Shipbuilding industry's perspective on the new IACS Common Structural Rules

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Abstract

The Common Structural Rules for Bulk Carriers and Oil Tankers (CSR) came into force last year. The new CSR not only replaced separate rules for bulk carriers and oil tankers with harmonised Rules but also introduced some new requirements. The shipbuilding industry has started applying these Rules for designing new tankers recently. However the substantially increased amount of FE analyses required by these Rules created a big burden which impacted the structural design period, man hours and design cost of shipbuilders.

Through the experience and insight gained in applying the CSR in the design of several types of tankers, the impact of these Rules on the shipbuilding industry shall be evaluated and some proposals shall be made for structural design of oil tankers with improved reliability. Furthermore the importance of having suitable software for the new Rules will also be emphasised.

1 Introduction

The IACS CSR-OT[1] Rules and CSR-BC[2] Rules were implemented as separate Rule sets in April 2006, and these were superseded by a new unified CSR (formal name CSR BC & OT[3], commonly referred to as HCSR or Harmonised CSR, hereinafter HCSR will be used for convenience) entering into force nine years later. Today, it is necessary to apply HCSR in designing oil tankers. Looking back over the past ten years on the development of the former CSR, the rules were required to be developed over a short period of time , which led to two teams working on the oil tankers and bulk carriers rules separately. As a result, the former CSR inherited some aspects of the Rules of those societies making up each development team.

Consequently, different methodologies were applied to the oil tanker and bulk carrier rules even in some fundamental technical matters which should be commonly treated for all types of ships. This was an important issue from the perspective of shipyards that undertake structural designs.

In regard to this issue, upon receiving industries' feedback that suggested common technological elements for both oil tankers and bulk carriers, IACS committed to develop unified CSR Rules at the time the former CSR was adopted. Based on this decision, harmonisation work for the two CSRs was initiated in 2008, which led to the current HCSR today.

Meanwhile, in regard to the adoption of GBS in IMO MSC 87, which was held in May 2010, CSR was placed as Tier IV "Prescriptive Regulations and Class Rules" within the aforementioned framework of GBS. Therefore, HCSR, which was being developed in the harmonisation project, had to satisfy the functional requirements stipulated by GBS.

HCSR was developed by ten project teams formed by IACS members, many of whom were experts in specific technical fields. A significant amount of human and financial resources were invested in the development, which signifies the extent of commitment put into the project by IACS. During the development, several reviews were conducted by stakeholders in the shipping and shipbuilding industries, which helped to make the content transparent. In addition, the industries' comments were considered with an open mind by IACS, for which the industries have given a high evaluation.

Also, to determine the conformity of HCSR with the IMO GBS's functional requirements, an audit has been conducted by the IMO. The conformity of HCSR with GBS functional requirements was finally confirmed in IMO MSC 96 held in May 2016, which opened the door to building of oil tankers that follow the rules stipulated by HCSR.

Now, the harmonisation work was an effort to unify the oil tankers CSR and the bulk carriers CSR that had quite different technical approach from each other. This challenge was very difficult from a technical perspective, and there is no doubt that the successful outcome was the culmination of the vast knowledge and efforts of the engineers of IACS. The unification work involved the successful amalgamation of two different rules as well as new requirement to comply with GBS. From the viewpoint of the shipbuilding industry, the level of demand to comply with HCSR is generally considered to be higher than the formerly implemented CSR.

Due to the implementation of HCSR, the shipbuilding industry faces new challenges requiring higher demand on resources and in standards in order to comply with the new rules compared to the former CSR, which can lead to the increase of hull structure weight. Rather than increasing the man-hours at the construction site, the extent of coverage in structural analysis at the designing stage mostly increased, and the parts and regions subject to detailed structural analysis have dramatically increased. Consequently the amount of structural analysis that should be made at the designing stage has significantly increased, which prolonged the design period. As a result, it has been more difficult than before to supply new ships to the ship owners in a timely manner. As for the cost increase due to the increased designing work, it may be unavoidable some of that increase is reflected in ship price, thus becoming a problem for the industry as a whole.

This point will be further discussed later.

