



GUIDANCE NOTES ON

STRUCTURAL DIRECT ANALYSIS FOR HIGH-SPEED CRAFT

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**American Bureau of Shipping
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American Bureau of Shipping
ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Updates

February 2014 consolidation includes:

- April 2011 version plus Corrigenda/Editorials

Foreword

These Guidance Notes are an extensive revision of and supersede the ABS *Guidance Notes on 'Dynamic Load Approach' and Direct Analysis for High Speed Craft* (February 2003). This revision is effective 1 April 2011.

These Guidance Notes provide information about the analysis procedure for Structural Direct Analysis, which is available to assess the strength of high-speed craft and high-speed naval craft. In addition, they provide guidance to be followed when submitting required direct analyses or such analyses submitted in place of standard calculations. In the text herein, this document is referred to as “these Guidance Notes”.

Sections 1-1-3 and 1-2-2 of the [ABS Rules for Conditions of Classification – High-Speed Craft \(Part 1\)](#) contains descriptions of the various basic and optional classification notations available for high-speed craft. The requirements for Direct Analyses are specified in Section 3-1-3 of the [ABS Rules for Building and Classing High-Speed Craft \(HSC Rules\)](#).

Sections 1-1-3 and 1-3-2 of the [ABS Rules for Conditions of Classification – High-Speed Craft \(Part 1\)](#) contains descriptions of the various basic and optional classification notations available for high-speed naval craft. The requirements for Direct Analyses are specified in Section 3-1-3 of the [ABS Guide for Building and Classing High-Speed Naval Craft \(HSNC Guide\)](#).

Users of these Guidance Notes are welcomed to contact ABS with any questions or comments concerning [these Guidance Notes](#). Users are advised to check periodically with ABS or by visiting the Rules and Guides section of the ABS website (www.eagle.org) that their version of these Guidance Notes is current.

GUIDANCE NOTES ON STRUCTURAL DIRECT ANALYSIS FOR HIGH-SPEED CRAFT

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SECTION 1 Introduction

1 Background

1.1 Types of High-Speed Craft

The size, speed, and installed power of high-speed craft and/or high-speed naval craft have steadily increased. Most of the craft built during the last decade may be categorized into the following three groups:

- Mono-hulls
- Catamarans
- Trimarans

A clear trend in the above types of high-speed craft is a continual increase in the length and complexity of craft that are being built. Most early high-speed craft were of the planing and semi-planing type, while the later and most recent builds have been shifting into the domain of the semi-displacement type. Although this has given rise to new technological challenges, it has also made it possible to apply well-established methods developed for conventional vessels to the design and analysis of these high-speed craft.

Distinct from the design criteria used for planing or dynamically-supported craft, where hydrodynamic impact governs the structural loads, these changes have brought about a shift of emphasis in load types and combinations, with global hull girder loads playing a more significant role than before. The trend towards larger craft sizes has also seen an increase in the range of different concepts such as multi-hulls and other novel designs.

1.3 Current Regulations on High-Speed Craft

The *International Code of Safety for High-Speed Craft* (IMO, 2000) is the only IMO document addressing high-speed craft. It applies to all types of craft operating internationally, but Chapter 3 of the IMO document deals with structures only in a basic manner. The requirements for direct analyses to be performed, based on craft length, speed and other special features, however, are stipulated in the following documents:

- i) ABS [Rules for Building and Classing High-Speed Craft \(HSC Rules\)](#)
- ii) ABS [Rules for Building and Classing High-Speed Naval Craft \(HSNC Rules\)](#)

1.5 Naval Requirements

ABS, with the assistance of the U.S. Navy, has developed the *HSNC Rules* for high-speed craft for a range of operations. Naval requirements specify that high-speed craft are to be designed to technical standards that will provide the safety and operational effectiveness required for the intended mission. Currently, most high-speed craft are designed, built or classed for restricted service. Use of any high-speed craft with a mission that requires unrestricted open-ocean operations should be evaluated for safety using the requirements of the *HSNC Rules*, especially if initially designed or classed for restricted service. This safety evaluation will invariably require a structural assessment that involves direct analysis designed to identify the operational limits.

