

GUIDE FOR

SPECTRAL-BASED FATIGUE ANALYSIS FOR VESSELS (FOR THE 'SFA (years)' CLASSIFICATION NOTATION)

JUNE 2016

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 Rules files which are available for download.

Rule Changes:

NOTICE NO. 1 – February 2017 (effective 15 February 2017)

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JUNE 2016 (Updated October 2017 – see next page)

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Updates

October 2017 consolidation includes:

- February 2017 version plus Notice No. 2

February 2017 consolidation includes:

- June 2016 version plus Notice No. 1 and Corrigenda/Editorials

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Foreword (1 October 2017)

This Guide provides information about the optional classification notations, ‘Spectral Fatigue Analysis’ – **SFA (years)** and **SFA (years, WWT)** – which are available to qualifying vessels as described in 1-1-3/21 of the *ABS Rules for Conditions of Classification (Part 1)*.

The source document for this Guide is the *Guidance Notes on Spectral-Based Fatigue Analysis for Vessels* (2004). Promoting the Guidance Notes to a Guide adheres to ABS standard practice as the source document was published more than ten years ago. Furthermore, classification notations are customarily provided by only Rules or Guides. Promotion to a Guide alleviates any confusion caused by deviation from standard practice.

The technical content in the Guide has not been significantly changed from that in the Guidance Notes. However, it has been significantly reorganized such that it more closely aligns with the procedure and steps commonly used to conduct spectral-based fatigue analyses for ship structures. Nomenclature has also been modified such that it is more consistent throughout the document. The organization of the Guide is detailed in Section 2. A flowchart depicting the spectral-based fatigue procedure is given by Section 2, Figure 1.

The table below shows how the existing Guidance Notes have been reorganized in the creation of this Guide.

Section in SFA Guide	Section in SFA Guidance Notes	Remarks
1 Introduction	1 Introduction	
2 Spectral-based Fatigue Analysis Procedure	1 Introduction	SFA procedure overview was expanded and moved to its own section.
3 Seakeeping Analysis	2 Establishing Fatigue Demand 4 Motion Analysis and Wave-induced Load Components 6 Loading for Global Finite Element Method (FEM) Structural Analysis Model	Seakeeping analysis was addressed in one section instead of across three sections. The content in the seakeeping analysis section is in agreement with the DLA/SFA System.
4 Structural Analysis	5 Wave-induced Load Components 6 Structural Modeling and Analysis	Structural analysis was addressed in one section instead of across two sections. The content in the structural analysis section is in agreement with the DLA/SFA System.
5 Spectral Analysis	9 Fatigue Life (Damage)	The discussion of spectral analysis was moved to its own section and expanded.
6 Fatigue Strength Assessment	8 Fatigue Strength 9 Fatigue Life (Damage)	The fatigue strength assessment section in the Guide contains most of the content in the fatigue strength and fatigue life sections from the Guidance Notes.

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

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

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



GUIDE FOR

SPECTRAL-BASED FATIGUE ANALYSIS FOR VESSELS

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SECTION 1 Introduction

1 Purpose and Applicability (1 October 2017)

Part 5C of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)* includes the fatigue assessment criteria for the classification of various types of specialized vessels covered by the Rules. Part 5A and 5B of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)* contains fatigue assessment guidance for vessels subject to the “Common Structural Rules for Bulk Carriers and Oil Tankers”. A brief description of the background and objectives of these fatigue criteria is given in Subsection 1/3.

In addition to the simplified fatigue strength criteria required for classification by ABS, the Owner may wish to apply more extensive Spectral-based Fatigue Analysis (SFA) techniques to the vessel’s structural systems. It may be an added objective of these Spectral-based Fatigue Analyses to demonstrate a longer design fatigue life than that required for classification.

Spectral-based Fatigue Analysis techniques are used in addition to the SafeHull Fatigue Assessment technique, a Permissible Stress Range method (discussed in Subsection 1/3). The fatigue life of each critical location in the structural system is assessed for adequacy. The critical locations are to be selected using the results of the SafeHull Fatigue Assessment technique which is to be employed in the overall structural design and analysis effort.

The list of critical structural locations which are to be subjected to Spectral-based Fatigue Analysis is to be submitted to ABS for approval.

