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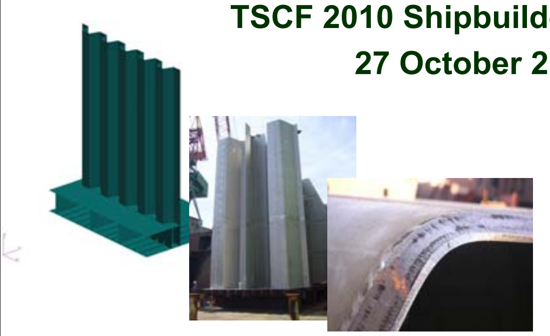
Design Development of Corrugated Bulkheads

TSCF 2010 Shipbuilders Meeting
27 October 2010



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Topics

- Purpose of corrugated bulkheads
- Structural types of corrugated bulkheads
- Types of damages
- Design development
- Latest rule requirements
- Conclusion

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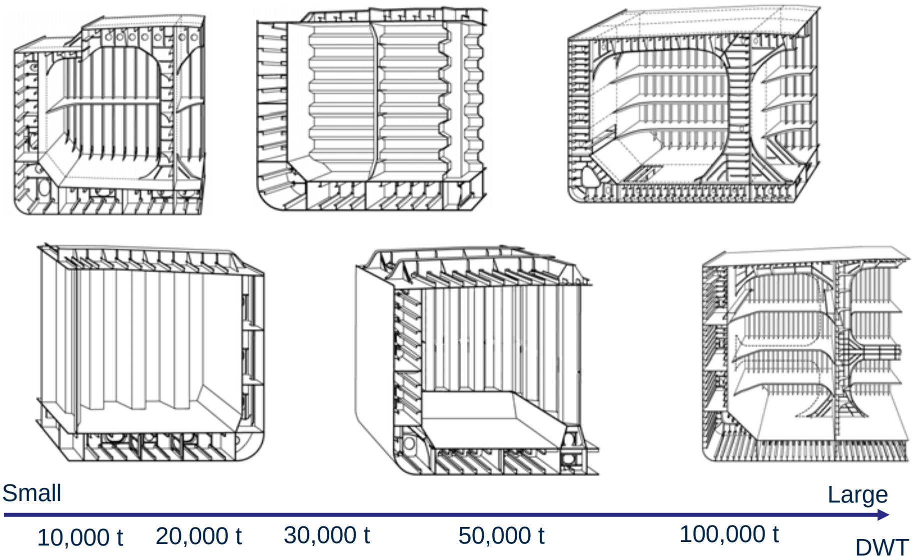
Typical Hull Structure of Tankers



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Purpose of corrugated bulkheads

Plane surface as cargo tank boundary

- **Complete cargo tank washing**
- **Minimize the cargo residue**
- **Maximum cargo tank capacity**

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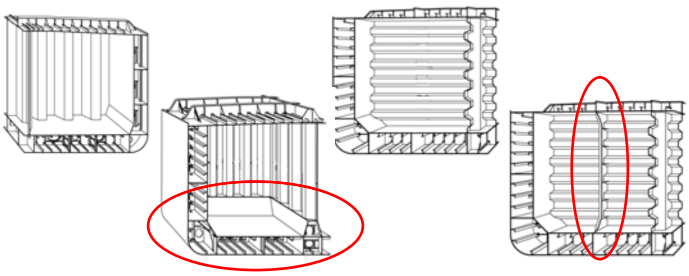
Structural types of corrugated bulkheads

Types of cargo tank bulkhead



	Vertically Corrugated BHD	Vertically Corrugated BHD	Horizontally Corrugated BHD	Horizontally Corrugated BHD
	Small	Large	Small	Large
Tank cleaning	◎	◎	◎	○
Tank capacity	◎	○	◎	◎

