Impact of IACS Harmonized CSR on Tankers

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Abstract

The external draft of Harmonized Common Structural Rules (CSR-H) for Bulk Carriers and Oil Tankers has been released for external review. Based on a consistent methodology at the adoption of the current CSR, CSR-H aims to be in compliance with the IMO GBS where GBS functional requirement fall within its scope and its safety level is equivalent to or higher than the current CSR criteria. In this paper, by consequence assessment on a 320K VLCC, a 163K Suezmax tanker, a 115K Aframax tanker, a 76K Panamax tanker and a 48K MR tanker, results of comparison on structural scantlings to CSR, evaluation on the increasing of steel weight and some critical technique issues are discussed.
Keywords：CSR-H, CSR, consequence assessment, steel weight

1 Introduction

The current used Common Structural Rules (CSR) for bulk carriers and oil tankers were developed separately and were based on different technical approaches. In order to be in compliance with the IMO Goal Based Standards (GBS), it spends nearly 6 six years for IACS to harmonize the current CSR based on a consistent methodology, where GBS functional requirements will be within the scope of the CSR-H. Up till now, the two periods of Industry Review have been finished.

For oil tankers, it seems that some rule requirements in CSR-H are similar to those in CSR-OT. But from the consequence assessments, it is found that there are still some impacts on tankers and some items to be modified or changed to enhance reliability and rationality of rule requirements.

In this paper, based on CANSI’s investigations of a series of CSR tankers, incl. a 320K VLCC, a 163K Suezmax tanker, a 115K Aframax tanker (plane bulkhead), a 76K Panamax tanker and a 48K MR tanker, the following technical issues are discussed by comparing CSR-H (External release 1 Apr. 2013) and CSR-OT (July 2012), except that the increase of steel weight is compared between CSR-H and as built scantlings.

- Overview of the increase of scantlings and steel weights
- Rule minimum thickness requirement
- Issue on the setting of pressure relief valve
- FE analysis for midship cargo region
- FE analysis for foremost cargo tank region

Table 1 lists the principal particulars of the referred tankers in this paper.

Table 1 Principal particulars

Size / Principals	VLCC	Suezmax	Aframax	Panamax	MR
LBP (m)	320	264	234	220	176
B (m)	60	48	42	32.26	32.2
D (m)	30.5	24	21.6	21.2	18.6
Ts (m)	22.5	17.5	15.45	14.7	12.4
DWT (kilo ton)	320	163	115	76	48
Classification	BV	DNV	CCS	CCS	DNV

2 Technical Issues

2.1 Overview of the increase of scantlings and steel weights

Table 2 lists the estimated results of structural steel weight increase within midship cargo region compared to CSR-OT.

Table 2 Steel weight increase within midship cargo region (t)

Size / Criteria	VLCC	Suezmax	Aframax	Panamax	MR
Prescriptive requirement	182	50	74	11	15
FE analysis (yield, buckling, fine mesh, hot spot fatigue analysis)	38	45	31	41	26
Total	+220	+95	+105	+52	+41

The increasing of steel weight within mid cargo region is about 1%~2%. The increase due to prescriptive requirement is normally more than that due to FE analysis for tankers of VLCC, Suezmax and Aframax. For Panamax and MR, the increase for corrugated bulkhead due to FE buckling is prominent.

It should be pointed out that for any particular ship size a range of steel weight differences is possible since the estimates are highly dependant upon the degree of structural optimization and the original as-built design although all complied with CSR-OT.

The criteria for the increasing are discussed below.

2.2 Rule Min. thickness requirements

The following table gives the comparison between CSR-H and CSR-OT only due to Rule Min. requirements, where the same requirements are omitted.

The impact on oil tankers and brief explanation is listed by our investigations for several oil tankers.

