STRUCTURAL ANALYSIS OF COMPOSITE SEARCH AND RESCUE VESSELS UNDER THE NEW BS EN ISO 12215-5

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SUMMARY

Amongst the new implementations to the forthcoming BS EN ISO 12215-5 features a workboat annex, namely Annex J. This will allow vessels in professional use, such as search and rescue crafts, to be designed under the updated regulation. Moreover, to account for the increasing design and operating speeds since the previous BS EN ISO 12215-5 published in 2008, the scope has been extended beyond 50 knots, while also accounting for higher accelerations. The technical background and practical applications of the new regulation for composite vessels will be presented, highlighting the increased factors of safety adopted to ensure reliability and account for the operating profile of the vessels.

NOMENCLATURE

For the purpose of this paper, the following nomenclature applies, as defined in the ISO 8666 [1] and ISO 12215 [2].

B_C	Chine beam (m) at 0.4 L_{WL}
g	Acceleration due to gravity (m.s^{-2})
$H_{1/3}$	Significant wave height (m)
k_{DYN1}	Dynamic load factor (equivalent to gs)
L_H	Length of the hull (m)
m_{LDC}	Maximum loaded displacement (kg)
t	Thickness (mm)
V_R	Recommended reduced speed (kts)
w	Dry mass of fibre reinforcement (kg.m^{-2})
w_{os}	Dry mass of outer skin reinforcement (kg.m^{-2})
$\beta_{0.4}$	Deadrise angle (°) at 0.4 L_{WL}

1. INTRODUCTION

Four years after the publication of the BS EN ISO 12215-5:2008 [2], the working group 18, part of the ISO technical committee 188, began the work on the revision that will later lead to the latest BS EN ISO 12215:2018 [3] standard. Despite not being intended for commercial vessels, a number of regulations, including the MGN 280 (M) [4] and the Brown Code [5] referred to the ISO standard for the structure of commercial vessels such as pilot boats, without any prior consultation of the working group 18. This therefore motivated the development of a workboat annex that extends the scope of the standard to now include commercial vessels.

The background to the revision and the main modifications from the previous version will be introduced, together with the changes to the scope. Then, the regulatory definition of workboats and inherent categories will be outlined, concluding on the specific requirement for those vessels.

2. BACKGROUND TO THE REVISION

Building on the practical experience of the application of the standard, a number of improvements have been suggested by the industry, and various observations resulting from the use of the standard made, including:

- Large panels were penalised, particularly when made in sandwich. Sandwich structures were further handicapped in terms of attached platting.
- Single curvature was considered, as per Class Regulations; however, for small crafts, accounting for double curvature would be very welcome.
- Vessels featuring a high freeboard appeared overly put at disadvantage compared to low freeboard vessels.
- The applicability of the deflection criterion for sandwich and stiffener was questioned.
- A more advanced analysis method of the quasi-isotropic CSM/WR laminates should be proposed. Furthermore, the simplified analysis for single skin was shown to sometimes give lower requirements than the ply-by-analysis; this was perceived as unfair by the industry as a more advanced analysis method with less uncertainty led to higher structural requirements
- The emergence of new design tools, such as Finite Element Methods (FEM) should be offered as an alternative to the standard.
- Higher accelerations than the 6gs considered previously should be investigated for high speed and light crafts operating in professional use (workboats).

The overall philosophy for the updated standard was to widen the opportunities for more modern structural analysis, however not ruling out the possibility to use simplified methods, better suited to smaller yards. Additionally, the revision aimed to ensure a smooth transition; therefore, it was necessary for vessels passing the 2008 standard to still pass the new one.

3. CHANGES TO THE SCOPE

3.1 MAXIMUM LENGTH

A length of 24m is absolutely critical to define the applicability of the regulatory framework; unfortunately, the definition of 24m is inconsistent. On the one hand, the RCD II [6] and ISO standards are applicable only up to a hull length of 24m. On the other hand, the next regulations (IMO, Class Society, etc…) start at 24m Load Line length

[7], defined as the greatest of 96% of the L_{WL} at 85% of the moulded depth, or the length from the front of the stem to the rudder stock axis. Consequently, vessels with large overhangs would typically be above the 24m hull length, but below the 24m Load Line, thus falling into a regulatory '*no man's land*'.

