

GUIDE FOR

'SAFEHULL-DYNAMIC LOADING APPROACH' FOR VESSELS

DECEMBER 2006

Guide to Color Coding Used in Online Version of the Guide

The following summarizes the colors corresponding to Rule Changes, Corrigenda items and editorial changes in the Guide files which are available for download.

Rule Changes:

NOTICE NO. 1 – August 2013 (effective 1 August 2013)

NOTICE NO. 2 – October 2015 (effective 1 October 2015)

Corrigenda:

CORRIGENDA/EDITORIALS – 1 August 2013

CORRIGENDA/EDITORIALS – 1 February 2014

CORRIGENDA/EDITORIALS – 1 January 2017

CORRIGENDA/EDITORIALS – 1 February 2017

Editorials:

Editorial Changes



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DECEMBER 2006 (Updated February 2017 – see next page)

**American Bureau of Shipping
Incorporated by Act of Legislature of
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Updates

February 2017 consolidation includes:

- January 2017 version plus Corrigenda/Editorials

January 2017 consolidation includes:

- October 2015 version plus Corrigenda/Editorials

October 2015 consolidation includes:

- February 2014 version plus Notice No. 2

February 2014 consolidation includes:

- August 2013 version plus Corrigenda/Editorials

August 2013 consolidation includes:

- December 2006 version plus Notice No. 1 and Corrigenda/Editorials

Foreword

This Guide provides information about the optional classification notation, SafeHull-Dynamic Loading Approach, **SH-DLA**, which is available to qualifying vessels intended to carry oil in bulk, ore or bulk cargoes, containers and liquefied gases in bulk. In the text herein, this document is referred to as “this Guide”.

Section 1-1-3 of the [ABS Rules for Conditions of Classification \(Part 1\)](#) contains descriptions of the various basic and optional classification notations available. The following Chapters of the ABS [Rules for Building and Classing Steel Vessels \(Steel Vessel Rules\)](#) give the design and analysis criteria applicable to the specific vessel types:

- Part 5C, Chapter 1 – Tankers of 150 meters (492 feet) or more in length
- Part 5C, Chapter 3 – Bulk carriers of 150 meters (492 feet) or more in length
- Part 5C, Chapter 5 – Container carriers of 130 meters (427 feet) or more in length
- Part 5C, Chapter 8 – LNG carriers
- [Part 5C, Chapter 12 – Membrane Tank LNG Vessels](#)

In addition to the Rule design criteria, SafeHull-Dynamic Loading Approach based on first-principle direct calculations is acceptable with respect to the determination of design loads and the establishment of strength criteria for vessels. In the case of a conflict between this Guide and the ABS *Steel Vessel Rules*, the latter has precedence.

This Guide is a consolidated and extended edition of:

- *Analysis Procedure Manual for The Dynamic Loading Approach (DLA) for Tankers*, March 1992
- *Analysis Procedure Manual for The Dynamic Loading Approach (DLA) for Bulk Carriers*, April 1993
- *Analysis Procedure Manual for The Dynamic Loading Approach (DLA) for Container Carriers*, April 1993
- *Guidance Notes on ‘SafeHull-Dynamic Loading Approach’ for Container Carriers*, April 2005

This Guide represents the most current and advanced ABS DLA analysis procedure including linear and nonlinear seakeeping analysis. This Guide is issued December 2006. Users of this Guide are welcome to contact ABS with any questions or comments concerning this Guide. Users are advised to check periodically with ABS to ensure that this version of this Guide is current.



GUIDE FOR

'SAFEHULL-DYNAMIC LOADING APPROACH' FOR VESSELS

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SECTION 1 General

1 Introduction

The design and construction of the hull, superstructure and deckhouses of an ocean-going vessel are to be based on all applicable requirements of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*. The design criteria of the *Steel Vessel Rules* are referred to as ABS SafeHull criteria.

