An Assessment of ISO 12215 Small Craft Hull Construction with Classification Society Rules

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SUMMARY

ISO 12215 is in the final stages of completion. Part 5 is being reviewed for approval by National Standards Organizations, Parts 1 to 4 are already EN, BS and ISO standards and Parts 6-9 are still in the developing stages. While ISO 12215 is similar in format to classification society Rules there are differences. These are identified and discussed so that users of ISO 12215; designers, builders and perhaps flag Administrations are aware of the differences and are also aware of additional measures that could augment ISO 12215 to provide an approval and compliance process closer to that of classification.

The discussion addresses ISO 12215, Parts 1 to 5, Parts 6 to 9 are not considered as they are still being developed.

1. DEVELOPMENT

1.1 General

Development by ISO WG 18 started in the late 1980s and has taken considerable time, for which there are several reasons.

First, the task was to provide requirements in an engineering format as parametrically complete as possible to reflect good industry practice. However, good industry practice was found to vary substantially worldwide. Good industry practice was found to have evolved largely from experience without apparent reference to any consistent worldwide engineering criteria, as evidenced by the very wide band of existing craft scantlings for the same type, length and speed craft. This was in part due to relatively few craft less than about 20m being designed or built to classification society Rules.

Second, the Convener of WG 18, responsible for about 14 years for the development of ISO 12215, wisely realized that as far as possible, all members of WG 18 should understand and agree with the requirements at all stages in the development. This was to ensure as far as possible, minimum objections during approval of the standards by the National Standards Organization – a 75% approval of the National Standards Organizations is required for adoption of the standard. This required lengthy discussions and explanations to resolve sometimes conflicting interests.

Third, during the first 14 years the membership of WG 18 was about 30 total, with maximum attendance at any one time generally not more than 15, the membership changed considerably. Membership comprised designers, builders, material manufacturers and classification society representatives, most of whom also represented a National Standards Organization.

When membership changed, often due to the introduction of new National Standards Organization representatives, the new members had to become familiar with the requirements already developed. Each time this required increasingly lengthy explanations and discussions, generally until the new members agreed with the requirements and on a few occasions, until the requirements were revised.

Mr. Fritz Hartz was Convener of WG 18 from the outset. In spite of the inherent difficulties in developing such an extensive standard, he successfully attained the objectives of the task. Tragically, Fritz died in 2002. This was and remains a big loss to the small craft industry.

Mr. Gregoire Dolto was appointed Convener and has since effectively directed WG 18 to completion of the standard.

1.2 Scantling Verification

There were two stages of verification of the scantling requirements of ISO 12215-5 Hull Construction – Scantlings.
The first compared category A craft scantling requirements with the scantling requirements of ABS, BV, GL, LR and RINA for six typical motor yachts and six typical sailing yachts over the parametric range of the standard. The scantling requirements of the standard were at about the lower one third level within the band of classification society scantlings for lengths of over about 12m. Below this length the scantlings of the standard were somewhat less than class society requirements.

It was an agreed intent of WG 18 that the scantlings of category A craft should be not less than classification society requirements for craft over about 12m length for comparable service.

The second and much later verification process compared existing craft scantlings with the standard. Builders and designers were requested to apply the standard to yachts they had built or designed and compare the standard with their practice and forward results to the National Standards Organizations. Participation in this process was not as extensive as WG 18 members had hoped.

However one member of WG 18 received many existing boat scantlings from various countries and builders and was able to develop an extensive comparison of the results with the standard.

The existing craft scantlings showed a very wide band of scantlings for the same craft type, length and speed; very much wider than the scantlings band for the five classification societies scantling requirements. This in itself confirmed that class society requirements had not been used generally for these existing craft.

The results indicated existing craft scantlings to vary between being notably greater than to being less than the standard.

The existing craft scantling band width and the comparison of the mean value with the standard was closer for single skin hulls.

For sandwich laminate hulls the existing craft scantling band was wider and comparison of the mean with the standard differed substantially – with existing craft having greater scantlings. This was possibly due to laminate stiffness criteria and core shear strength criteria exceeding the laminate bending strength criteria.

No doubt the accuracy of the comparison was affected by not being able to get the actual mechanical properties of the existing craft hulls, both for the skins and for the core materials.

