

GUIDE FOR

SLAMMING LOADS AND STRENGTH ASSESSMENT FOR VESSELS

MARCH 2011

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Foreword

This Guide describes the requirements for direct slamming strength assessment for vessels. Optional notations may be assigned to vessels that comply with the requirements in the Guide.

The slamming strength requirements in this Guide are supplementary to those in the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules, or the Rules)* and other Guides published by ABS for classification of vessels with regard to slamming strength in the hull structure.

The Guide contains a description of the direct slamming strength assessment procedure for bottom slamming, bowflare slamming, and stern slamming. The procedure consists of slamming load prediction and strength assessment.

The effective date of this Guide is the first day of the month of publication.

ABS welcomes comments and suggestions for improvement of this Guide. *Comments or suggestions can be sent electronically to rsd@eagle.org.*



GUIDE FOR SLAMMING LOADS AND STRENGTH ASSESSMENT FOR VESSELS

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SECTION 1 Introduction

1 General

This Guide describes a slamming strength assessment procedure for vessels. Typically, there are three types of slamming loads on commercial vessels: bottom slamming, bowflare slamming, and stern slamming depending upon the hull geometry at the bow and stern. Upon verifying compliance with the requirements in this Guide, optional notations may be assigned to a vessel.

A fundamental requirement of this Guide is that the scantlings of the hull structure are to be in accordance with the criteria as specified in the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*. The results of this Guide are not to be used to reduce the basic scantlings obtained from the application of the *Steel Vessel Rules*. That is, if the results from this Guide indicate the need to increase any basic scantlings, the increased scantlings are to be implemented above the rule requirements.

If software other than that provided by ABS is used, the analysis results for a benchmark case specified by ABS are to be submitted to demonstrate that the software is compatible with the procedure described in this Guide.

3 Slamming Phenomenon

In rough seas, the vessel's bow and stern may occasionally emerge from a wave and re-enter the wave with a heavy impact or slam as the hull structure comes in contact with the water. A vessel with such excessive motions is subject to very rapidly developed hydrodynamic loads. The vessel experiences impulse loads with high-pressure peaks during the impact between the vessel's hull and water. Of interest are the impact loads such as bowflare slamming, bottom slamming, stern slamming, green water and bow impact loads. These impact loads are of a transient nature and can cause severe structural damages. Although the loads are widely varying in their characteristics – magnitude, rise time, duration, etc. – all involve the impact at high relative velocity between the free surface of nearly incompressible seawater and the hull structure. The transient impact loads can be highly non-linear and may be strongly affected by the dynamic response of the hull structure. Thus, magnitudes of impact loads/pressures are important for structural design purposes. The following items are considered for the determination of the impact pressures:

- Intensity and duration of impact pressures
- Spatial distribution and time duration of impact pressures
- Equivalent static slamming pressures for direct strength assessment and scantling determination
- Bow and stern geometry

For vessels possessing significant bowflare, an impact occurs on the side plating of the bow as it is rapidly immersed into the water. This action results in a large fluid pressure covering a comparatively large impact area. There are two types of bowflare impact pressures: non-impulsive pressure and impulsive pressure. The magnitude of the non-impulsive type pressure is directly related to the bow submergence while the magnitude of the impulsive type pressure rises rapidly at contact and decays exponentially in time.

High slamming pressure can be experienced on stern and bottom hull structures as a vessel emerges and re-enters the water. In this Guide, bottom slamming is considered to occur in the bottom structure in the region of the flat bottom forward of $0.25L$ (L is the Rule length, as defined in *the Steel Vessel Rules*) measured from the forward perpendicular (FP). Due to the stern and bottom slamming, two noticeable effects may occur. First, there may be localized structural effects in the areas of the stern and bottom that experience large slamming pressure. This may result in set-up plating and buckled internal frames, floors and bulkheads. The second effect of the slamming is the vibratory response of the entire hull, or so called whipping, which is not within the scope of this Guide.

5 Application of Guide

This Guide can be applied to ocean-going vessels including oil carriers, bulk carriers, container carriers, and gas carriers. The basic principles and requirements in the *Steel Vessel Rules* are to be reflected in the hull structure. The following slamming loads are covered in this Guide:

- Bottom slamming for all vessel types when the heavy weather ballast draft forward is less than $0.04L$
- Bowflare slamming for container carriers, liquefied gas carriers, or other vessels possessing significant bowflare
- Stern slamming for vessels such as container carriers with significant overhanging sterns or liquefied gas carriers with relatively flat stern cross sections

For vessels with the stern and/or stern geometry features that deviate significantly from the conventional arrangements, the scope of direct strength assessment against slamming loads is to be determined in consultation with ABS.

