7 Explanations and notes to ISO 12215

7.1 Diving into the ISO 12215

The ISO 12215 Norm is a legal document including precise instructions to determine the scantling of a sailing or motor yacht. It includes several chapters, addressing different aspects of the scantling process:

1. **ISO 12215-2 and 3**: Materials.
2. **ISO 12215-4**: Shipyards and manufacturing.
3. **ISO 12215-5**: Monohulls with $L_H < 24m$. As a remainder:
   (a) We consider small leisure boats, including those for rental.
   (b) We consider small commercial and working boats.
   (c) Racing boats (designed for that purpose) are not considered
   (d) Concerning materials, we consider:
      - PRF, either monolithic or sandwich.
      - Non reinforced plastic hulls of $L_H < 6m$
      - Aluminum and steel alloys.
      - Glued wood or laminated board, not including traditional wood boat building.
4. **ISO 12215-6**: Structural devices and constructive details.
5. **ISO 12215-7**: Multihulls.
6. **ISO 12215-8**: Rudders.
7. **ISO 12215-9**: Keels and appendages for sailing yachts.
8. **ISO 12215-10**: Rig and masts.

7.2 Definition of plates and sections

At this stage we set the material for each plate or stiffener, the thickness of the former and the section and dimensions of the latter. The mechanical properties of these elements is also determined.

For composite materials, it is necessary to define the number and type of plies and, using formulas provided by the ISO 12215-5 Norm, calculate their mechanical properties, which depend to a large extent on the content of fiber.

Instructions for obtaining the mechanical properties of metals, wood and fibers are given in Appendices B, C and F. Appendix E deals with sandwich construction.

7.3 Composition and properties

A plate is assigned to each panel and a section to each stiffener. Depending on the mechanical properties of the plate or profile, the design stresses of the panel or stiffener are calculated according to the instructions in Table 17 of the ISO 12215-5.

7.4 Position in the hull

It has to be considered whether the elements belongs to the keel, bottom, side, or other area. Also, the longitudinal position of the element has to be defined as well as its situation with respect to waterline at the full loading condition.

Depending on the type of hull, other parameters are required such as the beam of the wetted deck, B_{WD}, the beam between hulls, B_{BH}, the height of the wetted deck with respect to the waterline, Z_{WDAx} (See figure 25), etc...

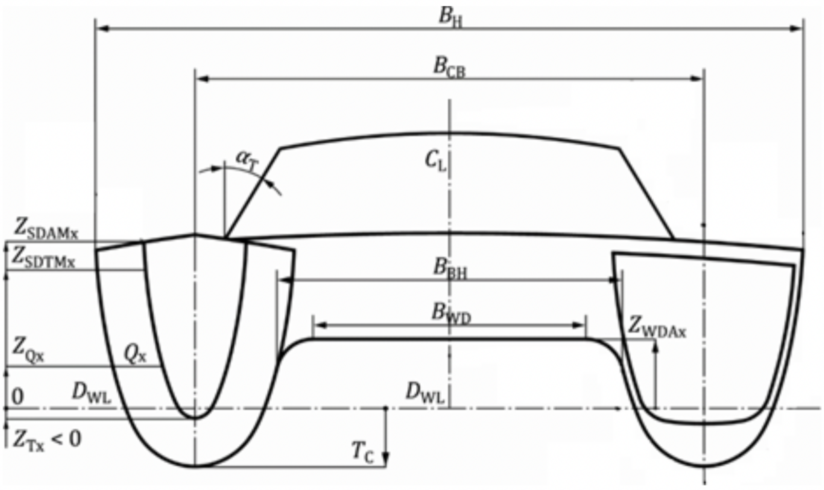

Figure 25: Parameters required in a multihull.

7.5 Design pressures

Design pressures represent the external loads that may affect the hull. There are a series of formulas to determine the design pressures, depending on several parameters:

1. Type of hull:
   - monohull,
   - multihull.
2. Type of propulsion:
   - motor yacht,
   - sailing yacht.
3. Longitudinal position of the element under study.
4. Hull zone:
   - keel,
   - bottom,
   - side,
   - bulwark,
   - superstructure,
   - bulkheads.

The design pressure is always computed by applying those factor to a base pressure value, $P_{BMDBASE}$, which depends only on the displacement at the full loading condition:

$$P_{BMD\ BASE} = P_{BMD\ BASE}(m_{LCD}) \tag{2}$$

This pressure is affected by different factors, that serve to adjust the pressure. Depending on the particularities of each case, the norm specifies the values of these factors.