In assessing the results of the comparison it should be understood therefore that the mechanical properties of the actual existing craft may well have been less than presumed, thus increasing the requirements obtained from the standard for the existing craft.

If the values for laminate 4a in Table 1 were presumed to be the mechanical properties of the existing craft hull laminates, the required section modulus for shell plate panels from ISO 12215-5 would be increased by 29%. The required thickness for single skin shell laminates would be increased by about 14% and the required thickness of the skins of sandwich laminates would be increased by 29.5%, possibly giving better correlation between the standard and existing craft.

2. ISO STANDARDS AND CLASS SOCIETY RULES

2.1 General

There are a number of inherent differences between ISO standards and classification society Rules.

An ISO standard is a stand-alone document; very specific, limited in content, scope and text; applicable generally to relatively simple items of equipment, materials, fittings, or auxiliary machinery.

Because of this there is generally no need for interpretations. ISO standards are written to be referred to in specifications and statutory regulations, where they are applied by and conformance is verified by an appropriately qualified engineer.

By contrast, classification society Rules are developed to be applied to complex ship or craft structures. They contain many inter-related engineering equations based on a number of different modes of failure, with extensive text on application. There are numerous supporting requirements for materials, welding, structural detail, workmanship and quality control.

Because of this interpretations on application are frequently needed.

Verification of compliance with and interpretations of classification society Rules can only be given by qualified members of the particular classification society who have a sound understanding of the development of and background to the Rules.

2.2 ISO 12215

ISO 12215 is applied to relatively complex craft structures; of different type and displacement craft, operating in different modes and speeds, with different hull forms, design loads, of different construction materials and modes of failure.

Because of this there were two possible methods of development of ISO 12215-5:
• A simple method in which a very limited number of parameters are used, i.e. length, speed, motor craft or sail craft. Because many of the other relevant parameters are excluded; i.e. displacement, hull form and vertical acceleration, etc, the requirements have to be conservative with larger factors of safety to cope with the effects of variation in the values of the excluded relevant parameters.

• A more complex method, similar in format to classification society Rules, in which as many relevant sea load, hull form and structural response parameters as possible are included. The inclusion of these relevant parameters means the factors of safety can be reduced and the scantlings much more closely engineered to the predicted sea loads; hull form and hull structural response of the craft.

The latter method was adopted for the main body of ISO 12215-5. The format used for motor craft is similar to that in ABS Guide for Building and Classing Motor Pleasure Yachts, requirements of which are based on the work of Heller and Jasper [1], Savitsky & Brown [2] and Allan and Jones [3]. The format and requirements are similar to those in the Rules of several other classification societies.

The format for sailing craft was taken from ABS Guide for Building and Classing Offshore Racing Yachts, which was developed by ABS and the International Technical Committee (ITC) of the Offshore Racing Council (ORC) in 1978 – 1980. The Guide for Building and Classing Offshore Racing Yachts was reviewed, revised and updated as necessary from 1981 until 1994 by ABS together with the ITC.

It is still used by ABS, modified for lengths greater than 24 m, to class sailing yachts over 24m length for “Yachting Service“ or “Commercial Yachting Service“, and by designers to qualify racing yachts of and under 24 m length for ocean races governed by ISF and for Volvo RTW races.

For craft up to 12m length a simplified method similar to that referred to above was developed and is included in ISO 12215-5 Annex A. The only variable parameters in this simplified standard are length, speed, and craft type, motor or sail. Other relevant parameters are implicitly included as numerical constants.

Annex A provides a much simpler and, by necessity, a more conservative standard that is very easy to apply and will not require interpretations.

For the parametrically complete method used in the main body of ISO 12215-5, interpretations will inevitably be needed. If interpretations are not made by the people that developed the standard there will be a greater possibility that the standard will not be applied as intended and there will be more inconsistencies in interpretations compared with the interpretations made of classification society Rules.

This is not due to any deficiencies in ISO 12215-5 but is inherent in the nature and mode of application of an ISO standard to structures as complex as those of small craft hulls.

2.3 Application Process

ISO standards and class society Rules differ in their application processes.

2.3(a) ISO 12215

ISO 12215 is applied by a type approval process. This comprises a design approval stage and a manufacturing stage carried out under a builder’s quality control system called the Builders Conformity Assurance procedure.

For craft less than 12m length, both the design approval stage and manufacturing stage may be certified by the builder.