Table 3 Rule Min. thickness requirement: Comparison and Impact

Elements	Scantling locations	Areas	CSR-H	CSR-OT	Impact on Oil Tankers and brief explanation
Min. net thickness for plating					
Shell	Keel		$7.5+0.03L_2$	$6.5+0.03L_2$	**0.5~1.0mm** ↑ for all OTs with longi. centerline BHD
	Bottom/Side shell/Bilge	Fore Part	$6.5+0.03L_2$	$4.5+0.03L_2$	Not critical
		Machinery space/ Aft part	$7.0+0.03L_2$		**0.5~2.0mm** ↑ except shell plating connected with stern frame
		Elsewhere	$5.5+0.03L_2$		**0.5~1.0mm** ↑ for regions outside fender contact zone
Inner bottom		Machinery space	$6.6+0.024L_2$	$6.5+0.02L_2$	Not critical
		Elsewhere	$5.5+0.03L_2$	$4.5+0.02L_2$	● **0.5mm** ↑ for some Suezmax ● If IB plating with HT36, more increasing
Other	Other plates in general		$4.5+0.01L_2$	None	Not critical
Min. net thickness for stiffeners					
Stiffeners and attached end brackets on N.W.T. boundary			$3.0+0.015L_2$	$2.5+0.015L_2$	Not critical
Min. net thickness for Primary Support Members (PSM)					
D.B centerline girder		Machinery space	$3.5+1.55L_2^{1/3}$	$5.5+0.025L_2$	Not critical
Other bottom girder		Machinery space	$1.0+1.7L_2^{1/3}$	$5.5+0.02L_2$	Not critical
		Fore part	$0.7L_2^{1/2}$		**0.5mm** ↑ for local areas
Bottom floor		Machinery space	$1.0+1.7L_2^{1/3}$	$5.5+0.02L_2$	Not critical
		Fore part	$0.7L_2^{1/2}$		**0.5mm** ↑ for local areas
		Elsewhere	$0.6L_2^{1/2}$		Not critical
Aft peak floor			$0.7L_2^{1/2}$	$5.5+0.02L_2$	**0.5mm** ↑
Web plates of other PSM in double hull		Machinery space	$0.6L_2^{1/2}$	$5.5+0.015L_2$	Not critical
		Elsewhere		$5.0+0.015L_2$	**0.5~1.0mm** ↑ for upper part of side trans. and platforms in DH
Web and flanges of other PSM		Aft part/Fore part	$0.7L_2^{1/2}$	$6.5+0.015L_2$	**0.5~1.0mm** ↑
		Elsewhere	$0.6L_2^{1/2}$	$5.5+0.015L_2$	Only for VLCC: ● **0.5mm** ↑ for deck trans. and upper part of vert. trans. in C.O.T. ● **0.5mm** ↑ for PSM in machinery space

It could be found that for some regions, although higher Rule Min. requirement by CSR-H, no critical impact for scantlings; while for other regions, the higher Rule Min. requirement by CSR-H will increase the scantlings.

It should be noted that Rule Min. requirement is the statistical data based on a lot vessels of same type. So for some parts, such statistical data or requirement for oil tankers or bulk carriers is not comparable. If simply taking the envelop Rule Min. requirement by CSR-OT and CSR-BC as that for CSR-H based on the *BASIC PRINCIPLES FOR CSR MAINTENANCE AND HARMONIZATION* by IACS, it will increase some unnecessary steel weights. It is suggested prescribing the Rule Min. requirement separately for oil tankers or bulk carriers.

2.3 Issue on the load combinations in S+D conditions for oil cargo tank

For the design load scenarios in liquid cargo tanks, the difference between CSR-H and CSR-OT is as follows:

Table 4 Difference between CSR-H and CSR-OT for the design load scenarios in cargo tanks

Design load combinations	CSR-H	CSR-OT
	Pt 1, Ch 4, Sec 7, Table 1	Sec 7, Table 7.6.1
Static (S)	$Max(P_{IS}, P_{ST})$	The greater of a) $P_{in-test}$ b) $P_{in-tk} + P_{valve}$
Static + Dynamic (S+D)	$P_{IS} + P_{Id}$	$P_{in-tk} + P_{valve} - 25 + P_{in-dyn}$

Where, $P_{IS} = \rho_L g(z_{top} - z) + P_{PV} = P_{in-tk} + P_{valve}$, $P_{PV} = P_{valve}$ (hereinafter called as P_{valve}), $P_{ST} = P_{in-test}$, P_{Id} is similar to P_{in-dyn}.