2 Influence due to HCSR

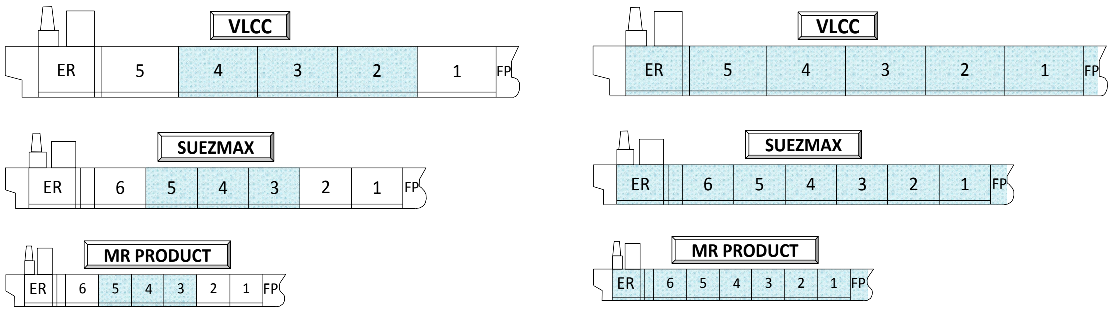
2.1 Prescriptive rule requirements

The items of key technical importance which were reviewed by the harmonisation work mainly involve wave load, buckling strength evaluation, direct strength analysis, fatigue strength evaluation, safety level, and structural design principles. These items are surely ones which should be common for both oil tankers and bulk carriers, and the efforts by IACS in this CSR development were affirmed.

As for buckling strength evaluation and fatigue strength evaluation, evaluation standards common for bulk carriers and oil tankers have been established. The evaluation method has partially been revised, which necessitates that the designers shift from the conventional evaluation procedures. As for the safety level and the principles, the expression “in general,” which has been used in the rule document to allow some degree of redundancy and freedom in the design, was eliminated in the finalisation of the rule in some parts. As a result, it becomes necessary to follow detailed requirements as written in the rule document. This leads to homogeneity and uniformity of details of the structure, which have been varied in terms of shipyard’s design procedures and standards so far. This will eliminate variations in all oil tankers and bulk carriers, and bring about very similar structural details. This means that the ships, regardless of whether they are made in a shipyard in Japan or other countries, will have similar structures. Meanwhile, there are doubts as to whether the detailed structural requirements defined by HCSR are the best in terms of structural strength and reliability. In a sense, there is a concern that freedom in design and each shipyard’s efforts for improvements can be hampered. It is likely that there have been enough discussions on this point within IACS already, but it may be necessary to re-examine what the rules are intended to be in the original sense.

2.2 Impact due to direct strength analysis

Now, one of the major challenges for the shipbuilding industry due to the adoption of HCSR is, as mentioned above, the increase in the demands regarding the direct strength analysis. While the former CSR required structural analyses for holds (tanks) in the midship part, HCSR requires analysis for the entire cargo area. The schematics for this are illustrated in Figures 1 & 2 and Table 1 below.



a) Former CSR   b) HCSR

Fig.1 Comparison of cargo hold regions for FE structural analysis

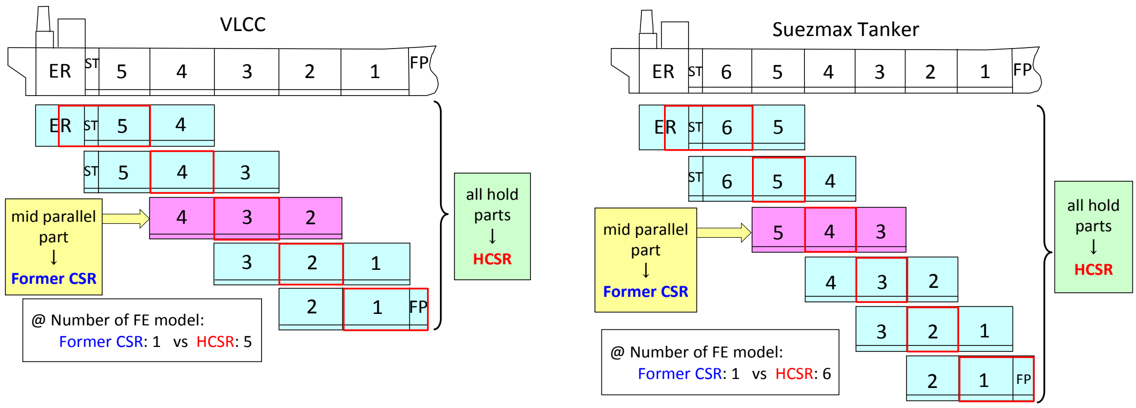


Fig.2 Comparison of number of FE model

The schematics show that in the former CSR, structural analysis is centred on the midship part, which is subject to the severest conditions in terms of strength, and the scantling and strength checks are accordingly conducted. For oil tankers, the conventional procedure was to first prepare the scantling, determined for the midship, for fore and aft cargo tanks, and then to determine the scantling of the entire cargo hold part. On the other hand, in HCSR, as shown in the schematics, it targets the entire cargo area and analyses the subject tanks one-by-one. Due to this change, the structural analysis with the three-cargo-hold model by targeting the midship had to change to one with as many models as the number of cargo tanks, increasing the structural analysis work by several times.