In order to bridge this regulatory gap, the working group 18 decided to extend the scope of the BS EN ISO 12215 up to 24m load line. It is to be noted that, at present, this has only been adopted for the ISO 12215, and not for other standards or the RCD II. It is however hoped this will provide a precedent that would, in time, lead to a more harmonious definition of 24m across regulatory bodies.

3.2 RACING YACHTS

Although beyond the scope of this paper, the question of racing yachts is worth mentioning. Following the publication of the 2008 version, the ISAF, now World Sailing, made compliance with the 12215 compulsory for offshore races, without prior discussion with the working group 18. While the standard is still not applicable to racing yachts designed for professional racing only, considerations for racing yachts features have been made. This includes correction coefficients for sports and racing crafts, as well as considerations for vessels using water ballast/canting keel.

3.3 WORKBOATS

The increasing recognition of the BS EN ISO 12215-5 by several counties as relevant to commercial vessels, despite the standard clearly not being intended to do so, led the working group 18 to consider the addition of workboats as part of the new version, eventually taking the form of Annex J. This prompted further extension of the scope in terms of accelerations and maximum speeds, to better reflect the mode of operation of commercial vessels.

The definition of workboats and inherent category will be presented in Section 5, while the requirements will be tackled in Section 6.

4 NEW CONSIDERATIONS

In addition to the changes to the scope, a number of new considerations and coefficients have been added [8]; some of the most significant ones are presented in the following subsections.

4.1 APPLICABLE METHODS

To broaden the range of methods available to the industry in analysing the structure, six methods will now be usable to determine the scantlings:

1. Simplified method: based on a simple thickness equation for quasi-isotropic GRP single skin.
2. Enhanced method: ply by ply analysis for quasi-isotropic GRP.
3. Developed method: application of CLT to all FRP structures.
4. Direct test: relying on mechanical testing, primarily intended for FRP.
5. FEM: finite element methods using the ISO design pressures and properties, also mostly aimed at FRP.
6. Drop test: applicable to vessels less than 6m in FRP and non-reinforced plastics.

4.2 ASSESSMENT METHOD FACTOR

As previously stated in Section 2, one of the industry criticism towards the previous version of the standard was that, in certain cases, simpler methods would give lower requirements than more advanced ones. To remedy this issue, and prevent it from happening with the larger number of methods available, an assessment method factor k_{AM} was introduced. The intention being to handicap cruder methods, and promote the use of more advanced ones, as reflected in the values of the coefficient shown in Table 1.

Assessment Method	Value of k_{AM} for FRP
Method 1: Simplified	0.90
Method 2: Enhanced	0.95
Method 3: Developed	1
Method 4: Direct Test	1
Method 5: FEM	1
Method 6: Drop Test	n/a

Table 1: *Values of K_{AM}.*

4.3 BOAT BUILDING QUALITY COEFFICIENT

In order to reflect the high impact of the build quality on the final mechanical properties of composite material, a build quality coefficient K_{BB} has been developed. The aim is to reward both the higher manufacturing qualities and higher manufacturing processes, and consequently penalise the mechanical properties for low quality and less advanced manufacturing methods. A summary of the K_{BB} values is presented in Table 2.

Quality	Builder Characteristics	Value of K_{BB}	
		Hand Laid	Infused / Pre-Preg
Tested	Mechanical properties tested and high quality control.	1	1
High	Measured fibre weight fraction and high quality control.	0.95	1
Low	No measurement or checking of fibre weight fraction	0.75	0.8

Table 2: *Values of K_{BB}.*

4.4 LONGITUDINAL PRESSURE DISTRIBUTION FACTOR

The longitudinal pressure distribution coefficient has been modified, following industry feedback, to reduce the requirements in the aft section, but also extending the coefficient beyond the Aft Perpendicular (AP) and Forward Perpendicular (FP). A comparison of the pressure distribution coefficient at accelerations of 6gs and 3gs is depicted in Figure 1.