It could be found that the vapour pressure (not to be less than P_{valve} as required) is both considered in S and S+D condition in CSR-H and CSR-OT. The only difference is that in S+D condition of CSR-OT, 25kN/m^2 is deducted; while in CSR-H, no deduction is made.

P_{valve} is the setting of pressure relief valve, which is in general located at the midpoint of the highest level of cargo tank. During voyage (S+D condition), if the pressure near the valve is higher than the setting value of P_{valve} (not less than 25kN/m^2), such valve will be opened automatically and the pressure will be decreased; when the pressure is lower than the closing pressure, such valve will be closed automatically. At the same time, such valve will ensure the cargo tank be not a vacuum space.

We carry out a testing calculation of the pressure distribution of a typical center COT of a VLCC to investigate whether the cargo oil pressure value of the pressure relief valve is higher than its setting value (25kN/m^2). The calculation is to meet the requirement of CSR-OT and CSR-H respectively. The following tables list the results of midpoints of the highest level of the COT. In such points, No.33 is where the setting valve would probably be located.

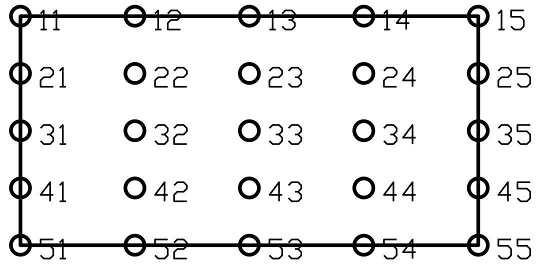


Fig 1 Point location in the highest level of a typical center COT of a VLCC

Table 5 cargo oil pressure distribution in S+D condition applied for CSR-OT

Design load set (S+D)		3 (due to cargo pressure)				
Load cases \ Point location		13	23	33	43	53
Head Sea	1	4.3	4.3	4.3	4.3	4.3
	2	8.6	8.6	8.6	8.6	8.6
	3	14.3	14.3	14.3	14.3	14.3
Oblique Sea	4a	4.3	4.3	4.3	4.3	4.3
	4b	4.3	4.3	4.3	4.3	4.3
Beam Sea	5a	44.3	33.5	22.7	11.9	1.1
	5b	1.1	11.9	22.7	33.5	44.3
	6a	27.3	21.9	16.5	11.1	5.7
	6b	5.7	11.1	16.5	21.9	27.3
	7a	32.8	26.3	19.8	13.3	6.9
	7b	6.9	13.3	19.8	26.3	32.8

Table 6 cargo oil pressure distribution in S+D condition applied for CSR-H

Design load set (S+D)	OT-1 (Full load condition)					OT-2 (Partial load condition)				
Load cases \ Point location	13	23	33	43	53	13	23	33	43	53
HSM-1	25.0	29.8	34.6	39.4	44.2	25.0	29.6	34.2	38.8	43.4
HSM-2	44.2	39.4	34.6	29.8	25.0	43.4	38.8	34.2	29.6	25.0
HSA-1	25.0	31.1	37.1	43.2	49.2	25.0	29.8	34.6	39.5	44.3
HAS-2	49.2	43.2	37.1	31.1	25.0	44.3	39.5	34.6	29.8	25.0
FSM-1	28.3	27.5	26.7	25.8	25.0	31.3	29.7	28.2	26.6	25.0
FSM-2	25.0	25.8	26.7	27.5	28.3	25.0	26.6	28.2	29.7	31.3
BSR-1P	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-2P	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-1S	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-2S	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5