Provided that Spectral-based Fatigue Analysis is conducted in accordance with the procedures included in this Guide or equivalent, ABS will grant the optional classification notation, **SFA (years)** or **SFA (years, WWT)**. In either case, as a minimum, a vessel is to meet the fatigue strength criteria in the *Steel Vessel Rules* as described above. The **SFA (years)** notation is granted if the design fatigue life value is equal to 20 years or greater under the wave conditions of unrestricted service defined in Section 5, Table 1. The **SFA (years, WWT)** notation is granted if the design fatigue life value is equal to 40 years or greater under the wave conditions of worldwide trading service defined in Section 5, Table 2.

If a vessel is primarily operating in seas that exceed the worldwide trading pattern (i.e., a vessel operating half or more than half of its life in onerous seas including North Atlantic or North Pacific), **SFA (years, WWT)** is not applicable. It should be noted that the calculated fatigue lives for different design wave conditions may produce significantly different fatigue lives.

The value in parentheses is the design fatigue life in years specified by the applicant in 5-year increments starting at 20 for **SFA (years)** and 40 for **SFA (years, WWT)**. The structural system as a whole is analyzed to verify that the calculated fatigue life values for the entire system meet or exceed the design fatigue life. The actual service life of a vessel is dependent on many factors such as initial design, operational and maintenance schemes. The **SFA (years)** or **SFA (years, WWT)** notation denotes the design fatigue life of a vessel and is not a guarantee that the vessel or structure will achieve the design fatigue life.

In order to obtain the **SFA (years)** or **SFA (years, WWT)** notations, SFA methods must be applied to the entire vessel.

For vessels complying with Part 5A and 5B “Common Structural Rules for Bulk Carriers and Oil Tankers” of the *Steel Vessel Rules*, the design fatigue life for Spectral-based Fatigue Analysis is equal to 25 years or greater in 5-year increments.

3 Background (1 October 2017)

In the application of Part 5C of the *Steel Vessel Rules*, the SafeHull Fatigue Assessment technique is typically used to evaluate fatigue strength. The SafeHull Fatigue Assessment technique is a permissible stress range approach that is readily applied to large portions of a vessel's hull structure. The technique is required for certain vessels such as an oil tanker with a Rule length greater than 150 m for which the technique is detailed in Appendix 5C-1-A1 of the *Steel Vessel Rules*. The technique was derived considering unrestricted ocean service wave loads representing the North Atlantic and a design fatigue life of 20 years.

Part 5A and 5B "Common Structural Rules for Bulk Carriers and Oil Tankers" of the *Steel Vessel Rules* requires a design fatigue life of 25 years with wave loads representing the North Atlantic and multiple fatigue assessment techniques are employed. A simplified stress analysis method based on beam theory is presented in Part 5A, Pt 1, Ch 9, Sec 4 of the *Steel Vessel Rules*, a finite element stress analysis approach is described in Part 5A, Pt 1, Ch 9, Sec 5 of the *Steel Vessel Rules* and structural design following the detailed design standards is discussed in Part 5A, Pt 1, Ch 9, Sec 6 of the *Steel Vessel Rules*.

Supplementary to the SafeHull Fatigue Assessment technique or methods employed for vessels complying with Part 5C of the *Steel Vessel Rules*, ABS may require the use of additional or alternative techniques to demonstrate the fatigue strength adequacy of structural components. These techniques may include Spectral-based Fatigue Analysis methods. In many instances the structural details cannot be adequately analyzed via the permissible stress range fatigue assessment approach. An optional classification notation, **FL (years)**, may be requested in cases in which the owner or designer increases the target fatigue lives of some or all of the structural components above the 20 year minimum value. This notation is discussed in the *Steel Vessel Rules* and does not require the use of SFA methods.

5 Areas for Fatigue Strength Evaluation

The *Steel Vessel Rules* provide guidance on which locations should be included in the fatigue assessment. Various appendices provide guidance on which locations should be included in the fatigue assessment for different vessel types. For example, 5C-1-A1/3.3 of the *Steel Vessel Rules* provides guidance for location selection for oil tankers with a Rule length greater than or equal to 150 m and 5C-3-A1/3.3 of the *Steel Vessel Rules* provides guidance for location selection for bulk carriers with a Rule length greater than or equal to 150 m.

7 Methodology and Assumptions

Spectral-based Fatigue Analysis is a complex and numerically-intensive technique and there are multiple valid implementations of the method. ABS does not wish to eliminate the use of any valid approach by over-specifying the SFA technique. However, it is necessary to be clear about the basic assumptions that form the basis of a valid method and highlight key details that are to be incorporated in the method to produce acceptable results. The remainder of this Guide is devoted in large part to the presentation of these topics.

