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CHANGES

General
This document supersedes the January 2011 edition.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes coming into force 1 January 2013
• Sec.5 Procedures and application
  — Subsec.C is amended with updated references.

Corrections and Clarifications
In addition to the above stated rule requirements, a number of corrections and clarifications have been made to the existing rule text.
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SECTION 1
PROCEDURES AND APPLICATION

A. General

A 100 Objective
101 The principal objective of the requirements specified in this chapter is to provide a framework for performing and documenting direct strength and hydrodynamic analyses for a high speed and light craft.

A 200 Application
201 Direct strength and hydrodynamic analyses are to be based on the operational restrictions for the craft. These restrictions are normally based on Ch.1 Sec.2 B200, which determines the relationship between maximum allowed speed and significant wave height for a given design vertical acceleration. The operational restrictions may also be based on hydrodynamic analysis or model tests.

202 Sec.1 to Sec.4 apply to high speed and light craft designs of any material defined in Pt.2. Sec.5 to Sec.6 apply to craft of steel or aluminium only, i.e. for craft classified in accordance with Ch.2 and Ch.3. Craft of fibre composites and sandwich constructions are not explicitly mentioned in this chapter, but the principles described are applicable for such craft. The acceptance criteria are to be adjusted accordingly.

203 Calculated global design wave loads can, if calculated and documented in accordance with the requirements in Sec.2, be used as an alternative to the global design wave loads as given in Ch.1 Sec.3. The Society reserves the right to evaluate received documentation and determine the design load level in each case.

204 The calculations specified in this chapter are to be carried out by computer programmes recognised by the Society. Recognised programmes are considered as all programmes where reliable results have been demonstrated to the satisfaction of the Society.

Wave load analysis programmes are to be documented in accordance with B300.

B. Documentation

B 100 Hydrodynamic analyses
101 Hydrodynamic analyses are to be documented in a technical report and submitted for information. The report is to give a detailed description of the analysed loading conditions, the model and the results from the analyses.

B 200 Structural analyses
201 The finite element analysis shall be documented in a technical report and submitted for information. The report is to give detailed information about the model with its boundary conditions and the analysis performed. Results are to be presented as plots giving an overview of the stress distribution and numerical values for detailed results. The strength is to be evaluated against the relevant acceptance criteria.

B 300 Computer programmes
301 The computer program applied in the wave load and motion analysis is, upon request, to be documented in a technical report which is to be submitted for information. The report is to document that the numerical method is valid for that particular design and investigated speed range.

C. Levels of Direct Calculations

C 100 Level 1: Local analysis
101 For all high speed and light craft designs, it may be necessary to perform local analyses of parts of the structure. Ch.2 Sec.9 and Ch.3 Sec.9 gives the background and assumptions for such analyses as well as allowable stresses.

102 The different finite element models that may be applied in the local strength analysis are described in Sec.5. These models are as follows:

— compartment model
— frame and girder model
Beam element models may normally be applied as an alternative to finite element models in the compartment and frame and girder analyses.

Direct stress analyses of local structures may be based on loads derived from hydrodynamic analysis. The applied loads are however not to be less than the minimum loads given by the rule formulas in Ch.1 Sec.2.

In Sec.2 the requirements for direct calculations of motions, accelerations and pressures are given.

Local analyses of water jet ducts and the surrounding structures are treated separately in D.

C 200 Level 2: Rule verification analysis

The level 2 procedure as described below may be applied for high speed and light craft designs with length above 50 m, of monohull or twin hull type, i.e. craft for which there exist a set of formulas for global design loads as given in Ch.1 Sec.3.

Guidance note:
Novel designs are to be documented in accordance with the procedure as described in 300. Level 2 procedure may be applied for initial design purposes only.

C 300 Level 3: Alternative rule analysis

The level 3 procedure as described below may be applied for all high speed and light craft designs with length above 50 m. For designs which are not specified by the global rule loading formulas in Ch.1 Sec.3, the level 3 procedure is to be applied as a minimum.