For craft of and over 12m length for Category A, B and C craft, both the design approval stage, compliance with the relevant parts ISO 12215, and the manufacturing stage, compliance with ISO 12215-4 and the builder’s quality system, are certified by the Notified Body.

Plans to be approved in the design approval stage are not specified in ISO 12215, but would include the shell structure, deck structure, bulkheads, deckhouses / superstructures, closing appliances, structural details, rudders, keels and chain plates.

The builder is required to provide the Builder’s Conformity Assurance procedure that is addressed in ISO 12215-4. It is not indicated if this procedure is to be submitted for approval to the Notified Body or approved as part of the Notified Body audits. Nor is the frequency of Notified Body audits given in ISO 12215.

2.3(b) Classification Society Rules

Classification society Rules are applied by approval of structural plans and by construction in accordance with the Rules, the approved plans, and the builders class society approved Building Process Description and Quality Manual.

The classification society specifically lists the plans to be submitted and the information to be included in the Building Process Description and Quality Manual.

During construction the class society surveyor attends to verify compliance with the Rules, the approved plans, the Building Process Description and the Quality Manual. The surveyor checks that the builder is monitoring and recording the required quality control.
data and verifies that the required material tests and production tests are carried out in accordance with the Rules.

2.3(c) Differences

There is much more responsibility delegated to the builder in the ISO certification process than in the classification process and the requirements to be complied with by the builder are much less specific than they are in the classification process.

Unlike classification society Rules, ISO 12215 does not require that the mechanical properties of the hull material be verified by testing. This is not so important for steel and aluminium but it could be significant for FRP hulls where the building process has a much greater effect on the material mechanical properties, noting that ISO 12215 uses the same design loads and design stresses as in classification society Rules.

Another difference between ISO 12215 and class society Rules is that ISO 12215 has no requirements for verifying the in-service condition of the hull, or for approval of repairs in the event of damages.

The classification process requires periodic surveys and damage surveys as a condition of maintaining class. In addition to operational safety these surveys provide valuable feedback on the performance of the vessels and on the Rules to which they were designed and built. Assessment of this feedback is an essential part of the classification society Rule development process.

The final difference between ISO 12215 and class society Rules is that changes to the latter can be implemented on short notice whereas changes to an ISO standard take much longer time.

3. MATERIAL REQUIREMENTS

3.1 FRP

3.1(a) ISO 12215-1

ISO 12215-1 contains minimum requirements for resins, glass reinforcement and for the reference cured glass reinforced laminate.

The required properties of liquid and cured form resin are similar to those included in classification society Rules.

The resin and glass manufacturers are required to declare in writing that their materials, as delivered, comply with the minimum requirements in ISO 12215-1. This clearly implies that the manufacturers are to carry out tests to verify compliance with the minimum mechanical and physical properties given in ISO 12215-1.

The given minimum mechanical properties for the reference glass reinforced laminate are to be used in ISO 12215-5. The reference laminate is a glass fibre, chopped strand mat, 30% glass by mass laminate.

The resin manufacturer is to declare in writing that the resin, as delivered, is capable of attaining the minimum mechanical properties given in ISO 12215-1 with the specified reference glass CSM reinforcement. This again implies that the resin manufacturer is to carry out the relevant tests.

Table 1 shows the recently compiled mechanical properties of E glass CSM from a number of recognised sources, in which for each source, quality control was probably at least at an average / good level.

Comparison with ISO 12215-1 suggests the minimum mechanical properties given in ISO 12215-1 are associated with a fairly good level of quality control. ISO 12215-5, Annex C, in reference to the mechanical properties of laminates predicted by methods in Annex C, cautions builders that “...the values are not absolute minimums and may exceed values which are achievable by lower quality production methods. In such cases, it is in the interest of the builder to conduct material tests…”

This is a very important caution that should also be applied to the minimum mechanical properties of the reference laminate given in ISO 12215-1.

It seems implicit in this caution that the only way builders’ can verify that their hull laminates are manufactured to the ISO standard’s quality production level is to carry out tests on a typical manufactured laminate.

3.1(b) ISO 12215-2

ISO 12215-2, Annex A, gives the minimum required mechanical properties for foam cores and balsa cores. The mechanical and physical properties addressed are similar to those required by classification societies except no minimum densities are specified.

