the regulation of IACS UR S20.

3.4.3 Flooding level

3.4.3.a The regulation is based on the regulation of IACS UR S20.

4 TESTING LATERAL PRESSURE

4.1 Still water pressure

4.1.1

4.1.1.a During local strength assessment of plate members and stiffeners for which hydrostatic testing is required, the still water pressure due to the hydrostatic test is estimated from the water head of the hydrostatic test, and compartments and positions of structural members.

SECTION 7 – LOADING CONDITIONS

1 APPLICATION

1.1 Ships having a length (L) less than 150 m

1.1.1

1.1.1.a IACS UR S25 is a regulation applicable to bulk carriers of 150 m and greater in length. For bulk carriers under 150 m in length, the requirement is to design based on the loading conditions actually assumed regardless of the requirements of IACS UR S25.

1.2 Ships having a length (L) of 150 m and above

1.2.1

1.2.1.a This regulation is in accordance with IACS UR S25.

1.2.2

1.2.2.a This regulation is in accordance with IACS UR S25.

1.2.3

1.2.3.a This regulation is in accordance with IACS UR S25.

1.2.4

1.2.4.a This regulation is in accordance with IACS UR S25.

1.2.5

1.2.5.a This regulation is in accordance with IACS UR S25.

2 GENERAL

2.1 Design loading conditions – General

2.1.1

2.1.1.a This regulation is in accordance with IACS UR S25.

2.1.2 BC-C

2.1.2.a This regulation is in accordance with IACS UR S25.

2.1.3 BC-B

2.1.3.a This regulation is in accordance with IACS UR S25.

2.1.4 BC-A

2.1.4.a This regulation is in accordance with IACS UR S25.

2.2 Applicable ballast conditions

2.2.1 Ballast tank capacity and disposition

2.2.1.a This regulation is in accordance with IACS UR S25.

2.2.2 Strength requirements

2.2.2.a This regulation is in accordance with IACS UR S25.

2.3 Departure and arrival conditions

2.3.1

2.3.1.a This regulation is in accordance with IACS UR S25.

3 DESIGN LOADING CONDITIONS FOR LOCAL STRENGTH

3.1 Definitions

3.1.1

3.1.1.a This regulation is in accordance with IACS UR S25.

3.2 Applicable general conditions

3.2.1

3.2.1.a This regulation is in accordance with IACS UR S25.

3.2.2

3.2.2.a This regulation is in accordance with IACS UR S25.

3.2.3

3.2.3.a This regulation is in accordance with IACS UR S25.

3.3 Additional conditions applicable except when additional service feature {no MP} is assigned

3.3.1

3.3.1.a This regulation is in accordance with IACS UR S25.

3.3.2

3.3.2.a This regulation is in accordance with IACS UR S25.

3.3.3

3.3.3.a This regulation is in accordance with IACS UR S25.

3.3.4

3.3.4.a This regulation is in accordance with IACS UR S25.

3.4 Additional conditions applicable for BC-A only

3.4.1

3.4.1.a This regulation is in accordance with IACS UR S25.

3.4.2

3.4.2.a This regulation is in accordance with IACS UR S25.

3.4.3

3.4.3.a This regulation is in accordance with IACS UR S25.

3.5 Additional conditions applicable for ballast hold(s) only

3.5.1

3.5.1.a This regulation is in accordance with IACS UR S25.

3.6 Additional conditions applicable during loading and unloading in harbour only

3.6.1

3.6.1.a This regulation is in accordance with IACS UR S25.

3.6.2

3.6.2.a This regulation is in accordance with IACS UR S25.

3.6.3

3.6.3.a This regulation is in accordance with IACS UR S25.

3.7 Hold mass curves

3.7.1

3.7.1.a This regulation is in accordance with IACS UR S25.

3.7.2

3.7.2.a This regulation is in accordance with IACS UR S25.

4 DESIGN LOADING CONDITIONS FOR DIRECT STRENGTH ANALYSIS

4.1 Loading patterns

4.1.1

4.1.1.a Loading conditions to be considered in direct strength analysis are categorized by type of ship (by notation) summarized in Table 1 of the Rules.

4.1.2

4.1.2.a Separate considerations are necessary for special loading.

4.2 Still water vertical bending moment and shear force

4.2.1

4.2.1.a The loading conditions and load cases (design wave) are combined in direct strength analysis, but in this case, the still water vertical bending moment to be considered is specified in Table 2 of the Rules. Basically, from the permissible hogging and sagging values, those values that yield more severe results for the assumed loading conditions, or both are to be considered. However, still water vertical bending moments that do not normally occur are exempted. Moreover, still water vertical bending moment in the homogenous loading condition is taken as 50% of the permissible value. As specified in Table 3 of the Rules, the permissible still water vertical shear force needs to be considered in shear force analysis, but the loading conditions for which analysis is to be performed were restricted to those in which high shear forces occur, such as the alternate loading condition. Also, only the H and F load cases corresponding to the head seas and following seas respectively, were considered.

4.2.2

4.2.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

4.3 Application

4.3.1

4.3.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

4.3.2

4.3.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

SECTION 8 – LOADING MANUAL AND LOADING INSTRUMENT

1 GENERAL

1.1 All ships

1.1.1

1.1.1.a The regulation is based on IACS UR S1 and S2.

1.2 Ships equal to or greater than 150 m in length (L)

1.2.1

1.2.1.a The regulation is based on IACS UR S1 and S2.