For high speed craft designs referred to in 201, the level 3 procedure is to be applied in the following cases:
— when the hull form is such that the rule formulas in Ch.1 Sec.3 are not expected to give reliable results
— when the operational profile of the craft is such that the rule requirements in Ch.2 and Ch.3 are not adequate
— when the designer or yard wants to deviate from the rule requirements to global strength.

For craft with long and slender foreship (such as SWATH, semi-SWATH or wave piercer), the case with impact pressure on one side of the hull(s) is of special importance.
306 An ultimate strength analysis in accordance with Sec.5 is to be performed.
307 A fatigue analysis in accordance with Sec.6 of critical areas is to be performed, which may require local finite element analyses for determination of the stress concentration factors.

D. Water Jets with Adjacent Structure

D 100 General

101 For all type of high speed and light craft designs a direct strength analysis of the water jet ducts and surrounding structure may be required.

102 In Ch.5 Sec.1 I100 to I400 the requirements for the duct design, design loads and allowable stresses for the water jet duct and transom structure design are given.

103 Classification Note 30.8 gives guidance on the modelling of loads, the analysis and evaluation of results.

D 200 Models

201 The extent of direct analysis needed is dependent upon the size of the water jet and the complexity of the structure, and has to be decided on a case by case basis.

202 A finite element model of the water jet compartment may be required if the reaction forces from the water jets are expected to give high stresses in the supporting structure or cause deflections above the level specified by the manufacturer of the water jet/shaft installation. The model is, as a minimum, to extend from the transom to the nearest transverse bulkhead in the longitudinal direction. Vertically, the model is to normally extend up to the main deck. The element fineness is to be as described in Sec.4 A203 for the frame and girder model.

203 For the evaluation of the secondary stiffening subject to high cycle loads, a fine mesh finite element model of the entire duct may be required. This model may be included in the model described in 202 or run separately with prescribed boundary conditions. The element’s fineness is to be as described in Sec.4 A303 for local structure models.

204 Critical details such as connection of duct flange to transom and/or discontinuities along the length of the duct shall normally be analysed by stress concentration models. The element size is to be as described in Sec.4 A400. The model is to be included in the model described in 203.

205 An axis-symmetric model as described in Classification Note 30.8 may in some cases be used as an alternative to the model in 204.
SECTION 2
WAVE LOADS AND MOTIONS

A. General

A 100 Wave loads and motions

101 Direct wave load calculations are to be performed in accordance with procedures accepted by the Society.

A 200 Appendages

201 High speed and light craft designs equipped with appendages such as motion damping devices are to be analysed with and without such equipment. Local design loads on the damping devices are to be determined in the analysis.

B. Static Loads

B 100 Loading conditions

101 The design loading conditions are normally to include the ballast, full load and part load conditions. The considered load conditions are to cover the full range of still water bending moments from maximum sagging to maximum hogging.

102 Different loading conditions should normally be used for the fatigue and ultimate load predictions. For the ultimate limit state analysis, the loading condition giving the worst moment/shear force is to be applied. For the fatigue limit state analysis, "average voyage" conditions, i.e. the most frequent loading conditions giving the best representation of the long term distribution of stresses are to be applied.

The loading conditions should cover an envelope of at least 90% of the operational life time.

103 For high speed and light craft with the additional notation Cargo, the harbour conditions are normally to be considered in addition to the conditions in 102, in the ultimate load prediction. For harbour conditions, only static loads are to be considered. Harbour conditions with asymmetric loadings are relevant to the extent that they do not result in unacceptable heeling.

104 For craft with the additional notation Passenger, Car Ferry A (or B), Naval or Crew, i.e. craft with relatively small variations of the deadweight, it is sufficient to base the wave load analysis on the full load condition, both for the ultimate limit and fatigue limit state analyses. If this approach is used, the calculated wave load should be combined with the static load condition giving the most unfavourable design load for the craft.

C. Wave Loads and Motions Analyses

C 100 Numerical methods

101 The numerical method is to be valid for the investigated speed range. Speed effects on the sea keeping behaviour are to be accurately incorporated.

102 Transfer functions are to be calculated based on a recognised linear strip theory method or better. Conventional strip theory approaches have to be applied with care for \(V/\sqrt{L} > 24\) (or \(F_n > 0.4\)). Alternative theories must then be considered.