The minimum mechanical properties for Grade 1, core materials for the hull and first tier superstructure / deckhouses, are similar to those associated with cores of density 60 to 80 kg/m³.

As with resins and glass reinforcements, manufacturers of core materials are required to provide data on the mechanical properties of the delivered core material, including guidance on thermal limits in manufacture and in operation.

3.1(c) Classification Society Rules

Classification societies give minimum required mechanical and physical properties for resins, fibre reinforcement, core materials and cured laminates.
Some classification societies require resins, reinforcements and core materials to be type approved by the Society. This requires classification society approval of the manufacturer’s quality system, classification society audits and tests to verify compliance with classification society requirements.

Other societies require the resins, reinforcements and core materials to be provided with certificates and results of tests as conditions of acceptance by the builders and the class society.

Generally the class society approve the builder’s Building Process Description, in which are to be included not only the minimum required mechanical properties of the materials, including the cured laminates, but also all of the necessary guidance for receiving, storing, handling and using the material in the manufacturing process.

3.1(d) Additional measures

If the builders, designers or flag Administrations wish to follow a process for resins, reinforcement and core materials closer to classification society requirements they should:

- require resin, fibre and core manufacturers’ written declarations to be supported by test certificates indicating mechanical properties in accordance with ISO 12215 Parts 1 and 2
- have the ISO 12215-4 required Builders Conformity Assurance procedure include the more extensive and specific material requirements of the classification society.
- as considered necessary, determine the laminate mechanical properties by material testing and / or use laminate production tests to verify actual hull laminate is same as approved design laminate.

3.2 Steel and Aluminium

3.2(a) ISO 12215-3

ISO 12215-3 gives requirements for steel, aluminium wood and other materials. Due to the intended scope of the paper, discussion is limited to steel and aluminium.

The minimum mechanical properties for steel are minimum ultimate strength = 340 N/mm² and minimum yield strength = 235 N/mm². At present the ISO standard does not give a maximum value for ultimate tensile strength. This needs to be given as while the minimum yield strength establishes the basis for the design stress, an upper limit to the ultimate tensile strength serves as a means of quality control, relating to the notch toughness and the weldability of the material.

In the requirements for aluminium the non-heat treatable alloys are the 5000 series (Al Mg / Mn) and the heat treatable alloys are the 6000 series (Al Mg Si). Unlike steel, the mechanical properties of aluminium alloys of both the 5000 and 6000 series are substantially reduced locally by welding; particularly the yield strengths.

As-welded yield strengths are given in classification society Rules but they vary considerably and the IACS Unified Requirement for aluminium gives only the unwelded mechanical properties.

ISO 12215-3 should refer to EN 13195-1 “Aluminium and Aluminium Alloys – Wrought and Cast Products for Marine Applications”.

It is suggested that builders and designers refer to EN 13195-1 for the as-welded mechanical properties of the 5000 and 6000 series alloys and for the very useful guidance on specific alloys given in Annex A to this EN standard.

3.2(b) Classification Society Rules

Classification society Rules give detailed specifications and minimum mechanical properties for steel and aluminium (unwelded and as-welded). Unless the steel mills or aluminium manufacturers have a quality system approved by the society, the materials are generally required to be tested at the manufacturers, witnessed by the classification society surveyor.

Class society Rules also specify the appropriate electrodes or welding consumable to be used for the various grades of steel and various aluminium alloys / tempers.

3.2(c) Additional measures

If builders, designers and flag Administrations wish to follow a process closer to classification society requirements they should:

- use class society grade A steel up to 20 mm thickness, noting that the upper limit is 12.5mm for the use of rimmed steel.
- use electrodes and welding consumables for steel and aluminium alloys as specified in classification society Rules.

It is also suggested that reference be made to EN 13195-1 for the as-welded mechanical properties of the 5000 and 6000 series alloys and for the very useful guidance on specific alloys given in Annex A to this EN standard.
4. WORKSHOP AND MANUFACTURING

4.1 FRP

4.1(a) ISO 12215-4

ISO 12215–4 gives requirements for workshop and manufacturing. The production requirements cover the same areas as classification societies; workshop conditions; materials receiving, storage, handling, molds, resin preparation, laminating process, curing and inspection.

There is a general requirement that certain specified procedures are to be carried out in accordance with the resin and core manufacturers’ recommendations.

