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Mala plovila - Konstrukcija trupa in zahtevane lastnosti - 9. del: Dodatni pribor jadrnic (ISO/DIS 12215-9:2024)

Small craft - Hull construction and scantlings - Part 9: Sailing craft appendages (ISO/DIS 12215-9:2024)

Kleine Wasserfahrzeuge -Rumpfbauweise und Dimensionierung– Teil9: Anhänge von Segelbooten (ISO/DIS 12215-9:2024)

Petits navires - Construction de coques et échantillons - Partie 9: Appendices des bateaux à voiles (ISO/DIS 12215-9:2024)

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Part 9: Sailing craft appendages

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO *[had/~~had not~~]* received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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This document was prepared by Technical Committee ISO/TC 188, *Small craft*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 464, *Small Craft*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 12215-9:2012), which has been technically revised.

The main changes are as follows:

— Editorial changes throughout to improve format, language, consistency, clarity, interpretation, readability, acknowledgement of current practice and compliance with this part of the standard

— The addition of consideration of canting keel actuator and keel support structure to Table 3

— Compliance: Annex A shall be completed in all instances. Wording has been clarified.

— The addition of qualified backing plate diameter and thickness treatment in the case of reduced hull thickness in Table D.2

— A specific caution about bolt proximity to welds in Clause D.4.7

— Re-assessment of Annex F *Simplified fatigue strength* assessment, doubling the operational life to 16 million stress cycles and associated MSF calculation

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

This document recognises the importance of adequate scantlings, construction practice and condition assessment for sailing craft appendages, principally the ballast keel.

The loss of a ballast keel leading to craft capsize is one of the major casualty hazards on sailing craft and therefore the structural effectiveness of all elements of the keel and its connection to the craft is paramount.

This document specifies the design loads and their associated stress factors. The user (e,g, the designer or builder) then has a choice of two options to assess the structural arrangement:

a) Use of computational methods which allow the structure to be modelled three-dimensionally. Methods include finite element analysis, matrix displacement or framework methods, **following which Annex A shall be completed for compliance**. General guidance is provided on modelling assumptions within Clause 8 of this document.

or

b) Use of simplified two-dimensional stress formulae. These are presented in Annexes B to F and, if this option is chosen, use of all applicable Annexes will be necessary to fulfil the requirements of this document, **following which Annex A shall be completed for compliance**.

This document has been developed in consideration of current practice and sound engineering principles. The design loads and criteria of this document may be used with the scantling determination formulae of this document or using equivalent engineering methods as indicated in a) above.

This document reflects current practice, provided the craft is correctly handled in accordance with good seamanship, is well designed and built[1)], maintained, equipped and operated at a speed appropriate to the prevailing sea state. Inspection of all appendages after grounding is essential.

Racing craft are not the principal focus of ISO 12215. In particular, users are strongly cautioned against attempting to design scantlings for racing craft such that scantlings only just comply.

Annex J of ISO 12215-5:2019 provides additional requirements for commercial craft and workboats. The principles of these requirements may also be considered applicable to craft that engage in racing, where their usage conditions warrant an independent maintenance and survey program set up by a qualified organization. This is further discussed in Clause 9 of this document.

1) Compliance with this document will not ensure a satisfactory design in all cases nor absolve the user, such as the designer or builder, of their design responsibilities, with whom such responsibilities are entirely vested.

Small craft — Hull construction and scantlings —

Part 9:
Sailing craft appendages

1 Scope

This document defines the loads and specifies the scantlings of sailing craft appendages on monohull sailing craft with a length of hull (L_H) measured according to ISO 8666 or a load line length (see NOTE 1 in Clause 1 of ISO 12215-5) of up to 24 m. It gives:

— design stresses,

— the structural components to be assessed,

— load cases and design loads for keel, centreboard and their attachments,

— computational methods and modelling guidance, and

— the means for compliance with its provisions.

2 Normative references

The following referenced documents are indispensable for the application 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. Dated versions are intended where this part makes direct reference to a section in that dated part of ISO 12215.

ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread*

ISO 3506-1, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes*

ISO 8666, *Small craft — Principal data*

ISO 12215-3, *Small craft — Hull construction and scantlings — Part 3: Materials: Steel, aluminium alloys, wood, other materials*

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

ISO 12215-6:2008, *Small craft — Hull construction and scantlings — Part 6: Structural arrangements and details*

ISO 12217-2, *Small craft — Stability and buoyancy assessment and categorization — Part 2: Sailing boats of hull length greater than or equal to 6 m*

3 Terms and definitions

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

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

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

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

3.1
design category
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 design categories are in line with the European Recreational Craft Directive 2013/53/EU.