◎: Very good ○: Good

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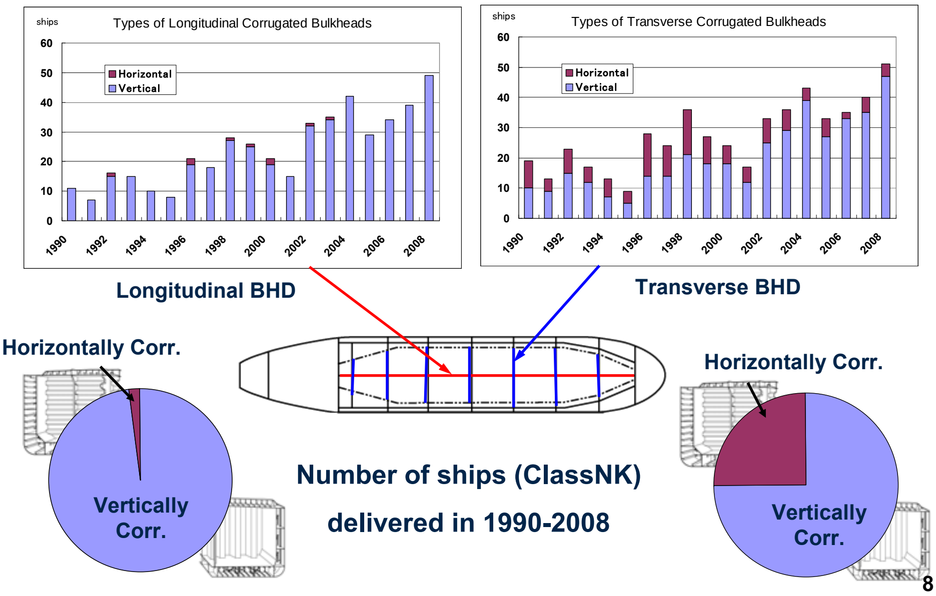
Structural types of corrugated bulkheads



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Next Topic

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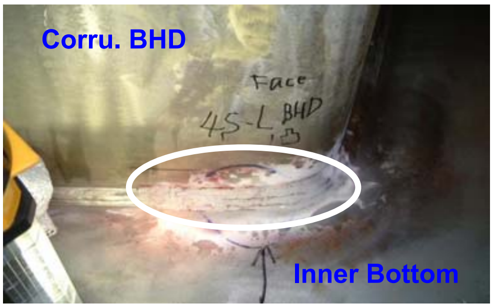
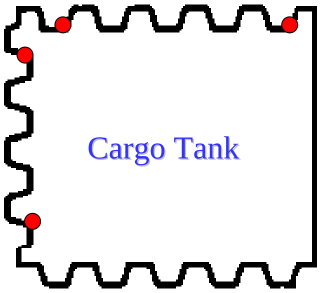
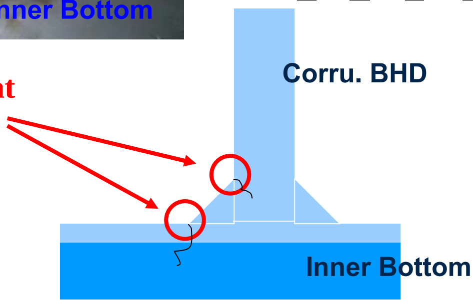
Typical damages of corrugated bulkheads





Stress concentration at toes of fillet welding



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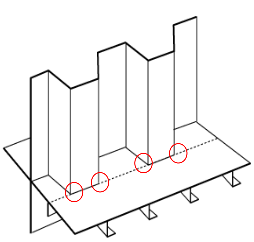
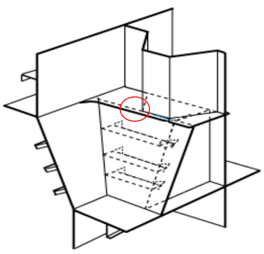
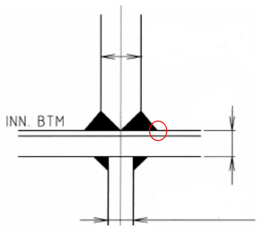
Typical damages of corrugated bulkheads