In addition, the structural strength, particularly of important stress concentrated parts, needs to be analysed using FE models with a detailed mesh for each stress concentrated part separate from the coarse mesh model described previously. The subject parts cover the whole cargo area, requiring evaluations of numerous structural parts.

Table 1 Number of load cases for FE analysis for each type of tanker

	Hold Number						Total load cases
	No.6	No.5	No.4	No.3	No.2	No.1	
VLCC		14/103	14/90	14/90	14/76	14/66	**425**
Suezmax	11/65	11/48	11/48	11/48	11/50	11/50	**309**
Aframax	11/65	11/48	11/48	11/48	11/50	11/50	**309**
MR Product	11/65	11/48	11/48	11/48	11/50	11/50	**309**

N1/N2
N1 = Number of loading pattern
N2 = Number of loading case

Yellow: Midship cargo hold region
Green: Forward cargo hold region
Pink: Foremost cargo hold
Light blue: Aftmost cargo hold

Note) The number of load case may be reduced according to the design condition of each vessel.

2.3 Relation between design process and structural analysis

Now it shall be explained why the structural analysis for the entire cargo area has a larger effect on the design process than the increase in analysis volume.

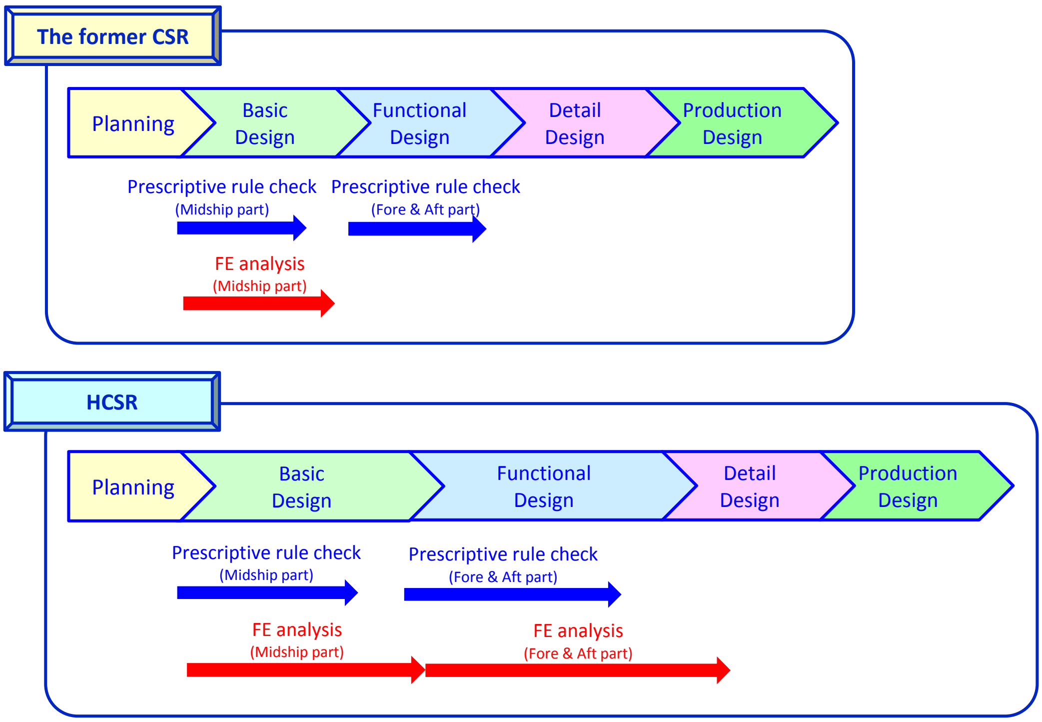


Fig.3 Comparison of design flow diagram between the former CSR and HCSR

In the planning stage, the principal dimensions, hull form, and performance are determined. In this stage, the basic conditions such as trim, longitudinal strength and stability are also fixed.
This is the starting point of structural design in a real sense. Based on the aforementioned longitudinal strength conditions, decisions are made for the structural arrangement of the midship part, i.e. parameters such as double bottom height, double side width, hopper tank shape, arrangement of primary supporting members, fore and aft transverse spaces, and longitudinal stiffener space on the cross section of the hull

structure. In addition, based on the structural arrangement plan set there, the scantling calculation is conducted according to HCSR, and the initial values of the plate thickness and size of the longitudinal stiffener of each part are determined. In the structural design practised 30 years ago, it was no exaggeration to say that this stage was where the scantling of the midship part would largely be determined.