103 Transom stern effects are to be accounted for if such effects influence the seakeeping performance and wave loads.

104 For twin hulls and multihulls, hydrodynamic interaction between the hulls is to be considered for the lower speeds. The hydrodynamic interaction may usually be disregarded for higher speeds.

105 Craft with large flare, wet deck or centre bow, which may be exposed to significant wave impact, are to be analysed by non-linear analyses for the ultimate limit state load prediction. Alternatively, the non-linear effects can be taken into account as correction factors from model tests or experience from comparable designs.

106 Linear modelling of the craft responses is normally sufficient for fatigue assessment purposes.

Guidance note:
For craft with high degree of non-linearities, e.g. wave piercers, the non linear effects on the fatigue strength should be assessed.
Model tests may be used in combination with or as an alternative to the numerical method. For craft with unusual hull form, model tests may also be required for verification of the hydrodynamic analysis.

**C 200 Design wave loads**

Design wave loads are to be calculated based on a 20-year return period or equivalent, and are to be based on the operational restrictions for the craft.

The loads are to be determined based on both a short term and long term design load evaluation. The worst response from each of these procedures is to be applied.

 Loads for the fatigue analysis are to be based on a long term design load evaluation.

Wave scatter diagrams and methods accepted by the Society are to be used. In a long term design load evaluation the wave loads can be calculated assuming that the amount of time in each wave heading is equal. A minimum of 8 headings is to be calculated as a basis for the total distribution of waves.

**Guidance note:**

In the case that a craft is to be designed for a specific route, the expected distribution of wave headings should be taken into account. This applies for both the ultimate limit state and the fatigue limit state load prediction. The applied loads should however not be less than the loads in 204, i.e. when assuming equal distribution of headings.

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In a short term design load evaluation, the extreme value equivalent to the 20 years long term value is defined as follows:

**Linear analysis:**

\[
R_{\text{linear}} = 5 \left[ \sigma(T_z, \mu, V) H_{S, \text{max}}(V) \right]_{\text{worst}}
\]

\( R_{\text{linear}} \) = linear design response

\( \sigma(T_z, \mu, V) \) = standard deviation (or RMS) value in a sea state with \( H_s = 1 \) m, function of zero crossing wave period \( T_z \), wave heading \( \mu \) and speed \( V \)

\( H_{S, \text{max}}(V) \) = maximum operational significant wave height as function of speed, see speed/sea state table for craft.

\( [\sigma(T_z, \mu, V) H_{S, \text{max}}(V)]_{\text{worst}} \) = highest product of standard deviation and significant wave height within steepness criteria in Classification Note 30.5 and speed/sea state table for the craft.

**Non-linear analysis:**

\[
R_{\text{non-linear}} = 1.25 R_{\text{most prop, 3h}} \left[ H_S, T_z, \mu, V \right]_{\text{worst}}
\]

\( R_{\text{non-linear}} \) = non-linear design response.

\( R_{\text{most prop, 3h}} \left[ H_S, T_z, \mu, V \right]_{\text{worst}} \) = most probable largest value during 3 hours in a seastate with worst combination of significant wave height, zero crossing wave period, wave heading and speed within steepness criteria in Classification Note 30.5 and speed/sea state table for the craft.

The linear and non-linear response expressions listed above are approximations for the extreme values with 1% probability of exceedance in a 3 hour seastate.

**C 300 Global design loads**

The global design loads for the ultimate strength analysis are to be derived by combining the design wave loads calculated by the procedures in 200 with the most unfavourable still water loading condition.

Global design loads (still water loads + wave loads) are to be determined for loading conditions giving maximum values for the following:

— vertical bending moment/shear force along the hull girder
— horizontal bending moment/shear force along the hull girder
— torsional bending moment along the hull girder
— racking due to transverse accelerations, see also C400.

**Guidance note:**

Longitudinal wave bending moments, both vertical and horizontal moments, and the corresponding shear forces
should be determined in all relevant transverse cuts and neutral axes. As a minimum, the moments and shear forces
should be determined amidships and in way of the fore and aft quarter lengths.
The torsional wave bending moments should be determined in all relevant transverse cuts, at least amidships and in
way of the fore and aft quarter lengths. The torsional moment should be calculated about the shear centre of the
section.