3 The Concept and Benefits of Structural Direct Analysis (SDA)

Direct analysis for high-speed craft provides enhanced structural evaluation capabilities to assess the adequacy of a structural design. In principle, a minimum requirement of direct analysis is that the preliminary design of the structure be in accordance with the *HSNC Rules* criteria. Should the direct analysis results indicate the need to increase basic scantlings, this increase is to be accomplished to meet the acceptance criteria of the direct analysis. If, however, these Guidance Notes are being used for alternative structural design in consultation with ABS and Naval Administration, scantling reductions justified by the results of the analysis may be considered.

The structural design portions of the *HSNC Rules* (i.e., especially Part 3, Chapter 2) are intended to provide the basis for a preliminary step-by-step design procedure of the structure of a high-speed craft. On the other hand, direct analysis is a process that emphasizes completeness and realism in both the extent of the structure modeled and the craft's loading conditions considered. The modeling and analysis process utilizes multiple levels that start with a global model of the structure. Results of each previous level of analysis are used to establish:

- i) Areas of the structure requiring finer (more detailed) modeling and analysis
- ii) The local loading to be re-imposed and the 'boundary conditions' to be imposed on the finer model

Central to this direct analysis method is the use of an advanced computational tool based upon linear and/or nonlinear seakeeping theory for calculating ship motions and wave-induced load effects in design wave conditions that best characterize the environmental and operating conditions of the craft.

The enhanced realism provided by the direct analysis approach has benefits that are of added value to the overall structural safety evaluation based on the attributes mentioned above. Additionally, the knowledge of structural behavior gained through this analysis is very useful in realistically evaluating and developing inspection and maintenance plans especially for aluminum and FRP hulls. Another potentially valuable benefit of direct analysis is that it provides access to a comprehensive structural evaluation model, which may be readily employed in the event of emergency situations that might arise during the service life of the craft, such as structural damage, repairs or modifications; ocean transit to a repair facility, or redeployment to another operating route.

5 Types of Structural Assessments

5.1 Strength

In general, structural assessments of high-speed craft will require the application of direct analysis methods, as their preliminary designs will invariably be based on craft service records or previous experience. This is discussed in detail in these Guidance Notes.

Global wave-induced load effects on high-speed craft are not significantly affected by elastic deformations in most cases because the rigid body motions are dominant. In this case, the external impact loads (generally called slamming loads), such as those due to bottom slamming, are determined through motion analysis. The slamming loads can then be applied to the structure to obtain the elastic hull girder responses, (generally called whipping responses).

For the enhanced structural assessments of modern high-speed craft, the slamming and whipping loads, in addition to the traditional wave-induced loads, are to be considered in the derivation of structural responses.

An addition to direct analysis would be to derive structural load effects from physically scaled model tests. Brief guidance on models used for this task is discussed in [Subsection 14/7](#). Rigid models may be adequate for direct measurements of wave-induced ship motions and slamming pressures, which are not significantly affected by elastic deformations. For direct measurement of wave induced springing and whipping loads, where flexibility and dynamics of the hull structure are important, use of a flexible model, dynamically scaled to represent hull girder structural characteristics, is recommended. This can be realized using either a continuous elastic model or a segmented model with elastic backbones.

5.3 Fatigue

The main factors that contribute to general fatigue problems are material used for construction, welding methods, and connection details, along with the stress range and the number of stress cycles.

High-speed craft are usually designed for optimized structural weight, which results in increased flexibility of the hull. The combination of the increased hull flexibility and the higher encounter frequency due to high operational speed would tend to accelerate fatigue damage.

While fatigue analysis is not a condition for classing high-speed craft, a fatigue assessment is recommended, especially for craft with novel hull forms.