Today, the following stages will involve structural analyses which require huge amounts of design man-power and design hours.
Based on the initially set structural arrangement and scantling, an FE model for three holds in the structural analysis is made from this stage, but it takes a considerable amount of labour and time to build up and finalize a model for FE analysis. Normally, a structural analysis model is made for each structural part based on gross thickness, and it has to be corrected to the plate thickness after subtracting 50% of the corrosion margin according to each compartment before analysing. The 50% subtraction work for FE model made by the gross thickness requires software specifically for HCSR provided by Classification Societies. Simple analysis of this point shows that the processing efficiency of the software provided by Classification Societies is likely to have large effects on reduction of the design workload at shipyards.

As mentioned above, the number of the structural analysis models for the hold part becomes several times compared with before, leading to the increase in the design processes.

In the former CSR, generally, the model for the midship hold is first made, the structural analysis is conducted, and an evaluation is made to finalise the structure scantling of the midship, which concludes the structural analysis process. At this stage, the basic design is completed.

In shipyards in Japan, the structure of the midship part is determined in the basic design stage in general. In the functional design stage, the structures of fore and aft holds, the engine room, fore part, and aft part are determined. At this stage, it is a general practice to make structural drawings for approval to be submitted to ship owner and Classification Society. As for the scantling of the fore and aft holds, based on the information determined in the midship, decisions are made on the suitability of using the same scantlings or otherwise, and structural analyses of the fore and aft holds were not necessarily conducted. In addition, the rules did not require them. This is illustrated in Figure 3.

HCSR demand structural analyses, not only for the fore and aft holds, but also for the engine room and part of the fore part. Thus it is required to first establish the initial scantling and structural arrangement in this stage, make new structural analysis models, and conduct structural analyses according to the previously mentioned procedure. Accompanying this change, the completion of the structural analysis process would drag further into the designing stage, which would also delay the determination of final scantling, and thus likely to exert pressure on the later designing processes. In particular, when conducting the analysis for the fore and aft holds, it is not possible to make an accurate structural analysis model without having first determined the arrangements of longitudinal stiffener on the outer shell plate. Therefore, the structural model has to be made after waiting for the design process, which will prolong the design period.

Another problem in creating the structural analysis model is the arrangement of the access route in tanks, in particular for positioning of manholes. For the manholes (openings) to be used as access routes after going into service, HCSR require removing part of the mesh from the FE model in way of such openings. Therefore, it is necessary to make a detailed access plan and to reflect the information of where the manholes are provided in the analysis model. If the access arrangement changes after the structural analysis, strictly speaking, it would be necessary to conduct the structural analysis again after revising the analysis model by reflecting the new manhole positions. However, in general, the access arrangement is determined at the outfitting design stage, and it is often that they are not finalised when structural analysis is to be conducted. Therefore, it is the case that the tentative analysis is conducted with the initial manhole arrangement, and sometimes it might be necessary to revise the model and conduct the structural analysis again later, resulting in a significant loss in design time and expenditure of labour.

2.4 Impact on design work load and design period

In any case, HCSR incur a significant increase in the number of structural analysis models, analysis cases, and the subject parts to be assessed in order to evaluate structural strength over a wide extent. If by merely increasing the volume of analysis structural safety could be enhanced as a whole, then the goal is considered to be accomplished. Meanwhile, the workload in the design process of the shipbuilding industry continues to increase, and in fact, the increases in design cost and prolongation of the design process is affecting the ship owners. IACS and ship owner associations should recognise this point.

A little more about the structural analysis shall be discussed.

As for a design scenario utilising FE structural analysis, it follows these steps as already described above: modelling of the structure, calculation by structural analysis codes, evaluation/assessment/summary of the results, and determination of the scantling of each part of the hull structure based on the final results. In this procedure, the calculation processes have made rapid speed improvements owing to enhancement of modern analysis codes and supporting software, and high-performance workstations, which lessen the burden on the designers. Meanwhile, for the modelling of the hull structure, the required number of structural models increased when compared to the conventional design methods. The drastic increase in the structural parts to be analysed and evaluated as detailed structures leads to a multifold increase in the work load on the part of structural designers comparing HCSR with the former CSR. Furthermore, stricter requirements are demanded by the rule for the mesh quality for FE structural analysis. The effort to realise such quality places a tremendous burden on the structural analysts.