For twin hulls/multihulls the additional load cases are to be determined:
— transverse bending (split moment)
— pitch connecting/torsional moment.

303 For high speed and light craft of novel design any other loads or combinations of loads that may be
relevant are to be considered.

C 400 Motions and accelerations

401 Transverse design accelerations, which are to be applied in the racking analysis, are to be calculated
based on a 20 year return period or equivalent short term value in 205.

402 Vertical design accelerations are to be calculated based on a 20 year return period or equivalent short
term value in 205.

C 500 Impact pressures

501 For craft with large flare, shallow draft, wet deck or centre bow, local design impact pressures are to be
considered.

Guidance note:
Design impact pressures can be taken as the space averaged pressure over the design load area for element considered.
The definition of design load area as given in Ch.1 Sec.2 C201 can normally be applied.

502 Impact coefficients may be based on model test, direct numerical analysis, or Classification Note 30.5.

503 For twin hulls or multihulls wet deck slamming pressures are to be calculated based on the relative
motion and the relative velocity between craft and wave. For craft with the notations; Passenger or Car
Ferry A (or B) the relative motions can be used for determining the required wet deck clearance, i.e. the
clearance that is necessary to avoid slamming in normal operation.

504 Impact pressures are to be calculated in accordance with 205.
SECTION 3
GLOBAL STRENGTH ANALYSIS

A. General

A 100 Documentation

101 The global finite element analyses are to be carried out and documented in accordance with the Classification Note 30.8.

B. Finite Element Analysis

B 100 Model

101 In this model a mesh extending over the total hull length is to be used to represent the overall stiffness and global stress distribution of the primary members of the hull.

102 The following effects are to be taken into account:

— vertical hull girder bending including shear lag effects
— vertical shear distribution along the hull
— horizontal hull girder bending including shear lag effects
— horizontal shear distribution along the hull
— pitch connecting/torsion of the hull girder
— transverse bending and shear.

103 For high speed and light craft designs requiring a level 3 procedure, as defined in Sec.1 C300. A frame and girder model, as described in Sec.4, is to be included in the global strength analysis, at least for a section amidships and in the fore- and aftbody.

104 Stiffened panels may be modelled by means of anisotropic elements. Alternatively, a combination of plate elements and beam elements may be used. It is important to have a good representation of the overall membrane panel stiffness in the longitudinal/transverse directions and for shear.

B 200 Loads

201 Loads are to be modelled as either line loads or as the disturbed pressure distribution from the hydrodynamic analysis depending on which of the calculation procedures, as described in Sec.1 C, is applicable.

202 The global strength analysis is to include all the relevant global loads referred to in Sec.2 C300. In addition, the worst combinations of these loads are to be considered.

203 When the line load approach is used for the modelling of loads, the combined wave loading conditions in 202 are to be established based on the correlation between the loads in the hydrodynamic analysis.

B 300 Results

301 Stresses and deflections from each of the analysed load cases are to be presented.

302 Results are to be presented as plots giving an overview of the stress distribution and numerical values for detailed results.

303 Plots of directional as well as equivalent stresses are to be presented. For analysis in accordance with Sec.1 C300, principle stresses are to be submitted in fatigue prone areas.
SECTION 4
LOCAL STRUCTURE MODELS

A. Local Finite Element Models

A 100 Compartment model

101 This model aims to analyse the deformation response and nominal stresses in primary members, in different parts of the craft.

102 The compartment model may be included in the global stiffness model.

103 The compartment model may provide the boundary conditions for the frame and girder model.

104 The element mesh is to be fine enough to enable the analysis of nominal stress variations in the main framing and girder system. In areas of special importance, the element size is to be as the frame and girder model in 200.

A 200 Frame and girder model

201 The frame and girder analysis is to be used to analyse the stresses and deformations in the frame and girder system. Reference is made to Classification Note no. 30.8 for applicable requirements and guidelines for such analysis.

