



**BUREAU
VERITAS**

Fatigue of longitudinal connections under shear mode

November 2004

**Rule Note
NR 515 DTM R00 E**

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MARINE DIVISION

GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine Division (the "Society") is the classification ("Classification") of any ship or vessel or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- prepares and publishes Rules for classification, Guidance Notes and other documents ("Rules");
- issues Certificates, Attestations and Reports following its interventions ("Certificates");
- publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as "Certification".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as "Services". The party and/or its representative requesting the services is hereinafter referred to as the "Client". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisalment given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisalment is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisalment or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the performance of the requested Services.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are not a code of construction neither a guide for maintenance or a safety handbook.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - **The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.**

3.3. - The Services of the Society are carried out by professional Surveyors according to the Code of Ethics of the Members of the International Association of Classification Societies (IACS).

3.4. - **The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.**

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- conducts surveys at the place of their construction;
- classes Units and enters their class in its Register;
- surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - **The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.**

5.2. - **The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.**

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - **The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder, respectively.**

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - **If the Services of the Society cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee.**

The Society bears no liability for indirect or consequential loss such as e.g. loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - **Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. hereabove subject to compliance with 2.3. hereabove and Article 8 hereunder.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. - **Overdue amounts are increased as of right by interest in accordance with the applicable legislation.**

8.3. - **The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.**

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit;
- copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society Member of the International Association of Classification Societies (IACS) in case of the Unit's transfer of class;
- the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units are passed on to IACS according to the association working rules;
- the certificates, documents and information relative to the Units classed with the Society may be reviewed during IACS audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France.

12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. - **These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

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1. INTRODUCTION

The purpose of this document is to give the methodology to assess fatigue strength of welded and non-welded connections of longitudinal ordinary stiffeners with transverse primary members under shear mode, with a simplified approach. This approach requires various calculations: nominal stress ranges, geometric stress concentration factors and the elementary damage ratios. Examples of connection details are shown in appendices.

2. GENERAL

2.1. Application

Fatigue strength assessment under shear mode is to be carried out for ordinary stiffeners connections with transverse primary members, located on side shell between $0.7T_B$ and $1.15T$, for oil tankers and FPSO more than 250 m in length.

Where:

T_B = Ballast draught

T = Full load draught

2.2. Shear phenomenon

Cracks under shear mode are mainly due to both global and local phenomena:

- The bending of primary members is called hull girder phenomenon. Thus, according to beam theory, maximum shear stress appears at the neutral fibre which is usually closed to the cut out.
- The local phenomenon is due to the shear stress brought by the longitudinal under lateral pressure.

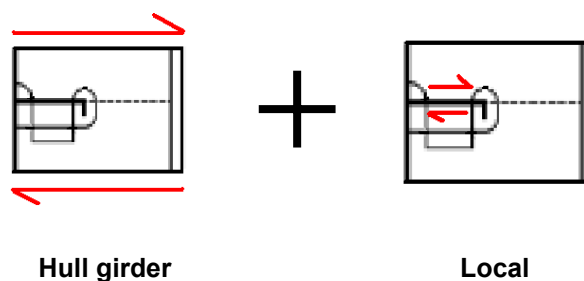
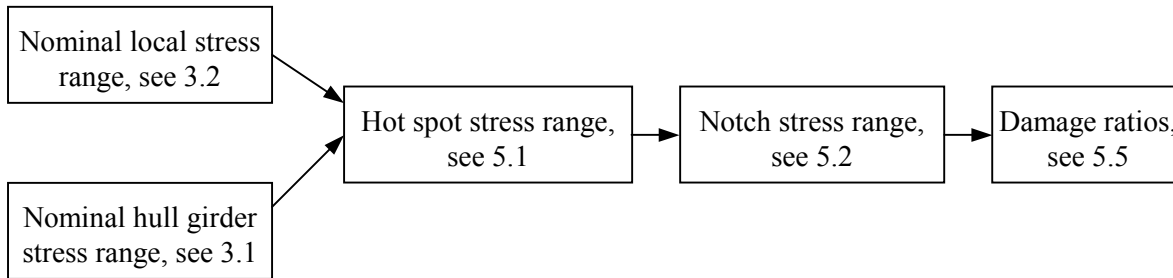


Figure 1 : Phenomenon of fatigue under shear mode

2.3. Fatigue strength assessment

The fatigue strength assessment under shear mode is normally performed by use of very fine mesh with FEM analysis. However, due to the great number of connections, a simplified approach based on nominal stress ranges, allowing extrapolations may be very useful. It is then strongly recommended to recalculate the most critical details with accurate FEM. The different steps of the simplified approach are summarized below:



3. NOMINAL STRESS RANGE CALCULATION

3.1. Nominal hull girder stress range

The nominal hull girder stress range is due to the bending of the primary member. Thus, nominal stress in this case is based on the maximum principal stress in the effective section of the primary structure.

