

THE COMMON STRUCTURAL RULES

INITIAL DESIGNS AND FUTURE DEVELOPMENTS

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Abstract

This paper will discuss the design of oil tankers built to the IACS Common Structural Rules (CSR). Several technical issues will be examined including the use of high tensile steel, requirements for shell plating thickness and the design of the hopper knuckle. The paper will also describe the work of the IACS CSR maintenance group and the CSR Knowledge Center. The paper will highlight future developments such as the tanker/bulk carrier harmonization project and key rule changes.

1 Steel Weight Increases and the Use of High Strength Steel

A long standing question has been what effect implementation of the IACS Common Structural Rules (CSR) for Double Hull Oil Tankers would have on overall steel weight. Studies carried out during development of the CSR predicted that steel weights would increase between 4 and 10% depending on which society's Rules were used to determine the scantlings of the base design.

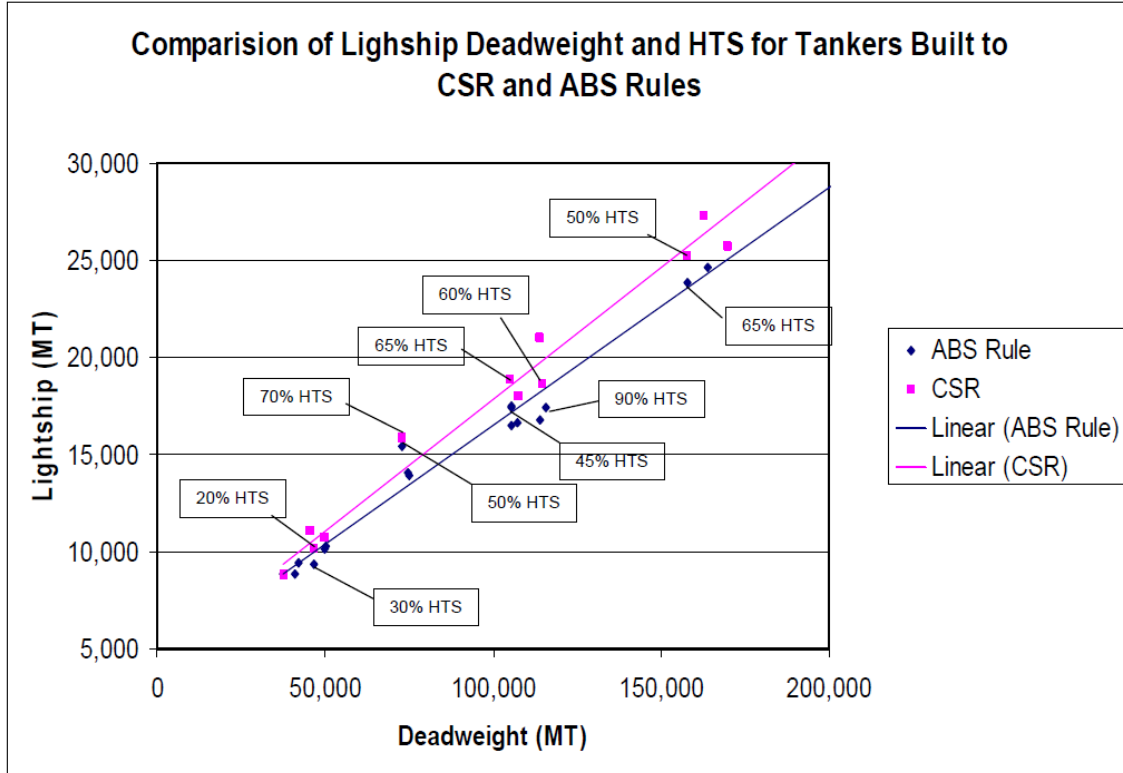
Although not an exact comparison of steel weight, we have compared the lightship weight and deadweight for approximately 35 designs of which 15 are CSR. While we have limited our study to only ABS classed vessels delivered since 2000 each of these designs is representative of a series of vessels. The table below depicts these results and shows that CSR designs of similar deadweight invariably have a higher lightship weight. The average lightship increase for CSR tankers is approximately 8% when compared to those designed to the ABS Rules for Building and Classing Steel Vessels, Vessels Intended to Carry Oil in Bulk (150 meters or more in Length), hereafter referred to as the ABS Rules, which were in effect prior to the CSR.