The design slamming pressures on the bottom, bowflare, and stern are defined as the most probable extreme loads on those areas during the 25 years of service life in the North Atlantic. A direct slamming strength assessment under this unrestricted service condition is required.

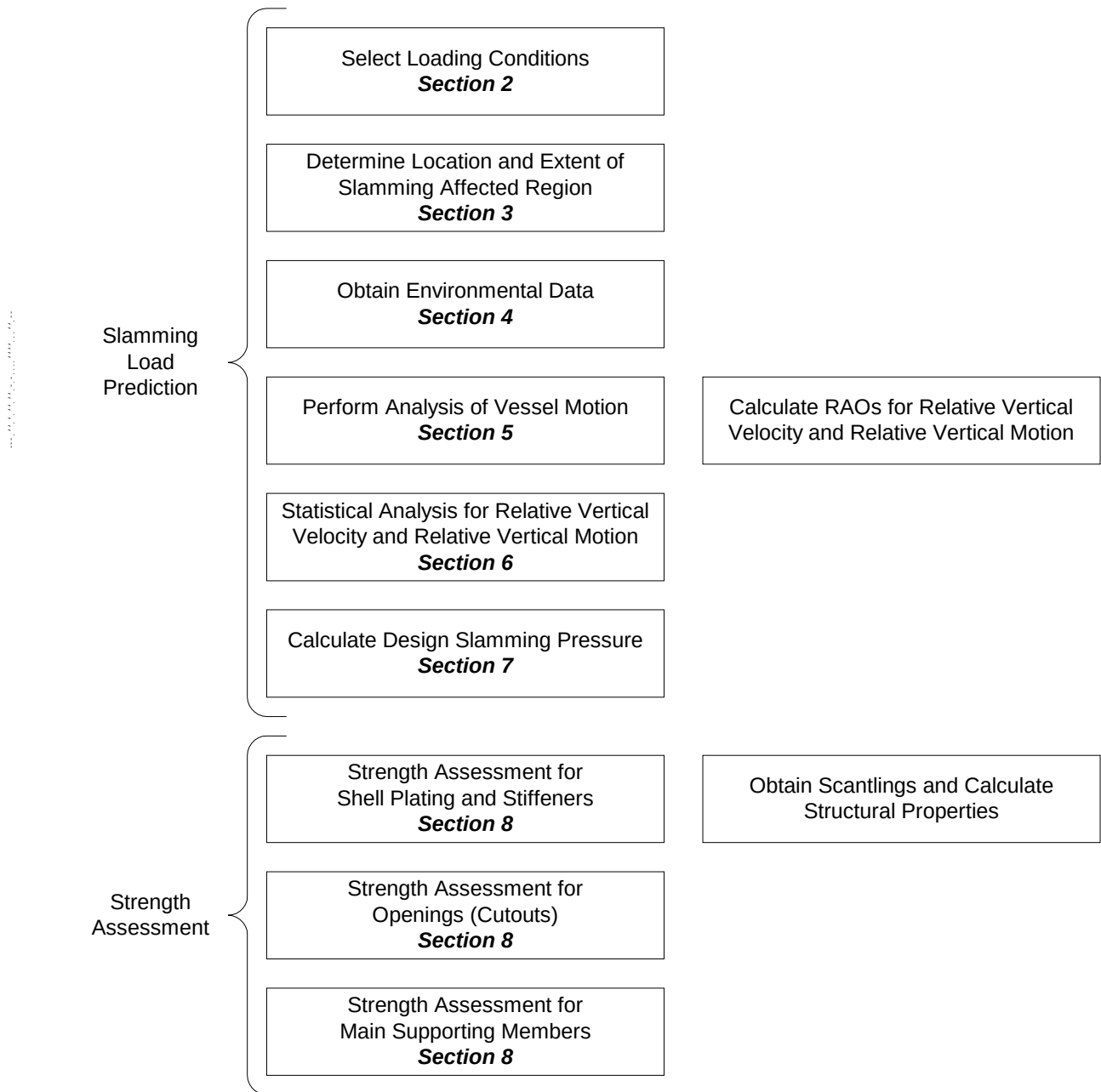
This Guide provides a rational, step-by-step, direct calculation method for the slamming strength assessment of the bottom, bowflare and stern structures.