The SafeHull criteria in the *Steel Vessel Rules* entail a two-step procedure. The main objective of the first step, referred to as Initial Scantling Evaluation (ISE), is scantling selection to accommodate global and local strength requirements. The scantling selection is accomplished through the application of design equations that reflect combinations of static and dynamic envelope loads; durability considerations; expected service, survey and maintenance practices; and structural strength considering the failure modes of material yielding and buckling. Also, a part of ISE is an assessment of fatigue strength primarily aimed at connections between longitudinal stiffeners and transverse web frames in the hull structure. The second step of the SafeHull criteria, referred to as Total Strength Assessment (TSA), entails the performance of structural analyses using the primary design Loading Cases of ISE. The main purpose of the TSA analyses is to confirm that the selected design scantlings are adequate (from a broader structural system point of view) to resist the failure modes of yielding, buckling, ultimate strength and fatigue.

The SafeHull-Dynamic Loading Approach (SH-DLA) provides an enhanced structural analyses basis to assess the capabilities and sufficiency of a structural design. A fundamental requirement of SH-DLA is that the basic, initial design of the structure is to be in accordance with the SafeHull criteria as specified in the *Steel Vessel Rules*. The results of the DLA analyses cannot be used to reduce the basic scantlings obtained from the direct application of the Rule criteria scantling requirements (see 3-1-2/5.3 of the *Steel Vessel Rules*). However, should the DLA analysis indicate the need to increase any basic scantling, this increase is to be accomplished to meet the DLA criteria.

3 Application

This Guide is applicable to ocean-going vessels of all size and proportions including tankers, bulk carriers, container carriers and LNG carriers. Specifically for a container carrier with length in excess of 350 meters (1148 feet), the hull structure and critical structural details are to comply with the requirements of this SafeHull-Dynamic Loading Approach (5C-5-1/1.3.3 of the *Steel Vessel Rules*).

5 Concepts and Benefits of DLA Analysis

5.1 Concepts

DLA is an analysis process, rather than a step-wise design-oriented process such as SafeHull criteria. The DLA Analysis emphasizes the completeness and realism of the analysis model in terms of both the extent of the structure modeled and the loading conditions analyzed. The DLA modeling and analysis process relies on performing multiple levels of analysis that start with an overall or global hull model. The results of each previous level of analysis are used to establish which areas of the structure require finer (more detailed) modeling and analysis, as well as the local loads and 'boundary conditions' to be imposed on the finer model.

The Load Cases considered in the DLA Analysis possess the following attributes:

- i) Use of cargo loading patterns, other loading components and vessel operating drafts that reflect the actual ones intended for the vessel (note that the Load Cases in SafeHull comprise mainly those intended to produce 'scantling design controlling' situations).
- ii) Load components that are realistically combined to assemble each DLA Analysis Load Case. The dynamically related aspects of the components are incorporated in the model, and the combination of these dynamically considered components is accommodated in the analysis method.

5.3 Benefits

The enhanced realism provided by the DLA analysis gives benefits that are of added value to the Owner/Operator. The most important of these is an enhanced and more precise quantification of structural safety based on the attributes mentioned above. Additionally, the more specific knowledge of expected structural behavior and performance is very useful in more realistically evaluating and developing inspection and maintenance plans. The usefulness of such analytical results when discussing the need to provide possible future steel renewals should be apparent. A potentially valuable benefit that can arise from the DLA analysis is that it provides access to a comprehensive and authoritative structural evaluation model, which may be readily employed in the event of emergency situations that might occur during the service life, such as structural damage, repairs or modifications.

5.5 Load Case Development for DLA Analysis

The basic concept, which must be understood to grasp the nature of DLA, concerns the creation of each Load Case to be used in the DLA analysis. A Load Case contains a Dominant Load component that is characterized by a Dominant Load Parameter (DLP) and the instantaneous load components accompanying the Dominant Load component.

A load component consists of dynamic and static parts. For example, the load component “external fluid pressure on the vessel’s hull in the presence of waves” has a hydrostatic component that combines with a dynamic pressure component. The determination of the static part of the load component is basic. The dynamic part reflects the wave-induced motion effects, which are the product of an inertial portion of the load and a portion representing the motion-induced displacement of the load relative to the structure’s axis system.

