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Consequence Assessment of **Harmonized CSR**

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THE SHIPBUILDERS' ASSOCIATION OF JAPAN

Contents

Summary of C.A.

The SAJ members carried out the **Consequence Assessment** of **CSR-H 2nd Draft**.

The calculation software is **PrimeShip-HULL**.

The excellent software package for the calculation of CSR-H.

The subject vessels are as shown below.

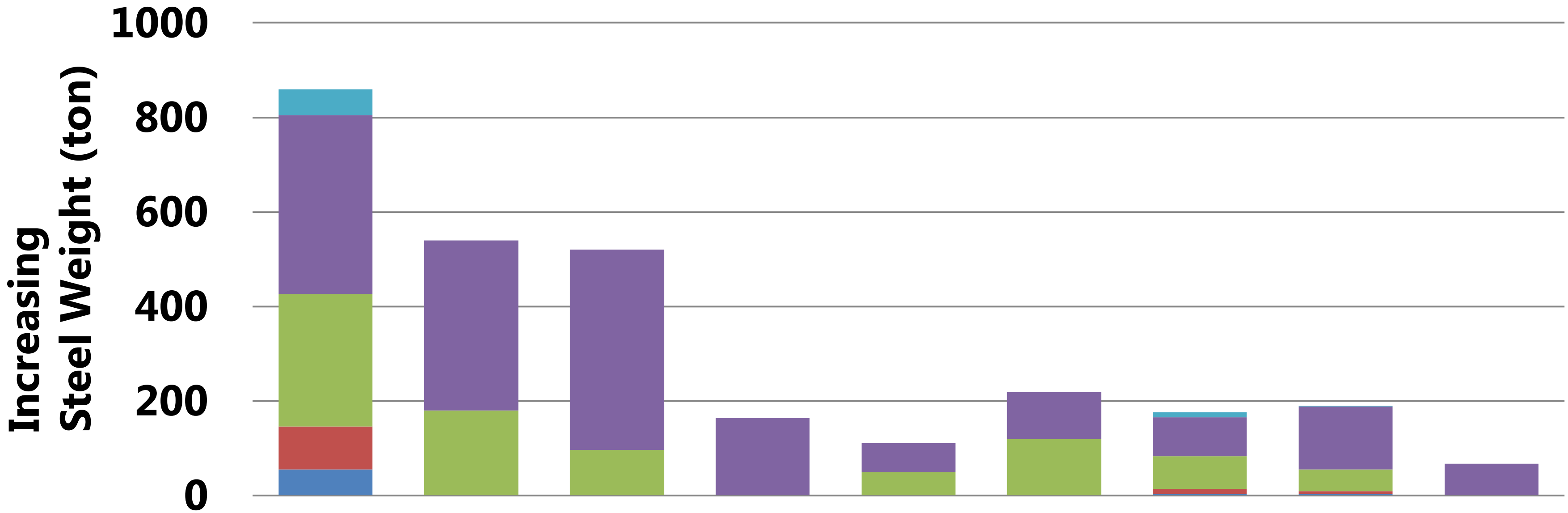
Bulk Carriers	**9 vessels**
Capesize	2
Over Panamax	1
Panamax	4
Handymax	2

Oil Tankers	**4 vessels**
VLCC	1
Aframax	1
MR Product	2

C.A. Conditions

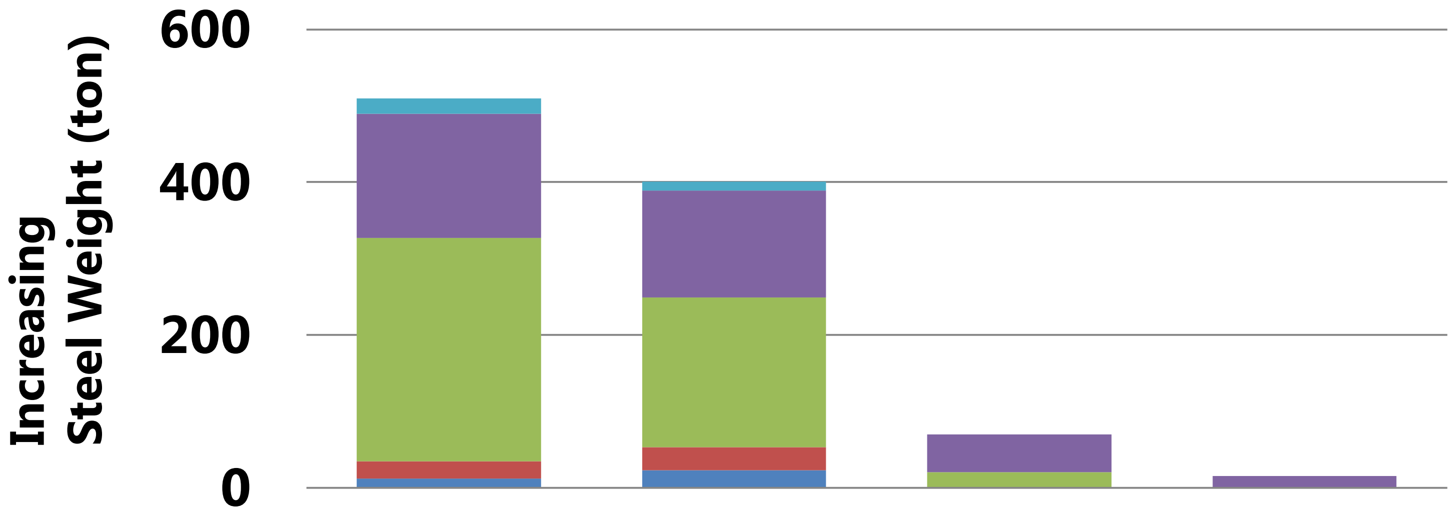
- The subject vessels are complied with CSR.
- No structural re-arrangement.
- No Steel Material Grade change.
- No Basic Design Condition change.
  (Principal Particulars, Bending Moment, etc.)
- No Optimization.
  (additional Seam, Seam Position modification, etc.)