202 The model may be included in the compartment analysis model. Alternatively, it may be run separately with prescribed boundary deformations or boundary forces from the compartment model.

203 The element mesh should be fine enough to be able to describe stress increase in critical areas (such as bracket with continuous flange). Normally an element’s size equal to the stiffener spacing is acceptable, while a finer mesh may be required in areas of large variation in the stresses (e.g. in way of hard chine and areas with curvature). A minimum of 3 elements, over the girder heights, is normally necessary if 4-noded elements are applied, while 2 elements are normally sufficient if 8-noded elements are applied.

A 300 Local structure models

301 Local structure analysis is to be used to analyse stresses in local areas. Such areas may be water jet ducts, intersection between wet deck and hull sides, engine/gear foundations, hatch, or laterally loaded local stiffeners subject to large relative deformation between girders, frames and bulkheads. Local structure models may also be used to determine the edge stresses in way of critical hatch corner openings for e.g. container craft.

302 Local structure models may be included in the compartment model or the frame and girder model or run separately with prescribed boundary deformations or boundary forces from the frame and girder model.

303 If 8-noded elements are applied, 3 elements are necessary over the girder height. Corresponding element sizes are to be applied for plate and flanges.

A 400 Stress concentration models

401 Fine mesh finite element models are to be applied at critical stress concentration details, which are required for fatigue assessment.

402 The size of the model is to be sufficiently large so that the calculated results are not significantly affected by assumptions made for boundary conditions and application of loads.

403 Element size for stress concentration analysis is to be at the order of the plate thickness. Normally, shell elements are to be used for the analysis, while solid elements may be used on a comparative basis to investigate the stress concentration factor in special areas.

Guidance note:
If solid modelling is used, the element size of the area of the hot spot may have to be reduced to half the plate thickness in case the overall geometry of the weld is included in the model representation. For further details, reference is made to Classification Note 30.7.
SECTION 5
ULTIMATE STRENGTH ANALYSIS

A. Acceptance Criteria

A 100 General

101 The hull girder and main girder system nominal and local stresses derived from the global strength analysis carried out in accordance with the "Alternative rule analysis", as defined in Sec.1 C300, is to be checked according to the criteria specified in 200 to 400.

A 200 Allowable stresses

201 Allowable equivalent nominal stresses referred to 20 year conditions are for steel:

Seagoing conditions:

\[ \sigma_e = 0.95 \sigma_f \text{ N/mm}^2 \]

Harbour conditions:

\[ \sigma_e = 0.85 \sigma_f \text{ N/mm}^2 \]

For aluminium structures the corresponding stresses are:

Seagoing conditions:

\[ \sigma_e = 0.85 \sigma_f \text{ N/mm}^2 \]

Harbour conditions:

\[ \sigma_e = 0.75 \sigma_f \text{ N/mm}^2 \]

\( \sigma_f \) = yield stress of material. For steel structures it is referred to Ch.2 Sec.2. For aluminium structures the reduced strength in heat affected zone shall be used. The yield stress in heat affected zone is not explicitly given in Ch.3 Sec.2, but is to be derived from the definition of the factor f1. See also 202.

\( \sigma_e \) = equivalent stress.

The harbour condition is normally relevant to check for craft with the additional notation Cargo, only.

202 Local linear peak stresses in areas with pronounced geometrical changes, as in hatch corners, single frame corners, single bracket toes etc., may need special consideration. Local peak stresses in this context are stresses calculated with local structure models and stress concentration models which have a finer finite element mesh representation than used for nominal stress determination. Local peak stresses, as given below, may be accepted provided plastic mechanisms are not approached (developed) in the associated structural parts.

For extreme 20 year loads the allowable equivalent plastic strain corresponding to a linear peak stress is for steel:

\[ \sigma_e = 400 f_1 \]

The corresponding allowable stress for aluminium structures is:

\[ \sigma_e = 300 f_1 \]

The reduced strength of aluminium in the heat affected zone shall be used when calculating the allowable equivalent stress. The tabulated f1 factors in Ch.3 Sec.2 Table B4 for the alloys NV-5083 and NV-5383 shall be reduced by 13.5 % and 9.0 % when applied in the above criteria, respectively.

