RULES FOR CLASSIFICATION

Yachts

Edition October 2016

Part 3 Hull

Chapter 6 Finite element analysis

DNV GL AS

FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

Any comments may be sent by e-mail to *rules@dnvgl.com*

CURRENT – CHANGES

This is a new document.

This document supersedes the December 2015 edition.

Main changes October 2016, entering into force as from date of publication

- Sec.2 Global strength analysis
  — Sec.2 [3.2]: Correction of the von Mises stress formula

- Sec.3 Local structural strength analysis
  — Sec.3 [4.2.2]: Correction of the permissible utilization factor

CONTENTS

SECTION 1 INTRODUCTION

1 General

1.1 Introduction

1.1.1 This chapter describes generic modelling techniques, loads, acceptance criteria and required documentation for finite element analysis of different type yachts built in steel or aluminium. Methodologies for finite element analysis of yachts built in composites are defined in Ch.5.

1.2 Calculations methods

1.2.1 The rules covers four levels of finite element analysis:

a) global direct strength analysis, to assess hull girder strength and to give correct boundary conditions to partial ship structural models and/or local FE models, when applicable
b) partial ship structural analysis, to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads
c) local structure analysis
d) very fine mesh analysis, to assess the local structural details for fatigue limit state.

The objectives of analyses together with their applicable acceptance criteria are described in Sec.2 and Sec.3.

1.3 Loading scenarios

1.3.1 The calculations shall be based on general design loads, defined in Ch.3.

1.3.2 General design loads are given in Ch.3 and FE design load cases for the different ship types are given in Pt.5.

1.4 Scantling application

1.4.1 In general , if not otherwise defined FE models can be based on the gross scantling approach (including t_C).
All buckling capacity assessment shall be based on scantling approach as defined in Ch.4 App.B.

2 Finite element types

2.1 Used finite element types

2.1.1 The structural assessment shall be based on linear finite element analysis of three dimensional structural models.

2.1.2 Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure, except for course mesh global models. The mesh requirements given in this chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

3 Documentation

3.1 Reporting

3.1.1 When direct strength analyses are submitted for information, such analyses shall be supported by documentation satisfactory for verifying results obtained from the analyses.

3.1.2 The documentation for verification of input shall contain a complete set of information to show the assumptions made and that the model complies with the actual structure. The documentation of the structure may be given as references to drawings with their drawing numbers, names and revision numbers. Deviations in the model compared with the actual geometry according to these drawings shall be documented.

3.1.3 The modelled geometry, material parameters, plate thickness, beam properties, boundary conditions and loads shall be documented preferably as an extract directly from the generated model.

3.1.4 Reaction forces and displacements shall be presented to the extent necessary to verify the load cases considered.

3.1.5 The documentation of results shall contain all relevant results such as:

— type of stress (element/nodal, membrane/surface, normal/ shear/equivalent)
— magnitude
— unit
— load case
— name of structure
— structural part presented
— evaluation of the results with respect to the acceptance criteria.

4 Computer programs

4.1 Use of computer programs

4.1.1 In general, any computation program recognised by the Society may be employed for structural assessment according to these rules provided the software combines effects of bending, shear, axial and torsional response.

4.1.2 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Society is regarded as a recognised program. Where the computer programs employed are not supplied or recognised by the Society, full particulars of the computer program, including example calculation output, shall be submitted. It is recommended that the designers consult the Society on the suitability of the computer programs intended to be used prior to the commencement of any analysis work.

5 Alternative procedures

Procedures other than those outlined in the rules and associated class guidelines issued by the Society may be accepted on a case-by-case basis.

SECTION 2 GLOBAL STRENGTH ANALYSIS

1 General

1.1 Introduction

1.1.1 A global FE analysis covers the whole ship and may be required if the structural response of the hull girder can otherwise not be sufficiently determined as for yachts:

— with stepped (non-continuous) decks and longitudinal bulkheads and walls over the vessel length
— with partly effective superstructure and/or partly effective upper part of hull girder
— with large opening in the hull, e.g. side doors.

1.1.2 Global analyses shall generally to be based on loading conditions that are representative with respect to the responses and failure modes to be evaluated, e.g. yield, buckling and fatigue.

1.1.3 The objective of the global strength analysis is to obtain a reliable description of the overall hull girder stiffness and to calculate and assess the global stresses and deformations of all primary hull members. Depending on the hull shape, the scope of the global FE analysis is in general to assess and verify compliance with relevant criteria.

2 Structural model

2.1 General

2.1.1 Extent

The global FE model should extend over the complete length, depth and breadth, and represent the actual geometry of the vessel with reasonable accuracy. All main structure contributing or partly contributing to the hull girder strength including all primary supporting members, transverse members, i.e. watertight bulkhead, non-watertight bulkhead, cross deck structures and transverse webs, shall be included in the model.

The omission of minor structures may be acceptable on the condition that the omission does not significantly change the response of the structure.