Weight Impact for Bulk Carriers



	Cape A		Cape B		Over Px		Pmax A		Pmax B		Pmax C		Pmax D		Hmax A		Hmax B	
	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM
MID HOLD	○	○	○	○	○	○	○	○	○	×	○	×	○	○	○	○	○	○
F&A HOLD	○	○	○	×	○	×	×	×	○	×	○	×	○	×	○	○	×	×
BOW	○		×		×		×		×		×		○		○		×	
ER	○		×		×		×		×		×		○		○		×	
STERN	○		×		×		×		×		×		○		○		×	

Weight Impact for Oil Tankers



	VLCC		Aframax		MR Product A		MR Product B	
	CAL	FEM	CAL	FEM	CAL	FEM	CAL	FEM
MID HOLD	○	○	○	○	○	○	○	×
F&A HOLD	○	○	○	○	○	×	×	×
BOW	○		○		×		×	
ER	○		○		×		×	
STERN	○		○		×		×	

Main Causes of Weight Impact

- Grab Requirement (Bulker)
- FEM Analysis (Both)
- Fatigue Analysis (Bulker)
- Increasing Internal pressure (Tanker)
- Minimum Thickness (Both)

Big Different between Current CSR & CSR-H

- Grab Requirement
- Fatigue analysis
- Minimum thickness
- Workload of FEM analysis

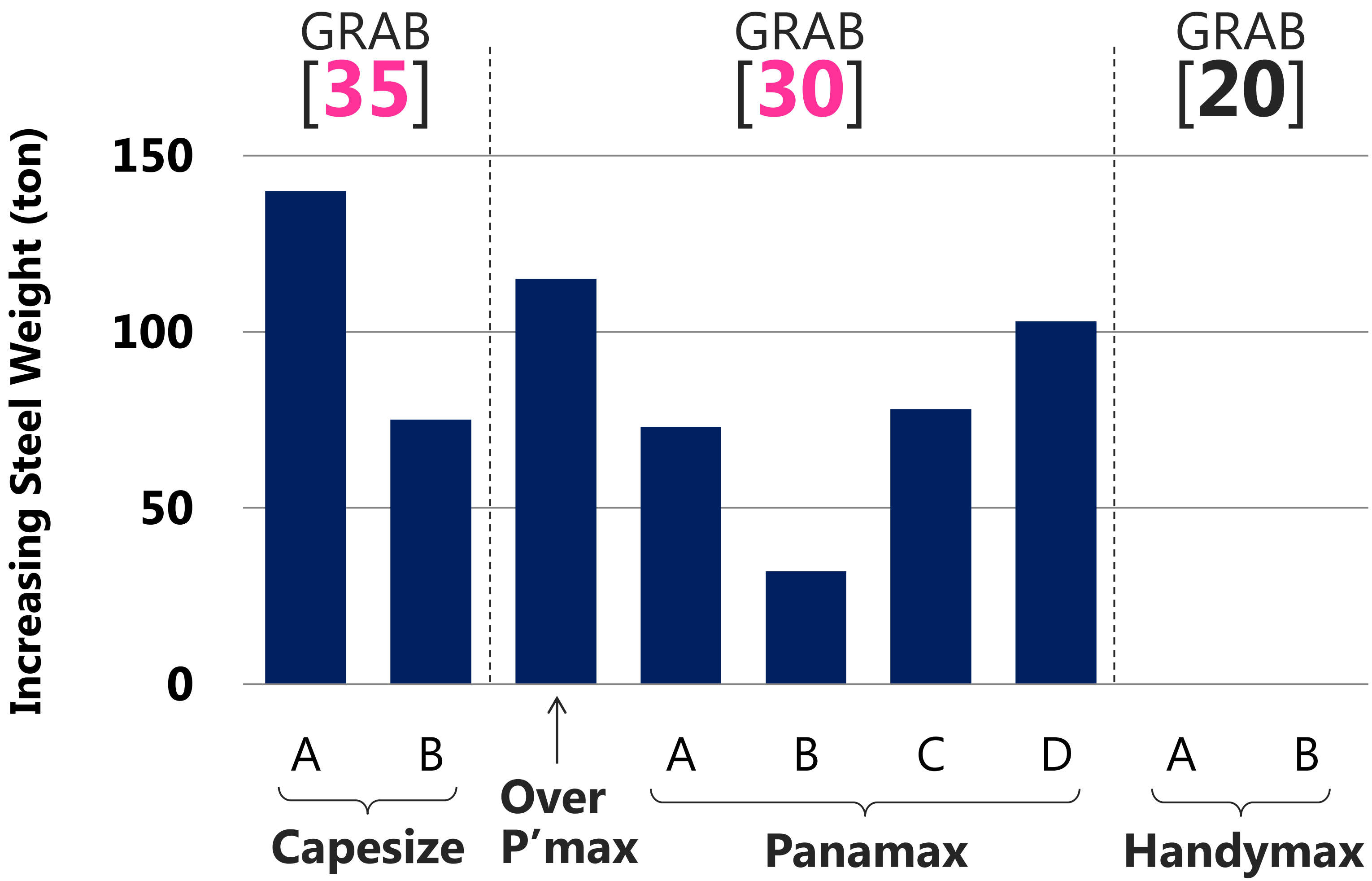
Grab Requirement

Big Difference Grab Requirement

GRAB Weight

CSR-B		CSR-H	
20MT	→	35MT	for ships with 250m≦L
		30MT	for ships with 200m≦L＜250m
		20MT	otherwise

Weight Impact due to Grab requirement



Grab Requirement

Impact of **Grab Requirement** is
30ton～140ton.