For example, the design pressure, P_{BMD}, for the bottom of a motor boat in displacement mode, the formula is as follows:

$$P_{BMD} = \min \begin{cases} P_{BMD\ BASE}\, k_{AR}\, k_{DC}\, k_L, \\ P_{BM\ MIN}, \end{cases} \tag{3}$$

with

$$P_{BMD\ BASE} = 2,4\, m_{LDC}^{0,33} + 20, \tag{4}$$

and

$$P_{BM\ MIN} = \max \begin{cases} \left(0,45\, m_{LDC}^{0,33} + 0,9 L_{wl}\, k_{DC}\right)\, k_L\, k_L, \\ 10\, T_c, \\ 7. \end{cases} \tag{5}$$

in the case of plates, or

$$P_{BM\ MIN} = \max \begin{cases} 0,85\, P_{BM\ MIN}, \\ 7, \end{cases} \tag{6}$$

in the case of stiffeners. In the previous equation, $P_{BM\ MIN}$ is the maximum value of those obtained for the plates.

As it can be seen, the pressure is obtained from a base pressure, which is the exclusive function of the displacement at the full load condition of the ship, affected by a series of factors that take into account various circumstances. These are called **pressure adjustment factors**, for which the standard indicates the values to be adopted in each case:

1. Design category factor, k_{DC}.
2. Dynamic load factor, n_{CG}.
3. Longitudinal pressure distribution factor, k_L.
4. Transverse or longitudinal pressure adjustment factors for wet cover (multihulls)
5. Pressure reduction factor for superstructures, k_{SUP}.
6. Factor for the front slope of the roof (multihulls).
7. Transversal and longitudinal factors of adjustment for the wetted deck (multihulls), k_{BWD}, k_{LWDx}.
8. Pressure correction factor due to the effect of "salmming" on sailboats, k_{SLS}.
9. Deadrise factor (multihulls) that considers that the deadrise reduces pressure when a glide multihull gives unheeled pancakes, k_{DRx}.
10. Deck and wetted deck frontal slope factor for multihulls, k_{SDx}.

The design pressure differs depending on whether it is a motor boat or a sailboat. Structural bulkheads and tank bulkheads also have different formulas for calculating their design pressures, based on the load height h_B, as depicted in Figure 26.

7.6 Mechanical properties of structural elements

The mechanical properties of each plate or profile used are deduced from the ultimate stress (direct or shear) and Young's modulus of the material. Sometimes, the yielding limit could also be used.

In the case of metal materials, the breaking stress must be applied before or after welding, depending on the type of joint chosen.

The values thus deduced are also affected by a number of factors:

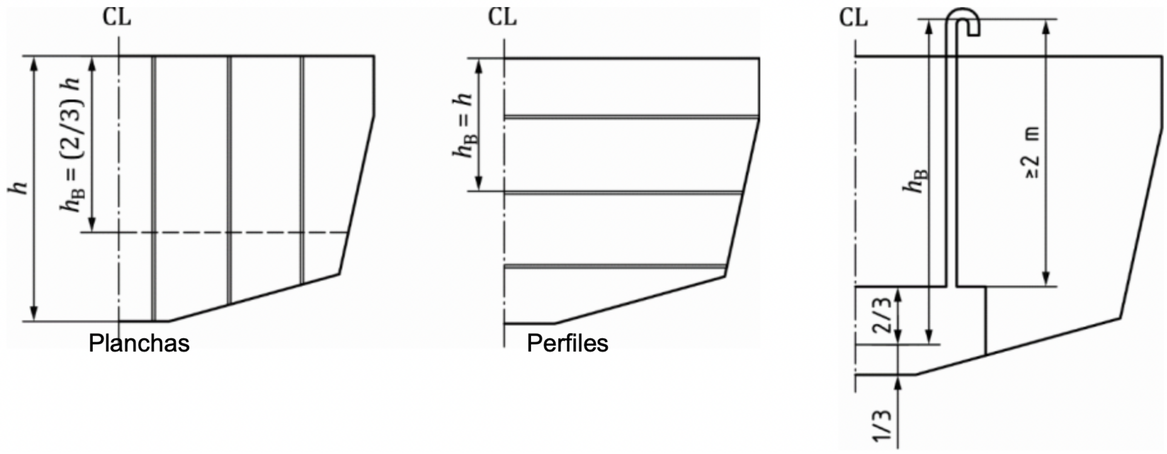

Figure 26: Load height h_B.