Design load set (S+D)	OT-1 (Full load condition)					OT-2 (Partial load condition)				
Point location / Load cases	13	23	33	43	53	13	23	33	43	53
BSP-1P	33.4	34.7	36.1	37.5	38.9	33.9	34.5	35.1	35.6	36.2
BSP-2P	38.9	37.5	36.1	34.7	33.4	36.2	35.6	35.1	34.5	33.9
BSP-1S	33.4	34.7	36.1	37.5	38.9	33.9	34.5	35.1	35.6	36.2
BSP-2S	38.9	37.5	36.1	34.7	33.4	36.2	35.6	35.1	34.5	33.9
OST-1P	35.3	33.3	31.3	29.3	27.3	36.1	33.4	30.8	28.1	25.5
OST-2P	27.3	29.3	31.3	33.3	35.3	25.5	28.1	30.8	33.4	36.1
OST-1S	35.3	33.3	31.3	29.3	27.3	36.1	33.4	30.8	28.1	25.5
OST-2S	27.3	29.3	31.3	33.3	35.3	25.5	28.1	30.8	33.4	36.1
OSA-1P	57.7	50.6	43.5	36.4	29.2	59.2	52.0	44.8	37.6	30.4
OSA-2P	29.2	36.4	43.5	50.6	57.7	30.4	37.6	44.8	52.0	59.2
OSA-1S	57.7	50.6	43.5	36.4	29.2	59.2	52.0	44.8	37.6	30.4
OSA-2S	29.2	36.4	43.5	50.6	57.7	30.4	37.6	44.8	52.0	59.2

It could be found that for CSR-OT, the pressures at Point No.33 are all below 25kN/m2; while for CSR-H, the pressures are all above 25kN/m2. If the setting valve is located at Point No.33, the pressures in all load cases are not to be higher than 25kN/m2.

On the other hand, the vapour pressure in cargo oil tank will be altered due to temperature variations, cargo dynamic motion and sloshing. At the same time, the vapour pressure will impact the motions of cargo oil. In CSR-H and CSR-OT, when calculating the internal dynamic pressure, vapour pressure is not considered. In the load combination for S+D, the vapour pressure is added by P_{valve} directly, but CSR-OT allows 25kN/m^2 reduction, while no reduction is considered by CSR-H. No consideration for the relationship between the vapour pressure and the internal dynamic pressure may sound unreasonable.

Also, it could be found in the calculation of scantling requirements: for CSR-OT, S condition will be dominant for some plates or stiffeners on the boundaries of COT due to design load set No.4; while for CSR-H, the dominant load sets for the boundaries of COT are only from S+D condition, i.e. OT-1 or OT-2, but no S condition due to OT-3. The reason for such phenomenon is that the pressure in S+D condition is too higher than that in S condition.

From the Consequence Analysis (CA) reports, it could be also found that for oil tankers, the scantlings of some plates or stiffeners on the boundaries of COT or some PSMs in the COTs are to be increased due to local oil pressure. In Figure 2 and 3, the consequence assessment of a 320K_VLCC by CANSI is shown as an example, with the comparison between CSR-H requirement and the As-built scantling.

We think that the design load combinations for CSR-H in S+D condition are not suitable. The deduction in S+D condition is suggested to be considered to ensure the pressures in all load cases near setting valves no higher than their setting value.

Such increase for cargo oil pressures in S+D condition will impact the scantlings due to prescriptive requirement, FE yield strength and FE buckling strength.