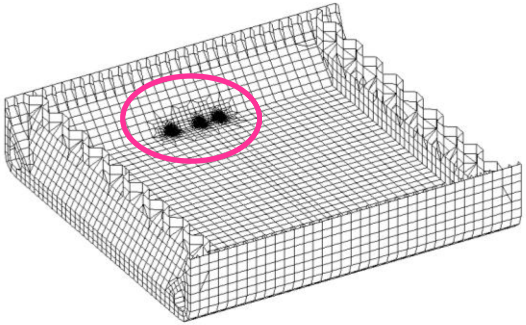
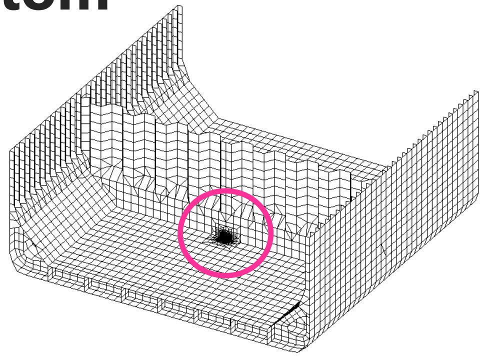
IACS should change to same as CSR-B because this rule change is beyond the harmonization work.

* Further revision of grab requirement formula is being expected in the third(TC) draft.

Fatigue analysis

Fatigue Analysis

Very fine mesh Fatigue Assessment of **CSR-H** is carried out.
And This result is **compared with CSR**.

Ship Type	**Handymax** BC
Evaluated Hold	No.3 Hold (**Ballast Hold**)
Evaluated Position	**Crosspoint** of **Lower Stool & Inner Bottom** **Crosspoint** of **Hopper & Inner Bottom**  

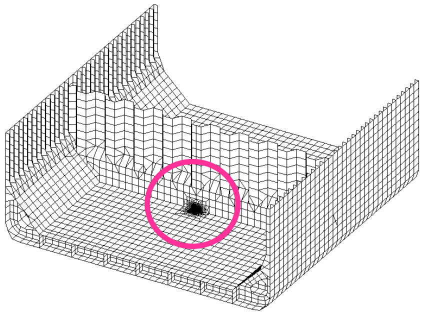
Result of Fatigue Assessment

Crosspiont of **Lower Stool & Inner Bottom**

* Evaluated by the Simplified Method

Materials	CSR-H	CSR-B *	CSR-B * with Grinder treatment
MS	18.7 years	24.7 years	41.5 years
HT32	18.7 years	19.4 years	32.4 years
HT36	15.1 years	18.0 years	30.1 years

- Fatigue Life of CSR-H is half of CSR-B.
- In case of HT36, Fatigue life is decreased.

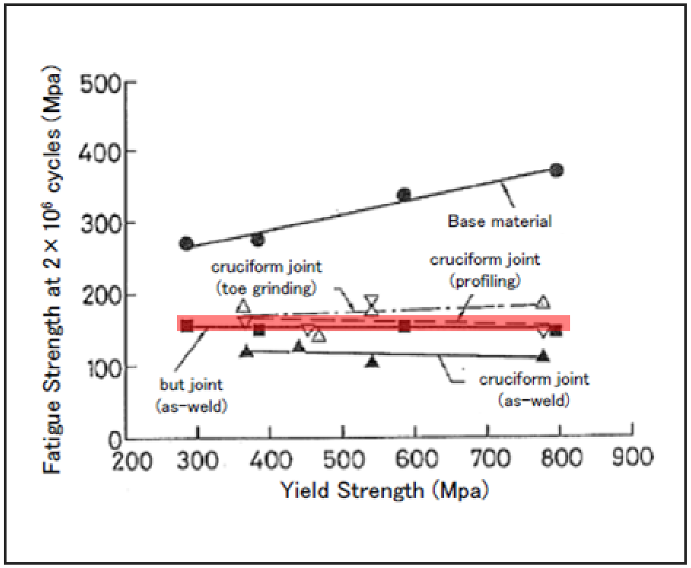


Problems of Fatigue Analysis

Technical Background Pt.1 Ch.9 Sec.3 3.1.3

For base material, it is recognised that the fatigue strength improves in proportion to the strength of the material such as tensile strength and yield strength. Figure 2 shows the relation between yield strength and fatigue strength at 2×10^6 cycles. Where as **the fatigue strengths of weld joints are constant regardless of the yield strength**, the fatigue strength of base material clearly shows the correlation with the yield strength. Differences of fatigue strength among the weld joints are coming from the differences of stress concentration due to the joint type and the weld bead profile.

Relation between yield strength and fatigue strength at 2×10^6



Problems of Fatigue Analysis

Pt.1 Ch.9 Sec.3 3.2.1 Correction factor for mean stress effect

The mean stress correction factor to be considered for each principal hot spot stress range of welded joint, $\Delta\sigma_{HS,\,i(j)}$, or for local stress range at free edge, $\Delta\sigma_{BS,\,i(j)}$, is taken as:

a) For welded joint:

$$f_{mean,\ i(j)} = \begin{cases} min\left[1.0,\ 0.9+0.2\dfrac{\sigma_{mCor,\,i(j)}}{2\Delta\sigma_{HS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\,i(j)} \geq 0 \\ max\left[0.3,\ 0.9+0.8\dfrac{\sigma_{mCor,\,i(j)}}{2\Delta\sigma_{HS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\,i(j)} < 0 \end{cases}$$

b) For base material:

$$f_{mean,\ i(j)} = \begin{cases} min\left[1.0,\ 0.8+0.4\dfrac{\sigma_{mCor,\,i(j)}}{2\Delta\sigma_{BS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\,i(j)} \geq 0 \\ max\left[0.3,\ 0.8+\dfrac{\sigma_{mCor,\,i(j)}}{2\Delta\sigma_{BS,\ i(j)}}\right] & \text{for } \sigma_{mCor,\,i(j)} < 0 \end{cases}$$

where:

$$\sigma_{mCor,\,i(j)} = \begin{cases} \sigma_{mean,\,i(j)} & \text{for } \sigma_{max} \leq R_{eEq} \\ R_{eEq} - \sigma_{max} + \sigma_{mean,\,i(j)} & \text{for } \sigma_{max} > R_{eEq} \end{cases}$$

$$\sigma_{max} = \begin{cases} max_{i,\,(j)}(\Delta\sigma_{HS,\,i(j)} + \sigma_{mean,\,i(j)}) & \text{for welded joint} \\ max_{i,\,(j)}(\Delta\sigma_{BS,\,i(j)} + \sigma_{mean,\,i(j)}) & \text{for base material} \end{cases}$$

$$R_{eEq} = max(315;\ R_{eH})$$

$\sigma_{mean,\,i(j)}$: Fatigue mean stress, in N/mm², for base material or welded joint calculated according to [3.2.2].

$$\sigma_{mCor,\,i(j)} = \begin{cases} \sigma_{mean,\,i(j)} & \text{for } \sigma_{max} \leq R_{eEq} \\ R_{eEq} - \sigma_{max} + \sigma_{mean,\,i(j)} & \text{for } \sigma_{max} > R_{eEq} \end{cases}$$

$$R_{eEq} = max(315;\ R_{eH})$$

In case of $\sigma_{max} > 315$

$\sigma_{mCor,i(j)}|$(MS/HT32) $\leq$ $\sigma_{mCor,i(j)}|$(HT36)

↓

$f_{mean,i(j)}$ **Increase ↑**

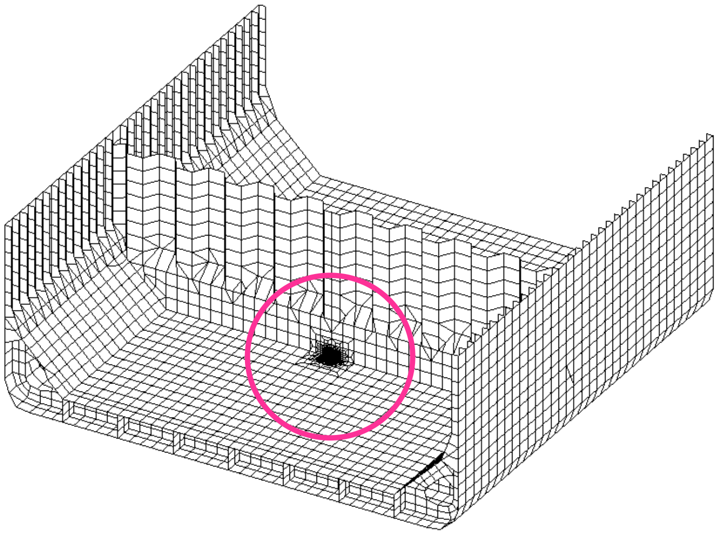
↓

Fatigue Life Decrease ↓

Problems of Fatigue Analysis

- Same Structure
- Same Thickness
- Same Stress
- **Different Material**

→ **Different Fatigue Life**



Materials	CSR-H
MS	18.7 years
HT32	18.7 years
HT36	15.1 years

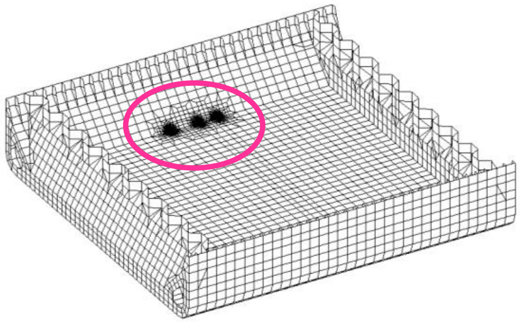
Rule ≠ Technical Buckground

Result of Fatigue Assessment

Crosspiont of Hopper & Inner Bottom

*Evaluated by the Simplified Method

Materials	CSR-H	CSR-B *
MS	8.0 years	35.6 years
HT32	8.0 years	29.1 years
HT36	7.5 years	28.0 years



- Fatigue Life of CSR-H is about quarter of CSR-B.
- Even if Inner bottom plate is increased to 40mm, Fatigue Life can not still comply with CSR-H.

Problems of Fatigue Analysis

- **Fatigue life is decreased when HT36 with same thickness is used instead of HT32 or MS.**

  This is caused by the correction of mean stress due to shake down effect.

  But it is different to the normal fatigue testing results.

- **Grinder treatment is not accepted in cargo hold for compensation of fatigue life.**

  In CSR-B, the effect of grinder treatment in cargo hold is applied.

  In view of the harmonization, it should be applied to CSR-H as well.

- **Fatigue life is much different between CSR-B and CSR-H.**

  The required design fatigue life of CSR-B is 25 years. However the calculated fatigue life is much decreased in case of CSR-H with same scantlings.

  Do the CSR-B applied vessels not comply with design life of 25 years???

  IACS should correct this contradiction.