Examples of Dominant Load Parameters are “Vertical Bending Moment Amidships” and “Vertical Acceleration at Bow”. The specific Dominant Load Parameters that are recommended for inclusion in the DLA Analysis of each vessel type are given in Subsection 2/7. The other instantaneous load components accompanying the Dominant Load component in a Load Case include internal and external fluid pressures and lightship weights, including structural self-weight.

The combination of the load components composing a Load Case is done through a process where each Dominant Load is analyzed to establish its Response Amplitude Operator (RAO). Using a combination of ship motion analysis, involving ocean wave spectra, and extreme value analysis of the Dominant Load Parameter, an equivalent design wave is derived. The design wave (defined by wave amplitude, frequency, heading and phase angle with respect to a selected reference location) is considered equivalent in the sense that when it is imposed on the structural model it simulates the extreme value of the DLP. The process to perform this derivation is given in Sections 4, 5 and 6.

In this Guide, emphasis is given to the development of hydrodynamic loadings based on seakeeping analysis. It is assumed that the user has the needed theoretical background and computational tools for seakeeping and spectral analysis, which are required in the determination of the Load Cases.

From the seakeeping analysis, the instantaneous magnitude and spatial distributions of the Dominant Load component and the other load components accompanying the Dominant Load component are to be obtained. The procedures to establish these load components accompanying the DLP are given for the various other load component types in Sections 6, 7, 8, 9 and 10.

Using the described basic procedure there are many additional considerations and refinements that can be included and accommodated in DLA Analysis. These include items such as the following:

- i) Operational considerations of the vessel in extreme waves
- ii) Directionality of waves
- iii) Energy spreading of sea spectra
- iv) Various formulations to characterize the sea spectra
- v) Various exceedance probability levels to characterize extreme values of Dominant Load Parameters

The point to bear in mind is that the procedure is robust enough to accommodate these items. In addition it is to be noted that the DLA analysis could also be carried out considering Load Cases comprised of Dominant Stress values and Dominant Stress Parameter, in lieu of Dominant Load components and Dominant Load Parameter, in much the same manner as previously described. In such case the combination of the stress components, rather than load components, comprising a Load Case, can be done through a process where each Dominant Stress is analyzed to establish its stress RAO. This generally requires much more extensive calculations to determine the stress values in the many dynamic conditions and therefore is beyond the scope of this Guide.

5.7 General Modeling Considerations

In general, it is expected that the inaccuracies and uncertainties, which can arise from use of partial or segmented models, will be minimized by the use of models that are sufficiently comprehensive and complete to meet the goals of the analysis. This specifically means that to the maximum extent practicable, the overall model of the vessel should comprise the entire hull structure. The motion analysis should consider the effect of all six degrees of freedom motions. There is also to be sufficient compatibility between the hydrodynamic and structural models so that the application of hydrodynamic pressures onto the finite element mesh of the structural model can be done appropriately.

The results of overall (global) FE analysis are to be directly employed in the analysis of the required finer mesh, local FE models. Appropriate 'boundary conditions' determined in the larger scale model are to be imposed on the local models to assure appropriate structural continuity and load transfer between the various levels of models.

7 Notations

The **SH-DLA** notation signifies the satisfaction of the DLA analysis procedure of this Guide. The notation **SH-DLA** signifies:

- i) The design is based on an analysis which more explicitly considers the loads acting on the structure and their dynamic nature, and
- ii) In no case is an offered design scantling to be less than that obtained from other requirements in the *Steel Vessel Rules*.

In this regard, all the supporting data, analysis procedures and calculated results are to be fully documented and submitted for review.

9 Scope and Overview of this Guide

This Guide provides a description of the analysis procedures to be pursued to obtain the optional classification notation SafeHull-Dynamic Loading Approach, **SH-DLA**. Emphasis is given here to the determination of dynamic loads rather than the structural FEM analysis procedure. This has been done mainly because structural analysis practices are well established and understood among designers, but the dynamic load determination is a less familiar subject. Therefore, the procedures for FEM analysis are only briefly described for ready reference and completeness.