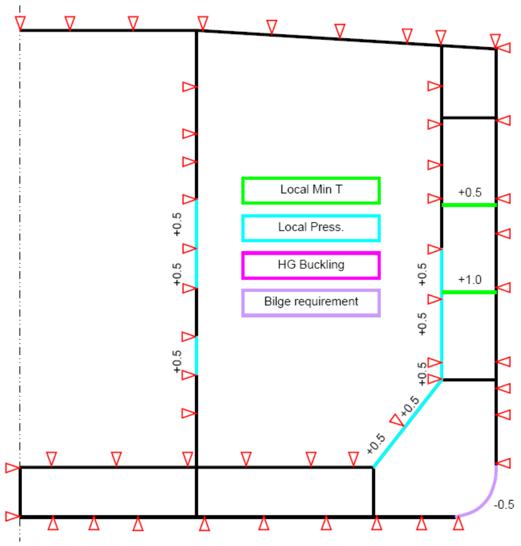


Fig 2 Plate thickness comparison between CSR-H and As-built scantling (320K_VLCC)

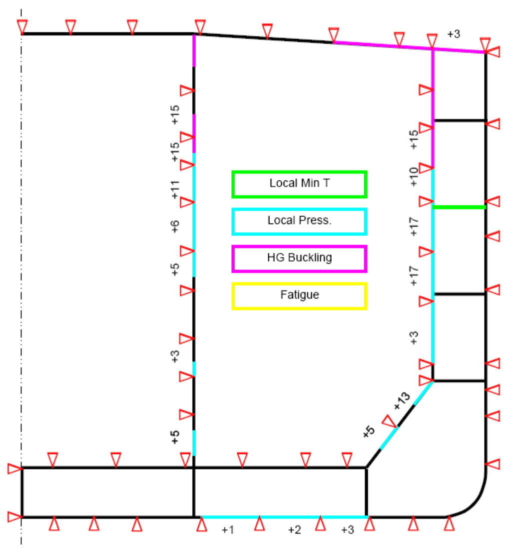


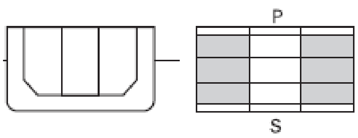
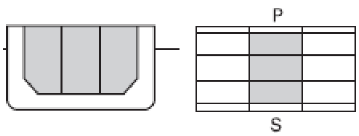
Fig 3 Sectional Modulus comparison between CSR-H and As-built scantling (320K_VLCC)

2.4 FE analysis for midship cargo region

2.4.1 Load combinations for FE analysis

Comparing the load combinations for FE analysis between CSR-H and CSR-OT in Table 7, it is found the main difference is for the draughts in loading pattern A3, A5, A11 and A13 for tankers with two oil-tight bulkheads, e.g. VLCC, except for the new dynamic load cases.

Table 7 Comparison for the load patterns for FE analysis between CSR-H and CSR-OT

No.	Loading Pattern	Draught		Notes
		CSR-H	CSR-OT	
A3		$0.65T_{SC}$	$0.55\ T_{SC}$	If conditions in the ship loading manual specify lesser draughts for loading pattern A3 or A13, then the max. specified draught in the ship's loading manual for the loading pattern is to be used.
A13		$0.7T_{SC}$	$0.65T_{SC}$	
A5		$0.65T_{SC}$	$0.8\ T_{SC}$	If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the min. specified draught in the ship's loading manual for the loading pattern is to be used.
A11		$0.6T_{SC}$	$0.7\ T_{SC}$	

For VLCC, cargo oil tanks are normally segregated into three groups in Table 8. In that case, the condition with all cargo tanks abreast empty and the neighbor cargo tanks full will not exist.

Table 8 Reasonable segregation for VLCC (OPTION 1)

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	3	2	1	P
3		2	1	3	3	C
1	2	1	3	2	1	S

If carrying two groups for such arrangement, the possible segregations are shown in Table 9. For such cases, the condition with all cargo tanks abreast empty or full will appears, with the neighbor cargo tanks partially loaded which is different from A3, A5, A11 or A13 load patterns.

Table 9 Possible segregation for VLCC with two groups (OPTION 1)

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	1	1	3	1	1	P
3		1	1	3	3	C
1	1	1	3	1	1	S

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	1	2	1	P
1		2	1	1	1	C
1	2	1	1	2	1	S

For only carrying one group of oil, the condition with all cargo tanks abreast empty or full would seldom appear unless unreasonable operations. Such unreasonable operations could be avoided by draught limitation and permissible SWBM/SWSF. That is to say, such load patterns of A3, A5, A11 and A13 would seldom appear.