As high tensile steel (HTS) may be used to reduce steel weight, we have also studied the percentage of HTS used and the effect on lightship weight. We studied the midship drawings for vessels of similar dimensions built at the same yard to each of the two sets of Rules. One designer was able to limit the lightship weight increase to 2% by increasing the percentage of HTS in the CSR design by 25%. Two comparable vessels with the same percentage of HTS saw a lightship weight increase of 8% from the ABS Rules to CSR. The largest percentage increase between two similar vessels was 14%. It may be worth noting that these values represent total lightship weight. Assuming the weight of equipment and outfitting have remained relatively constant, the effect of CSR on steel weight is even greater. The percentage of high tensile steel used in this study is an approximation based primarily on the longitudinally effective structure shown on the midship drawing.

It has been noted by many in the industry that, with the adoption of CSR, designs contain significantly more high tensile steel (HTS). However, half the vessels sampled have actually incorporated less HTS in the CSR design. One possible explanation may be that the CSR approach to buckling and fatigue is onerous and can lead to the steel weight decreases for HTS being minimized. It is also possible that for these designs the percentage of HTS was limited by owner requirements.

Concerns with the increased use of high tensile steel include fatigue, buckling and a general decrease in the robustness of designs due to lighter scantlings. CSR has addressed each of these. The minimum

required fatigue life has been increased to 25 years. Buckling calculations are carried out at the minimum thickness to renewal, an approach which is again more conservative. As can be seen by the table below, even those designs that incorporate a higher percentage of HTS have a greater overall lightship weight.



2 CSR Approach to Selected Critical Areas

In their paper titled “The Development, Implementation and Maintenance of IACS Common Structural Rules for Bulk Carriers and Oil Tankers,” Gary Horn, ABS and Philippe Baumans, Bureau Veritas stated:

Rule requirements must contain a balance between incorporating highly technical advanced methods and practical deterministic application needs. General industry has been increasingly calling for the use of advanced predictive models in rule evaluations while at the same time calling for rule formats that lend themselves to quick determinations of initial designs as well as being able to fit rule evaluations within accelerated design and building cycles.

The CSR focus on a single vessel type with limited configurations and incorporate the combined experience of a greater number of class societies representing a larger portion of industry. The end result is a more detailed set of prescriptive requirements that limits analysis for certain items while providing greater design flexibility and a more robust set of criteria. Two examples that this paper will examine in detail are the requirements for corrugated bulkheads and hopper knuckles.

3 Corrugated Bulkheads

A comparison of the CSR to the ABS Rules, shows that many of the prescriptive requirements address arrangements that had previously been required to be confirmed by analysis. This may be considered a benefit of having compared the prescriptive requirements of numerous societies and checked against the service histories of vessels built to the different requirements.

The CSR specifically require a lower stool when the depth of the vessel exceeds 16 meters. For vessels with a depth less than 16 meters the CSR outlines additional prescriptive and analysis requirements that may be met in order to eliminate the lower stool. By comparison, the ABS Rules are less specific in outlining additional requirements that would allow omission of the lower stool. Pre-CSR designs did occasionally omit the lower stool however the required analysis had to be determined on a case by case basis.

The ABS Rules also contained more stringent prescriptive requirements for the height and depth of the upper and lower stools, with alternatives permitted after more detailed analysis. Based on this analysis, satisfactory service experience and IACS Unified Requirements, CSR has reduced the required height of the lower stool from three times the minimum required corrugation depth (length of corrugation/15) to one times the depth of corrugation.

