FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 12215-10

ISO/TC **188**

Secretariat: SIS

Voting begins on:
2019-11-26

Voting terminates on:
2020-01-21

Small craft — Hull construction and scantlings —

Part 10: Rig loads and rig attachment in sailing craft

Petit navires — Contruction de la coque et échantillonnage —

Partie 10: Charges dans le gréement et points d'attache du gréement dans les bateaux à voiles

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Reference number
ISO/FDIS 12215-10:2019(E)

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Foreword

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This document was prepared by ISO/TC 188, *Small craft*.

A list of all parts in the ISO 12215 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The reason underlying the preparation of the ISO 12215 series is that scantlings rules and recommended practices for small craft differ considerably, thus limiting the general worldwide acceptability of craft.

This document has been set towards the minimal requirements of the current practice.

The dimensioning according to this document is regarded as reflecting current practice, provided the craft is correctly handled in the sense of good seamanship and equipped and operated at a speed appropriate to the prevailing sea state.

This document is not a design standard and designers/builders are strongly cautioned from attempting to design craft such that nearly all structural components only just comply.

The connection between the rig attachment and the structure is required to be stronger than the rig attachment itself. It is therefore considered that unforeseen overload will not entail its detachment from the structure, and that the watertight integrity will be maintained.

Small craft — Hull construction and scantlings —

Part 10:
Rig loads and rig attachment in sailing craft

1 Scope

This document specifies methods for the determination of:

— the design loads and design stresses on rig elements; and

— the loads and scantlings of rig attachments and mast steps/pillars;

on monohull and multihulls sailing craft.

It also gives, in Annexes, "established practices" for the assessment of mast steps/pillars or chainplates

NOTE 1 Other engineering methods can be used provided the design loads and design stresses are used.

This document is applicable to craft with a hull length L_H up to 24 m but it can also be applied to craft up to 24 m load line length.

NOTE 2 The load line length is defined in the OMI "International Load Lines Convention 1966/2005", it is smaller than L_H. This length also sets up, at 24 m, the lower limit of several IMO conventions.

Scantlings derived from this document are primarily intended to apply to recreational craft, including charter vessels.

This document is not applicable to racing craft designed only for professional racing.

This document only considers the loads exerted when sailing. Any loads that may result from other situations are not considered in this document.

Throughout this document, and unless otherwise specified, dimensions are in (m), areas in (m^2), masses in (kg), forces in (N), moments in (N m), stresses and elastic modulus in N/mm^2 (1 N / mm^2 = 1 Mpa). Unless otherwise stated, the craft is assessed in fully loaded ready for use condition.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3506-1:—[1)], *Mechanical properties of corrosion-resistant stainless steel fasteners — Part 1: Bolts, screws and studs*

ISO 12215-5:2019, *Small craft — Hull construction and scantlings — Part 5: Design pressures for monohulls, design stresses, scantlings determination*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) Under preparation. Stage at the time of publication: ISO/FDIS 3506-1:2019.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
design categories
description of the sea and wind conditions for which a craft is assessed to be suitable

Note 1 to entry: The design categories are defined in ISO 12217 (all parts).

Note 2 to entry: The definitions of the design categories are in line with the European Recreational Craft Directive 2013/53/EU.

[SOURCE: ISO 12215-5:2019, 3.1]

3.2
loaded displacement
m_{LDC}
mass of water displaced by the craft, including all appendages, when in the fully loaded ready-for-use condition

Note 1 to entry: The fully loaded ready-for-use condition is further defined in ISO 8666.

[SOURCE: ISO 12215-5:2019, 3.2]

3.3
sailing craft
craft for which the primary means of propulsion is wind power

Note 1 to entry: It is further defined in ISO 8666.

[SOURCE: ISO 12215-5:2019, 3.3, modified — Note 2 to entry deleted.]