Some of these are required to be included in the Builders Conformity Assurance procedure and some are required to be monitored and documented; see Table 2.

ISO 12215 gives the option for the builder to use the mechanical properties of the reference laminate in ISO 12215-1, or to use the mechanical properties predicted by the equation methods in Annex C (12215-5) or to verify the laminate mechanical properties by tests. This puts a much greater responsibility on the builder than does the classification society process.

The only laminate quality control check in the use of non-tested laminates is the required check on fibre content during lamination, for which neither the required test nor frequency are specified. Nor does it appear to require this be recorded, although we believe it should be.

4.1(b) Classification Society Rules

Classification society requirements are generally more extensive and specific; see Table 3.

The major difference is that the classification societies procedure requires qualification testing of the cured laminate during manufacture. This is to verify that the mechanical properties of the manufactured laminate are not less than those on which approval of the structural plans has been based. Burn-out tests of the manufactured laminate sample are to be carried out, including determination of the number, the glass content and the type of plies of the laminate.

In addition, production tests are required to ensure the laminates of the hull, as built, are the same as those on the approved plans and those on which the qualification tests were carried out. This is determined by burn-out tests as referred to above.

During construction the surveyor attends to verify at regular intervals that the builders are monitoring and documenting the required quality control data and to attend key steps in the construction procedure.

4.1(c) Additional measures

If builders, designers or flag Administrations wish to follow a process closer to the classification society requirements, they should:

- include all of the items in Table 3 in the ISO required Builders Conformity Assurance procedure.
- where the builder’s practice is found to be use of laminates of thickness and fibre content (g / m²) in excess of the requirements of ISO 12215-5 and this practice is to be continued, check and record the thickness and the fibre content (g / m²) on each boat from cut-outs for portlights, water intakes and overboard discharges to verify they are not less than required by ISO 12215-5.
- where the builder’s practice is found to be use of laminates in excess of the thickness and fibre content (g / m²) of the requirements of ISO 12215-5 and the builder opts to reduce the laminate thickness / fibre content (g / m²) to that required by ISO 12215-5: carry out tests to verify that the mechanical properties are not less than those used to determine the laminate thickness / fibre mass required by ISO 12215-5. This should be done initially with the tested laminate cured thickness and fibre content recorded.
- where the builder’s practice is found to be use of laminates of thickness and fibre content (g / m²) less than ISO 12215-5 and they are increased to meet ISO 12215-5: check and record thickness and fibre content (g / m²) on each boat from cut-outs from portlights, etc., to verify they are not less than the requirements of ISO 12215-5.

5. ISO 12215-5 SCANTLINGS

5.1 General

In selecting a format for ISO 12215 it was decided to adopt those of a classification society, including for category A and B craft essentially the same acceptance criteria, i.e., design pressure / design stress. The reason for this is that classification society requirements are recognised as proven industry standards having been applied to many vessels for many years with performance monitored and documented by survey.

There are nevertheless a number of differences between ISO 12215-5 and classification society requirements. Some of these are:

5.2 Operating Categories

The definitions of the categories in which the craft are intended to operate did not originate in ISO 12215 and they are not entirely consistent with the classification society definitions. There is still ongoing discussion on this issue.
5.3 Material Testing

Hull material mechanical properties are not required to be verified by tests as being not less than the values on which the structural plans are approved. Nor are production tests required to verify that the actual hull laminate is similar to that on which the mechanical properties were verified.

How much this will affect the reliability of an FRP craft in physically complying with the strength requirements of the standard will depend on how accurately ISO 12215-5 Annex C equations predict the mechanical properties of any specific laminate and on the quality of the manufactured laminate to comply with these predicted mechanical properties.

ISO 12215-5, Annex C is a key part of ISO 12215 where mechanical tests are not carried out. Paragraph the C.1.2 cautions builders that the Annex C predicted mechanical properties are not absolute minimums and that should builders have doubts, it is in their interests to verify that the mechanical properties of their manufactured laminate are not less than the values on which the structural plans have been approved.

It would also be in the interests of builders to ensure they have the required documentation from the manufacturers that the resins, reinforcements and core material comply with ISO 12215, Part 1 and 2.

The mechanical properties, thickness and glass content (g / m²) of the design laminate should be indicated on the approved plans and would likely be similar to those given in ISO 12215 –1 or predicted from ISO 12215-5 Annex C.