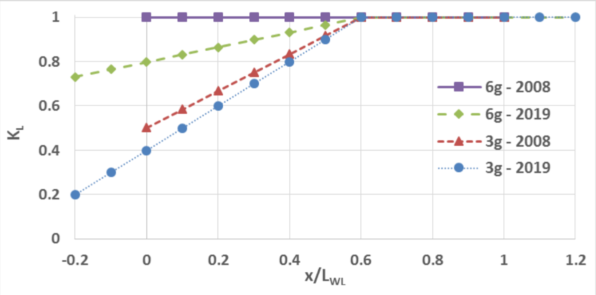

Figure 1: *Changes in the values of K_L.*

While the pressure was assumed to remain constant aft of the AP in the previous version, the new standard will consider a more realistic decrease in pressure over the aft overhang. In the case of workboats, for accelerations between 6 and 8gs, the longitudinal pressure coefficient is to remain at a value of 1 over the entire length.

4.5 ADDITIONAL FACTORS

Among the newly implemented elements of the standard will feature the use of double curvature, and a refined definition for the natural stiffeners on round bilge hull.

On the one hand, while single curvature has long been considered, double curvature was not until now. This is particularly relevant to small crafts, where the curvature can be significant in both directions. The coefficients that will be part of the new standard have primarily been derived from Timoshenko's work [9].

On the other hand, further investigation into the effect of curvature on structures allowed to provide a new definition for natural stiffeners applicable to round bilge hull form. This should prove particularly helpful in reducing the number of stiffeners, particularly in the aft sections of vessels, often deemed 'over structured' by the industry.

5. DEFINITION OF WORKBOATS

5.1 GENERAL

Featured in the inherent normative annex, the definition of workboats distinguishes between charter, light duty and heavy duty crafts. All types are defined as commercial vessels; the distinction then depends on the type of operation and limiting environmental conditions (Beaufort wind speed and significant wave height).

While military crafts and vessels operating in ice conditions are excluded, the intended usage considers a range of boats, from pilot boats and transport vessels for less than 12 passengers to search and rescue crafts.

5.2 CHARTER

Rental and charter vessels do not have any environmental restriction with the exception of the design category conditions. As a commercial vessel, relevant maintenance and survey program are to be implemented. Furthermore, the vessel is expected to be handle with 'good seamanship', and speed reduction when operating above category D should be considered

5.3 LIGHT DUTY

A light duty workboat, is expected to operate in category D, or up to category C restricted to Beaufort 5 and a significant wave height of 1 m. The operating conditions for light duty workboats should not include rough seas, and the comfort of passengers should be paramount, leading to appropriate course and speeds at sea, i.e. strong consideration for seakeeping in order to minimise passenger discomfort. Maintenance and surveying programme shall be undertaken as appropriate, based on the usage and weather conditions experimented.

5.4 HEAVY DUTY

A heavy duty workboat is characterized as operating from the upper end of category C, up to category A, however restricted to Beaufort 9 and 5 m significant wave height. In this particular case, it is assumed that, due to the operating profile of vessels such as search and rescue crafts, the course would not be altered and the speed would not be reduced, and the boat would experience rough seas routinely. Consequently, the 50 knots top speed has been lifted, and accelerations up to 8gs may be considered on the structure; this represents another major change to the scope of the standard. This would obviously require special seating to be provided to the crew in order to remain in full ability to manoeuvre the vessel and be comfortable, as well as imply additional structural requirements. Once again, a suitable maintenance and survey plan shall be implemented.

6. SPECIFIC REQUIREMENTS

6.1 GENERAL

In all three cases, the owner's manual shall provide the appropriate definition of the commercial craft usage conditions, as well the relevant recommendation linked to the specific application. For charter and light duty workboat, this is the only additional requirement incurred by Annex J. Heavy duty workboats however need to satisfy a number of extra criteria.