Cause of damages

- ✓ *Defects of welding (Overlapping, Undercutting)*
- ✓ *Lack of supporting structures*
- ✓ *Lack of continuity (misalignment)*







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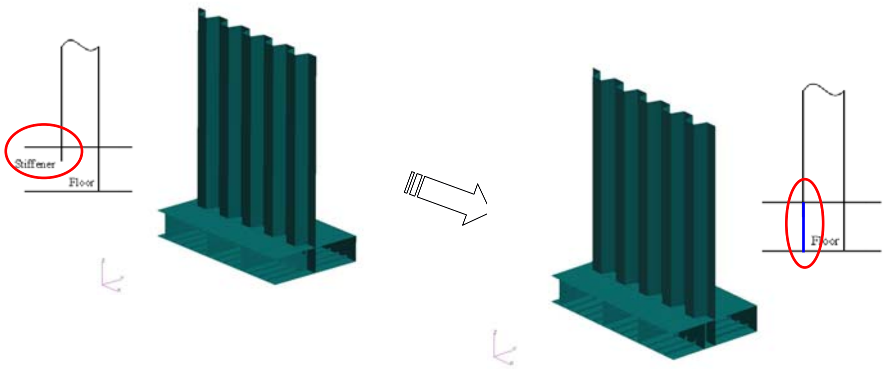
Design development

1. Design of supporting structures

Stiffeners under corrugation flange



Floors and girders under corrugation flange

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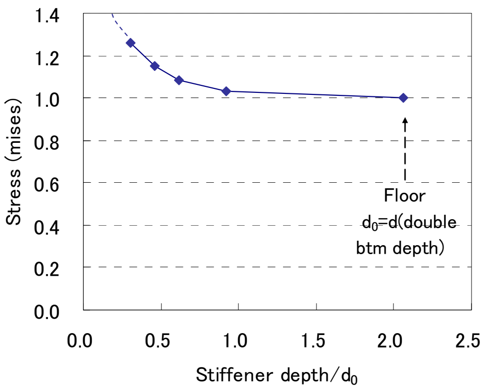
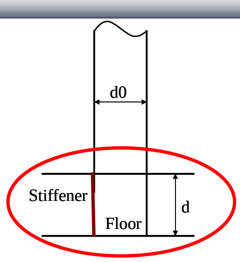
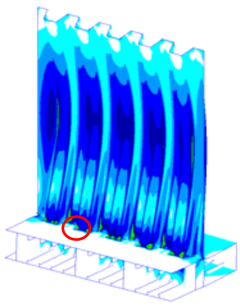
Design of supporting structures

Effectiveness of supporting structure

Case	1	2	3	4	5
Depth of stiffener / d0	0.31	0.46	0.62	0.92	2.06







Relative stress at the corner of corrugation

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Design of supporting structures

Outcome;

- ***Stress of end connection decreases by deeper supporting structure***
- ***Half of corrugation depth is considered as effective support depth***
- ***Floors/girders are suitable as supporting structure***

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Suitable supporting structure under flange plate of corrugated bulkhead gives higher reliability

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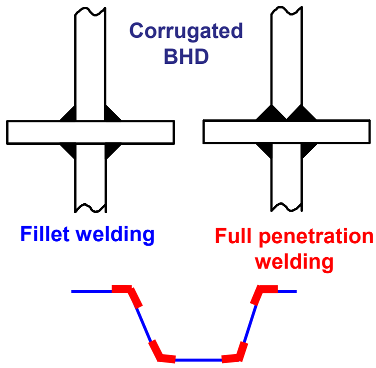
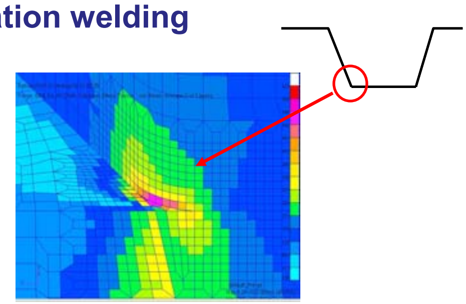
Design development

