# SECTION 3 ADMISSIBLE STRESSES

## Symbols

SF : Safety factor

$R_{p0,2}$ : Minimum guaranteed yield stress, in N/mm$^2$

$R_m$ : Minimum breaking tensile strength, in N/mm$^2$.

$\sigma_{VM}$ : Combined stress calculated according to Von Mises criteria for steel or aluminium structures, and according to Tsaï-Wu criteria in case of composites structures.

## 1 General

### 1.1 Characteristics of materials

#### 1.1.1 Steel and aluminium

The characteristics of the materials to be used in the construction of ships are to comply with the applicable requirements of Rule Note NR216 Materials and Welding.

Materials with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

#### 1.1.2 Composites

The mechanical characteristics of a given laminate are deduced from the theoretical breaking strength of the elementary layer (reinforcements and resins), as given in [5].

### 1.2 Admissible stresses

**1.2.1** The admissible stress levels are depending on type of loads.

**1.2.2** The admissible stress values are given with reference made to:

- yield stress for steel and aluminium materials
- breaking strength for composites materials.

**1.2.3** The structure scantlings safety coefficients are taking into account the admissible stress values.

## 2 Types of stress

### 2.1 General

**2.1.1** As a rule, the notations used for the stresses are:

$\sigma$ : Bending stress, compression or tensile stress

$\tau$ : Shear stress.

**2.1.2** Following index are used depending of types of stress considered in the present Rules:

$\sigma_{am}$, $\tau_{am}$ : Design admissible values of stresses, as defined in the present Chapter

$\sigma_{gl}$ , $\tau_{gl}$ : Stresses resulting from global loads as defined in Part B, Chapter 6

$\sigma_{loc}$, $\tau_{loc}$ : Stresses resulting from local loads as defined in Part B, Chapter 7

## 3 Steel structures

### 3.1 Material factor k

#### 3.1.1 General

Unless otherwise specified, the material factor k has the values defined in Tab 1, as a function of the minimum guaranteed yield stress $R_{p0,2}$.

For intermediate values of $R_{p0,2}$, factor k may be obtained by linear interpolation.

Steels with a yield stress lower than 235 N/mm$^2$ or greater than 390 N/mm$^2$ are considered by the Society on a case by case basis.

**Table 1 : Material factor k**

| $R_{p0,2}$ , in N/mm$^2$ | k |
|---|---|
| 235 | 1,00 |
| 315 | 0,78 |
| 355 | 0,72 |
| 390 | 0,68 |

### 3.2 Admissible stresses

**3.2.1** The admissible stresses are calculated on basis of the yield stress value corresponding to ordinary steel and of material factor k, as indicated in Tab 2.

**3.2.2** The admissible stress values to be considered for specific component of the structure may be taken different from the values given in Tab 2. In such a case, the admissible stress values to be considered are indicated in the dedicated parts of the present Rules, dealing with the specific component under consideration.

## 4 Aluminium alloys for hull structure

### 4.1 Influence of welding on mechanical characteristics

**4.1.1** Welding heat input lowers locally the mechanical characteristics $R_{p0,2}$ and $R_m$ of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000), where:

**Table 2 : Admissible stresses for steel structures**

| Type of stress considered | Structural component considered | Design admissible stress (N/mm²) |
|---|---|---|
| Global stress induced by longitudinal hull girder loads **(1) (2)** | Plating | $\sigma_{glam} = 0,50 \cdot 235 / k$ |
| | | $\tau_{glam} = 0,40 \cdot 235 / k$ |
| | Stiffeners | $\sigma_{glam} = 0,50 \cdot 235 / k$ |
| | | $\tau_{glam} = 0,40 \cdot 235 / k$ |
| | Safety factor for buckling - plating and stiffeners | SF = 1,8 |
| Local stress induced by local hydrodynamic loads **(1) (2)** | Plating | $\sigma_{locam} = 0,70 \cdot 235 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,65 \cdot 235 / k$ |
| | | $\tau_{locam} = 0,40 \cdot 235 / k$ |
| | Safety factor for buckling - plating and stiffeners | SF = 1,8 |
| | Von Mises stress | $\sigma_{VMam} = 0,80 \cdot 235 / k$ |
| Local stress induced by slamming loads on bottom or by impact pressure on side shells **(2)** | Plating | $\sigma_{locam} = 0,75 \cdot 235 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,70 \cdot 235 / k$ |
| | | $\tau_{locam} = 0,45 \cdot 235 / k$ |
| Local stress induced by tank testing loads or by exceptional damage loads **(2)** | Plating | $\sigma_{locam} = 0,80 \cdot 235 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,80 \cdot 235 / k$ |
| | | $\tau_{locam} = 0,45 \cdot 235 / k$ |

**(1)** Admissible stress values indicated in this Table may be increased by 10% when a Finite Element Calculation is submitted to the Society.
**(2)** Admissible stress values indicated in this Table may be increased by 10% where stainless steels are used.