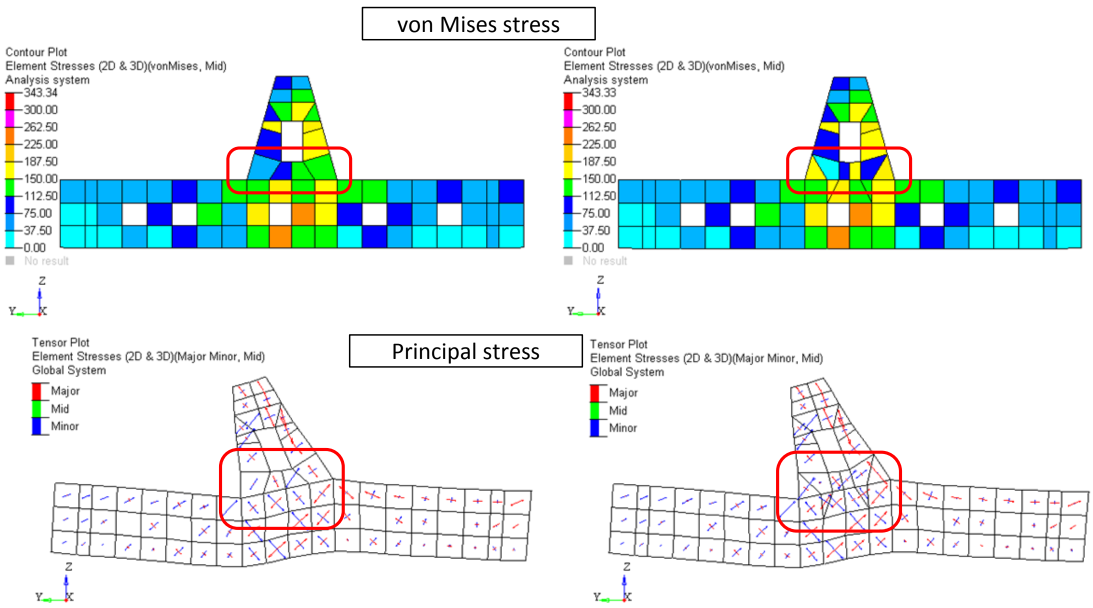


Fig.4 Influence due to the quality of mesh division on the stress results

As for the evaluation and assessment of the structural analysis results, it is a matter of course that the work load increases in proportion to, for example, the number of loading conditions, the number of models, and the number of subject locations to be analysed. In this regard, each Classification Society develops its own software for HCSR and offers it to the shipbuilding industry, with which ship designers are expected to use to verify compliance of the design with the Rules. In other words, it is practically impossible to design oil tankers without the software provided by Classification Societies. Therefore, today, the cost of structural design for shipyards is directly affected by the quality, convenience, functionality, efficiency, and accuracy of the software provided by Classification Societies.

As mentioned above, processing a huge amount of analysis cases leads to a huge amount of calculation output. The calculation sheets which describe the analysis results would also be voluminous.

For example, when evaluating yielding strength, a general method is to do so via contour plotting, which separates the level of von Mises stress by colour plot. The stress value can be that given in the loading conditions which produce the harshest results. In other words, when looking into the stress contour plot of a certain structural part, it is quite possible that, while element number 1 shows the stress in loading case A, the neighbouring element, number 2, shows the stress in a different loading case B. From an engineering point of view, it is difficult to visualise the physical phenomena behind such results. Therefore, to practically implement the analysis process, the analysis results are often evaluated without understanding the stress field for a certain loading case. This is necessary for processing the significant amount of calculations required by HCSR. However, for the hull structure, it would take a tremendous amount of effort and time to understand the physical phenomena such as what kind of hull structure response there would be to a certain kind of wave condition, and which parts would be under significant stress. This is something that is difficult to understand, not only for ship designers, but also for Classification Society approval surveyors and ship owners. There is no doubt that the fastest method to determine scantling is to extract the maximum stress for each part without distinguishing the results for different loading conditions and to determine the plate thickness and the dimension of stiffeners based on these values. However, for developing the engineering sense of the ship design engineers, it is essential for them to grasp the stress flow and hull structure deformation mode after surveying the results for all loading conditions. Such information is also necessary to provide comprehensible explanations and reports to ship owners.

2.5 Availability of software tool

The purpose of the software for HCSR provided by Classification Societies is not only to check the conformity of the shipyard's design results with HCSR. It is necessary for Classification Societies to recognise that it is also a tool for shipyards and designing companies for designing HCSR compliant ships. Therefore, the software should satisfy the following conditions.

- Ease of inputting design information, visibility of the information, and ease of modification of inputs
- In respect of structural analysis, full functions for creating the analysis models satisfying the rule requirement.
- Calculation time without causing tediousness
- In respect of output, ease of visual checking of results
- Particularly for the display of the dominant loading case
- Display functions for deformation plots and principal stress
- Comprehensible reporting capabilities

The above points are useful for evaluating the strength assessment results of a HCSR compliant oil tanker not only for shipyards, but also for explanation of the evaluation results to ship owners.

2.6 Modelling technique of FE analysis

As mentioned earlier, HCSR treat three holds as a unit when considering the entire hold part and require a model for each hold and structural analysis and evaluation of strength for each hold. When modelling the three holds of the midship, because the holds are contiguous at the fore and aft, applying the hull vertical bending moment and hull vertical shear force as boundary conditions is considered as relatively rational method.