6.2 HEAVY DUTY

Firstly, as introduced in Section 5.4, accelerations up to 8gs may be considered, and only the first dynamic coefficient criterion k_{DYN1} may be considered. Moreover, the factor of safety for FRP, sandwich core and bulking material has been raised from the standard 2 to 3. The change was deemed relevant by the working group 18, as industry practice is to typically apply a factor of safety of 3 for static loads, and 1.5 for dynamic loads, the latter being rapidly absorbed by the structure. This is achieved by modifying the coefficients in the allowable direct and shear design stress for the materials. In addition, the recommended minimum thickness for single skin and sandwich becomes required, with the addition of a 15% margin (t, w and w_{os} to be multiplied by 1.15). Finally, an equation is provided to suggest the suitable reduction in speed according to the significant wave height experienced, as given equation 1:

$$V_R = \sqrt{\frac{m_{LDC}}{B_C^2} \times \frac{3.125 k_{DYN1}}{\left((50 - \beta_{0.4}) \times \left(\frac{H_{1/3}}{B_C} + 0.084 \right) \right)}} \quad (1)$$

In which:

- V_R Recommended reduced speed (kts)
- m_{LDC} Maximum loaded displacement (kg)
- B_C Chine beam (m) at 0.4 L_{WL}
- k_{DYN1} Dynamic load factor
- $\beta_{0.4}$ Deadrise angle (°) at 0.4 L_{WL}
- $H_{1/3}$ Significant wave height (m)

7. CONCLUSIONS

The background to the revision of the BS EN ISO 12215-5 and its impact on the design of composite search and rescue crafts has been presented. Building on the motivation behind the new version, the main changes to the scope have been outlines, including an extension of the applicability up to 24m Load Line, and the inclusion of workboats. Moreover, a number of modern features, such as the applicable methods, assessment method factor, boatbuilding quality factor, longitudinal pressure distribution factor, double curvature and natural stiffeners have been introduced. The definition of workboats and the three subcategories, namely charter, light duty and heavy duty, have been outlined, also detailing the specific requirements for each type. This provides a strong insight into the new regulatory framework and its application to composite vessel in professional use, ahead of the standard being published and becoming compulsory.

8. DISCLAIMER

The views expressed in this paper are those of the author only and do not necessarily reflect those of the ISO/TC188/WG18. All information presented is subject to changes and publication of the final standard.

9. REFERENCES

1. ISO, 'BS EN ISO 8666:2016 – Small Craft – Principal Data', *International Organisation for Standardization*, 2016.

2. ISO, 'BS EN ISO 12215-5:2008+A1:2014 - Small Craft – Hull Construction and Scantlings. Part 5: Design Pressures for Monohulls, Design Stresses, Scantlings Determination', *International Organisation for Standardization*, 2014.

3. ISO, 'BS EN ISO 12215-5:2018 - Small Craft – Hull Construction and Scantlings. Part 5: Design Pressures for Monohulls, Design Stresses, Scantlings Determination', *International Organisation for Standardization*, 2019 (expected).

4. MARITIME AND COASTGUARD AGENCY, 'MGN 280 (M) Small Vessels in Commercial Use for Sport or Pleasure, Workboats and Pilot Boats - Alternative Construction Standards', *Maritime and Coastguard Agency*, 2004.

5. MARITIME AND COASTGUARD AGENCY, 'Code of Practice for the Safety of Small Workboats and Pilot Boats (brown)', *Maritime and Coastguard Agency*, 2001.

6. EUROPEAN PARLIAMENT, 'Directive 2013/53/EU on Recreational Craft and Personal Watercraft', *Official Journal of the European Union*, 2013.

7. INTERNATIONAL MARITIME ORGANIZATION, 'International Convention on Load Lines, International Maritime Organization, 2003.

8. SOUPPEZ, J.-B. R. G. and RIDLEY, J., 'The Revisions of the BS EN ISO 12215', *Marine Sector Showcase – Composite UK*, 2017.

9. TIMOSHENKO, S. P., 'Theory of Plates and Shells', *McGraw-Hill*, Second edition, 1959.

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