3.4
monohull
craft with only one hull

3.5
multihull
craft with two or more hulls with a connecting wet deck/platform or beams above the loaded waterline, as opposed to a tunnel boat or scow

3.6
mast step
element fitted at the bottom of the mast that supports the mast compression and transmits it to the rest of the structure

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mast pillar
pillar
in a deck stepped rig, structural element that transmits the mast compression to the rest of the structure

3.8
chainplate
rig attachment
component(s) to which the rig elements are attached, transmitting their load to the rest of the structure, including tie rods where relevant

EXAMPLE Metal chainplate, strapped composite chainplate, Note 1 to entry: See Annex D.

3.9
connection
<of mast step, pillar or chainplate to the structure> all elements or group of elements connecting the rig attachment to the structure of the craft

EXAMPLE Bolts, lamination.

Note 1 to entry: Some of these elements can be part of the chainplate.

3.10
m_{LDC} condition
maximum load condition corresponding to the *loaded displacement* (3.2)

4 Symbols

Unless specified otherwise, the symbols, factors and parameters given in Table 1 apply.

Table 1 — Symbols, factors, parameters

Symbol	Unit	Designation/Meaning of symbol	Reference
1 - Main dimensions of the craft			
B_{CB}	m	Beam between centers of buoyancy: between center of buoyancy of hulls, for catamarans; and between C_B of center hull and C_B of float, for trimarans	Table 5, Fig 3
B_{CP}	m	Beam between chainplates (from port to starboard)	Table C.1, Fig 3
B_H	m	Beam of hull	It 1 of Table 5
GZ_{30}	m	Righting lever at 30° heel for monohulls	Table 5
L_{WL}	m	Length of waterline in m_{LDC} condition	7.5, Table 10
V_{CG}	m	Height of craft center of gravity above T_C bottom	Table 5, Fig 3
m_{LDC}	kg	Loaded displacement mass (3.2) or condition (3.10)	3.2, Clause 13
n_{PH}	1	Number of persons hiking	It 1 of Table 5
T_C	m	Draught of canoe body	Table 5, Fig 3
2 - Main dimensions of the rig and connected data			
A_i	m^2	Sail area, index *i* defining the sail name or combination	Tables 5 to 8 etc.
F_{Ai}	N	Aerodynamic force, index *i* defining which force it corresponds to	Tables 5 to 8
F_{DMC}	N	Design compression force on single mast step/pillar	8.4. Annex C
F_{DMCi}	N	Design compression force on mast step/pillar of two-masted rig where index *i* = 1 or 2	8.4. Annex C
M_D	Nm	Design moment under sail	Tables 5 and 6
M_{Hi}	Nm	Heeling moment, where index *i* = $_{UP, MAX, BROACH, DOWN,}$	Tables 5 and 6
M_{Ri}	Nm	Righting moment, where index *i* = $_{UP,\ \phi UP,\ MAX}$	Table 5
$V_{ACEK\ i}$	knots	Design apparent wind speed, in knots, at the center of area of sails, where index *i* stands for sail configuration S_{Ci}	Tables 5 and 7
$V_{ACEM\ i}$	m/s	Design apparent wind speed, in m/s, at the center of area of sails, where index *i* stands for sail configuration S_{Ci}	Tables 5 and 7
$V_{AMT\ i}$	m/s (knots)	Design apparent wind speed at mast top, where index *i* stands for sail configuration S_{Ci}	Note 5 in Table 5
See Table 8 for detailed dimensions of rig, areas, etc.			

Table 1 *(continued)*

Symbol	Unit	Designation/Meaning of symbol	Reference
3 - Factors			
k_{DCR}	1	Design category factor for rig	It 5 of Table 3
k_{DSR}	1	Dynamic sail and rig factor	It 1 of Table 10
k_{HF}	1	Foresail center of pressure height factor	It 1of Table 9
k_{HMS}	1	Mainsail center of pressure height factor	It 3 of Table 9
k_{LC}	1	Load case factor	Tables 3 and 7
k_{MAT}	1	Material factor	It 3 of Table 3
k_{ROACH}	1	Roach factor	Table 8
k_{SAGF}	1	Forestay or inner forestay sag factor = stay sag sagitta/stay length	It 3 of Table 10
k_{SAGM}	1	Mainsail leech sag factor	It 3 of Table 10
k_{ϕ}	1	Factor assessing heel angle of multihulls	It 1 of Table 5
4 - Other variables			
S_{Ci}	1	Sail configuration where *i* is the configuration index	Table 7
S_{Fi}	1	Safety factor against *i*, the index *i* being y (yield) or u (ultimate)	Table 4
s_i, σ_i, τ_i	N/mm^2	Direct or shear stress, where *i* may be LIM, u, uw, yw, uc, ut, uf	Table 3
ϕ	degree	Heel angle, which may be 30° for monohulls or ϕ_{LIM} for multihulls	Table 5