But if the segregation of cargo oil tanks is not reasonable as shown in Table 10, the condition will all cargo tanks abreast empty or full would appear and is to be specified in the loading manual.

Table 10 Unreasonable segregation for VLCC (OPTION 2)

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	3	2	1	P
3		2	3	1	3	C
1	2	1	3	2	1	S

If specifying A3, A5, A11 and A13 loading conditions in loading manual for existing VLCCs, the draught in correspoinding loading condition is limited by the design envelop of SWBM and SWSF. The following is the statistics for the draughts of Chinese VLCCs in such non-typical loading conditions:

Table 11 Draughts of VLCCs in A3/A5/A11/A13 loading conditions

No.	VLCC1	VLCC2	VLCC3	VLCC4	Average
A3	0.68Tsc	0.72Tsc	0.67Tsc	0.65Tsc	0.68Tsc
A5	0.83Tsc	0.71Tsc	0.74Tsc	0.73Tsc	0.75Tsc
A11	0.81Tsc	0.70Tsc	0.74Tsc	0.73Tsc	0.75Tsc
A13	0.67Tsc	0.68Tsc	0.67Tsc	0.65Tsc	0.67Tsc

It could be found that the draughts in A3 and A13 will be close to that required by CSR-H; while the draughts in A5 and A11 will be close to that required by CSR-OT.

2.4.2 Acceptance yielding criteria for FE analysis

For the acceptable yielding criteria for N.W.T. plating and face plate of PSM in coarse mesh FE analysis required by CSR-H and CSR-OT, the comparison is shown in Table 11.

Table 11 Comparison for the allowable criteria for FE analysis between CSR-H and CSR-OT

	CSR-H		CSR-OT	
Rule reference	Pt 1, Ch 7, Sec 2, Tab 10		Sec 9, Tab 9.2.1	
Allowable stress *R*	R_y=235/*k*		R_{eH}	
MS (MPa)	235		235	
HT32 (MPa)	301.3		315	
HT36 (MPa)	326.4		355	
Yield utilization factor λ				
N.W.T. plate, PSM face plate	1.0 (S+D)	0.8 (S)	1.0 (S+D)	0.8 (S)

The acceptable criteria ($\lambda \cdot R$) for N.W.T. structural members in CSR-H is higher than that in CSR-OT (for HT32 steel 4.6% criteria increased; for HT36 steel 8.8% criteria increased). At the same time, the cargo oil pressure in S+D condition for CSR-H is higher than that required for CSR-OT. Both factors will induce steel weight increase for N.W.T. plating and face plate of PSM in oil tankers with high tensile steel used.

2.5 FE analysis for foremost cargo region

The strength analysis of a foremost cargo region of a typical 320K VLCC is carried out. It is found that FE buckling is a big problem for upper deck plating, inner hull longitudinal bulkhead plating and collision bulkhead plating as shown in Figure 4 to Figure 7.