- Quality factor of the construction, k_{BB} (only in composite materials), which differs depending on the quality of the considered procedure: tested, enhanced or low.
- Factor for the evaluation method, k_{AM}, which aims to "balance" the results of different evaluation methods, ensuring that the most simplistic methods give more conservative results than the most technologically advanced methods:
  1. "Simplified" Method.
  2. "Enhanced" Method (ply-by-ply analysis).
  3. "Developed" method.
  4. "Direct Test" method.
  5. Calculations based on the "Finite Element Method".

So, the general process for any laminate formed by different plies follows two steps:

1. Obtain the mechanical properties of each individual ply.
2. Use the following formulae to get the properties of the whole laminate:

$$\begin{cases} w &= \sum_i w_i, \\ t &= \sum_i t_i, \\ E &= \frac{\sum_i E_i\, t_i}{t}, \\ G &= \frac{\sum_i G_i\, t_i}{t}, \\ \psi &= \frac{\sum_i \psi_i\, w_i}{w}, \\ \rho_f &= \frac{\sum \rho_i\, t_i}{t}, \end{cases} \tag{7}$$

where the sub-index i indicatee the ply. A detailed example of the computations described in this section is given in section 9

7.7 Design stresses

Once the ultimate stresses have been computed, Table 17 shows the formulas used to obtaining the design stresses for plates and stiffeners depending on the material.

Design stresses are the maximum values to which a structural element can be subjected. They are deduced by applying a safety coefficient (between 0.4 and 0.7) to the ultimate stress and applying, in addition, the quality factor of the k_{BB} construction (Table 15) and the factor by the evaluation method k_{AM} (Table 16).

7.8 Obtention of requirements

Formulas are provided to obtain the **shear force** and the **design bending moment**, which are different depending on whether they are plates or profiles.

The Norm provides in Table A.4 (ISO 12215-5) formulae to compute both the design shear force and the design bending moment in the case of panels with fully fixed edges (FF) at their boundaries. These formulae depend on whether the bending moment is considered in the largest or the shortest direction of the panel. As an example, we give the design shear force and corrected design bending moment n the l direction:

$$F_{dl} = k_c \, k_{SHl} \, P \, b \sqrt[4]{\frac{EI_l}{EI_b}} \, 10^{-3}, \tag{8}$$

$$M_d = \left(-\frac{1}{6} \, k_{2l} \, P \, b^2 \sqrt{\frac{EI_l}{EI_b}} \, 10^{-3} \right) k_c. \tag{9}$$

In these formulas, P stands for the **design pressure** and b is the shortest dimension of the panel. Also, several "adjustment factors" are considered:

1. k_2 and k_{SH} are function of the effective aspect ratio of the panel, EA_R, and are given in Table A.2 o the Norm. These factors are specific to the dimension of the panel, so one has k_{2b}, k_{2l}, k_{SHb} and k_{SHl}.

2. k_c, the transverse and longitudinal curvature of the panel (Given in Table A.3) as a function of the curvature. More details about the measurement of the curvature are given below .

3. k_{CS}, the curvature of the stiffener (Table A.10).

4. k_{SF} and k_{BM}, position in the stiffener and type of junction at the end (Table A.8).

Regarding the curvature of panels and stiffeners, it is modeled by the factor k_c, given in Table A.3 of the Norm. That table gives the values of k_c as a function of c_b/b and c_l/l (see Figure 27).

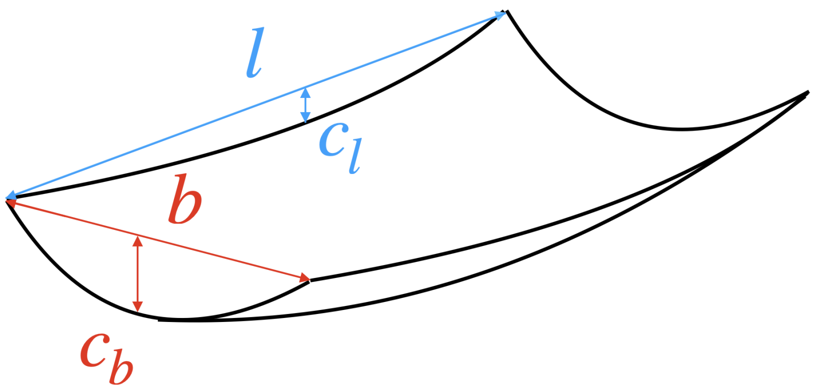

Figure 27: Measurement of the curvature of the panel.