5 Application of the document

5.1 General

This document allows the determination of the design loads and design stresses on rig elements of sailing small craft to assess the design loads on mast step/pillar and chainplates and their connection to the craft's structure:

1) by a simplified method, or

2) by a developed method.

These methods are defined step by step in Table 2.

The developed method also allows to determine the rig loads needed to assess the global loads in the structure of multihulls in ISO 12215-7:—[2)].

5.2 The simplified method

Clause 14 requires that the mast/rig manufacturer provide the design load on mast steps/pillars and on each rig element, the dimensions of end fittings, etc. assessed according to 7.1.3. If this information is not available, the "Simplified method" applies through "Established practice" Annexes: Annex C for "basic" or "enhanced" methods for mast steps/pillars, or Annex D for chainplates or their connections.

5.3 The developed method

This method involves the full determination of the design loads on mast steps/pillars and on each rig element, the dimensions of end fittings, etc. assessed according to Clause 7. The assessment of the mast step(s), mast pillar(s), chainplates, and their connections to the craft shall then be checked either by the

2) Under preparation. Stage at the time of publication: ISO/FDIS 12215-7:2019.

"Established practice" methods of Annexes C and D or by any relevant engineering method, including finite elements methods (FEM).

NOTE The actual dimensioning of mast and rig being a complex mast bending and buckling problem, where the tuning of rig elongation is paramount, mast scantlings are purposely left out of the scope of this document, even if the values of the loads defined is a useful information.

5.4 Steps of the methods and corresponding clauses of this document

Table 2 sums up the steps for both methods and gives the corresponding Clauses of this document.

Table 2 — Assessment methods

Step	Methods	Clause & Table
	1- SIMPLIFIED METHOD for mast step/pillar or chainplate	5.2
1.1	Design stress determination	Clause 6 and Table 3
1.2	If no information is available from the mast/rig manufacturer/provider, the "Established practice" methods of Annex C -"basic" or "enhanced"- allow a simple determination of the design compression force F_{DMC} and scantlings of mast steps/pillars and their connections to the structure. Tables C.4 and C.5 also give examples of mast step/pillar floor calculation according to the design force.	Annex C
1.3	For chainplates and their connection, use the "Established practice" of Annex D	Annex D
1.4	Structural components to be assessed – mast step or chainplate	Clause 9
1.5	Use of the Annexes for the simplified method	Clause 10
1.6	Application of this document and application sheet	Clause 12, Annex A
1.7	Information in the owner's manual	Clause 13
1.8	Information to be given to the boatbuilder from rig/mast manufacturer/provider	Clause 14
	2- DEVELOPED METHOD for rig load, mast step/pillar or chainplate Computation of all the loads in the rig	5.3
2.1	Design stress determination	Clause 6 and Table 3
2.2	Developed method - General assessments, design moment Determination of the design moments/forces according to sail configuration S_{Ci}: — Formulas for the determination of upwind design moments and forces — Formulas for the determination of downwind design moments and forces — Sail configurations, design heeling/righting moments and apparent wind speed — Rig dimensions and default values for dimensions, areas and point of application — Transverse forces on sails	Clause 7 and: 7.2 and Table 5 7.2 and Table 6 7.2 and Table 7 7.3 and Table 8 7.5 and Table 9
2.3	Design loads in rigging elements: — Forces in forestay, inner forestay, mainsail leech and halyards — Forces in backstay or running backstay or equivalent	Clause 8 and: 8.2 and Table 10 8.3 and Table 10
2.4	Structural components to be assessed – mast step or chainplate	Clause 9
2.6	Application of the developed method	Clause 11
2.7	Application of this document and application declaration	Clause 12, Annex A
2.8	Information in the owner's manual	Clause 13
2.9	Information to the boatbuilder	Clause 14

6 Simplified and developed methods — Design stresses

6.1 General

The design stresses defined in Table 3 shall be used.