2. Application of full penetration welding



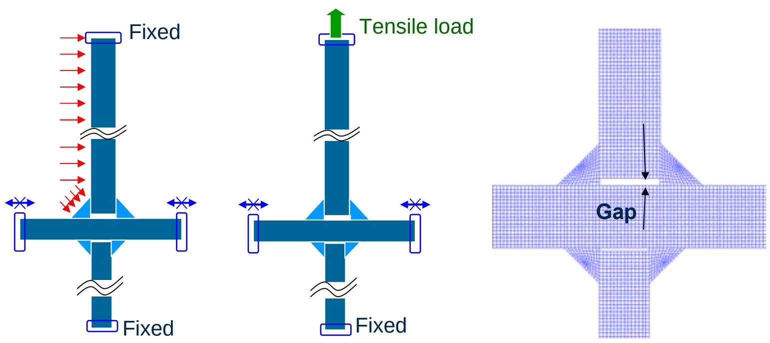


Detail stress distribution of corrugation corner

Full penetration welding has been recently applied at the corner of corrugation of lower end connection with weld toe grinder

Design development

Effectiveness of full penetration welding

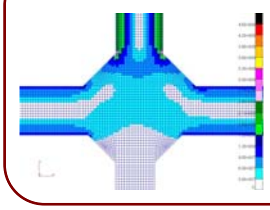


Comparative stress evaluation

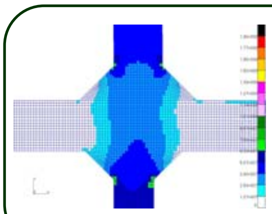
- by bending load and tensile load
- with various gaps

Von-Mises stress caused by bending / tensile load

Bending load

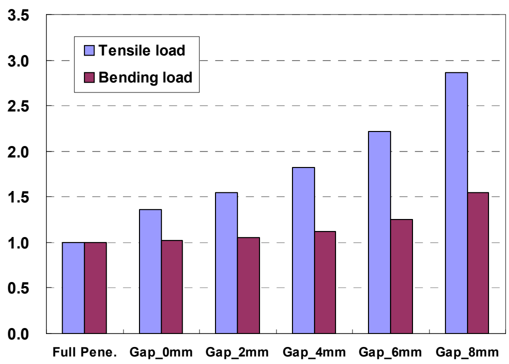


Full penetration | Gap 0mm (Fillet) | Gap 2mm

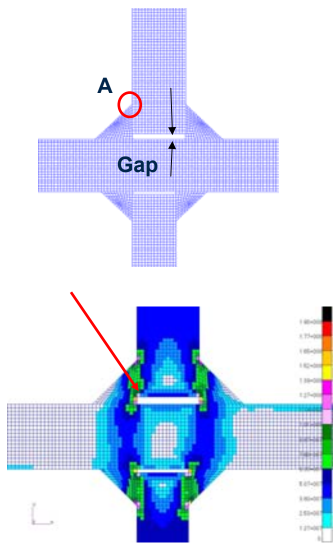


Tensile load

Von-Mises stress by tensile load



Relative stress at Position A
(Stress of Full Penetration = 1.0)



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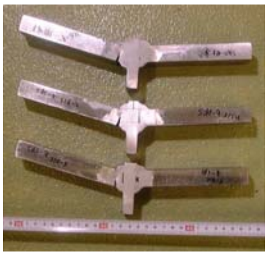
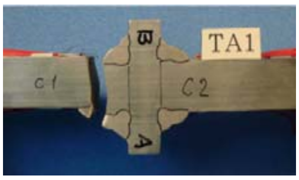
Experimental test of stainless steel (SUS316L)



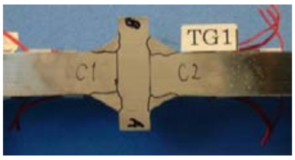
bending test (as weld)