However, when undertaking a structural analysis for the fore and aft holds, particularly the foremost and aftmost holds, it is necessary to model the fore and aft holds to include the fore part and engine room, where the structure configuration changes quite abruptly. Moreover since these are regions where the hull vertical bending moment rapidly reduces, thus making it difficult to apply boundary conditions, hull vertical bending moment, and shear force on the hull structure.

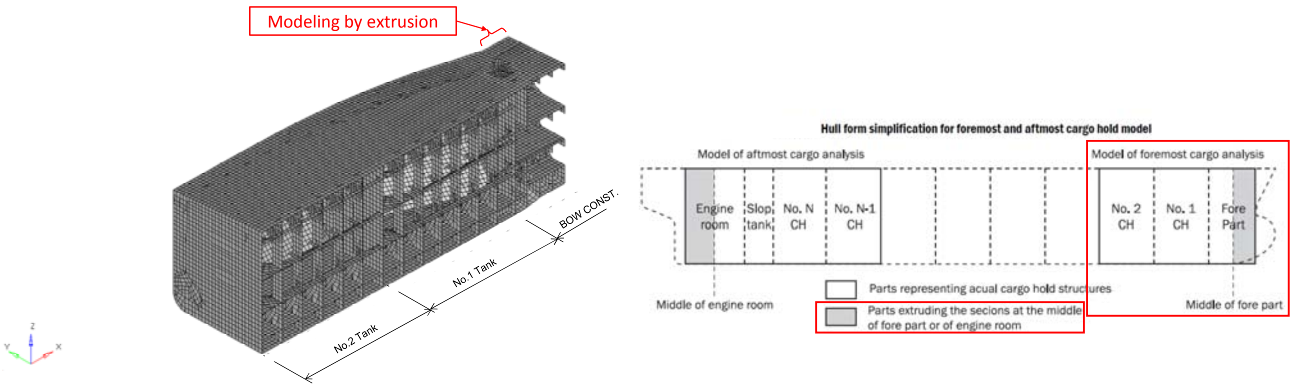


Fig.5 Example of hull form simplification for the foremost cargo hold FE model

In order to avoid spurious deformation and stress response near the model boundaries, modelling such as that shown in Figure 5 is sometimes used. However, the hull structure is not supported at the fore and aft ends by the continuous hulls but is instead free. It is therefore reasonable to come up with a model that can express such characteristics.
In the industry review of HCSR, there was a proposition that it would be more reasonable to utilise a whole ship model instead of the three-hold unit model. IACS pointed out that it is difficult to apply unified loading conditions to whole ship models given the variety of hull forms and, thus, IACS selected the three-hold model units approach.
In the three-hold model approach, there are many models to be made, but the shipyards can, for example, build a whole ship model and divide it into units of three-hold. Each shipbuilding company needs to find an efficient solution to design cost reduction.

2.7 Fatigue evaluation

For many ship owners, it is considered that the most sensitive viewpoint in terms of the evaluation of hull structure is the fatigue strength. If fatigue of a structure leads to cracks, which in turn can lead to function loss such as leakage from cargo tanks or fuel tanks, the consequence and reputational and financial damage could be tremendous. Therefore, shipyards are often requested to make highly robust design and construction in terms of fatigue strength.
The evaluation of fatigue strength focuses on structural discontinuities and high stress parts, and it is implemented by methods such as the prescriptive analysis method by the rule and FE structural analysis. The output value of the evaluation is "fatigue life", which indicates the number of years that the structure can endure under the harsh environmental conditions in the North Atlantic Ocean. Shipyards, Classification Societies, and ship owners would pay meticulous attention to whether or not the lifetime is less than or greater than 25 years.

However, it is also necessary to objectively evaluate what this fatigue life of 25 years represents. This is a result that was obtained merely based on the conditions set by HCSR; the fatigue life would not be the same if evaluated by the former CSR even for oil tankers with same scantling. Moreover, it is possible that the hull structure, which had a fatigue life of 25 years or more according to the former CSR, does not have a fatigue life of 25 years, which would require a modification in the design. It is not true that the ships designed according to the former CSR lack soundness. It is important to avoid the misunderstanding that the ships, designed by the former CSR and with lower evaluations according to HCSR, were less sound. Each industry needs to recognise that the value is obtained merely from the evaluation standards and underlying assumptions of HCSR, and it is necessary to respond to the evaluation results in an informed and sensible way.