The Dynamic Loading Approach uses explicitly determined dynamic loads, and the results of the analysis are used as the basis to increase scantlings where indicated, but allows no decreases in scantlings from those obtained from the direct application of the Rules' scantling equations.

While outside the scope of this Guide, the local impact pressure and global whipping loads due to slamming are to be separately addressed for the strength assessment of the hull structure. Also, the green sea loads due to the shipment of green water on deck is to be addressed for the scantlings of the forecastle deck and breakwater. For this purpose, the adequacy of the selected software may need to be demonstrated to the satisfaction of ABS.

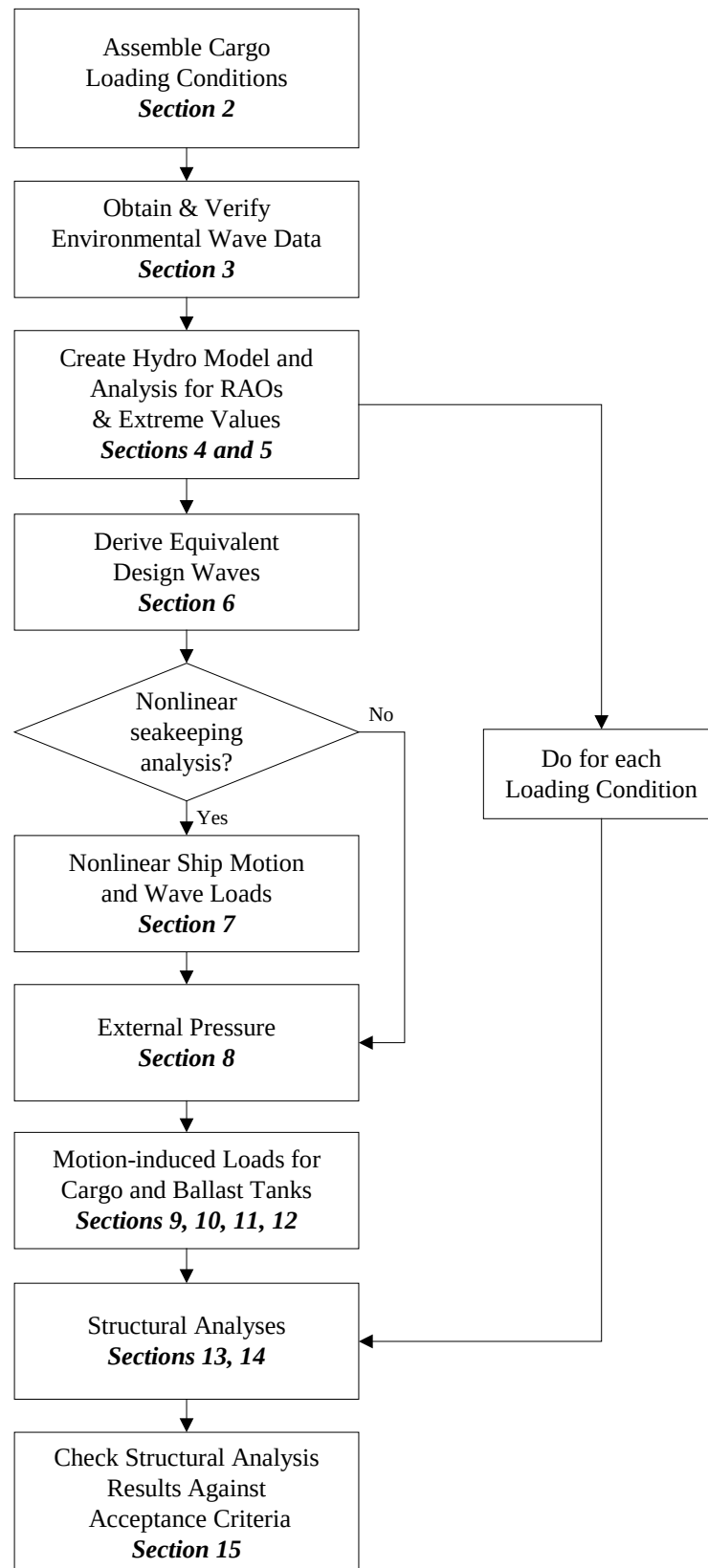
This Guide systematically introduces the assumptions in the load formulations and the methods used in the response analysis underlying the DLA analysis. These include the following topics:

- i) Specification of the loading conditions
- ii) Specification of the Dominant Load Parameters
- iii) Response Amplitude Operators and extreme values
- iv) Equivalent design waves
- v) Wave-induced load components and the assembly of Load Cases
- vi) Structural FE model development
- vii) Permissible stresses used in the acceptance criteria.