Section 2 provides recommendations for the loading conditions, speeds, and headings. The locations to be analyzed are explained in Section 3. Environmental conditions are described in Section 4, which is followed by the calculation of vessel motions in Section 5. Statistics of motion is explained in Section 6. The calculation of design slamming pressure is explained in Section 7. Then, the strength assessment is covered in Section 8.

7 Slamming Strength Assessment Procedure

Section 1, Figure 1 shows a flow chart describing the slamming strength assessment procedure.

FIGURE 1
Slamming Strength Assessment Procedure
(For Each Loading Condition)



9 Optional Class Notations

In recognition of full compliance with the strength criteria in Section 8, optional class notations may be granted. A summary of requirements and a brief description is given in Section 1, Table 1.

TABLE 1
Optional Class Notations

<i>Notation</i>	<i>Description</i>	<i>Requirements</i>
SLAM-B	Strengthened against Bottom and/or Bowflare slamming	The vessel needs to satisfy the ABS bottom slamming and/or bowflare slamming procedure and criteria in the bow area, depending on vessel type and hull form
SLAM-S	Strengthened against Stern slamming	The vessel needs to satisfy the ABS stern slamming procedure and criteria in the stern area

11 Nomenclature

The following symbols are used in this Guide. For some symbols, additional details are given where the symbols are used in this Guide. Also, some symbols, such as symbols for constants, are not listed in this section. Refer to the description with each formula for those not listed.

A_c	=	effective shear sectional area of the support or of both supports for double-sided support, ($= A_{lc} + A_{ld}$), in cm^2 (in^2)
A_{lc}	=	shear connection area of lug plate ($= f_1 \ell_c t_c$), in cm^2 (in^2)
A_{ld}	=	shear connection area excluding lug plate ($= \ell_d t_w$), in cm^2 (in^2)
A_s	=	attached area of the flat bar stiffener, in cm^2 (in^2)
A_s	=	cross-sectional area of the spring rod, in cm^2 (in^2)
A_{shear}	=	effective shear area of a hull girder cross section, in cm^2 (in^2)
AP	=	After Perpendicular
B	=	breadth of vessel, in m (ft)
C_{3D}	=	three-dimensional correction factor ($= 0.83C_L$) for slamming pressure
C_a	=	permissible bending stress coefficient
C_d	=	plate capacity correction coefficient ($= 1.0$)
C_L	=	location factor for bottom slamming pressure near FP
C_p	=	local pressure coefficient
C_s	=	dynamic load factor, as described in 7/3.7
d_i	=	vertical distance from the still water surface to the location, in m (ft), if the location is above the water surface, then it becomes zero.
d_m	=	mean draft of vessel, in m (ft)
E	=	modulus of elasticity of the material, may be taken as $2.06 \times 10^7 \text{ N/cm}^2$ ($2.1 \times 10^6 \text{ kgf/cm}^2$, $30 \times 10^6 \text{ lbf/in}^2$) for steel
f	=	spreading function for short-crested waves, as defined in Subsection 4/3