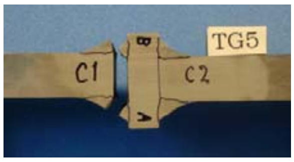
Tensile test (as weld)

Tensile test (as weld)
Higher tensile load

Weld toe grinding



Tensile test (Grinder)



Tensile test (Grinder)
Higher tensile load

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Application of full penetration welding

Outcome;

- ***Cracks by bending load initiate from weld toe regardless of root gap***
- ***Cracks by tensile load initiate from weld toe or root***
- ***Root gaps lead to higher stress at weld toe and root by tensile load***
- ***Gap control and satisfactory throat thickness are important***
- ***Full penetration welding contributes ;***
  - ***to mitigate the risk of gap control***
  - ***to give satisfactory throat thickness***
- ***Grinder or TIG welding which gives more smooth surface further contributes to lower the stress concentration at weld toe***

Full penetration welding and smoothed weld toe at corrugation corner gives higher reliability

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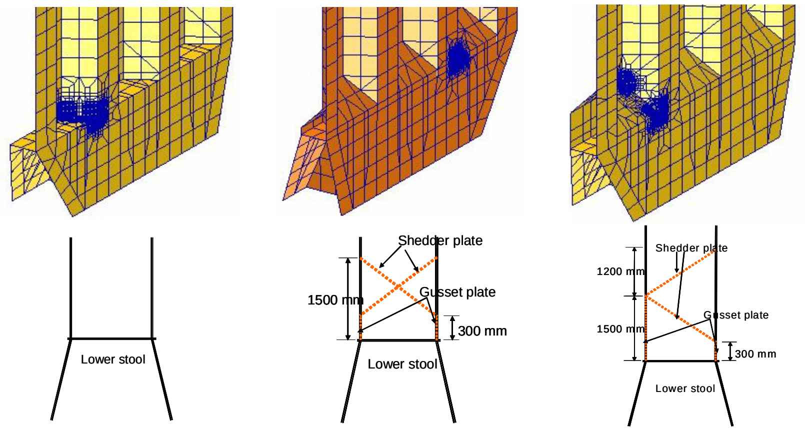
Design development

3. Verification of designs with gussets and shedder plates



Impact by gusset and shedder plates were investigated

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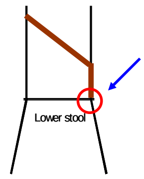
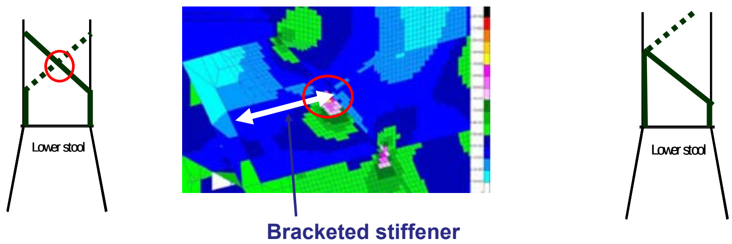
Impact to the design by gusset and shedder plates

1. Reduced stress at critical point



2. Stress concentration at the crossing of shedder plates



3. Extended enclosed space leads to a loss of cargo capacity

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Reinforcement by gusset and shedder plate

Outcome;

- ***Gusset and shedder plates are often used in the design of corrugated bulkheads in bulk carriers and recommended in CSR for tankers.***
- ***Gusset and shedder plates definitely contribute to lower the stress***
- ***However, following deep considerations are necessary ;***
  - ***Manholes and air holes to avoid formation of any gas pocket***
  - ***Bracketed Stiffener where adjacent shedder plate cross***
  - ***Careful workmanship of welding in narrow space***
- ***Extended gusset plate leads to some loss of cargo capacity***

⇩

Better to keep just as recommendation instead of mandatory requirement in tanker designs

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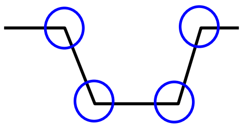
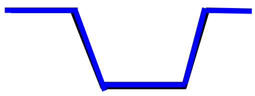
CSR Requirements