Refer to Section 1, Figure 1 for a schematic of the DLA analysis procedure.

While the DLA can, in principle, be applied to all forms of floating marine structures, the focus of this Guide is on tankers, bulk carriers, container carriers and LNG carriers. In the case of other ship types clients should consult with ABS to establish appropriate analysis parameters. This applies particularly to the choice of loading conditions and Dominant Load Parameters.

FIGURE 1
Schematic Representation of the DLA Analysis Procedure





SECTION 2 Load Cases

1 General

The Dynamic Loading Approach (DLA) requires the development of Load Cases to be investigated using the Finite Element (FE) structural analysis. The Load Cases are derived mainly based on the ship speed (see Subsection 2/3), loading conditions (see Subsection 2/5), and Dominant Load Parameters (see Subsection 2/7).

For each Load Case, the applied loads to be developed for structural FE analysis are to include both the static and dynamic parts of each load component. The dynamic loads represent the combined effects of a dominant load and other accompanying loads acting simultaneously on the hull structure, including external wave pressures, internal tank pressures, bulk cargo loads, container loads and inertial loads on the structural components and equipment. In quantifying the dynamic loads, it is necessary to consider a range of sea conditions and headings, which produce the considered critical responses of the hull structure.

For each Load Case, the developed loads are then used in the FE analysis to determine the resulting stresses and other load effects within the hull structure.

3 Ship Speed

In general, the speed of a vessel in heavy weather may be significantly reduced in a voluntary and involuntary manner. In this Guide, for the strength assessment of tankers and bulk carriers, the ship speed is assumed to be zero in design wave conditions, which is consistent with IACS Rec. No.34. For the strength assessment of container and LNG carriers with finer hull forms, the ship speed is assumed to be five knots in design wave conditions.

5 Loading Conditions

The loading conditions herein refer to the cargo and ballast conditions that are to be used for DLA analysis. The following loading conditions, typically found in the Loading Manual, are provided as a guideline to the most representative loading conditions to be considered in the DLA analysis.

Other cargo loading conditions that may be deemed critical can also be considered in the DLA analysis. The need to consider other loading conditions or additional loading conditions is to be determined in consultation with ABS.

5.1 Tankers

- i) Homogeneous full load condition at scantling draft
- ii) Partial load condition (67% full)
- iii) Partial load condition (50% full)
- iv) Partial load condition (33% full)
- v) Normal ballast load condition

5.3 Bulk Carriers

- i) Homogeneous full load condition at scantling draft
- ii) Alternate full load condition at scantling draft
- iii) Alternate load condition (67% full)
- iv) Heavy ballast load condition
- v) Light ballast load condition

5.5 Container Carriers

- i) Full load condition at scantling draft
- ii) Light container full load condition with maximum SWBM amidships
- iii) Partial load or jump load condition with highest GM

5.7 LNG Carriers

- i) Homogeneous full load condition at scantling draft
- ii) Normal ballast load condition
- iii) One tank empty condition
- iv) Two adjacent tanks empty condition

7 Dominant Load Parameters (DLP)

Dominant Load Parameters (DLP) refer to the load effects, arising from ship motions and wave loads, that may yield the maximum structural response for critical structural members. The instantaneous response of the vessel can be judged by one of the several Dominant Load Parameters. These parameters are to be maximized to establish Load Cases for the DLA analysis.

Other DLPs that may be deemed critical can also be considered in the DLA analysis. The need to consider other DLPs or additional DLPs is to be determined in consultation with ABS.