5.5 Vibration

Generally, vibration analysis is not a requirement for classing high-speed craft. However, in some high-speed craft designs subject to increased flexibility of structures, especially those involving water-jet propulsion, flow-induced vibrations could significantly contribute to structural responses that result in accelerated fatigue damage. The methods for dynamic response analysis developed for conventional vessels can be applied to vibration problems on high-speed craft. However, when applicable, the flexible stiffness and significantly different structural damping characteristics of FRP hulls (relative to steel hulls) must be taken into account. It is recommended that these methods be utilized to investigate vibration-induced fatigue of high-speed craft fitted with water-jet propulsion.

5.7 Hydroelastic Considerations

In some cases, especially in multi-hull craft made of lightweight structural materials such as aluminum, there is true interaction of loads and responses, in which case they cannot be treated separately. This is particularly the case when the craft operates at high speeds which are associated with high encounter frequencies resulting in large dynamic amplification.

Some cases of slamming impact on local flexible structures are also known to be of a hydroelastic nature. In these cases, the loads can only be specified if the flexibility of the structure is incorporated into the load formulation. For high-speed craft, typical hydroelastic phenomena that require close attention are:

- i) Springing, as in the “squeezing/prying” mode of multi-hulls (global)
- ii) Dynamic response of panels to slam impact pressures (local)

It has been shown through experiments that hydroelastic effects are most important for impacts with short duration close to the natural period of the structure. Such impacts occur when a large area of the structure comes in contact with the water surface, as in the case of slamming on the wet deck of a catamaran. Here, as in other nearly flat structures (deadrise angles in the range 0 to 5 degrees), air entrapment and cushioning effects will be significant, as they tend to lengthen the duration of impact.

As preliminary guidance, the following recommendation with respect to the role of hydroelasticity in local structural response can be given. If the ratio of the impact rise time to the first natural period of vibration of the dry panel structure is greater than 2.0, the effect of hydroelasticity may be neglected. On the other hand, if the ratio is less than 2.0, the hydroelastic structural response of the panel is recommended to be taken into account in the calculation of impact loads on the panel.

7 Scope and Overview

Structural direct analysis is a strength assessment methodology based on first principles approach. In this regard, acceptance criteria are applied to verify that predicted stress levels do not exceed a specified percentage of yield strength and do not exceed buckling and ultimate strength. This analysis satisfies the requirements of Required Analyses specified in [1-1-4/5.1 of the ABS Rules for Conditions of Classification – High-Speed Craft \(Part 1\)](#). The Guides also note that Supplementary Analyses may be required. The most likely such requirements are fatigue and vibration analyses. While outside the scope of these Guidance Notes, they are, nevertheless, discussed in general terms. However, these Guidance Notes do not provide specific guidance for assessing these failure modes.

Section 1, Figure 1 shows an overview of the SDA procedures for high-speed craft, wherein the strength analysis is highlighted and the supplementary analyses are shown shaded. In these Guidance Notes, special consideration is provided to include the slamming and whipping load effects in the strength analysis.

These Guidance Notes systematically introduce the analysis procedures in the load formulation, and the methodology underlying the analysis procedures used in applying direct analysis to high-speed craft. These include the following topics:

- Specification of the loading conditions and load cases
- Environmental and service conditions
- Formulation of equivalent design waves
- Calculation of nonlinear wave loads
- Structural finite element (FE) model development
- Strength analysis
- Application of the acceptance criteria

These topics are presented in the following Sections 2 through 14. Refer to Section 1, Figure 2 for a schematic representation of the steps involved in the direct structural analysis procedure.