Minimum thickness

Rule Comparison of Minimum Thickness

Minimum Net Thickness for Plating

	CSR-B	CSR-T	CSR-H
Keel		6.5+0.03L	7.5+0.03L
Bottom/Side/Bildge	5.5+0.03L (BTM) $0.85L^{1/2}$ (Side)	4.5+0.03L	6.5+0.03L (Fore) 7.0+0.03L (ER/Aft) 5.5+0.03L (Else)
Strength Deck	4.5+0.02L	4.5+0.02L	4.5+0.02L
Inner Bottom	5.5+0.03L 6.6+0.024L (ER)	4.5+0.02L 6.5+0.02L (ER)	5.5+0.03L 6.6+0.024L (ER)
Primary Support Member	$0.6L^{1/2}$	5.0+0.015L	$0.6L^{1/2}$

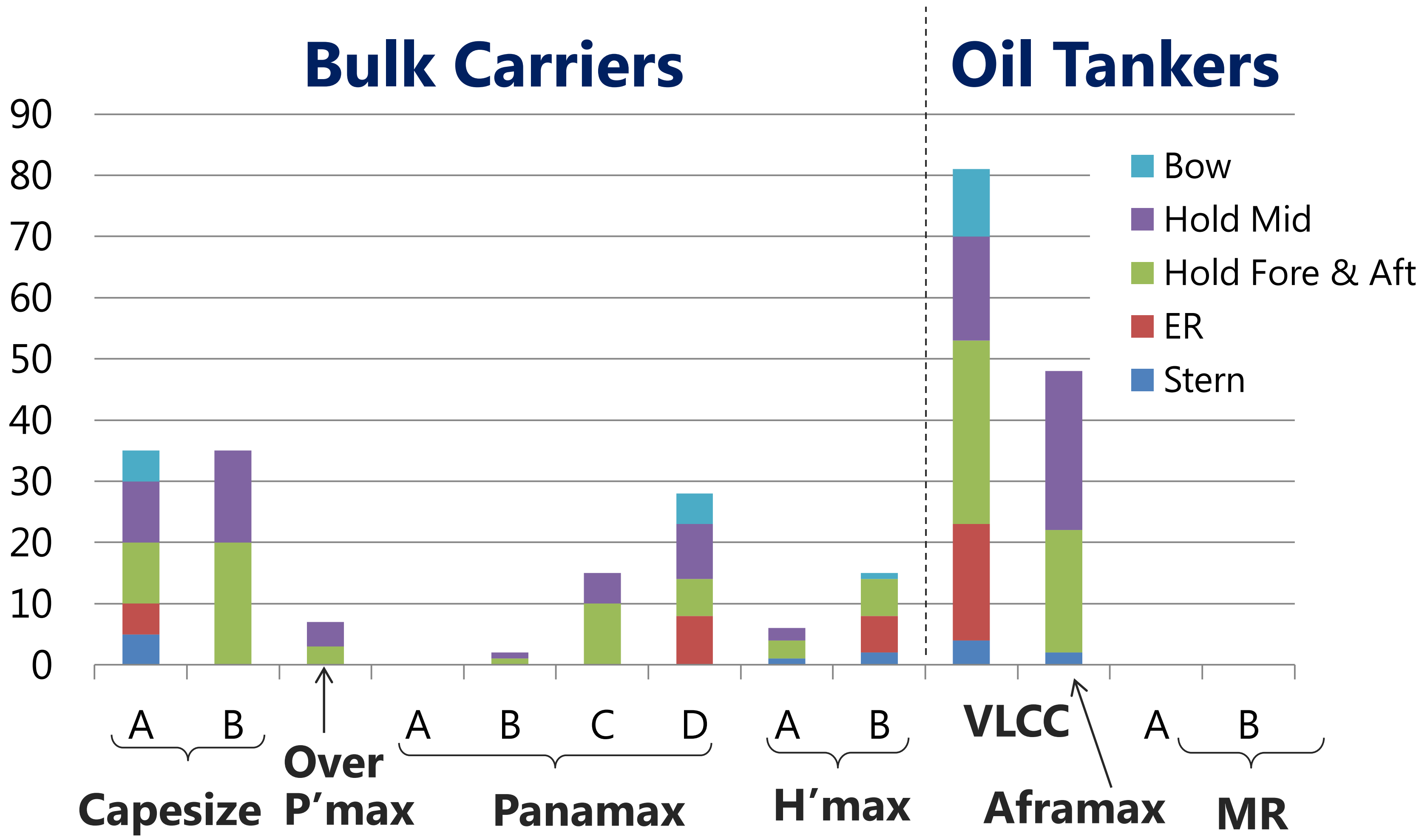
Rule Comparison of Minimum Thickness

Minimum Net Thickness for Plating

L = 300m

	CSR-B	CSR-T	CSR-H
Keel		15.5	→ 16.5
Bottom/Side/Bildge	14.5 14.5	13.5	→ 15.5 (Fore) 16.0 (ER/Aft) 14.5 (Else)
Strength Deck	10.5	10.5	10.5
Inner Bottom	14.5 13.8 (ER)	10.5 12.5 (ER)	→ 14.5 13.8 (ER)
Primary Support Member	10.5	9.5	→ 10.5

Weight Impact for minimum Thickness



Problems of Minimum Thickness

Minimum thickness requirement of CSR-H choose the severe rule between CSR-B and CSR-T.

There is not a little weight impact of minimum thickness especially VLCC.

There is no technical back ground for this rule.

This is basically based on the experience.

Therefore minimum thickness requirement of Bulk Carriers & Oil Tankers may be separated and different each other in CSR-H.