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

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

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.

3.4
mass of keel
m_{KEEL}
mass of the ballast keel, i.e. keel fin plus bulb, where fitted, and, for twin or multiple keels, of a single keel

Note 1 to entry: The mass of keel is expressed in kg.

4 Symbols

For the purposes of this document, unless specifically otherwise defined, the symbols given in Table 1 apply.

Table 1 — Nomenclature

Symbol	Unit	Designation/meaning of symbol	Ref/Subclause
A_{CB}	m^2	Area of fully deployed centreboard	7.7.1
A_S	m^2	Reference sail area (mainsail + fore triangle + wing mast) as per ISO 12217-2	7.7.1
a	m	Distance along keel centreline, from centre of gravity (CG) of keel to keel junction with hull or tuck	7.2
b_f	mm	Overall breadth of the appendage aerofoil section	E.1
c	m	Distance along keel centreline from keel junction to floor mid-height	7.2
c_a	m	Average value of c for several floors	7.5.1
e	m	Proportion of the total side force taken by the centreboard	7.7.1
F_i	N	Design force with i according to load case	7
g	m/s^2	Acceleration of gravity = 9,81 m/s^2	7
h_{CE}	m	Height of centre of area of A_S	7.7.1
h_K	m	Height of keel between its bottom and hull connection	7.5.1
h_{F4}	m	Height of application of force F_4 (load case 4)	7.5.1
I_L	cm^4	Longitudinal second moment appendage aerofoil section	E.2.2
k_{DC}	–	Design category coefficient	5, Table 2
k_f	–	Appendage section shape factor	Table E.1

Table 1 *(continued)*

Symbol	Unit	Designation/meaning of symbol	Ref/Subclause
k_{f1}	–	Appendage section shape factor	Table E.1
k_{LC}	–	Load case coefficient	5, Table 3
k_{LD}	–	Length displacement coefficient	7.7.1
k_{MAT}	–	Material coefficient	5, Table 2
L_f	mm	Chord length of appendage aerofoil section	E.1
L_{WL}	m	Length of waterline in m_{LDC} conditions	7.7.1
m_{LDC}	kg	See definition 3.2	3.2, 7
m_{KEEL}	kg	See definition 3.4	3.4, 7.4
M_{IJ}	N·m	Design bending moment, with index I and J according to load case	7
SM_L	cm^3	Appendage aerofoil shape longitudinal section modulus	E.2.2
st_i	N/mm^2	Stress, which can be σ or τ, and where *i* can be LIM, d, u, y, yw or yu	5
t_f	mm	Wall thickness of hollow appendage aerofoil section	E.1
α	deg.	Angle of attack of centreboard	7.7.1
ε_R	%	Elongation at break	Table B.2
θ	deg.	Angle between keel axis and centreline for canting keels	7.3.1

5 Design stresses

The maximum stress shall be calculated for each relevant structural component and load case.

The design stress, st_d, is the relevant limit stress multiplied by various stress coefficients:

$$st_d = st_{LIM} \times k_{MAT} \times k_{LC} \times k_{DC} \text{ in N / mm}^2 \quad (1)$$

where

st_{LIM} is the limit stress, with *st* representing either *σ*, the direct stress, or *τ*, the shear stress, and index LIM is as follows:

— for metal in the unwelded state or well clear of the heat affected zone (HAZ), $\min(st_y;0{,}5 \times st_u)$ where index y is the yield strength and index u is the ultimate strength, i.e. σ_y,σ_u for direct stress, τ_y,τ_u for shear stress and σ_{by},σ_{bu} for bearing stress;

— for metal within the HAZ, $\min(st_{yw};0{,}5 \times st_{uw})$ where index y is the yield strength and index u is the ultimate strength, i.e. σ_{yw},σ_{uw}, for direct stress, τ_{yw},τ_{uw} for shear stress and for $\sigma_{byw},\sigma_{buw}$ bearing stress;

— for wood and fibre-reinforced polymer (FRP), the ultimate strength in tensile σ_{tu}, compressive σ_{cu}, flexural σ_{fu}, bearing, σ_{bu} or shear stress τ_u;

k_{MAT} is the material coefficient as defined in Table 2, with the design stress adjusted according to the material;

k_{LC} is the load case coefficient as defined in Table 3, with the design stress adjusted according to the load case;

k_{DC} is the design category coefficient as defined in Table 2, with allowance for an increase in design stress for lower design categories.

Table 2 gives details on these variables.