The builder can verify the mechanical properties of the manufactured laminate by carrying out tests. This would either verify or not verify compliance with those on which plan approval is based, or it would allow credit for laminate mechanical properties found in excess of those predicted in Annex C or given in ISO 12215-1, and allow an appropriate reduction in the thickness / fibre content of the laminate.

In carrying out the tests the thicknesses of the manufactured laminates should be recorded as if they differ from the design thickness or Annex C thickness, an appropriate adjustment would need to be made to the mechanical properties for the effects of the thickness difference.

5.4 Scantling Equations

In the concluding stages of development there were a number of changes introduced from sources other than the classification society requirements on which the standard was based.

By introducing these various structural details and theoretical design presumptions the potential for problems they could perhaps cause needs to be considered.

One set of classification society Rules, or other specific standard, may have numerous implicitly interdependent related requirements that combine to form one specific standard.

If these different interrelated requirements are replaced with those from another source, there is the possibility that the standard may be critically affected.

Where a craft built to classification society scantling requirements which, because of their more complete parametric format, may engineer the structure more closely to the sea loads and structural response of the structure, the structural details and theoretical presumptions in that class society Rules need to be applied, or if different structural details or theoretical concepts are introduced they need to be carefully assessed. Assessment would be of the acceptance criteria, i.e., design pressure / design stress, the equations and parametric context in which they are applied and the operational service of the source from which they were extracted.

Considering the foregoing, the following changes introduced in the closing stages of ISO 12215-5 are discussed below.

5.4(a) Snipe ended stiffeners

Snipe ended frames, longitudinals and bulkhead stiffeners were introduced in which the section modulus is increased by 50% for the simply supported end condition.

Classification society Rules generally only permit snipe ended members (with the same 50% increase in section modulus) where they are not subject to repetitive flexural loads, or to vibration, i.e. to bulkhead stiffeners and floor stiffeners, generally clear of the engine room.

Service experience has shown that the stress raising features at the snipped ends of shell frames and shell longitudinals result in fatigue fractures.

Also where snipe ended members are permitted, requirements need to be given for the strength of the plating in way of the snipped ends to carry the shear force on the snipe ended stiffeners.

In doing this it should be noted that for FRP construction, the plating design shear stress should be based on the inter-laminar shear strength of the plating laminate, and not on the in-plane shear strength, on which the stiffener web design shear stress is based.
5.4(b) Curved frames and beams

A factor has been introduced to reduce the section modulus requirements for curved beams and frames by up to 30%. Engineering theory indicates the effect of curvature on beams to be negligible where the radius of curvature is more than 10 times the depth of the beam. This scantling reduction method appears in the Rules of one classification society.

How valid this factor might be when applied out of its Rule context needs to be determined, for example what is the level of acceptance criteria, i.e., design pressure / design stress, used with this factor in its original source. Separate default minimum requirements are also generally used with such factors and may have been contained in the original source of the factor.

5.4(c) Shear strength of stiffeners

The equation for the required shear strength of the webs of frames, stiffeners, longitudinals etc includes consideration for the shell or bulkhead plating to carry some of the shear force on the member where the area of the plating exceeds the stiffener web area. This results in a substantial reduction in the required area of the stiffener web.

This provision is not to our knowledge included in any class society requirements. The source and validity of this reduction provision needs to be assessed, particularly as it is applied to flat plating.

5.4(d) Chineless monolithic frameless hulls

This is an important requirement for very small craft that is not, to our knowledge, addressed in any class society requirements. Some of the conditions in the means of assessing the self-supporting characteristics of a curved unstiffened shell do not reflect classification society practice nor engineering theory. These conditions need to be further assessed and validated against many existing frameless craft.

5.5(e) Floating frames

This form of construction is not addressed in ISO 12215-5, but it could be proposed in a steel or aluminium hull design.

It generally comprises shell flat bar longitudinals supported by transverse webs, of which the unstiffened outboard edge of the web of the transverse is notched over the shell longitudinals, but is not welded to the shell plating. There being a gap between the web of the transverse and the inner surface of shell plating of 25 to 35 mm, depending on the depth of longitudinals.

These arrangements are not permitted by some classification societies and are not, as far as we know, considered in the Rules of any classification society.