A report detailing the analysis should be submitted for review and approval along with finite element models used in the analysis. As a minimum the report should include the following information:

- i)* Craft's loading conditions and weight distribution
- ii)* Craft's operational profile or Wave Scatter data for the area of operation
- iii)* A brief description of all software used in the analysis
- iv)* A detailed description of the analysis procedure and steps
- v)* All results of the hydrodynamic analysis and results of the Extreme Values analysis
- vi)* Model test data, with a comparison with analysis results (if applicable)
- vii)* Material properties and the allowable stresses applicable to the craft
- viii)* A brief description of the Finite Element model and the mesh size used
- ix)* Details of the Finite Element Analysis results
- x)* Graphs for all areas of non-compliance
- xi)* Detailed discussion of non-compliance areas and proposed fixes
- xii)* Description of the buckling analysis and a sample calculation
- xiii)* Any other available information related to the analysis

FIGURE 1
Overview of the Structural Direct Analysis for High-Speed Craft

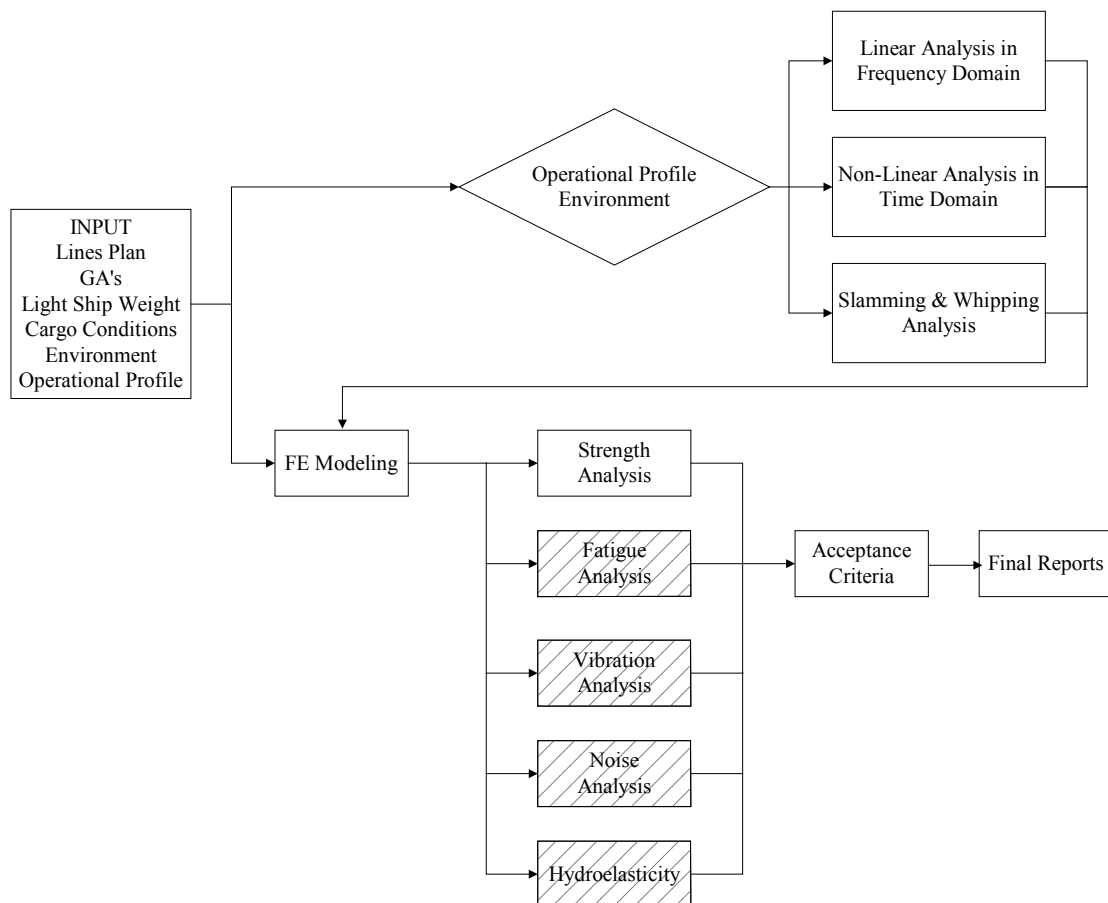


FIGURE 2
Schematic of the Structural Direct Analysis Procedure