Workload of **FEM analysis**

Workload of FEM Analysis

Hold FEM

	CSR-T	CSR-B	CSR-H
Foremost	–	–	○
Fore Part	△	△	○
Mid Part	○	○	○
Aft Part	△	△	○
Aftmost	–	–	○

Workload of FEM Analysis

Fine mesh FE

	CSR-T	CSR-B	CSR-H
Mandatory	○	-	○
Mesh size	50mm	200mm	50mm

Workload of FEM Analysis

Screening

	CSR-T	CSR-B	CSR-H
Screening	O	O	O
Allowable	Different allowable stress is defined at each member.	95% σ_{all}	Same as CSR-T Bulker: 75% σ_{all} for not defined position by CSR-T

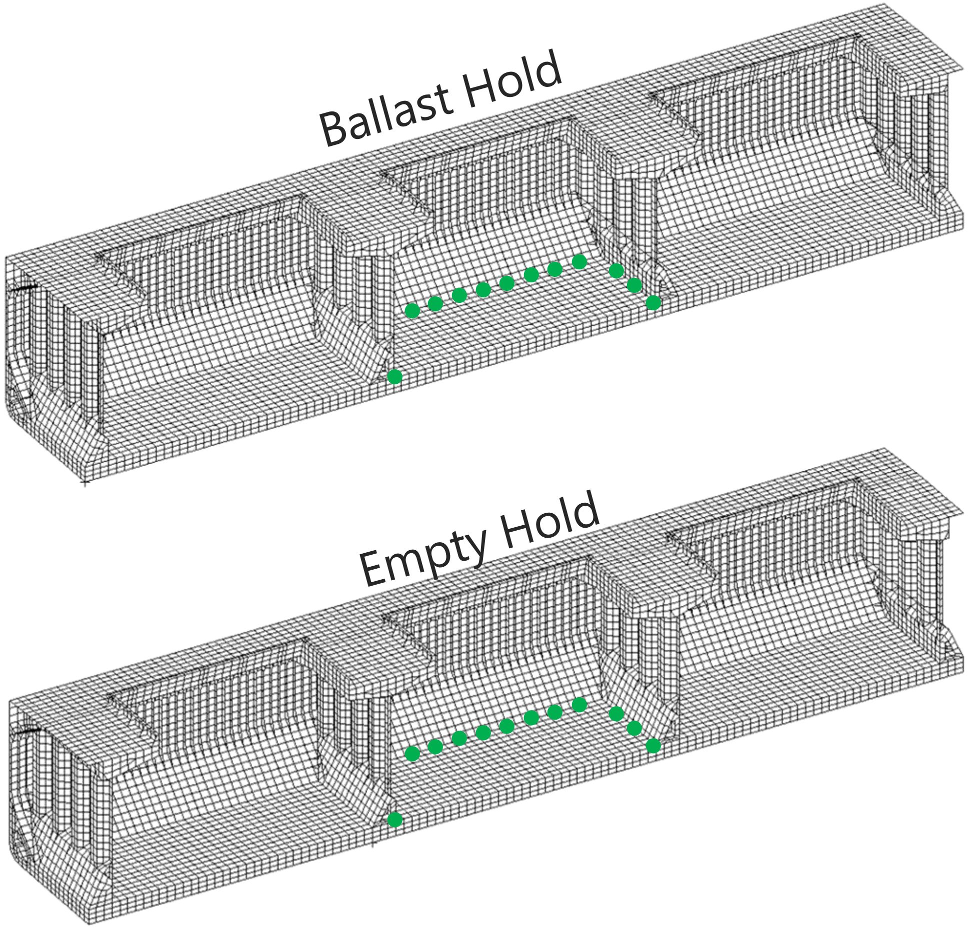
Workload of Fatigue Analysis

Fatigue Assessment

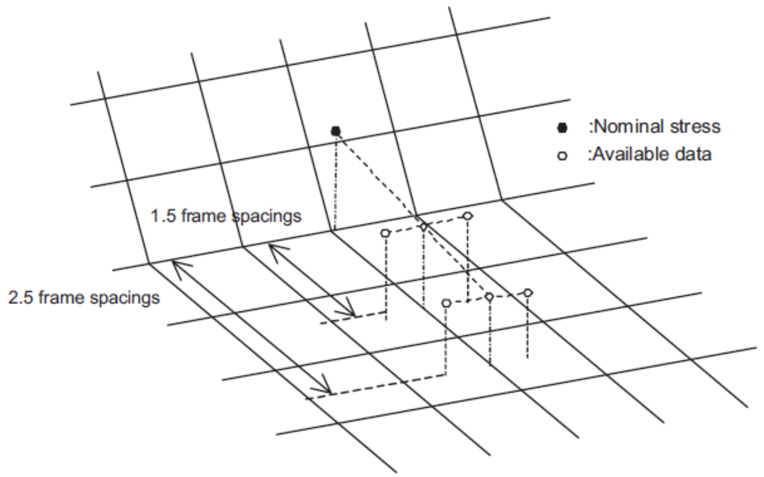
	CSR-T	CSR-B	CSR-H
Method	Very Fine Mesh	Simplified/ Very Fine Mesh	Very Fine Mesh
Mesh size	t_{mm}	Frame Space , Longl Space / t_{mm}	t_{mm}
Screening	–	–	50_{mm}

Workload of Fatigue Analysis

Fatigue evaluation example (CSR-B)