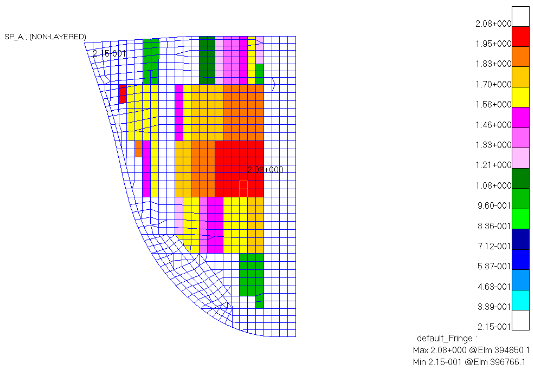


Fig. 4 Buckling utilization factor for the collision BHD

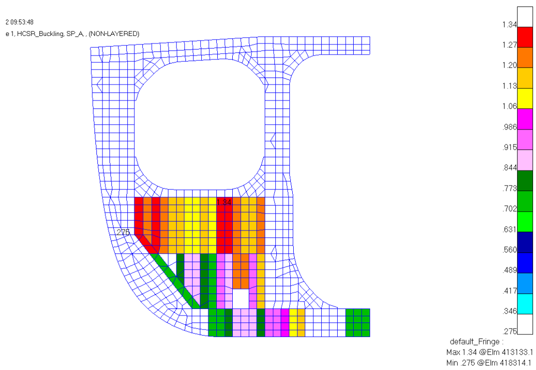


Fig. 5 Buckling utilization factor for the Swash BHD in foremost COT

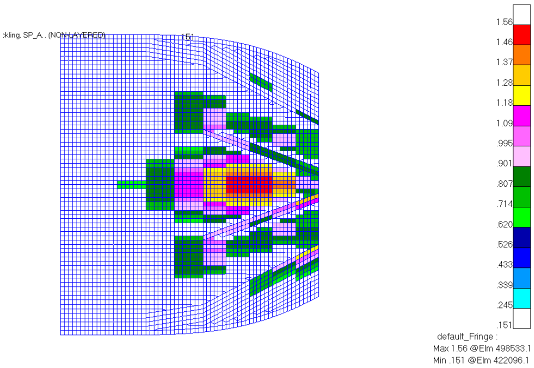


Fig. 6 Buckling utilization factor for upper deck

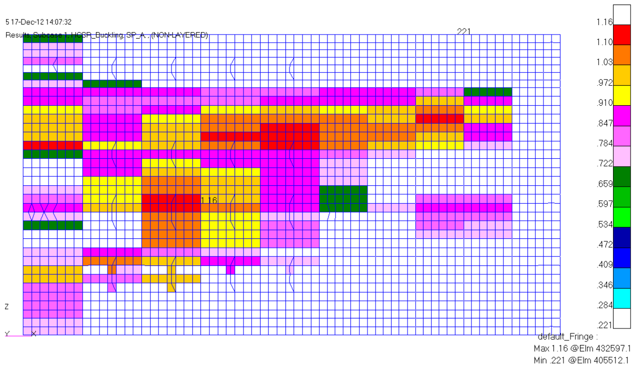


Fig. 7 Buckling utilization factor for Longi. BHD

The buckling results, for typical plate panel in upper deck region between foremost cargo tank and midship cargo tank with the same panel dimension and same location of y and z, are compared as shown in Table 12.

It could be found that for the plate panels with same transverse and vertical location for upper deck, the value of σ_b in foremost cargo region is increased much more than that in midship cargo region due to the increased green sea load. For modification, it could meet the buckling criteria by CSR-H when the plate thickness in foremost cargo area is to be same as that in midship cargo area or lots of buckling stiffeners are to be arranged.

For other areas in foremost or aftmost cargo region, the same phenomena would occur for the buckling evaluation. That is to say, the increased external or internal loads will induce buckling issues for the foremost and aftmost cargo area, which should be paid more attention to.

Table 12 Comparison for buckling results for foremost cargo tank and midship cargo tank

Critical Load case	Panel in midship cargo tank	Panel in foremost cargo tank	
A1-HSM1		original	modified
σ_x (MPa)	205.0	68.3	60.4
σ_y (MPa)	13.2	85.0	78.2
τ (MPa)	14.5	1.4	1.6
t_{net} (mm)	14.5	12	14.5
Material	HT32	HT32	HT32
Buckling factor η_{act}	0.811	1.331	0.949
Allowable factor η_{all}	1.0	1.0	1.0
Buckling Ratio (η_{act}/η_{all})	0.811	1.331	0.949

2.6 Issue on the ultimate buckling capacity for stiffeners

The ultimate buckling capacity for stiffeners is required considering interactive lateral and warping (torsional induced) buckling modes.