The problem with this form of construction is that the unstiffened edges of the webs of the bottom transverses supporting the longitudinals are inadequate to resist buckling under the compressive bending stresses experienced by the webs of the transverses under bottom slamming loads.

In addition, especially where flat bar longitudinals are used, the connections of the longitudinals to the transverse webs, due to the lack of lateral support of the longitudinals at the connections, can result in tripping of the longitudinals at these connections under impact loading.

6. CONCLUSION

There are clearly differences between ISO 12215 and classification society requirements. They are in part due to ISO 12215 being to some degree a design standard more than a design and construction standard typical of classification society Rules.

They are even more due to the fact that ISO 12215 –5 is for craft of and over 12 m, by necessity, a complex standard based on classification society format that had, as far as possible in its development, to reflect industry input.

Also for craft less than 12 m length, classification society Rules did not fully address such very small craft features as unstiffened hulls.

If the material testing and the more extensive and explicit quality control required by classification societies, as discussed in this paper, are adopted in the process of applying ISO 12215, one of the major differences with the classification process would be eliminated.

The other differences are generally in the scantling equations in ISO 12215-5, in the form of reduction factors or structural design theories from other sources. A number of these are identified and discussed in this paper. As most of these tend to result in reduced scantlings they need to be further assessed and validated.

7. ACKNOWLEDGEMENTS

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8. REFERENCES


9. AUTHOR’S BIOGRAPHY

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ISO 12215 PARTS OF STANDARD
ISO 12215-1 Materials – Thermosetting resin, glass-fibre reinforcement, reference laminate
ISO 12215-2 Materials – Core materials for sandwich construction
ISO 12215-3 Materials – Steel, aluminium, wood and other materials
ISO 12215-4 Workshop and construction
ISO 12215-5 Design pressures for mono-hulls, design stresses, scantlings determination
ISO 12215-6 Structural arrangements and details
ISO 12215-7 Multi-hulls
ISO 12215-8 Rudders
ISO 12215-9 Sailing craft attachments
### Table 1

Glass chopped strand mat – mechanical properties

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<th>Laminate</th>
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<th>$\sigma_T$</th>
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<th>$\sigma_C$</th>
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<td>96</td>
<td>103</td>
<td>158</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4c</td>
<td>35</td>
<td>138</td>
<td>131</td>
<td>213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a</td>
<td>(25-30)</td>
<td>90</td>
<td>7500</td>
<td>120</td>
<td>8000</td>
<td>155</td>
<td>6500</td>
</tr>
<tr>
<td>5b</td>
<td>(30-35)</td>
<td>90</td>
<td>7500</td>
<td>120</td>
<td>8000</td>
<td>155</td>
<td>6500</td>
</tr>
<tr>
<td>5c</td>
<td>(35-40)</td>
<td>110</td>
<td>9000</td>
<td>140</td>
<td>9500</td>
<td>175</td>
<td>8000</td>
</tr>
<tr>
<td>ISO 12215-1</td>
<td>30</td>
<td>80</td>
<td>6350</td>
<td>135</td>
<td>5200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\sigma_T$ = tensile strength, N / mm$^2$

$E_T$ = tensile modulus, N / mm$^2$

$\sigma_C$ = compressive strength, N / mm$^2$

$E_C$ = compressive modulus, N / mm$^2$

$\sigma_F$ = flexural strength, N / mm$^2$

$E_F$ = flexural modulus, N / mm$^2$
### Table 2
**ISO 12215-4 FRP Construction – Quality Control**

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
<th>Documentation / Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop Conditions</td>
<td>In accordance with resin manufacturers requirements</td>
<td>Temperature and humidity monitored in appropriate locations in mould shop and recorded</td>
</tr>
<tr>
<td>Material Receipt, Storage and Handling</td>
<td>In accordance with material manufacturers requirements</td>
<td>Verification that received material is as specified and in accordance with ISO 12215-1 and ISO 12215-2</td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td>Data sheets of all materials including material manufacturers recommendations/requirements and (if any) test reports</td>
</tr>
</tbody>
</table>
| Resin Preparation                 | In accordance with resin manufacturers requirements | • Where resins blended by builders results of tests to verify suitability of blended resin  
• Where resin contains fillers/addition outside manufacturers limits, results of tests to verify suitability of resin |
| Laminating process                | In accordance with resin and core manufacturers requirements | Uniformity of the laminate and glass content to be checked at regular intervals  
• Spray up equipment calibrated and monitored for required resin/catalyst setting and resin/reinforcement at beginning of each day |
| Laminate Curing                   | In accordance with resin manufacturers requirements, and for post cure of sandwich laminates also with core manufacturers requirements | • Curing schedule  
• Post cure temperatures |
| Sandwich Construction             | In accordance with resin and core manufacturers requirements |                                                  |
| Faults and Repairs                | Acceptance/rejection criteria not given           | Record of faults and repairs                                                           |
| Final Inspection & (if any) product testing | Acceptance/rejection criteria not given           | Report of final inspection and (if any) results of product testing                     |
### Table 3
Classification Society Requirements FRP Construction – Quality Control