The values of st_{LIM} — i.e. $\sigma_{\mathrm{y}}, \sigma_{u}, \tau_{u}$ for unwelded metals, $\sigma_{\mathrm{yw}}, \sigma_{\mathrm{uw}}, \tau_{\mathrm{yw}}, \tau_{\mathrm{uw}}$ for welded metals in a HAZ, or σ_{tu}, σ_{cu}, σ_{fu}, σ_{bu} or τ_{u} for wood and FRP — shall be taken

— in accordance with ISO 12215-5:2019, i.e. according to tests or default values specified in its Annex C for FRP, its Annex E for sandwich core, and its Annex F for laminated wood and plywood,

— in accordance with Annex B for the listed metals, including, where relevant, ISO 3506-1 for stainless steel fasteners and ISO 898-1 for carbon steel or alloy steel fasteners, and

— for other metals, either from a recognized standard or from tests made in accordance with the relevant International Standard.

Table 2 — Design stresses and stress coefficients

Variable	Material/designation	Value
st_{LIM}	Metals, unwelded or well clear of HAZ [a]	$\min.(st_{\mathrm{y}};0{,}5\times st_{\mathrm{u}})_{\mathrm{b,c}}$
	Metals, within HAZ, in welded condition [a]	$\min.(st_{\mathrm{yw}};0{,}5\times st_{\mathrm{uw}})_{\mathrm{b,c}}$
	Wood or FRP as dictated by sense of applied stress	$\sigma_{\mathrm{uc}}, \sigma_{\mathrm{ut}}, \sigma_{\mathrm{uf}}, \sigma_{\mathrm{ub}}$ and τ_{u} as relevant [c]
k_{MAT}	**Stress factor**	
	Metals with elongation at break, ε_{R} % ≥ 7	0,75
	Metals with elongation at break, ε_{R} % <7	min.(0,062 5ε_{R} + 0,312 5;0,75) [d]
	Wood and FRP	0,33
k_{LC}	**Stress factor** (see Table 3)	
k_{DC}	**Stress factor**	
	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 as being 50 mm from the weld (see F.3.4.3).

[b] For metals, $\tau = 0{,}58 \times \sigma$.

[c] Bearing stress depends on material type (Ref [8] gives $\sigma_{\mathrm{ub}}/\sigma_{\mathrm{uc}}$ = 2,8 for Glass CSM and 0,91 for roving), metal regulation usually gives 2,4 to 3 for bolts (but with restrictions: far from edges, min. bolt spacing, min. thickness/bolt d). Values derived from tests are recommended.

[d] The factor gives 0,75 for $\varepsilon_{\mathrm{R}} \geq 7$ %, and 0,375 for ε_{R} =1 % and linear interpolation in between. Values of ε_{R} are given in Table B.2.

Table 3 — Value of k_{LC} stress factor according to load case

Load case	Keels and appendages — Load case description	Subclause	Value of k_{LC}
1	Keel bolt [a]	7.2	0,67
	Other elements of fixed keel—metal	—	0,8
	Other elements of fixed keel—FRP [b]	—	0,9
2	Canting keel—metal	7.3	0,8
	Canting keel—FRP	7.3	0,9
	Canting keel—metallic actuator/metallic actuator and keel support structure	7.3	0,8
	Canting keel—FRP actuator/FRP actuator and keel support structure	7.3	0,9
3	Keel vertical pounding	7.4	1

[a] Load case 1 treats bolts differently from other structural components. The design stress of bolts is lower than that of other structural components in recognition of stress concentration effects in bolts, according to long-standing practice.

[b] Caution: The requirements of this document are based on strength criteria. In some cases, such as keel fins constructed of lower modulus materials, the need to limit deflections and/or increase natural frequencies may require a substantial increase in scantlings above those requirements. Such cases are outside the scope of this document.

Table 3 *(continued)*

Load case	Keels and appendages — Load case description	Subclause	Value of k_{LC}
4	Keel longitudinal impact	7.5	1
5	Dinghy capsize recovery (strength of centre/dagger board)	7.6	1,34
6	Centre/dagger board upwind	7.7	1,0

[a] Load case 1 treats bolts differently from other structural components. The design stress of bolts is lower than that of other structural components in recognition of stress concentration effects in bolts, according to long-standing practice.

[b] Caution: The requirements of this document are based on strength criteria. In some cases, such as keel fins constructed of lower modulus materials, the need to limit deflections and/or increase natural frequencies may require a substantial increase in scantlings above those requirements. Such cases are outside the scope of this document.

6 Structural components to be assessed

CAUTION — Keel loss can be attributed to insufficient thickness of bottom plating in the keel region. In particular, connecting bolts or inadequately assessed load paths between connecting bolts and the corresponding structure and bolts located too far from the relevant stiffener are causative. It is strongly recommended that the provisions of D.5 and Table D.2 be followed and, in particular, for bolts located too far from a stiffener, those provisions of Table D.2, item 3. Keel loss can also be attributed to insufficient fatigue strength of keel fins. In such cases, the provisions in Annex F should be followed.