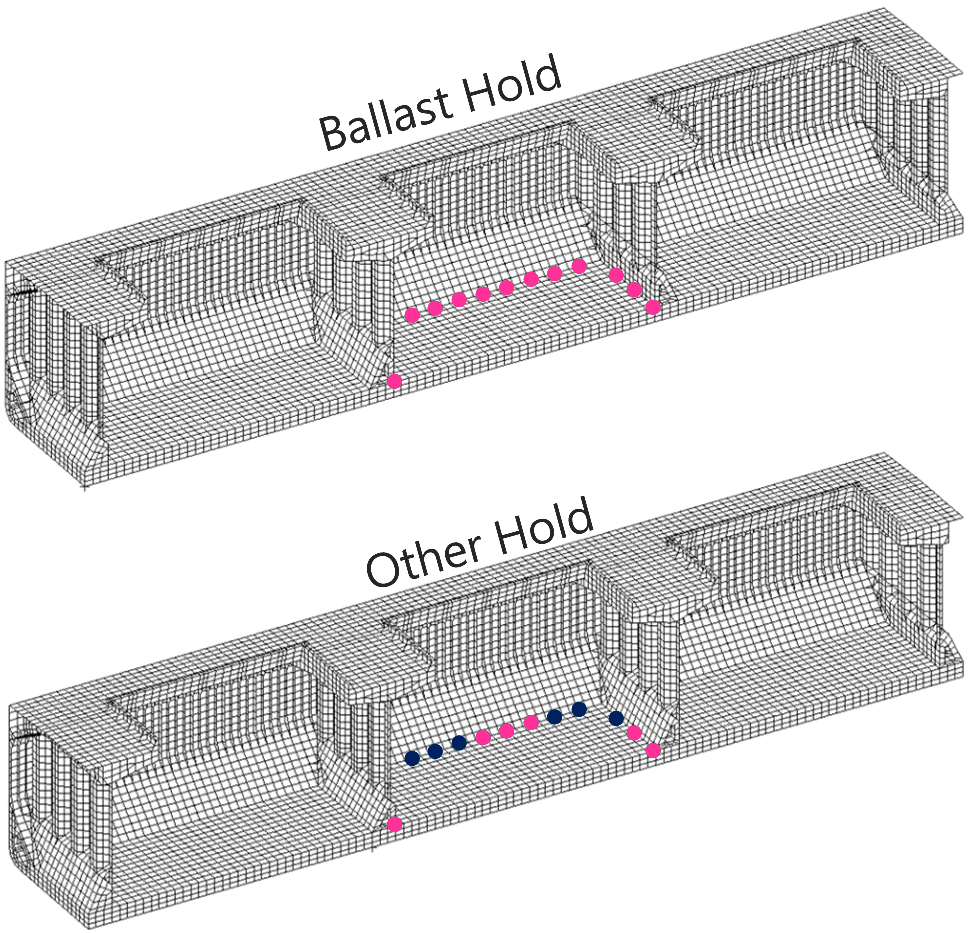


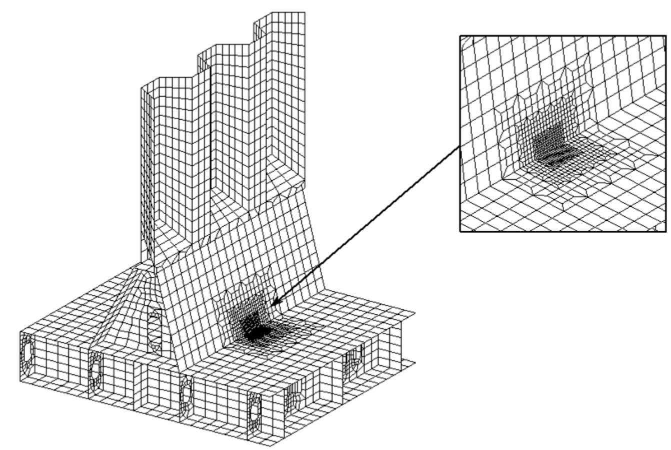
Simple method is available



Workload of Fatigue Analysis

Fatigue evaluation example (CSR-H)





Very Fine mesh (t × t)

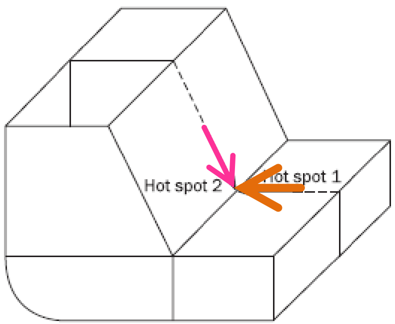
↑

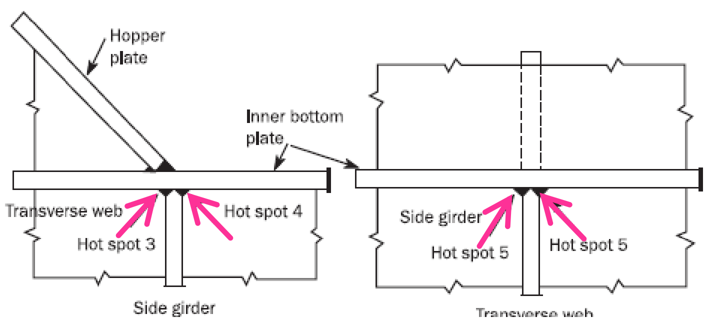
Screening (50 × 50 mm)

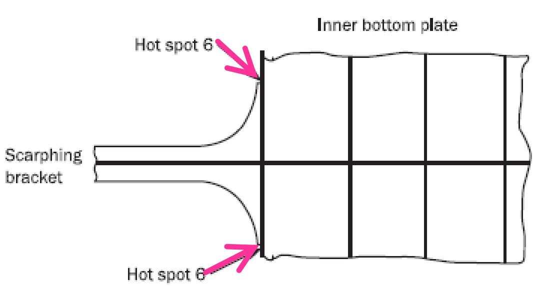
Workload of Fatigue Analysis

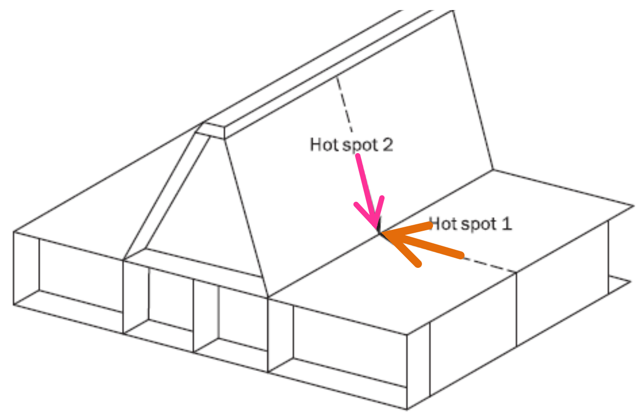
Fatigue evaluation example (CSR-H)