$R_{p0,2}$ : Guaranteed yield stress of the parent metal in delivery condition, in N/mm², as indicated by the supplier

$R_m$ : Guaranteed tensile strength of the parent metal in delivery condition, in N/mm², as indicated by the supplier.

**4.1.2** Consequently, where necessary, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone.

The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

**4.1.3** Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

**4.1.4** Aluminium alloys of series 5000 other than condition 0 or H111 are subject to a drop in mechanical strength in the welded areas.

The mechanical characteristics to consider are normally those of condition 0 or H111.

Higher mechanical characteristics may be taken into account, provided they are duly justified.

**4.1.5** Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas.

The mechanical characteristics to be considered are normally indicated by the supplier.

When no information is provided by the supplier, the values of Tab 3 may be used.

**Table 3 : Aluminium alloys**
**As welded mechanical characteristics**

| Aluminium alloy | Temper condition | $R'_{p0,2}$ **(1)** | $R'_m$ **(1)** |
|---|---|---|---|
| 5000 serie | 0 or H111 | $R_{p0,2}$ | $R_m$ |
| 5000 serie | Other | Values of 0 or H111 condition | |
| 6005 A (Open sections) | T5 or T6 | 0,45 $R_{p0,2}$ | 0,6 $R_m$ |
| 6005 A (Closed sections) | T5 or T6 | 0,50 $R_{p0,2}$ | 0,6 $R_m$ |
| 6061 (Sections) | T6 | 0,53 $R_{p0,2}$ | 0,6 $R_m$ |
| 6082 (Sections) | T6 | 0,45 $R_{p0,2}$ | 0,6 $R_m$ |
| 6106 (Sections) | T5 | 0,45 $R_{p0,2}$ | 0,6 $R_m$ |
| 6060 (Sections) **(2)** | T5 | 0,60 $R_{p0,2}$ | 0,6 $R_m$ |

**(1)** $R_{p0,2}$ and $R_m$ are defined in [4.1.1].
**(2)** 6060 alloy is mentioned therein, as it may be proposed by suppliers. However, this aluminium alloy is not accepted for yachts structure according to the present Rules, as it is not to suited to support slamming and impact loads and generally delivered without minimum mechanical characteristics guaranteed by the supplier.

### 4.2 Extruded plating

**4.2.1** Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

**4.2.2** In general, the application is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case by case basis.

**4.2.3** Extruded plating is preferably to be oriented so that the stiffeners are parallel to the direction of main stresses.

**4.2.4** Connections between extruded plating and primary members are to be given special attention.

### 4.3 Material factor k

**4.3.1** The material factor k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{100}{R'_{lim}}$$

where:

$R'_{lim}$ : Minimum of $R'_{p0,2}$ and $0,7 \cdot R'_m$, in N/mm²

$R'_{p0,2}$ : Minimum guaranteed yield stress of the parent metal in welded condition, in N/mm², determined according to [4.1.4] and [4.1.5]

$R'_m$ : Minimum guaranteed tensile strength of the parent metal in welded condition, in N/mm², determined according to [4.1.4] and [4.1.5].

**4.3.2** In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

### 4.4 Admissible stresses

**4.4.1** The admissible stress values are calculated according to Tab 4.

**4.4.2** The admissible stress values to be considered for specific component of the structure may be taken different from the values given in Tab 4. In such a case, the admissible stress values to be considered are indicated in the dedicated parts of the present Rules, dealing with the specific component under consideration.

## 5 Composites structures

### 5.1 General

**5.1.1** In the present Rules, the design review of composites structures is based on safety coefficients applied on the theoretical breaking stresses of the elementary layers (resin systems, fibres and reinforcements) used for the full lay-up laminates.

**5.1.2** The theoretical breaking stresses of elementary layers constituting the full lay-up laminate are to be determined as indicated in Ch 12, Sec 3, [5].

Theoretical breaking stresses of core materials used for sandwich laminates are given for general guidance in Ch 12, Sec 2, [4].