As for the fatigue strength evaluation obtained via structural analysis, while the former CSR treated oil tankers and bulk carriers separately, HCSR unified the two procedures completely. However, it is said that a definitive methodology for the fatigue strength has yet to be established, and HCSR also inherits the conventional method, known as the Palmgren-Miner Rule. While Palmgren-Miner Rule is a simple and practical fatigue strength evaluation method, it does not take into account the effect of load history on the crack initiation time. It is important to recognise that the fatigue life obtained from this method is merely an estimate.

Furthermore, the structural analysis for the fatigue strength uses a FE model with the mesh size of the plate thickness, e.g. very fine 20 mm x 20 mm mesh. HCSR has detailed requirements for the quality of the mesh, stress extraction method, and evaluation location, which demands a significant amount of work during the analysis process to meet the requirements.
However, the FE model is based on a surface model, so such model has plate thickness not as three dimensional shape but only property data as illustrated in the example structure shown in Figure 6. The actual structure has plate thickness as well as welding bead, so the FE model cannot yield complete results in terms of three dimensional shape. Moreover, there remains more discussion to be done on the evaluation method of hot spot stress, and fatigue strength evaluation is based upon these assumptions, which should be recognised by the ship designers, Classification Society approval surveyors, and ship owners. They need to consider these backgrounds of the fatigue strength evaluation as well as the fatigue life.

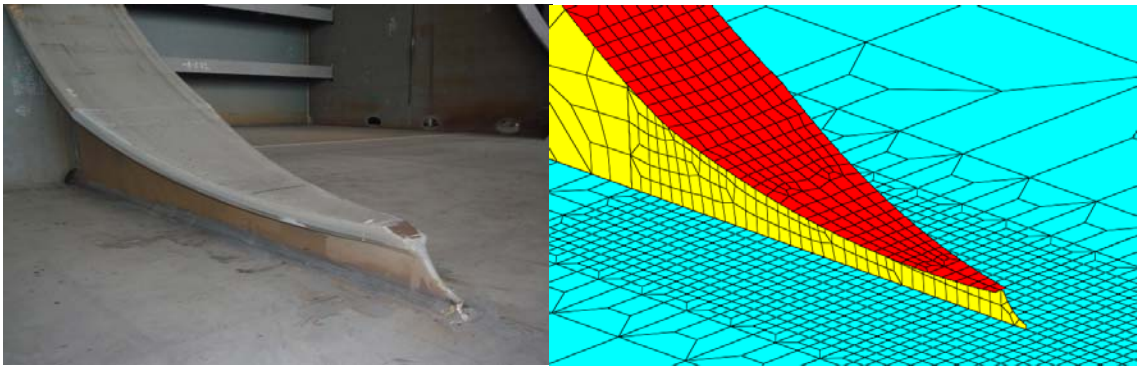


Fig.6 Comparison between the actual structure and the FE model

2.8 Calculation reports

Thus far, it has been pointed out that HCSR not only unified the rules for oil tankers and bulk carriers, but also impose new requirements and modifications. As explained the workload significantly increased, particularly in terms of structural analysis, thus having a significant impact and burden on the design processes in shipyards.

Now, the fact that the number of structural analyses increased drastically indicates that the calculation reports will also increase. Shipyards submit to Classification Societies calculation reports as a reference when undergoing an examination and the point is how to consolidate the report. HCSR require the use of the software provided by Classification Societies to the industry. At the stage for making the calculation reports at a shipyard, the quality and page number of the calculation report depends on how reasonable an output this software generates. On this aspect, shipbuilding industries consider it a point of evaluating the effort on the software development by each Classification Society.

Numerous analysis models, stowage conditions, loading conditions, fine mesh analyses for checking stress concentrated parts, and very fine mesh analyses for checking fatigue strength all add up to a tremendous amount of analyses and reports. Summarising in calculation sheets involves selecting necessary parts, but it requires efforts to satisfy the conditions for examination of Classification Societies. Since the analysed results must all be checked, calculation sheets should include not only von Mises stress, the base for yielding strength, but also principal stress which shows the direction of stress, and the deformation diagram, which must be checked to visually capture the phenomenon. Including all the above would lead to several thousands of pages for one ship, or even ten thousand pages. It is quite a daunting task to check the detailed contents of such calculation reports; therefore, engineering sense is required just to check, after the analysis, the accuracy of the input data set before the analysis.

At the same time, calculation reports have information about structural response, which expresses the structural characteristics of the ship. So they are very important documents for the shipyards, and these have to be guarded as intellectual properties. In future, as HCSR-compliant ships are delivered, these voluminous calculation reports will be stored in an archive centre as ship construction files (SCF). When the ship owners need the results in the calculation reports, they will be shared after following careful procedures.