2.1.2 Modelling

The mesh size, model idealisation and boundary conditions to be as described in the Society's document DNVGL-CG-0127 Sec.2.

2.1.3 Loading conditions

The selection of loading conditions and the application of loads will depend on the scope of the analysis. Application of loads is specified in the Society's class guidelines for the relevant ship types.

3 Analysis criteria

3.1 General

The analysis criteria apply for global FE model are described in this section.

3.2 Yield strength

Nominal axial (normal), shear and von Mises stresses derived from a global analysis shall be checked according to the acceptance criteria given in Sec.3 [4.2]. Alternatively: For all plates of the structural members the von Mises stress, σ_{vm}, in MPa, shall be calculated based on the membrane normal and shear stresses of the shell element. The stresses shall be evaluated at the element centroid of the mid-plane (layer), as follows:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau_{xy}^2} \qquad (1)$$

where:

σ_x, σ_y	=	element normal membrane stresses, in MPa
τ_{xy}	=	element shear stress, in MPa.

The normal, shear and von Mises stress shall not exceed $k * R_y$, each. Regarding definition of k and R_y refer to Ch.4 Sec.4.

3.3 Buckling strength

All structural elements in FE analysis shall be assessed individually against the buckling requirements as defined in Ch.4 App.B.

3.4 Fatigue strength

General assumptions, methodology and requirements for the fatigue strength assessment are given in Ch.4 App.D.

SECTION 3 LOCAL STRUCTURAL STRENGTH ANALYSIS

1 Objective and scope

1.1 General

1.1.1 Local FE strength analysis may be required for longitudinals subject to large relative deflections.

1.1.2 The structural details shall be assessed by fine mesh FE analysis according to the general principles stated in this section. Detailed procedures are given in the Society's document DNVGL-CG-0127 Sec.4.

1.1.3 The selection of critical locations on the structural members and the fine mesh structural models shall be in accordance with the requirements given in the Society's document DNVGL-CG-0127 Sec.4 in general and in class guidelines for specific ship types issued by the Society.

1.1.4 For details where very high surface stresses are expected, an advanced analysis of hot-spot stresses covering both low cycle and high cycle fatigue may be required, see the Society's document DNVGL-CG-0129. Such analysis may also be accepted in lieu of local structural strength analysis according to this section.

2 Structural modelling

2.1 General

2.1.1 Fine mesh analysis

2.1.2 The fine mesh analysis may be carried out by means of a separate local finite element model with fine mesh zones, in conjunction with the boundary conditions obtained from the global FE model.

2.1.3 Model extent

The extent of the local finite element models shall be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads.

2.1.4 Fine mesh zone

The fine mesh zone shall represent the localized area of high stress. In general, the extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation.

3 FE load combinations

3.1 General

3.1.1 The fine mesh detailed stress analysis shall be carried out for all FE load combinations applied.

3.2 Application of loads and boundary conditions

3.2.1 Where a separate local model is used for the fine mesh detailed stress analysis the displacements or forces from the global model shall be applied to the corresponding boundary contour on the local model. All loads, including local loads and loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model shall be applied to the model.

The static and dynamic load factors can be set to 1.0 for the applied local loads. The global load factor can be set to 0.75 for simultaneously considered global membrane or axial stress.

4 Analysis criteria

4.1 Reference stress

Reference stress is von Mises stress, σ_{vm}, which shall be calculated based on the membrane direct axial and shear stresses of the plate element evaluated at the element centroid.

4.2 Acceptance criteria

4.2.1 The acceptance criteria as given in [4.2.2] are applicable for structural details and conditions given in [1.1]. For other structural details, the acceptance criteria may be considered on a case by case basis.

4.2.2 The structural assessment is to demonstrate that the von Mises stresses obtained from the finite element analysis do not exceed the maximum permissible stress, as follows:

$$\lambda_f \leq \lambda_{fperm}$$

where:

$\lambda_f = \frac{\sigma_{vm}}{R_y}$ for shell elements in general

$\lambda_f = \frac{\sigma_{axial}}{R_y}$ for shell elements in general

σ_{vm} = von Mises stress, in yield N/ mm^2
σ_{axial} = axial stress in rod element, in N/mm^2
λ_{fperm} = permissible utilisation factor.

The structural assessment shall satisfy the following:

λ_{fperm} = $0.75 \cdot k$ for working stress design method, see Ch.1 Sec.2 [5]
= $k/\left(\gamma_f \cdot \gamma_m\right)$ for partial safety factor design method, see Ch.1 Sec.2 [5]
k = material factor according to Ch.4 Sec.4
γ_f = mean factor of γ_{stat} and γ_{dyn} considering the static and dynamic load factors and load portions.

CHANGES – HISTORIC

December 2015 edition

General

This is a new document.

The rules enter into force 1 July 2016.

DNV GL
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16 000 professionals are dedicated to helping our customers make the world safer, smarter and greener.

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