The following shall be considered when assessing or designing the structure covered by this document.

— Keel-to-hull connection (bolts, wedge connection, stub keel, etc.) — see Figures 1, C.3, C.4 and D.1.

— Bottom shell plating in respect of the keel bolts and transition arrangements beyond the keel bolting zone into the hull structure. Keels should not be bolted to a hull bottom of sandwich construction. The structural arrangement shall ensure that all loads — keel compression loads, bolt preload, etc. — are safely transferred. Note that the terms “pre-stress” and “preload” are used interchangeably.

— Backing plates (usually rectangular steel plates installed on the hull plating inner surface that spread load)/steel washers (annular, placed under securing nuts or bolt heads).

— Floors, girders and associated supporting structure.

— Keel boxes, canting keel actuators and support structure.

— Fins, centreboards, dagger boards of aerofoil cross-section (note: hydrofoils are not considered).

Assessment should be conducted either by numerical methods in accordance with Clause 8 or the established practice methods given in Clause 9.

7 Load cases

7.1 General

7.1.1 Status of design load cases

CAUTION — For load cases 1 and 2 — where keels have a large sweep angle, the centre of gravity (CG) of the bulb/fin can be located a significant distance aft or forward of the fin or bolt group longitudinal centre at the root. This will induce a torsional moment in addition to the bending moment. In such cases, it will be necessary to combine direct stresses owing to bending with shear stresses due to the torsion. The resulting von Mises equivalent stress shall not exceed the design stress given in Formula (1), also noting Clause 7.8. See also Clause 7.8.1.

The design stress shall be assessed for each load case using Formula (1), together with the design stress coefficients given in Table 2 and Table 3, as follows:

— 7.2 defines the *fixed keel 90° knockdown* load case 1 and corresponding force, F_1, and design bending moment, M_1, at 90° heel, for the keel at its root/bolt level and floor neutral axis, respectively; it shall be used for fixed keels, either vertical or angled as in the case of twin keel craft, and axially lifting or swing ballast keels;

— 7.3 defines *canted keel* load case 2 and the corresponding force, F_2, and design bending moment, M_2, at 30° steady heel plus a dynamic overload factor; it shall only be used for canting keels;

— 7.4 defines *vertical pounding* load case 3 and design vertical force, F_3;

— 7.5 defines *longitudinal impact* load case 4 and design horizontal force, F_4, that considers a longitudinal impact with a fixed or submerged object or marine life;

— 7.6 defines *dinghy capsize recovery* load case 5 and the design vertical force, F_5, in 90° knockdown, applied on the tip of a centreboard for dinghy capsize recovery;

— 7.7 defines *centreboard/dagger board* load case 6 and the transverse horizontal force, F_6, applied to centreboard or dagger board used while sailing upwind;

— 7.8 considers other load cases, particularly where specific designs cause combined stresses.

7.1.2 Limitation of load cases

This document is based on the presumption that load magnitudes are set at such a high level of severity that the number of expected occurrences during the lifetime of the craft will be low. Hence, all load cases are considered to be static and used in conjunction with static design stresses according to Tables 2 and 3.

For keels of welded construction, compliance with the static load cases cannot guarantee that fatigue failure due to cyclic loading will not occur. In such cases, an explicit fatigue life assessment and inspection regime shall be considered (see Annexes A and F). It is of the utmost importance that the response of structures experiencing cyclic loading is less than the fatigue strength. Fatigue analysis is required when the stresses are high in magnitude and when structures feature welds that required detailed design and documentation.

Keel configurations resembling the types shown in Figure C.4 require case-by-case consideration.

In addition, the load cases consider that, for bolted connections, the methods for assessing keel bolts are based on the presumption of a broadly uniform distribution of diameter and spacing along the fin root or keel flange (see D.4 for details).

7.2 Load case 1 — Fixed keel at 90° knockdown

This case corresponds to a 90° knockdown case (heeled at 90°) (see Figure 1), which is usually the most severe transverse bending load for fixed ballast keels:

$$F_1 = m_{\text{KEEL}} \times g \quad (2)$$

expressed in N as the vertical force, at 90° knockdown, exerted by gravity at the keel CG

$$M_{1.1} = F_1 \times a \quad (3)$$

expressed in N·m as the keel heeling design moment at the keel junction

$$M_{1.2} = F_1 \times (a + c) \quad (4)$$

expressed in N·m, keel heeling moment at floor mid height