f_1	=	shear stiffness coefficient in slot connection check, or an adjusted yield point of material in shell plating check
f_2	=	an adjusted yield point of material in shell plating check
f_b	=	calculated ideal bending stresses in buckling check, in N/cm ² (kgf/cm ² , lbf/in ²)
f_b	=	an adjusted yield point of material in stiffener check
f_{bdg}	=	bending moment factor in stiffener check
f_c	=	collar load factor for slot connection check
f_{ci}	=	critical buckling stress with respect to uniaxial compression, bending or edge shear, separately, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{Ei}	=	a buckling stress with respect to uniaxial compression, in N/cm ² (kgf/cm ² , lbf/in ²)
f_y	=	minimum specified yield point of the material, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{Lb}	=	calculated uniform compressive stress in buckling check, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{LT}	=	calculated total in-plane shear stress in buckling check, in N/cm ² (kgf/cm ² , lbf/in ²)
f_{yi}	=	a yielding stress with respect to uniaxial compression, bending, or edge shear
f_u	=	ultimate tensile strength of material
FP	=	Forward Perpendicular
g	=	gravitational acceleration, 9.81 m/s ² (32.2 ft/s ²)
H	=	Response Amplitude Operator (RAO) of a response
H_s	=	significant wave height, in m (ft)
I_v	=	moment of inertia amidships, in m ⁴ (ft ⁴)
K_i	=	buckling coefficient, as given in Section 8, Table 4
ℓ	=	length of stiffener between effective supports in buckling check, in cm (in.), or = unsupported span of the frame, in m (ft), or = spacing of transverse in slot connection check
ℓ_c	=	length of connection between longitudinal stiffener and lug plate in slot connection check (see Section 8, Figure 3), in cm (in.)
ℓ_d	=	length of direct connection between longitudinal stiffener and transverse member in slot connection check (see Section 8, Figure 3), in cm (in.)
ℓ_s	=	length of spring rod in main supporting member check, in cm (in.)
ℓ_t	=	cargo hold length between transverse bulkheads in main supporting member check, in cm (in.)
L	=	Rule length, as defined in 3-1-1/3.1 of the <i>Steel Vessel Rules</i> , in m (ft)
LS	=	longitudinal spacing
L tons	=	long tons in US units
m_n	=	n -th spectral moment at a main heading angle
n	=	number of spring rod elements in main supporting member check, or = a constant for pressure-velocity relationship

n_s	=	a factor in stiffener check
p_s	=	design slamming pressure, in N/cm ² (kgf/cm ² , lbf/in ²)
$(\bar{p}_s)_{\max}$	=	maximum of average slamming pressure over each location
P_1	=	load transmitted through flat bar stiffener in slot connection check, in N (kgf, lbf)
P_2	=	load transmitted through shear connection in slot connection check, in N (kgf, lbf)
P_r	=	proportional linear elastic limit of the structure, may be taken as 0.6 for steel
s	=	spacing of longitudinal or transverse frames in stiffener check, in mm (in.), or spacing of longitudinals/stiffeners in slot connection check, in cm (in.)
S_m	=	strength reduction factor for various steel grades
S_y	=	spectral density function of a response
S_ζ	=	wave spectrum, in m ² -sec (ft ² -sec)
SM	=	section modulus of stiffener
SM_{pl}	=	section modulus of stiffener considering plasticity
t	=	required net thickness of web plating in buckling check, in cm (in.), or total duration time in estimation of extreme response, in sec
t_c	=	thickness of lug plate in slot connection check (see Section 8, Figure 3), in cm (in.)
t_n	=	net thickness of the plate in buckling check, in cm (in.)
t_{tw}	=	thickness of transverse member in slot connection check (see Section 8, Figure 3), in cm (in.)
T_2	=	mean period of relative vertical velocity, in sec
T_p	=	peak period of wave (= 1.408 T_z), in sec
T_z	=	zero crossing period of wave, in sec
v	=	relative vertical velocity between water and hull, in m/s (ft/s)
V	=	vessel speed
V_d	=	design speed of the vessel, in knots
W	=	width of the cut-out for an asymmetrical stiffener in slot connection check, measured from the cut-out side of the stiffener web (see Section 8, Figure 1), in cm (in.)
α	=	aspect ratio of the panel (longer edge/shorter edge) in shell plating check
α_b	=	local body plan angle measured from the horizontal, in degrees
α_p	=	correction factor for the panel aspect ratio
β	=	wave heading, following sea is 0, and head sea is π , in rad
β_0	=	main wave heading of short-crested wave, in rad
Δ	=	vessel displacement, in tons (L tons)
Δ_i	=	virtual displacement, including added mass of water, in tons (L tons)
μ	=	a constant used in 2-node vibratory frequency calculation
ν	=	Poisson's ratio, may be taken as 0.3 for steel

σ_{fb}	=	flat bar mean stress, in N/cm ² (kgf/cm ² , lbf/in ²)
σ_r	=	standard deviation of relative vertical motion, in m (ft)
σ_v	=	standard deviation of relative vertical velocity, in m/s (ft/s)
τ_{dc}	=	direct collar plate mean stress, in N/cm ² (kgf/cm ² , lbf/in ²)
ω	=	frequency of wave, in rad/sec
ω_1	=	2-node hull girder vertical vibratory frequency, in rad/sec
ω_e	=	encounter frequency of vessel motion, in rad/sec
ω_p	=	peak frequency of wave ($= 2\pi/T_p$), in rad/sec

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