**5.1.3** The safety factors SF in each elementary layer are defined as being the ratio between the considered theoretical breaking stresses as mentioned in [5.1.2] and the applied stresses.

**Table 4 : Admissible stresses for aluminium structures**

| Type of stress considered | Structural component considered | Design admissible stress (N/mm²) |
|---|---|---|
| Global stress induced by longitudinal hull girder loads **(1)** | Plating | $\sigma_{glam} = 0,5 \;\; 100 / k$ |
| | | $\tau_{glam} = 0,45 \;\; 100 / k$ |
| | Stiffeners | $\sigma_{glam} = 0,5 \;\; 100 / k$ |
| | | $\tau_{glam} = 0,45 \;\; 100 / k$ |
| | Safety factor for buckling - plating and stiffeners | SF = 1,6 |
| Local stress induced by local hydrodynamic loads **(1)** | Plating | $\sigma_{locam} = 0,75 \cdot 100 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,7 \;\; 100 / k$ |
| | | $\tau_{locam} = 0,45 \;\; 100 / k$ |
| | Safety factor for buckling - plating and stiffeners | SF = 1,6 |
| | Von Mises stress | $\sigma_{VMam} = 0,9 \;\; 100 / k$ |
| Local stress induced by slamming loads on bottom or by impact pressure on side shells | Plating | $\sigma_{locam} = 0,8 \;\; 100 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,75 \;\; 100 / k$ |
| | | $\tau_{locam} = 0,5 \;\; 100 / k$ |
| Local stress induced by tank testing loads or by exceptional damage loads | Plating | $\sigma_{locam} = 0,9 \;\; 100 / k$ |
| | Stiffeners | $\sigma_{locam} = 0,9 \;\; 100 / k$ |
| | | $\tau_{locam} = 0,5 \;\; 100 / k$ |
| **(1)** Admissible stress values indicated in above Table may be increased by 10% when a Finite Element Calculation is submitted to the Society. | | |

## 5.2 Types of stress in the elementary layer

**5.2.1** Three stresses are considered corresponding to the loading mode of the fibres:

- Stress parallel to the fibre (longitudinal direction). These stresses may be tensile stresses or compressive stresses, and are mostly located as follows:
  - in 0° direction of unidirectional tape or fabric reinforcement systems
  - in 0° and 90° directions of woven roving

  In the present Rules, the corresponding notations are:
  - $\sigma_{LFT}$ in case of tensile stress
  - $\sigma_{LFC}$ in case of compressive stress
- Stress perpendicular to the fibre (transverse direction). These stresses may be tensile stresses or compressive stresses, and are mostly located as follows:
  - in 90° direction of unidirectional tape or combined fabrics when the set of fibres are stiched together without criss-crossing

  In the present Rules, the corresponding notations are:
  - $\sigma_{TFT}$ in case of tensile stress
  - $\sigma_{TFC}$ in case of compressive stress
- Shear stress parallel to the fibre. These shear stresses may be found in all type of reinforcement systems

  In the present Rules, the corresponding notation is $\tau_{F.}$

## 5.3 Breaking criteria

**5.3.1** Three breaking criteria are used in the present Rules:

a) maximum stress criteria leading to the breaking of the component resin/fibre of one elementary layer of the full lay-up laminate

b) Tsaï Wu (or Hoffman) combined stress criteria with the hypothesis of in-plane stresses

c) critical buckling stress criteria.

The breaking criteria defined in a) and b) are to be checked for each individual layer.

The breaking criteria defined in c) is to be checked for the global laminate.

**5.3.2** The Tsaï Wu (or Hoffman) combined stress criteria considered in the present Rules is defined as follows:

$$\left|\frac{\sigma_1^{\ 2}}{\sigma_{br1,T}\cdot\sigma_{br1,C}}+\frac{\sigma_2^{\ 2}}{\sigma_{br2,T}\cdot\sigma_{br2,C}}-\frac{\sigma_1\sigma_2}{\sigma_{br1,T}\cdot\sigma_{br1,C}}+\frac{\sigma_{br1,C}-\sigma_{br1,T}}{\sigma_{br1,T}\cdot\sigma_{br1,C}}\sigma_1+\frac{\sigma_{br2,C}-\sigma_{br2,T}}{\sigma_{br2,T}\cdot\sigma_{br2,C}}\sigma_2+\frac{\tau_{12}^{\ 2}}{\tau_{br12}^{\ 2}}\right|^{-1/2}\geq SF_{CS}$$

where:

$\sigma_1$, $\sigma_2$, $\tau_{12}$: Local stresses in the individual layer, in N/mm², expressed in local axis, as defined in Ch 12, Sec 4, [4.2.2]

$\sigma_{br1\ T}$, $\sigma_{br1\ C}$: Theoretical breaking stresses, in N/mm², respectively in traction and compressive, of the individual layer in the direction 1 of its local coordinate system, as defined in Ch 12, Sec 3, [5.2.1]

$\sigma_{br2\ T}$, $\sigma_{br2\ C}$: Theoretical breaking stresses, in N/mm², respectively in traction and compressive of the individual layer in the direction 2 of its local coordinate system as defined in Ch 12, Sec 3, [5.2.1]

$\tau_{br12}$ : Theoretical in-plane breaking shear stress, in N/mm², of the individual layer as defined in Ch 12, Sec 3, [5.2.1]

$SF_{CS}$ : Minimum admissible safety factor for combined stresses, as defined in [5.4.2].

Note 1:

For $\sigma_1$, $\sigma_2$, the values are positive in traction and negative in compressive.

For $\sigma_{br1\ T}$, $\sigma_{br1\ C}$, $\sigma_{br2\ T}$, $\sigma_{br2\ C}$, the values are to be taken positive in traction and also in compressive.

**5.3.3** It is considered that the full lay-up laminate breaking strength is reached as soon as the lowest breaking strength of any elementary layer is reached. This is referred to as "first ply failure".

## 5.4 Safety Coefficients

### 5.4.1 Application to maximum stress criteria

As a general rule, the minimum admissible safety factor SF applicable to maximum stress, considered in the present Rules is to be calculated as follows:

$SF = C_V\ C_F\ C_R\ C_I$

where:

$C_V$ : Coefficient taking into account the ageing effect of the composites. This coefficient is generally taken as 1,2 for monolithic laminates (or face-skins laminates of sandwich) and 1,1 for sandwich core materials

$C_F$ : Coefficient taking into account the fabrication process and the reproducibility of the fabrication. This coefficient is directly linked to the mechanical characteristics to be considered during a composites hull construction and is generally taken as 1,2 in case of a prepreg, or 1,3 in case of infusion and vacuum process, and 1,4 in case of a hand lay up process

$C_F$ is taken as 1,0 for the core materials of sandwich composites

$C_R$ : Coefficient taking into account the type of load carried out by the fibres of the reinforcement fabric. As a rule, this coefficient is taken as:

- 2,6 for a tensile or compressive stress parallel to the continuous fibre of the reinforcement fabric (unidirectional tape, bi-bias, three unidirectional fabric, woven roving)
- 1,2 for tensile or compressive stress perpendicular to the continuous fibre of the reinforcement fabric (unidirectional tapen bi-bias, three unidirectional fabric)

- 2,0 for a shear stress parallel to the fibre in the elementary layer and for interlaminar shear stress in the laminate
- 2,5 for a shear stress in the core material of sandwich laminate
- 2,0 whatever the type of stress in an elementary layer of mat type

$C_I$ : Coefficient taking into account the type of loads. $C_I$ is be taken equal to 1,0 for hydrodynamic sea pressure and 0,8 for slamming loads on bottom or impact pressure on side shell or for test pressure.

Note 1: For structural adhesive joint, see Ch 12, Sec 2, [5.2].

#### 5.4.2 Application to Tsaï Wu (or Hoffman) combined stress criteria

As a general rule, the minimum admissible safety factor $SF_{CS}$ considered for the combined stress in the present Rules (determined in [5.3.2]) is to be calculated as follows:

$SF_{CS} = 2,2\ C_V\ C_F$

where:

$C_F$ : Coefficient as defined in [5.4.1]

$C_V$ : Coefficient as defined in [5.4.1]

#### 5.4.3 Application to critical buckling stress criteria

As a general rule, the minimum admissible safety factor $SF_B$ considered in the present Rules is to be calculated as follows:

$SF_B = 3,8\ C_F$

where:

$C_F$ : Coefficient as defined in [5.4.1].

#### 5.4.4 Additional consideration on safety factors

In some cases, safety factors other than those defined in [5.4.1], [5.4.2] and [5.4.3] may be accepted for one elementary layer when the full lay-up laminate exhibits a sufficient safety margin between the theoretical breaking of this elementary layer and the theoretical breaking of the other elementary layers.