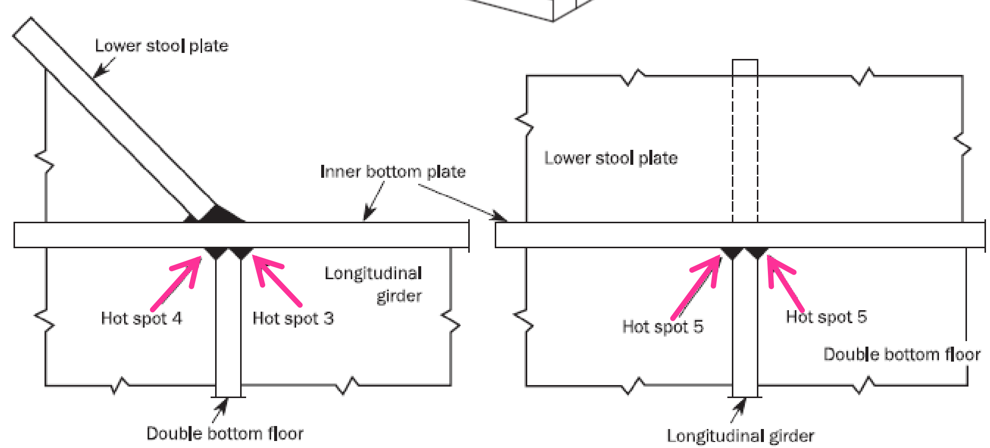
← Evaluation point in **CSR-B**
← Additional Evaluation point in **CSR-H**











Problems of Workload of FEM

Workload of FE analysis is very heavy.

The working period of FE analysis must be much longer than current CSR.

Total design period should be longer and design cost will be much increased.

It is difficult for the class to check the FEM calculation.

It will also become a big burden for the approval section in the classification society.

Conclusion

- **Weight impact of CSR-H** is **1%~4%.**
  This is beyond the harmonization work.

- **The result of Fatigue analysis** is **much severer** than the current CSR.
  IACS is strongly requested to reconsider the fatigue evaluation.

- Shipbuilders have not completed the C.A. yet because of **heavy workload of the FE analysis.**
  Therefore CSR-H still may have some problems which have not been found so far.

THANK YOU

for your attention.

Workload of FEM Analysis

Mandatory Location of Fine Mesh FE
for **Bulk Carrier**

Part	CSR-B	CSR-H
Mid	–	・Hopper knuckles ・Side frame ・Longitudinal stiffeners – transverse bulkhead ・Connections between corrugation and adjoining lower structure
Fore Aft	–	–

Workload of FEM Analysis

Mandatory Location of Fine Mesh FE for Oil Tanker

Part	CSR-T	CSR-H
Mid	・Hopper knuckles ・Large openings ・Longitudinal stiffeners – transverse bulkhead ・ Connections between corrugation and adjoining lower structure	・Hopper knuckles ・Side frame ・Longitudinal stiffeners – transverse bulkhead ・Connections between corrugation and adjoining lower structure
Fore Aft	–	–

Workload of FEM Analysis

Screening Location for Bulk Carrier

Part	CSR-B	CSR-H
Mid	▪Hopper knuckles ▪Connections between corrugation and adjoining lower structure ▪Hatch corner	▪ Openings ▪ Lower stool – inner bottom ▪ Lower stool – hopper tank ▪ Lower hopper – lower stool ▪ Topside tank – inner side ▪ Corrugation – upper stool ▪ Hatch corner
Fore Aft	–	▪ Hopper knuckles ▪ Side frame ▪ Connections between corrugation and adjoining lower structure ▪ Openings

Workload of FEM Analysis

Screening Location for Oil Tanker

Part	CSR-T	CSR-H
Mid	▪ Openings ▪ Bracket toes ▪ Heels of transverse bulkhead horizontal stringers	▪ Openings ▪ Bracket toes ▪ Heels of transverse bulkhead horizontal stringers ▪ Lower stool – inner bottom ▪ Lower stool – hopper tank ▪ Corrugation – upper stool
Fore Aft	–	▪ Hopper knuckles ▪ Openings ▪ Connections between corrugation and adjoining lower structure

Workload of Fatigue Analysis

Mandatory Location of Fatigue Assessment for Bulk Carrier

Part	CSR-B	CSR-H
Mid	･Hopper knuckles ･Lower stool – inner bottom ･Hatch corner ･Transverse BHD ･Hold frames ･Ordinary stiffeners	･ Hopper knuckles(Ballast Hold) ･ Lower stool – inner bottom (Ballast Hold) ･ Hatch corner and Longitudinal hatch coaming end bracket. ･ Upper side frame toe (in case of flat bottom of TST)
Fore Aft	–	･ Hatch corner and Longitudinal hatch coaming end bracket.

Workload of Fatigue Analysis

Mandatory Location of Fatigue Assessment for Oil Tanker

Part	CSR-T	CSR-H
Mid	・Hopper knuckles	・Hopper knuckles ・Lower stool – inner bottom
Fore Aft	–	–

Workload of Fatigue Analysis

Screening Location for Bulk Carrier

Part	CSR-B	CSR-H
Mid	–	・Hopper knuckles (EA&FA Hold) ・Lower stool – inner bottom (EA&FA Hold)
Fore Aft	–	–

Workload of Fatigue Analysis

Screening Location for Oil Tanker

Part	CSR-T	CSR-H
Mid	–	・Bracket toes
Fore Aft	–	–