Another example of a revision to the ABS Rules is the angle of corrugation. The ABS Rules requirements had limited the angle of corrugation to 60 degrees, though permitted lower angles so long as a direct analysis was carried out. The CSR now permit an angle of 55 degrees without any additional requirements. This additional allowance was based again on satisfactory service experience for vessels constructed with the lower angle and the analysis carried out to justify the same.

The CSR also has more specific requirements for the plating thickness of the corrugations themselves. Prescriptive requirements address the bottom 15%, midspan, and upper 33% of the corrugation while the ABS Rules did not differentiate between the bottom 15% and midspan. CSR also provides prescriptive requirements that allow for different web and flange thicknesses.

As the CSR was, in part, developed from the ABS Rules, there are a number of requirements that remain the same such as alignment, prohibition of scallops in brackets in lower stools, sloshing loads and stool thickness. Similarly, both CSR and the ABS Rules require that the global strength of the corrugated bulkhead be verified using FEA

It can be concluded that the CSR incorporate a number of additional features that permit greater design flexibility. The Rules more specifically address features that may be accepted based on prescriptive requirements and more thoroughly outline required analysis for deviations. There are also a few examples where requirements have been lowered as the acceptability has been proven through the combined analysis and experience of a greater number of class societies.

4 Hopper Knuckle

The CSR contain significantly more detailed requirements for the design, construction and analysis of the lower hopper knuckle.

The ABS Rules addressed this location with two main requirements. The allowable stress in the total strength analysis was lower within two stiffener spaces of the knuckle connection. Secondly the upper and lower hopper knuckles were critical locations that required a fine mesh fatigue analysis.

CSR now contains a number of additional requirements for these details. The upper and lower hopper knuckles are required to be supported by a girder, stringer or deep stiffener. This support is to be located

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no further than 50 mm from the knuckle. The CSR limits the radius of cold formed plating to not less than 4.5 times the gross plate thickness and outline requirements that allow for a radius of as little as 2 times. CSR also addresses the use of weld toe grinding to increase the fatigue life in this area, but only after a specified base life has been reached neglecting any grinding. CSR mandates increased fillet welds or penetration welds for the connections between the lower hopper plate and floors or girders.

In addition, the CSR contain very detailed requirements for analysis of the lower hopper knuckle. Per the CSR criteria, this is the only location which is always subject to very fine mesh fatigue analysis. Figures are included within the text of the CSR to show typical models, mesh size and meshing techniques. This eliminates inconsistencies that may arise due to modeling techniques.

The CSR also contain screening criteria to determine whether openings need to be included in the FE model. Highly stressed areas, or those close to critical locations such as the lower hopper knuckle, need to have openings modeled.

CSR does state that alternatives to the prescriptive requirements may be permitted as long as a hot spot fatigue analysis is also carried out.

5 Plating outside 0.4L

One issue that has emerged when comparing pre-CSR tankers to the first CSR designs has been the decrease in plating thickness outside the midship 0.4L. Many tankers designed to the 2006 CSR were constructed with (1 to 4 mm) lighter deck and shell plating thickness than the pre-CSR designs in the regions of 0.2-0.3L and 0.7-0.8L.

The ABS SafeHull criteria 5C-1-6/1.3 states “the scantlings of longitudinal structural members and elements in way of cargo spaces beyond the 0.4L amidships may be gradually reduced toward 0.125L from the ends, provided that the hull girder section modulus complies with 3-2-1/3.7.1 and that the strength of the structure satisfies the material yielding, buckling and ultimate strength criteria specified in 5C-1-5/3 and 5C-1-5/5.”

CSR addresses the subject in 8/3.1.3.1 and 8/4.1.3.1 by stating that scantlings of the shell envelope, upper deck and inner bottom are to be properly tapered towards the forward and aft ends. Furthermore, 8/1.6.1.2 states that scantlings outside of 0.4L amidship as required by the rule minimum moment of inertia and section modulus as given in 1.2.2 may be gradually reduced to the local requirements at the ends provided the hull girder bending and buckling requirements, along the full length of the ship, as given in 1.2.3 and 1.4, are complied with.