NOTE They are similar to those used in ISO 12215-9:2012, except that the dynamic factor for rig k_{DSR} increases the loads for light craft and therefore have a "dynamic behavior", see Item 1 of Table 10.

This document differentiates two types of load cases: "Normal" and "Exceptional", see 7.1, which means two different design stresses.

The stresses are obtained by multiplying, where relevant, see Tables 2 and 3, the actual stresses σ_{act}, $\tau_{act,}$ etc. by k_{DSR}, and they shall not be greater than the design stresses σ_d, τ_d, etc.

The “limit” stresses σ_{LIM} or τ_{LIM} are given in Table 3 and correspond to the following stress states:

— for metals, the one-letter indexes for the stresses below are: y, for yield, and u, for ultimate; the second character of the two-letter indexes is w, for welded state within heat affected area (see table footnote a in Table 3),

— for FRP and wood, the second character of the indexes, u, means ultimate stress; the first character respectively is t, for tensile, c, for compressive, and f, for flexural or bearing stress.

The sources for the values of these stresses, i.e. σ_y, σ_u or τ_u for non-welded metals, or σ_{yw}, σ_{uw} or τ_{uw} for welded metals in heat affected zones, or σ_{tu}, σ_{cu}, σ_{fu}, σ_{bu} or τ_u for wood and FRP shall be:

— either the "default" values according to Annexes B or D or to written data provided by the rig manufacturer/provider;

— for other metals than the ones used in rig, according to Annex B for the listed metals, or documented values for other metals, from a recognized standard, or from tests made according to a recognized standard;

— for FRP or wood/plywood, respectively according to Annexes C or F of ISO 12215-5:2019.

Table 3 — Design stress and adjustment factors

1 - Design stress		
σ_d or τ_d	$\sigma_d = \sigma_{LIM} \times k_{MAT} \times k_{LC} \times k_{DCR}$, or $\tau_d = \tau_{LIM} \times k_{MAT} \times k_{LC} \times k_{DCR}$ at yield, or ultimate, and bearing, as relevant, see 6.1 where the adjustments factors are defined below	
2 – Limit stress		
Limit stress	**Material / designation**	**Value**
σ_{LIM} or τ_{LIM}	Metals, unwelded or well clear of heat affected zones[a,b,c]	$\sigma_{LIM} = \min(\sigma_y;0,5\ \sigma_u)$ or $\tau_{LIM} = \min(\tau_y;0,5\ \tau_u)$
	Metals, within heat affected zones, in welded condition[a,b,c]	$\sigma_{LIM} = \min(\sigma_{yw};0,5\ \sigma_{uw})$ or $\tau_{LIM} = \min(\tau_{yw};0,5\ \tau_{uw})$
	Wood or FRP as dictated by sense of applied stress	$(\sigma_{uc}, \sigma_{ut}, \sigma_{uf}, \sigma_{uc}, \sigma_{uc}$ and $\tau_u)$[c] as relevant
3 - Stress factor for material k_{MAT}		
k_{MAT}	Metals with elongation at break $\varepsilon_R \geq 7$ %	$k_{MAT} = 0,75$
	Metals with elongation at break $\varepsilon_R < 7$ %	$k_{MAT} = \min(0,062\ 5\ \varepsilon_R + 0,312\ 5;0,75)$[d]
	Wood and FRP	$k_{MAT} = 0,33$