In order to obtain the actual axial stress on the stiffener due to effective width of attached plate, the following formula is introduced with an increasing factor for nominal axial stress:

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1}t_p + A_s}$$

where, the factor is represented by $F = \frac{st_p + A_s}{b_{eff1}t_p + A_s}$.

But as CSR required, $\sigma_a = \sigma_x$, no considering for an increasing factor.

By the statistics for series of oil tankers, it is found that the increase for the effective axial stress is a bit larger (15%~30%) due to such factor as shown in Table 13.

The increase of axial stress has negative effect on the longitudinals with little margin for the buckling utilisation factor, which will lead to the fact that the prescriptive buckling results cannot meet the HCSR requirement for the longitudinals in the main deck and 0.1D below for most tankers, shown in figure 3 for 320K_VLCC as a example.

Table 13 Increasing factor for nominal axial stress to effective axial stress

Vessel/Location		s (mm)	t_p (mm)	A_s (mm^2)	b_{eff1} (mm)	F (Factor)	CSR-H η_{act}	CSR-OT η_{column}	CSR-OT $\eta_{torsion}$
VLCC	DL	876.8	14.5	6508	669.0	1.186	1.02	0.73	0.89
	IHL	800	13.0	5120	605.6	1.195	1.07	0.73	0.89
Aframax	DL	820.8	14.0	6088	641.9	1.166	0.91	0.72	0.87
	IHL	790	11.0	2860	548.3	1.299	1.12	0.68	0.88
	LL	750	11.0	3042	528.8	1.275	1.04	0.67	0.86
Panamax	DL	786	11.5	2890	552.6	1.290	1.08	0.74	0.84
	IHL	670	9.0	2453	452.3	1.300	0.96	0.62	0.75
	LL	640	9.5	2098	459.5	1.265	1.11	0.71	0.82
MR	DL	800	10.0	2944	559.2	1.283	1.05	0.71	0.80
	IHL	648.8	9.5	2223	512.6	1.182	0.96	0.65	0.74
	LL	781.3	9.5	2613	549.3	1.282	1.06	0.68	0.74

3 Estimation of design period

It could be found that the design, verification and approval period of CSR-H will be a big increase compared to the current CSR due to the following requirement:

- For FE analysis, it is required to cover the whole cargo area by CSR-H, not only for midship cargo area same as that required by CSR, but also for the foremost and aftmost cargo area.
- For fine mesh analysis,

    - the mandatory structural details is added by CSR-H, especially for the bulk carriers, and
    - the screening areas are increased by CSR-H, especially for the outside midship cargo hold regions.
- For fatigue analysis,
    - list of details for mandatory very fine mesh analysis is increased, and
    - additional design requirements by design standard are added: if not compliance with such standards, very fine mesh analysis is required. And
    - fatigue screening procedures of less critical details are introduced.
- Not only for prescriptive requirement but also for FE and fatigue analysis, loading patterns by CSR-H are increased.

By conservative estimation for the modeling and FE analysis for the foremost and aftmost cargo areas, at least 1.5 times more than that for the midship cargo area is required, respectively. If no efficient FE modeling tools, more time will be possible. Therefore, the design, verification and approval period will be estimated 3~5 times more than that for CSR.

4 Conclusion

CSR-H has been reviewed by industry for 2 periods. Some requirements or contents have been revised based on the comments from industry. But so far, there are still some issues, some of them are listed in this paper, which are to be discussed and considered by IACS.

By our consequence assessment for a serial of CSR tankers, the impact of CSR-H on tankers can be summarized as following:

- The increase by prescriptive requirement is normally more than that by FE analysis for VLCC, Suezmax and Aframax with plane bulkhead. For Panamax and MR, the increase for corrugated bulkhead due to FE buckling is prominent.
- The total increase of steel weight in midship cargo area is about 1%~2%.
- The design, verification and approval period will be 3~5 times more than that for CSR.