3 Views on HCSR from shipbuilding industry

Thus far, the differences between the former CSR and HCSR and the effects on the ship design have been explained from a shipbuilder’s perspective. HCSR for oil tankers and bulk carriers involve a level of detail and high volume of items that were not conceivable in the traditional rules. It also demands a significant amount of structural analysis. The fact that the rules are common for twelve Classification Societies of IACS is revolutionary from a rule-making point of view.

The purpose of the CSR is obviously to design and build safe oil tankers and bulk carriers, which is the goal of GBS. The structural safety of oil tankers and bulk carriers has surely increased in the time span from before 2006 when each Classification Society had different rules to the intervening 10 years of the former CSR when HCSR had not yet been established. HCSR not only create rules for the structural design of the hull structure but also mention detailed criteria for various structures, which makes it something like a textbook. By giving detailed requirements, it unifies the design of each ship building company and increases the structural safety as a whole. Meanwhile, it can be argued that it restricts freedom of design, which could inadvertently impede future design advancements of oil tankers and bulk carriers.

Today, most oil tankers are primarily built in Japan, China, and Korea. With the homogeneity introduced by the rules, how would it be possible to distinguish the hull structure of each shipyard? The only way for differentiation from each other seems to be by securing and increasing the structural quality. For example, even for two oil tankers that are made according to the rules that have the same plate thickness, scantling, and almost identical designs, the final quality and actual strength level of hull structures would be different depending on the extent of quality assurance during the building process. In particular, the quality of welding and accuracy control of structural connections significantly affects the actual structural strength. Therefore, the responsibility of shipyards for truly securing the safety of the hull structure includes securing a high level of structural quality and realising the calculated structural strength in the actual hull structure. Whether or not this goal can be realised may be the key to distinguishing shipyards.

Meanwhile, our desire is that IACS will make sure to follow-up on the former CSR and HCSR, which affected both ship owner associations and the shipbuilding industry.

First, an evaluation of oil tankers, designed according to the CSR, is needed after delivery. If designed according to the rules, they are supposed to last 25 years in terms of operation in the North Atlantic Ocean. When damage occurs to the hull structure, the reason, whether it is a problem in the rules or the structural quality, should be investigated and evaluated. IACS should share the information with industries and IMO to ensure the transparency and validation of the CSR. Also, IACS should be able to explain to ship owners whether the former CSR ships have sufficient structural safety.

Also, even though the rules have been unified, there is no such unification in the software needed for HCSR; each Classification Society develops their own software. Shipyards must select the most efficient software. As mentioned above, based on the fact that compliance with HCSR is practically impossible without reliance on software provided by Classification Societies, our desire is that Classification Societies develop software in a user-centric manner and makes further improvements. This should be recognised as an important point in distinguishing classification societies.

It is easy to make the rules relatively enhanced compared to the conventional ones. However, it is IACS's responsibility to judge the reasonable and necessary extent of strictness.
In order to do so, it is our desire that IACS conducts follow-up investigations and studies on the service records after delivery of the former CSR and HCSR ships and feeds the information back to the industries.

Shipbuilding industries invest human and financial resources for application of the CSR. The corresponding cost increase affects the ship owners in the end. It is our desire that IACS takes into account the economical as well as technological points of view when considering how to further enhance the rules.

4 Conclusion

Finally, how should shipbuilding industries respond to the new era of HCSR?

They need to minimise the increase in the design work load and, thus, in the design cost; ideally, they should keep the cost as low as it was in the former CSR to minimise the increase in the cost for the ship owners.
In order to do so, the point is how to reasonably conduct the structural analysis, which is the main cause of increases in the design workload. With the assumption that FE structural analysis is needed for almost the whole ship, it is necessary to not only review the design process and use the software from Classification Societies, but to also develop supporting software to increase the efficiency.

Also, the efficiency of submission and approval processes of the design information by Classification Societies is also necessary; for example, shipyards would need to not only make electronic versions of the numerous calculation reports but also efficiently make summary reports and simplify these for the good understanding of Classification Societies and the ship owners.

Although not mentioned extensively in this document, it is necessary to check, for example, whether there is a significant increase in the scantling of a HCSR oil tanker compared to the former CSR in any shipyard and for any hull form. Shipbuilding industries also need to summarise the evaluation results and feedback to IACS.

Shipbuilding industries should flexibly respond to the rules of HCSR and continue making efforts toward further enhancing the safety and reliability of the hull structure of oil tankers. Also, they should minimise the cost increase factors due to the new rules by making their own creative effort, creating stronger cooperation with IACS and Classification Societies to build oil tankers that are not only robust but fit for the purpose intended.

References

[1] IACS, Common Structural Rules for Double Hull Oil Tankers, July 2012

[2] IACS, Common Structural Rules for Bulk Carriers, July 2012

[3] IACS, Common Structural Rules for Bulk Carriers and Oil Tankers, 1 Jan 2015