A typical spectral fatigue analysis for a structural location is to evaluate its fatigue strength by comparing its stress range distribution against its fatigue capacity. The following definitions are used in the context of this Guide:

- **Stress Range Distribution:** Stress range probability density functions calculated per this Guide.
- **Fatigue Capacity:** S-N data (S-N curves) representing the number of stress cycles at fatigue failure.
- **Fatigue Strength:** Fatigue life (or damage) calculated per this Guide.
- **Fatigue Demand:** Design fatigue life.

The main underlying assumptions of the Spectral-based Fatigue Analysis method are:

- i) Ocean waves are the source of the fatigue stress range acting on the structural system.
- ii) The load and structural analyses are assumed to be linear as required for the frequency domain formulation and the associated probabilistic analysis to be valid. As such, scaling and the superposition of stress transfer functions from unit amplitude waves are considered valid.
- iii) Non-linearities due to non-linear roll motion and intermittent loads, such as wetting of the side shell in the splash zone, can be effectively accounted for using correction factors.
- iv) Due to their insignificant contributions in typical load cases it is appropriate to disregard structural dynamic amplification, transient loads and effects such as springing. This allows for the use of quasi-static finite element analysis.

For the specific SFA method presented in Appendix 2, it is assumed that the short-term stress variation for a given sea-state is a random, narrow-banded, stationary process. Therefore a Rayleigh distribution can be used to represent the short-term stress range distribution.

The Spectral-based Fatigue Analysis method is applied to each of the selected structural locations by implementing the following process:

- Determine the stress range distributions.
- Determine fatigue capacity (S-N data).
- Calculate fatigue strength (fatigue life or damage).

Section 2 provides an overview of the spectral-based fatigue analysis procedure. A schematic representation of the SFA procedure can be found in Section 2, Figure 1.

An effort is made in this Guide to avoid the discussion of complicated formulae and instead to focus on the concepts being presented. It is necessary to present the complex formulae used in the calculation of fatigue damage resulting from the predicted stress range distributions, which are presented in Appendix 2. It should be noted that the contents of Appendix 2 are intended to serve as an example of a valid SFA method. It is not necessary that the process be followed exactly; however, any method used should adhere to the same principles.



SECTION 2 Spectral-based Fatigue Analysis Procedure Overview

1 General

This Section provides an overview of the spectral-based fatigue analysis procedure for sea-going vessels. The section in which a detailed discussion of each step can be found is included in parentheses.

The spectral fatigue analysis for ocean-going vessels covers a wide scope of technical disciplines ranging from the analysis of ship's Response Amplitude Operators (RAOs) to the assessment of fatigue damages of structural details. Four main steps are typically involved:

- Seakeeping Analysis: to determine ship motion and wave pressure RAOs.
- Structural Analysis: to determine stress transfer functions.
- Spectral Analysis: to determine stress range distributions.
- Fatigue Strength Assessment: to determine fatigue life or damage.

The tasks that comprise each step are described below.

1.1 Seakeeping Analysis (Section 3)

1.1.1 Selection of Loading Conditions (Subsection 3/3)

Vessel loading conditions that a vessel is expected to experience during its service life are to be reviewed and selected. At least two loading conditions are to be analyzed – one representative of the most probable deepest draft and one representative of the most probable shallowest draft.

1.1.2 Development of Hydrodynamic Models (Subsection 3/5)

A hydrodynamic model is to be created for each loading condition to be evaluated. This Guide is written with the assumption that the seakeeping analysis will be conducted using a three dimensional panel method. As such, all discussion of a seakeeping model in this Guide will be with respect to a three dimensional panel model.

1.1.3 Determination of Ship Motion and Wave Pressure RAOs (Subsection 3/11)

The primary objective of seakeeping analysis is the determination of Response Amplitude Operators, which are mathematical representations of the vessel responses and load effects to unit amplitude sinusoidal waves. The ship motion and wave pressure RAOs are to be calculated for each vessel loading condition.

1.3 Structural Analysis (Section 4)

1.3.1 Development of Structural Models (Subsection 4/7)

A model representing the entire hull structure is to be created in order to determine the stress transfer functions. Typically, a three dimensional finite element model is used. However, a more simplified approach such as beam theory may be used instead. This Guide is written with the assumption that a finite element model will be created.

The global structural finite element model should adequately represent the stiffness and inertial properties of the vessel. In order to analyze fatigue critical details, the creation of fine mesh models is typically necessary.