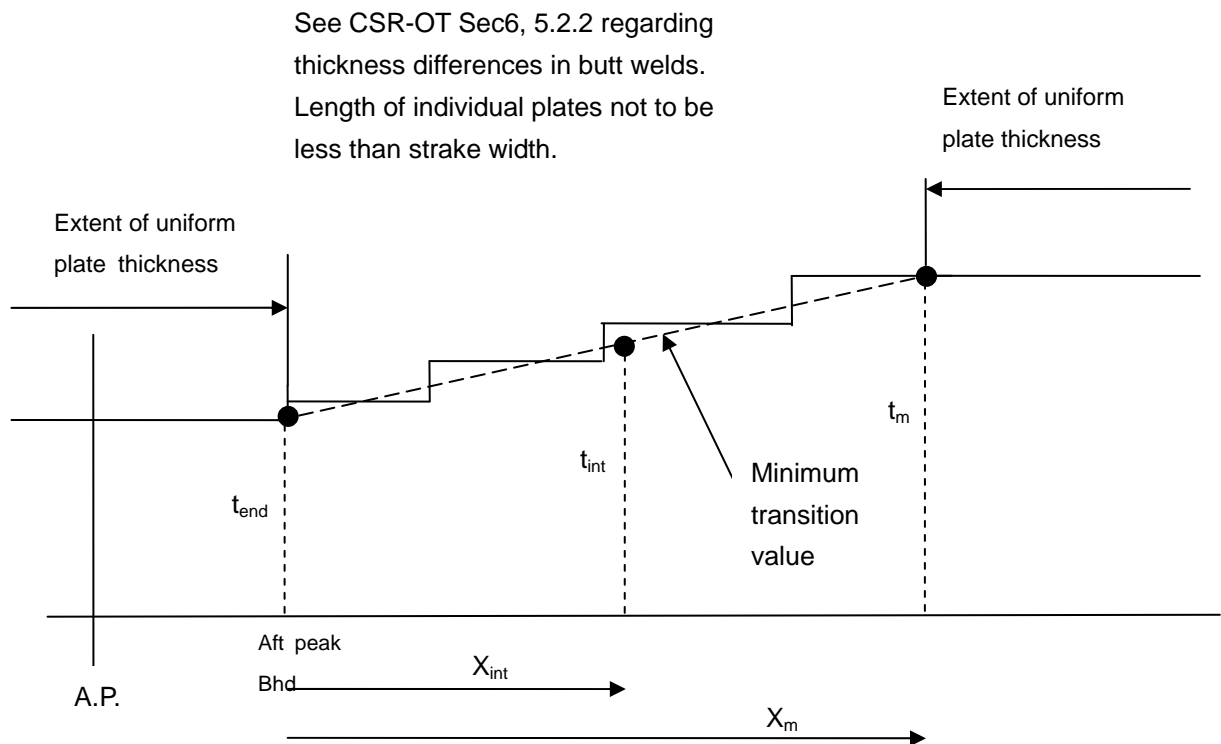
The term “properly tapered” is subject to considerable interpretation, making it difficult to gain uniform application of the rule. CSR specifically requires that local, hull girder and buckling requirements be met and “properly tapered” may be interpreted to mean that the scantlings should not be reduced below these requirements. It is worth noting that 8/1.6.1.2, which requires gradual reduction of the amidship 0.4L scantlings, refers only to the scantlings required to comply with the minimum hull girder section modulus requirements. As CSR specifically excludes midship scantlings governed by local or combined wave induced and still water bending moment requirements, it lends further to the interpretation that “properly tapered” does not mean a gradual reduction of the midship scantlings outside 0.4L.