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
<th>Documentation / Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Process Description</td>
<td>Approved in accordance with Rules</td>
<td>To be complied with by builder, verified by Surveyor</td>
</tr>
<tr>
<td>Quality Manual</td>
<td>Approved in accordance with Rules</td>
<td>To be complied with by builder, verified by Surveyor</td>
</tr>
<tr>
<td>Structural plans &amp; structural details</td>
<td>Approved in compliance with Rules</td>
<td>To be complied with by builder, verified by Surveyor</td>
</tr>
<tr>
<td>Workshop Conditions</td>
<td>Approved Building Process Description and material manufacturers requirements</td>
<td>Records of temperature and humidity in laminating shop</td>
</tr>
</tbody>
</table>
| Material receipt, storage and handling    | Approved Building Process Description and material manufacturers requirements | • Verification that material meets the specifications in the approved Building Process Description  
                                          |                                                                                            | • Results of tests on materials                                                        |
| Materials                                 | Rules and approved Building Process Description                             | Specifications and data sheets for resins, reinforcing materials and core materials and material manufacturers requirements for  
                                          |                                                                                            | − Resin preparation                                                                     |
|                                          |                                                                             | − Laminating instructions                                                              |
|                                          |                                                                             | − Curing control                                                                       |
|                                          |                                                                             | − Vacuum bagging                                                                       |
|                                          |                                                                             | − Post curing                                                                          |
| Resin preparation                         | Building Process Description and resin manufacturers requirements           | Types and amounts of catalyst, accelerators, hardeners, additives and fillers          |
| Laminating process                        | Building Process Description and resin and core manufacturers requirements   | • Record of ply lamination in each laminating session                                   |
|                                          |                                                                             | • Record of resin/fibre content in each laminating session                              |
|                                          |                                                                             | • Record of temperature and humidity during each laminating session                    |
|                                          |                                                                             | • Record of spray up equipment calibrated and resin/catalyst and resin/reinforcement amounts |
| Laminate Curing                           | Building Process Description and resin and core manufacturers requirements   | • Temperature to be recorded and checked against resin/catalyst for control of curing cycle  
<pre><code>                                      |                                                                             | • Record of time of start of vacuum bagging in relation to resin gel time and record during vacuum bagging |
</code></pre>
<p>|                                          |                                                                             | • Record post cure temperature and time                                               |
| Sandwich Construction                     | Building Process Description and core manufacturers requirements             | Manufacturer’s requirements                                                             |
| Secondary bonding                         | Rules and Building Process Description                                      |                                                                                         |</p>
<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
<th>Documentation / Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faults and repairs</td>
<td>Acceptance/rejection criteria in Building Process Description</td>
<td>Reports on faults and repair inspections</td>
</tr>
<tr>
<td>Laminate Qualification tests</td>
<td>Rules and Building Process Description</td>
<td>Results of tests carried out to verify mechanical properties of laminates to verify they are not less than values used in plan approval</td>
</tr>
<tr>
<td>Laminate Production Tests</td>
<td>Rules and Building Process Description</td>
<td>Results of burn-out tests carried out on a suitable number of plugs from the actual hull to verify fibre content not less than qualification tests and that ply number, ply fibre content and ply type comply with approved plan laminates</td>
</tr>
<tr>
<td>Barcol hardner tests</td>
<td>Rules and Builders Process Description</td>
<td>Recorded values prior to mould release</td>
</tr>
<tr>
<td>Final Inspection</td>
<td>Building Process Instruction and Quality Manual</td>
<td>Verification that construction processes and inspections are completed, documented with no outstanding non-conformities</td>
</tr>
</tbody>
</table>