Prescriptive requirements :

- Local strength (Plate thickness, Section Modulus)
- Arrangement of supporting structures
- Full penetration welding to lower end of vertical corrugated bulkhead connections



Corner Part
Full penetration welding
+
Grinder
Recent practice



All Part
Full penetration welding
CSR

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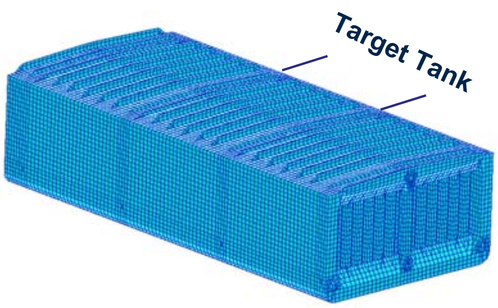
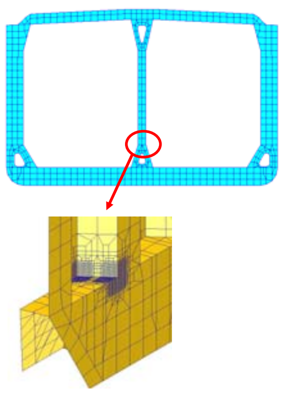
CSR Requirements

Requirements of Finite Element Analysis (FEA):

✓ Overall stress and buckling analysis by Coarse Mesh

✓ Detail stress analysis of lower end connection of vertically corrugated bulkhead by Fine Mesh





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Sensitivity of mesh size at corrugation corner

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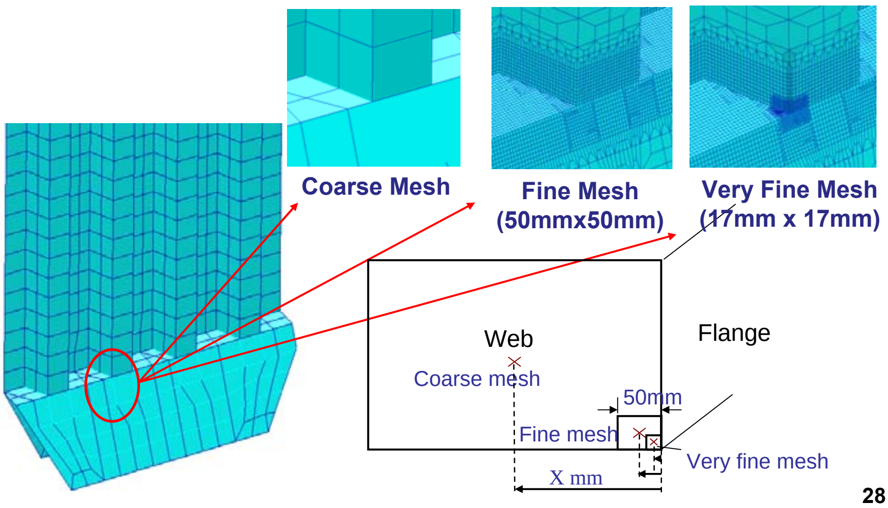
Parametric analysis to know the sensitivity of mesh size



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Sensitivity of mesh size at corrugation corner

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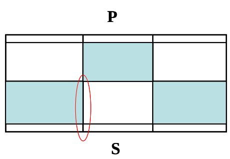

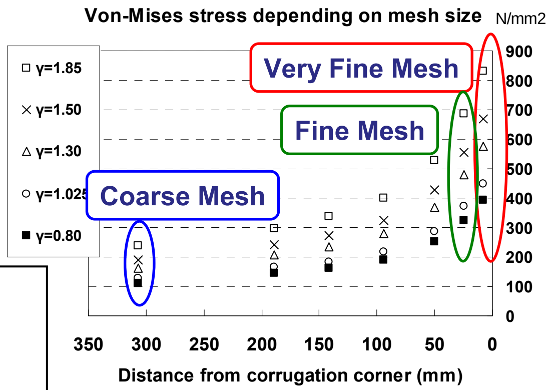

- ✓ *MR Tanker*
- ✓ *Load Case : B4-1 (Zig-Zag)*
- ✓ *Thickness : 22mm(net)*
- ✓ *S.G.(t/m³)=0.8, 1.025, 1.3, 1.5, 1.85*