7.1 Tankers

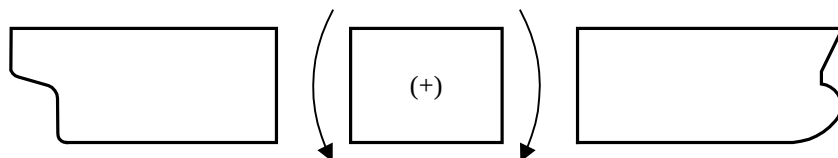
Below five Dominant Load Parameters have been identified as necessary to develop the Load Cases for tankers:

7.1.1 Maximum VBM

- Vertical bending moment amidships, (+) hogging (see Section 2, Figure 1)
- Vertical bending moment amidships, (–) sagging

The DLP refers to the maximum wave-induced vertical bending moment amidships calculated with respect to the neutral axis.

FIGURE 1
Positive Vertical Bending Moment

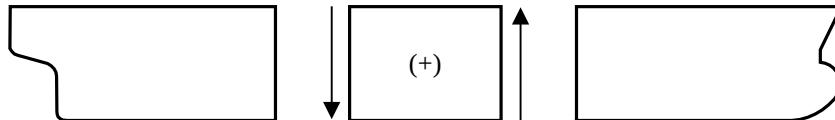


7.1.2 Maximum V_{SF}

- Vertical shear force, (+) upward shear force on a positive face (see Section 2, Figure 2)
- Vertical shear force, (–) downward shear force on a positive face

The DLP refers to the maximum wave-induced vertical shear force at two locations ($1/4$, $3/4$ of the vessel length).

FIGURE 2
Positive Vertical Shear Force



7.1.3 Maximum V_{acc}

- Vertical acceleration at FP, (+) upward
- Vertical acceleration at FP, (–) downward

The DLP refers to the maximum vertical acceleration at bow. The reference point of the vertical acceleration may be taken from the fwd tank top center or corner. As a simplified alternative, unless otherwise specified, the reference point may be taken at the intersection of FP, CL and WL.

7.1.4 Maximum L_{acc}

- Lateral acceleration at bow, (+) towards portside
- Lateral acceleration at bow, (–) towards starboard side

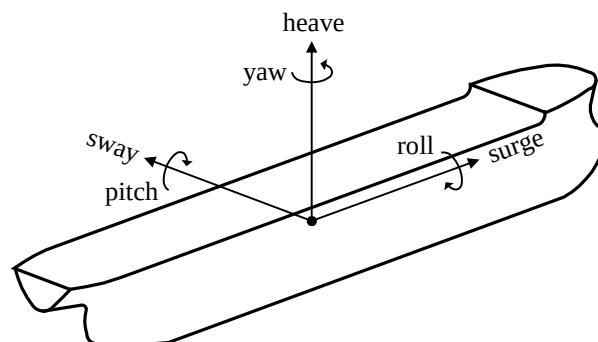
The DLP refers to the maximum lateral acceleration at bow. The lateral acceleration may be taken at the same reference point for vertical acceleration.

7.1.5 Maximum Roll θ

- Roll angle, (+) port side up
- Roll angle, (–) starboard side up

The DLP refers to the maximum roll angle calculated with respect to the ship center of gravity

FIGURE 3
Definition of Ship Motions



7.3 Bulk Carriers

Below five Dominant Load Parameters have been identified as necessary to develop the Load Cases for bulk carriers:

7.3.1 Maximum V_{BM}

- Vertical bending moment amidships, (+) hogging
- Vertical bending moment amidships, (–) sagging

The DLP refers to the maximum wave-induced vertical bending moment amidships calculated with respect to the neutral axis.

7.3.2 Maximum V_{SF}

- Vertical shear force at critical bulkhead, (+) upward shear force on a positive face
- Vertical shear force at critical bulkhead, (–) downward shear force on a positive face

The DLP refers to the maximum wave-induced vertical shear force at two locations ($1/4$, $3/4$ of the vessel length).