2 LOADING MANUAL

2.1 Definitions

2.1.1 All ships

2.1.1.a The regulation is based on IACS UR S1 and S2.

2.1.2 Ships equal to or greater than 150 m in length (L)

2.1.2.a The regulation is based on IACS UR S1 and S2.

2.2 Conditions of approval

2.2.1 All ships

2.2.1.a The regulation is based on IACS UR S1 and S2.

2.2.2 Ships equal to or greater than 150 m in length (L)

2.2.2.a The regulation is based on IACS UR S1 and S2.

2.3 Language

2.3.1

2.3.1.a The regulation is based on IACS UR S1 and S2.

3 LOADING INSTRUMENT

3.1 Definitions

3.1.1 All ships

3.1.1.a The regulation is based on IACS UR S1 and S2.

3.1.2 Ships equal to or greater than 150 m in length (L)

3.1.2.a The regulation is based on IACS UR S1 and S2.

3.2 Conditions of approval

3.2.1 All ships

3.2.1.a The regulation is based on IACS UR S1 and S2.

3.2.2 Ships equal to or greater than 150 m in length (L)

3.2.2.a The regulation is based on IACS UR S1 and S2.

3.2.3

3.2.3.a The regulation is based on IACS UR S1 and S2.

3.2.4

3.2.4.a The regulation is based on IACS UR S1 and S2.

3.2.5

3.2.5.a The regulation is based on IACS UR S1 and S2.

4 ANNUAL AND CLASS RENEWAL SURVEY

4.1 General

4.1.1

4.1.1.a The regulation is based on IACS UR S1 and S2.

4.1.2

4.1.2.a The regulation is based on IACS UR S1 and S2.

4.1.3

4.1.3.a The regulation is based on IACS UR S1 and S2.

5 GUIDANCE FOR LOADING/UNLOADING SEQUENCES

5.1 General

5.1.1

5.1.1.a The regulation is based on IACS UR S1 and S2.

5.1.2

5.1.2.a The regulation is based on IACS UR S1 and S2.

5.1.3

5.1.3.a The regulation is based on IACS UR S1 and S2.

5.1.4

5.1.4.a The regulation is based on IACS UR S1 and S2.

5.1.5

5.1.5.a The regulation is based on IACS UR S1 and S2.

5.1.6

5.1.6.a The regulation is based on IACS UR S1 and S2.

APPENDIX 1 – HOLD MASS CURVES

1 GENERAL

1.1 Application

1.1.1

1.1.1.a CSR for Bulk Carriers is applicable to typical bulk carriers with topside tanks and bilge hopper tanks. For these ships of length 150 m and greater, class notations "BC-A," "BC-B," or "BC-C" may be assigned according to the regulations of 3.1, Section 1, Chapter 1.

1.1.2

1.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

1.1.3

1.1.3.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

1.1.4

1.1.4.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2 MAXIMUM AND MINIMUM MASSES OF CARGO IN EACH HOLD

2.1 Maximum permissible mass and minimum required masses of single cargo hold in seagoing condition

2.1.1 General

2.1.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.1.2 BC-A ship

2.1.2.a The examples of hold mass curves for BC-A ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

2.1.3 BC-A ship with {No MP}

2.1.3.a The examples of hold mass curves for BC-A ships with {No MP} covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

2.1.4 BC-B and BC-C ships

2.1.4.a The examples of hold mass curves for BC-B and BC-C ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

2.1.5 BC-B and BC-C ships with {No MP}

2.1.5.a The examples of hold mass curves for BC-B and BC-C ships with {No MP} covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

2.2 Maximum permissible mass and minimum required masses of single cargo hold in harbour condition

2.2.1 General

2.2.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.2.2 All ships

2.2.2.a The examples of hold mass curves for all ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

3 MAXIMUM AND MINIMUM MASSES OF CARGO OF TWO ADJACENT HOLDS

3.1 Maximum permissible mass and minimum required masses of two adjacent holds in seagoing condition

3.1.1 General

3.1.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

3.1.2 BC-A ships

3.1.2.a The examples of hold mass curves for BC-A ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

3.1.3 BC-B and BC-C ships

3.1.3.a The examples of hold mass curves for BC-B and BC-C ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph

3.2 Maximum permissible mass and minimum required masses of two adjacent cargo holds in harbour condition

3.2.1 General

3.2.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

3.2.2 All ships

3.2.2.a The examples of hold mass curves for all ships covered by the standard loading conditions in Chapter 4 Section 7 are described in this paragraph.

APPENDIX 2 – STANDARD LOADING CONDITION FOR DIRECT STRENGTH ANALYSIS

Regulations related to loading conditions, drafts, load cases, still water vertical bending moment and so on, to be considered for direct strength calculation are given in Section 7, Chapter 4 of the Rules. Details of these requirements, however, are summarized in Appendix 2. The loading conditions assumed were denoted using figures, and the drafts, load cases, still water vertical bending moment and so on, were also summarized together for the convenience of designers. From the results of test calculations, load cases that were determined as dominant were specified.

APPENDIX 3 – STANDARD LOADING CONDITION FOR FATIGUE ASSESSMENT

Regulations related to loading conditions and load cases to be assumed in direct strength calculation implemented for fatigue strength assessment are specified in Section 1, Chapter 8 of the Rules. Further details of these requirements are summarized in Appendix 3 of the Rules.