Table 3 *(continued)*

4 - Values of load case factor k_{LC},[e],				
		Type of load:	normal	exceptional
k_{LC}	Mast/rig	Metal	(1,11)	(1,33)
	Rig	Pure fibre	(1,30)	(1,56)
	Mast/rig	FRP or wood	(1,20)	(1,44)
	Step of mast/pillar, chainplate	Metal	1,10	1,32
	Step of mast/pillar, chainplate	FRP/Wood	1,05	1,26
	Strapped FRP chainplates	(UD straps only)[f]	0,35	0,42
	Connection of above to structure	Metal	0,92	1,10
	Connection of above to structure	FRP/wood (bolts, screws, etc.)	0,88	1,05
	Connection of above to structure	FRP co-cured or glued[f]	0,83	1,00
5 - Values of design category factor for rig k_{DCR}				
k_{DCR}	Craft of design categories A and B		1,00	
	Craft of design categories C and D		1,25	

[a] Generally the heat affected zone is considered within 50 mm from welds.

[b] For metals, τ = 0,58 σ often rounded to 0,6 as in EN 1993.

[c] Bearing stress depends on material type and dimensions. Item 4 of Tables D.6 or D.7 give recommended values. (See References [13] and [15]).

[d] The formula gives 0,75 for $\varepsilon_R \geq 7$ % (e.g. main building metals and ductile cast iron) and 0,375 for $\varepsilon_R < 7$ % for lamellar graphite cast iron, with linear interpolation in between.

[e] The design stresses correspond either to "normal" or "exceptional" cases in Table 7, the "exceptional" stresses are 120 % the "normal "stresses i.e. the safety factor is 83 % of normal stresses. The "normal" design loads for mast step/pillar or chainplates are 120 % of the ones for mast/rig, and the values of connection of mast step/chainplate to the structure is again 120 % of the mast step/chainplate i.e. 144 % of mast/rig loads. k_{LC} varies as the inverse of these ratios (see Table 4 for explanations).

[f] The values for the UD of strapped chainplate are low to take into account stress raisers during the UD path around the pin bushing, but this is not necessary for the co-curing/gluing of the whole chainplate, provided the correct glue allowable shear stress is valid, see D.6.

NOTE The design stresses in Table 3 and safety factors (S_{Fu} or S_{Fy}) in Table 4 and loads for rig and mast elements are between brackets, for information only, as they are not covered by this document. The safety factor at ultimate is stated (2,4) for metal rig) but in practice it frequently varies between 2 and 3,5 for monohulls according to the practice of the builder/designer and the type of craft racing/cruising. For light multihulls if may go down to 1,5 for the ones that "lift a hull" as this situation is non-frequent (exceptional) except for sheer sports multihulls. In addition, the rig is frequently much stronger than stated to limit rig elongation for mast stability reasons, particularly for non-metal rigging system.

NOTE The lowering of k_{LC} (or increase of safety factor S_F) from rig load to mast step/chainplate, then their connection to structure ensures that the mast step/chainplate connection will be stronger that the mast compression/rig tension (i.e. the chainplate shall break after the rig), taking due consideration to the uncertainties of calculation of the connection effective stresses.

6.2 Design load vs safety factor

The applicable limit stresses in the first row of Table 3 are multiplied by several factors like k_{DCR}, design category factor, k_{MAT}, material factor, and k_{LC}, load case factor. As many users or regulations refer to safety factors, S_F, for comparison purposes Table 4 transforms the requirements of Tables 2 and 3 in terms of safety factors or equivalent. Taking R_y and R_u as respectively the yield and ultimate strength of a structural element, and F_{RIG} as the load in a rig element, it gives in the rows of Metal or FRP respectively the ratio R_y/F_{RIG}, or R_u/F_{RIG} with, special consideration for metal whether $\sigma_y > 0{,}5\ \sigma_u$ or $\sigma_y \leq 0{,}5\ \sigma_u$.

For simplicity, Table 4 only calculates in column 7 the safety factor at ultimate $S_{FU} = 1/(\sigma_d/\sigma_u)$, and in column 8 the ratio $S_{FU}/S_{FU\ RIG}$ for "normal "load cases, showing the progression of the safety factors