- ➢ ***Element stress strongly depends on the mesh size near the corner***
- ➢ ***Definition of mesh size is important when detail analysis is required***

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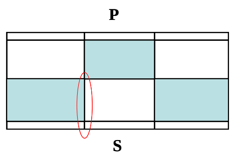
Impact on scantlings by CSR Fine Mesh

Case studies to investigate the impact of CSR criteria

- *MR Tanker*
- *Transverse Corrugate Bulkhead (Vertical)*
- *Critical Load Case : B4-5a (Zig-Zag)*
- *S.G. = 1.025*



Ships for study

Ship A : New design vessel which fully complies with CSR

Ship B : Non-CSR ship with successful service experiences without any damage records

Ship C : Non-CSR ships with damage records

Ship C_with bracket : After reinforcement of ShipC without any further damage records

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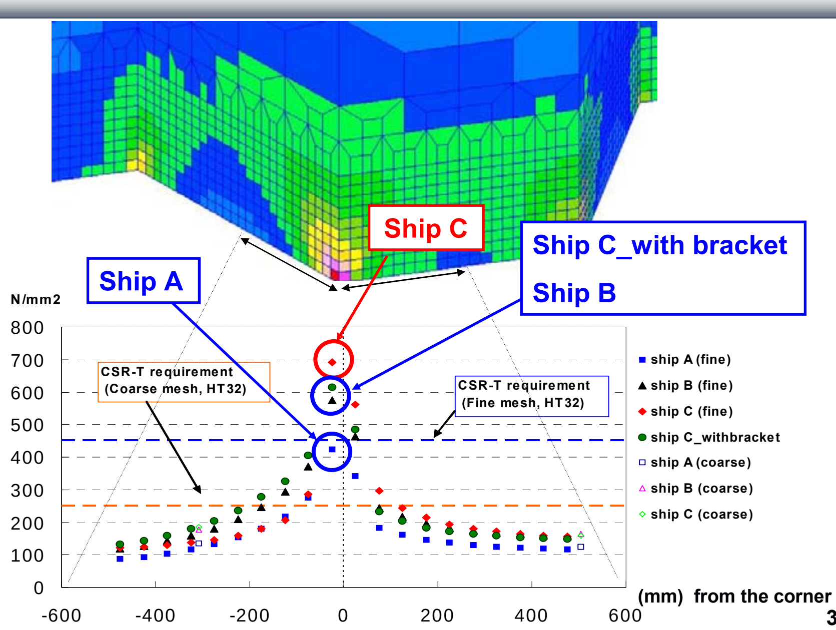
Impact on scantlings by CSR Fine Mesh



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Impact on scantlings by CSR Fine Mesh

➢*CSR contribute to more robust corrugated bulkhead designs*

Feedback from Japanese shipyards

➢*Considerable scantling increase even from designs having demonstrated history of successful service experiences*

➢*Required thickness tends to reach to the maximum allowable thickness for the fabrication of cold-bending*

➢ *Modification of corrugation span by fitting upper/lower stools or reduction of design cargo density has been required, which inevitably leads to a loss of cargo capacity and deadweight*

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Further rule development considering such as edge treatment and anti-fatigue steel is anticipated

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Conclusion

◆***Corrugated bulkheads are essential structure for product / chemical tankers***

◆***Sufficient service records have proved the advantage***

◆***Rules and designs have been improved to cover complexities of fabrications and operations***

◆***However it has been also reported that designers need to modify the initial design to save unacceptable scantling increase due to latest CSR requirements***

◆***Continuous update of rules allowing establishment of new technologies should also be performed, while watching valuable service experiences of existing designs***

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