The nominal hull girder stress range, in N/mm², is to be calculated for each load case and each loading condition with the following formula:

$$\Delta\sigma_{\text{Nom hg}} = \frac{h}{h'} \cdot \max \left\{ \left| \frac{\Delta\sigma_{xx} + \Delta\sigma_{yy}}{2} + \sqrt{\left(\frac{\Delta\sigma_{xx} - \Delta\sigma_{yy}}{2} \right)^2 + \Delta\tau_{xy}^2} \right|, \left| \frac{\Delta\sigma_{xx} + \Delta\sigma_{yy}}{2} - \sqrt{\left(\frac{\Delta\sigma_{xx} - \Delta\sigma_{yy}}{2} \right)^2 + \Delta\tau_{xy}^2} \right| \right\}$$

with:

- $\Delta\sigma_{\text{Nom hg}}$: Nominal hull girder stress range, in N/mm², due to hull girder shear stress in web frame
- $\Delta\tau_{xy}$: Shear stress range, in N/mm², in web frame calculated using a coarse mesh fatigue analysis.
- $\Delta\sigma_{xx}$: Compressive stress range, in N/mm², in web frame calculated using a coarse mesh fatigue analysis along the X local axis.
- $\Delta\sigma_{yy}$: Compressive stress range, in N/mm², in web frame calculated using a coarse mesh fatigue analysis along the Y local axis.

- h : Web frame height, in mm (see Figure 2).
- h' : Web frame height minus height of the cut out, in mm (see Figure 2 and Figure 3):
- $$h' = h - (d - v)$$

In case of opening such as manholes or lightening holes in primary members, the height of these openings should be deducted when determining h' except if the opening is modelled in the FE model.

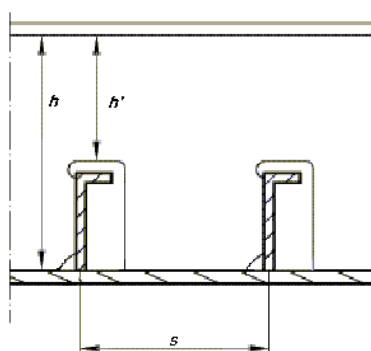


Figure 2 : Definition of h and h'

Note : a coarse model is a FEM with one element over the height of the web frame.

A fine mesh model, whose element size is around the value of the stiffener spacing, can also be used for determining the hull girder nominal stress but they should be considered on case by case basis. In case of double hull or double bottom they could be averaged over the distance h .

3.2. Nominal local stress range

3.2.1. Geometric parameters

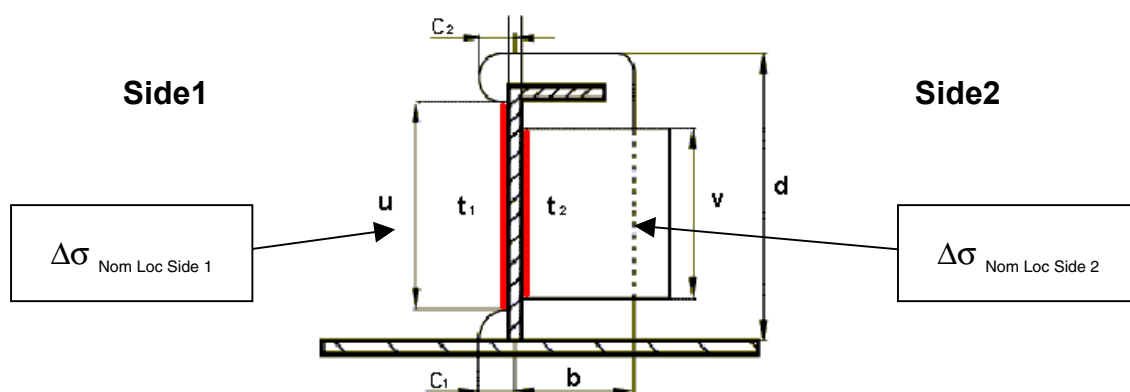


Figure 3: definition of geometric parameters

b, c_1, c_2, d, u, v : Dimensions of the cut-out, in mm, see Figure 3.

$c = \max(c_1; c_2)$,

t_1 : Thickness of the web frame, in mm, see Figure 3

t_2 : Thickness of the collar plate, in mm, see Figure 3

3.2.2. Calculation

The nominal local stress range, in N/mm², is to be calculated for each load case and each loading condition, depending on the side location (see Figure 3), with the following formulae:

$$\Delta\sigma_{\text{Nom Loc Side 1}} = \frac{10^3}{ut_1} sl \left(1 - \frac{s}{2l}\right) (1-k) \Delta P \frac{K_2}{K_1 + K_2} \left[\frac{3(c + 0.2d)}{2u} + \sqrt{1 + 9 \frac{(c + 0.2d)^2}{4u^2}} \right]$$

$$\Delta\sigma_{\text{Nom Loc Side 2}} = \frac{10^3}{vt_2} sl \left(1 - \frac{s}{2l}\right) (1-k) \Delta P \frac{K_1}{K_1 + K_2} \left[\frac{3(b + 0.2d)}{2v} + \sqrt{1 + 9 \frac{(b + 0.2d)^2}{4v^2}} \right]$$

with:

$$K_1 = \frac{c + 0.2d}{Gut_1} + \frac{(c + 0.2d)^3}{2Et_1u^3}$$

$$K_2 = \frac{b + 0.2d}{Gvt_2} + \frac{(b + 0.2d)^3}{2Et_2v^3}$$

$$\Delta P = |P_{\max} - P_{\min}|$$

$P_{\max}, P_{\min}$: Local lateral pressures, in N/mm², for each load case and each loading condition, cases “max” and “min”, constituted by still and dynamic local pressures.

E : Young modulus of steel (206 000 Mpa)

G : Coulomb modulus $G = \frac{E}{2(1+\nu)}$

ν : Poisson coefficient $\nu = 0.3$

s : Stiffeners spacing (see Figure 2), in m.