As the CSR wave induced hull girder bending moment is maximum from 0.4 to 0.65L or roughly the amidships 0.25L, the load drops considerably outside 0.4L. The resulting wave induced bending moment is 75% of the maximum at the aft end of 0.4L and 86% at the forward end.

While there may be concern with the reduction in plating thickness outside 0.4L it is worth noting that this region is still being checked for the maximum shear loads, as well as fender loads.

It may be noted that the hull girder shear loads are maximum from 0.2-0.3 and 0.7-0.85

After feedback from industry, Rule Change No. 1, January 2009 was introduced. This change increased the minimum thickness for plating within the cargo tank region. The minimum thickness was increased one millimeter for bottom and side shell up to 4.6 m above the draft. In addition Common Interpretation CI-T8, originally published in December 2009, explicitly outlines steps to be taken to provide a gradual reduction in plating thickness outside 0.4L. The figure below, copied from CI-T8, graphically depicts the tapering procedure. Further changes to the CSR to address the transition issues included in CI-T8 are currently under consideration.



6 CSR Maintenance

As with any set of rules, keeping the rules up-to-date and able to address the latest designs under development is the main objective of maintenance. Maintenance also includes making any necessary corrections to the rules as found necessary during application. Corrections become necessary if the rules contain errors that obviously result in incorrect requirements, such as too low or overly excessive thicknesses. This is where feedback from the in-service history of vessels is important. Feedback is closely monitored by class societies both internally via class surveyors and externally via client feedback. While each class society will generally have their own system to handle this, for the CSR, IACS has developed a "Knowledge Center" which is used for entering feedback, monitoring the process of deciding how to address it, and then finally tracking how it was addressed. The initial feedback and final action information of the Knowledge Center is open to the public on the IACS web site (www.iacs.org.uk), the internal monitoring and intermediate tracking steps are accessible to all IACS societies.

The actual outcome of the feedback can range from a simple question and answer, a clarification of a rule application, the issuance of a Common Interpretation or a change to the CSR.

A Common Interpretation (CI) is a clarification of the CSR that is intended to give information that augments the rules in order to assist with the application process. It is not intended to be a new rule or to impact scantlings as a rule would. However, it is acknowledged that if the process described in the CI was not being applied by a designer then when that designer starts to apply the CI in the manner that the rules intended, that particular designer may see a change in the requirements. The CIs are posted on the IACS web site.

The actual rule change procedure for the CSR is similar to that of most individual class societies. There is a development phase where a small project team, made up of about 4 to 6 members, works on the detail rule proposal, consequence assessment and the technical background. This project team work is then reviewed by the Hull Panel which is made up of all 11 IACS members. The rule change will then be subjected to external industry review culminating in the review of the societies' Technical Committees and rule governance bodies. Once the changes are through external review and accepted by the Hull Panel, the General Policy Group and Council makes a final review and approves adoption of the rule. It is then published and typically will become effective 6 months later. The rules are then in place and the technical background documents are posted on the IACS web site.

7 Future Developments

The future developments of CSR are being handled in two distinct but related ways. The first is the rule maintenance which was previously described. The second is a larger long-term project addressing the harmonization between the CSR for Oil Tankers and the CSR for Bulk Carriers. It is acknowledged that there are different loads imposed on these vessel types owing to the nature of cargo carried and subsequent structural arrangements, there are some basic first principle aspects that should be treated similarly. When the two rule sets were first developed, this was done by two separate project teams that applied different technical approaches in some areas. When they were first introduced, industry requested and IACS agreed to harmonize the rules. Therefore the harmonization of the CSR deals principally with key technologies such as wave loads, fatigue, finite element analysis and buckling. Once harmonized, the CSR will consist of three parts – a common part for general hull requirements for both ship types and two separate parts for ship type specific requirements applicable to bulk carriers and oil tankers, respectively. The harmonization project is currently well underway and the planned completion is scheduled to culminate with the submission of the CSR to the IMO for compliance with the IMO Goal-Based Ship Construction Standards (GBS).

ACKNOWLEDGEMENTS

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