7.3.3 Maximum V_{acc}

- Vertical acceleration at bow, (+) upwards
- Vertical acceleration at bow, (–) downwards

The DLP refers to the maximum vertical acceleration at bow. The reference point of the vertical acceleration may be taken from the fwd cargo hold bottom center or lower corner. As a simplified alternative, unless otherwise specified, the reference point may be taken at the intersection of FP, CL and WL.

7.3.4 Maximum T_M

- Torsional moment at five locations, (+) bow starboard down
- Torsional moment at five locations, (–) bow starboard up

The DLP refers to the maximum torsional moment at five locations ($1/4$, $3/8$, $1/2$, $5/8$, $3/4$ of the vessel length) calculated with respect to the shear center.

7.3.5 Maximum Roll θ

- Roll angle, (+) port side up
- Roll angle, (–) starboard side up

The DLP refers to the maximum roll angle calculated with respect to the ship center of gravity.

7.5 Container Carriers

Below five Dominant Load Parameters have been identified as necessary to develop the Load Cases for container carriers:

7.5.1 Maximum V_{BM}

- Vertical bending moment amidships, (+) hogging
- Vertical bending moment amidships, (–) sagging

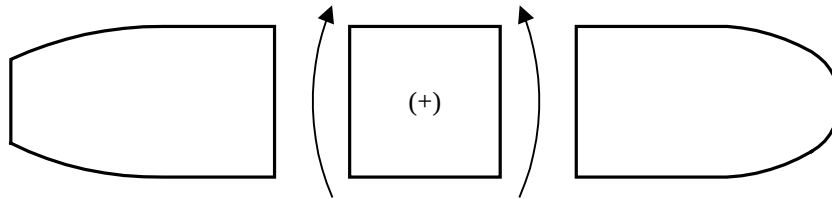
The DLP refers to the maximum wave-induced vertical bending moment amidships calculated with respect to the neutral axis.

7.5.2 Maximum H_{BM}

- Horizontal bending moment amidships, (+) tension on the starboard side (see Section 2, Figure 4)
- Horizontal bending moment amidships, (–) tension on the port side

The DLP refers to the maximum wave-induced horizontal bending moment amidships

FIGURE 4
Positive Horizontal Bending Moment

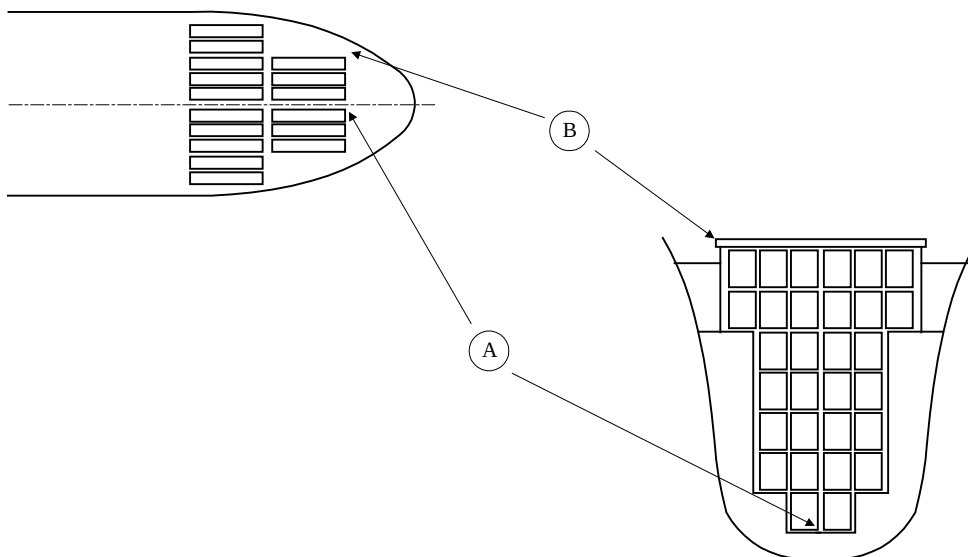


7.5.3 Maximum V_{acc}

- Vertical acceleration at bow, (+) upwards
- Vertical acceleration at bow, (–) downwards

The DLP refers to the maximum vertical acceleration at bow. The vertical acceleration may be taken from the typical reference points shown in Section 2, Figure 5. As a simplified alternative, unless otherwise specified, the reference point may be taken at the intersection of FP, CL and WL.