Guidance note:

Areas above yield determined by a linear FEM analysis may give an indication of the actual area of plastification. Otherwise, a full non-linear FEM analysis may need to be carried out in order to trace the full extent of the plastic zone.

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A 300 Buckling control

301 The buckling control of panels (plate and stiffener combinations) is to be performed as given in Classification Note 30.1. The usage factor for stiffened panels is not to exceed 0.9.

302 The buckling control of girders is to be performed as given in Classification Note 30.1. The usage factor for girders is not to exceed 0.75.
A 400 Hull girder capacity

401 The ultimate longitudinal sagging and hogging bending capacity of the hull girder is to be determined. The requirements specified assume intact condition. Damage conditions are normally not relevant to consider, but such analyses may be required in special cases and for novel designs.

402 The ultimate hull girder bending capacity is to comply with the following limits:

\[ M_S + 1.1 M_W \leq \frac{M_U}{1.15} \]

- \( M_S \) = maximum design sagging/hogging still water bending moment applied in the global strength analysis
- \( M_W \) = design wave sagging/hogging bending moment applied in the global strength analysis
- \( M_U \) = ultimate hull girder bending moment capacity
- 1.15 = material factor
- 1.1 = partial safety factor on the environmental loads.

403 The hull girder capacity may be calculated for the intact midship section by summing up the buckling and the yield capacities of the intact structural elements for the whole section:

\[ M_U = \sum_{j} \sigma_{crj} A_j z_j + \sum_{k} \sigma_{f} A_k z_k \]

- \( A \) = area of panel
- \( z \) = distance from panel to plastic neutral axis using the actual yield and or buckling capacities in the tension and or compression side, respectively
- \( \sigma_{cr} \) = critical buckling stress of panels on the compression side according to Classification Note 30.1
- \( \sigma_{f} \) = yield stress of panels on the tension side
- \( j \) = includes all panels on compression side
- \( k \) = includes all panels on tension side.

\( M_U \) is to be calculated for both sagging and hogging conditions.
SECTION 6
FATIGUE ANALYSIS

A. General

A 100 Introduction

101 The following areas are normally critical and are to be considered in a fatigue strength analysis:

— stiffener transition through web frames or bulkheads in critical sections
— cross structure in a twin hull or a multihull craft, particularly in the transition between cross structure and pontoon
— details in the midship area with large stress concentrations such as tripping brackets etc.
— engine foundations and water jet area (high cycle loading)
— areas with doublers
— pillar connections
— cross bracing connections
— at discontinuities
— tapered riders
— termination of primary and secondary members.

Other areas where the dynamic stress level is considered as high, and/or subject to high cycle loading, the fatigue strength is to be considered.

B. Loads and Design Criteria

B 100 Loads

101 The craft is to be evaluated for global and local loads. For local loads, stresses due to internal and external pressures may be calculated separately and combined using a correlation factor between sea pressure loads and internal pressure/inertia loads.

102 The fatigue strength evaluation is to be based on the most frequently used design load conditions. The fraction of lifetime operating under each considered loading condition is to reflect the intended operational trading pattern for the craft.

B 200 Design criteria

201 The fatigue analysis is to be based on a period of time equal to the planned life and usage profile of the craft. The period is, however, normally not to be taken less than 20 years, using wave scatter diagrams representative for the service restrictions for the craft and accepted by the Society.

202 The cumulative effect of the stress history may be expressed by linear cumulative damage usage factor (Miner-Palmgren). In structures where a failure is local and can be detected before it leads to any critical event, the damage usage factor is not to exceed the value \( h = 1.0 \). For structures with low/no redundancy or the failure is difficult to detect, the acceptable usage factor is to be considered in each individual case.

The design criteria specified are to be fulfilled based on S-N data for mean value minus 2 times the standard deviation.

B 300 Calculation methods

301 The Society can provide support documentation, in regard to acceptable calculation methods.

302 The influence of corrosive environments are to be taken into account where applicable, e.g. bilge and water ballast tanks, through appropriate SN-curves or an equivalent correction to the damage usage factor.