FIGURE 5
Reference Point for Acceleration



7.5.4 Maximum TM

- Torsional moment at five locations, (+) bow starboard down
- Torsional moment at five locations, (–) bow starboard up

The DLP refers to the maximum torsional moment at five locations ($1/4$, $3/8$, $1/2$, $5/8$, $3/4$ of the vessel length) calculated with respect to the shear center.

7.5.5 Maximum Roll θ

- Roll angle, (+) port side up
- Roll angle, (–) starboard side up

The DLP refers to the maximum roll angle calculated with respect to the ship center of gravity.

7.7 LNG Carriers

Below five Dominant Load Parameters have been identified as necessary to develop the Load Cases for LNG carriers:

7.7.1 Maximum V_{BM}

- Vertical bending moment amidships, (+) hogging
- Vertical bending moment amidships, (–) sagging

The DLP refers to the maximum wave-induced vertical bending moment amidships calculated with respect to the neutral axis.

7.7.2 Maximum V_{SF}

- Vertical shear force, (+) up
- Vertical shear force, (–) down

The DLP refers to the maximum wave-induced vertical shear force at two locations ($1/4$, $3/4$ of the vessel length).

7.7.3 Maximum V_{acc}

- Vertical acceleration at bow, (+) upwards
- Vertical acceleration at bow, (–) downwards

The DLP refers to the maximum vertical acceleration at bow. The reference point of the vertical acceleration may be taken from the fwd tank top center or corner. As a simplified alternative, unless otherwise specified, the reference point may be taken at the intersection of FP, CL and WL

7.7.4 Maximum L_{acc}

- Lateral acceleration at bow, (+) towards port side
- Lateral acceleration at bow, (–) towards starboard side

The DLP refers to the maximum lateral acceleration at bow. The lateral acceleration may be taken at the same reference point for vertical acceleration.

7.7.5 Maximum Roll θ

- Roll angle, (+) starboard down
- Roll angle, (–) starboard up

The DLP refers to the maximum roll angle with respect to the ship center of gravity.

9 Instantaneous Load Components

The instantaneous load components are the load components that are considered to be simultaneously acting on the vessel at the instant of time when the Dominant Load Parameter reaches its maximum considering the equivalent design wave determined for each Load Case. The method to determine the equivalent design wave is presented in Section 5. Calculation methods to develop the accompanying load components are presented in the following Sections:

- i) Section 8 – external hydrodynamic pressures
- ii) Section 9 – internal tank pressures
- iii) Section 10 – bulk cargo loads
- iv) Section 11 – container loads
- v) Section 12 – inertial loads on lightship structure and equipment

11 Impact and Other Loads

Impact loads due to bow flare and bottom slamming and other loads including green sea loads, tank fluid sloshing, vibrations, thermal loads and ice loads may affect global and local structural strength. These are not included in the DLA analysis, but the loads resulting from these considerations are to be treated separately in accordance with the current *Steel Vessel Rules* requirements.

13 Selection of Load Cases

Load Cases are the cases to be investigated in the required structural FE analysis for DLA. Each Load Case is defined by a combination of ship speed (Subsection 2/3), loading condition (Subsection 2/5), a specified DLP (Subsection 2/7) and instantaneous loads accompanying the DLP (Subsection 2/9).

For the DLP of interest, the equivalent design wave is to be determined from the linear seakeeping analysis (Section 4) and long-term spectral analysis (Section 5). With the derived equivalent design wave (Section 6), the instantaneous loads accompanying the DLP are to be determined from linear seakeeping analysis with nonlinear adjustment (Subsections 6/9 and 6/11) or directly from the nonlinear seakeeping analysis (Section 7).

A large number of Load Cases may result from the combination of loading conditions and the DLPs. Each Load Case is to be examined by performing the ship motion and wave load analysis. In general, not all the Load Cases may need to be included in the FE analysis. If necessary, the analyst may judiciously screen and select the critical Load Cases for the comprehensive structural FE analyses.