COMPARATIVE STUDY OF DAMAGE STABILITY CALCULATIONS FOR SOLAS 2009 AND SOLAS 2020 OF RO-RO PASSANGER VESSEL

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SOLAS History
Probabilistic method was taken as a primary calculation method for passenger vessels.

Required subdivision index $R$ for cargo ship was determined based on statistics collected from collisions. Attained index $A$ was determined based on probabilistic. For passenger ships, deterministic method was still in use.

SOLAS convention which includes all amendments made thus far. This convention was made also to introduce a new procedure which would ensure that future amendments would enter into force with short period of time.
SOLAS probabilistic method frames

In the probabilistic method, R-index and A-index are calculated and for the ship to be stable and sufficiently safe.

\[ A \geq R \]

\[ A = \sum s_i p_i \]

where

- \( p_i \) - probability that the one compartment or group of compartments under consideration may be flooded.

- \( s_i \) - probability of surviving after flooding of the compartment or group of compartments
SOLAS 2020
In the absence of a building contract the keel of which is laid or which are at similar stage of construction on or after

1st January 2020
Shipbuilding contract is placed on or after

1st July 2020

1st January 2024
The delivery of which in on or after
Relation between wave height and GZmax - EMSA2 Study

- EMSA2 Study showed a big difference in model test for ro-ro passenger vessel
- According to EMSA2 test model increase of GZmax and Range to 0.25 meter and 25 degrees would make s-factor measure with 90% confidence.
- Based on Harder statistic GZmax=0.12 and Range=16 degrees for SOLAS 2009
SURVIVABILITY S-FACTOR FORMULA CHANGED FOR RO-RO SPACES

\[ S_{\text{final}, j} = K \left( \frac{GZ_{\text{max}}}{TGZ_{\text{max}}} \cdot \frac{\text{Range}}{TRange} \right)^{\frac{1}{4}} \]

Where:

- \( TGZ_{\text{max}} = 0.20 \text{ m} \), for ro-ro passenger ship each damage case that involves a ro-ro space, \( = 0.12 \), otherwise;
- \( TRange = 20^0 \), for ro-ro passenger ships each damage case that involves a ro-ro space, \( = 16^0 \), otherwise;

CARGO SHIP REQUIREMENT REMAINED UNCHANGED (AS IT WAS DEFINED IN SOLAS 2009)

REQUIREMENT INDEX R FORMULA RELATED ONLY TO PASSENGER ON BOARD NUMBER

<table>
<thead>
<tr>
<th>Persons on board</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N &lt; 400 )</td>
<td>( R = 0.722 )</td>
</tr>
<tr>
<td>( 400 \leq N \leq 1,350 )</td>
<td>( R = N / 7,590 + 0.66323 )</td>
</tr>
<tr>
<td>( 1,350 &lt; N \leq 6,000 )</td>
<td>( R = 0.0369 \times \ln (N + 89.048) + 0.579 )</td>
</tr>
<tr>
<td>( N &gt; 6,000 )</td>
<td>( R = 1 - (852.5 + 0.03875 \times N) / (N + 5,000) )</td>
</tr>
</tbody>
</table>

Where:

\( N = \text{total number of persons on board.}^* \)
Cross flooding arrangements for reduced heel angle

• Cross flooding ducts decrease the heeling angle
• High capacity cross flooding ducts increasingly popular recently
• Higher required R due to new (SOLAS 2020) interpretation of instantaneous flooding
• Previously - official interpretation of Reg. II-1/7-2.2 (*) was already source of discussion

*) that allowed intermediate stages of flooding to be disregarded as instantaneous in case when fluid equalization is achieved in 60s or less
INDEX R

International Conference on Postgraduate Research in the field of Maritime Technology
Gdynia, 22 April 2020
Basic Design of ro-ro passenger vessel
• The basic design is a typical ro-ro passenger ship with transverse subdivision and lower hold.
• Vessel is fitted with three vehicle decks.
• For better unloading and loading process there are aft side ramp as well as fore side ramp.
• Vessel can load trailers on two decks, private cars are fitted in lower hold od Deck1 and Deck2.
• The ship is subdivided on 18 watertight zones by 17 main transverse bulkheads.

Main dimensions of the vessel:
Length over all: 200m
Breadth: 30m
Height of bulkhead deck: 10m
Draft: 7m
Damage stability calculation results
**SOLAS 2009**

Attained subdivision index $A$: 0.77454  
Required subdivision index $R$: 0.75253

<table>
<thead>
<tr>
<th>Damages</th>
<th>$W^*P^*V^*S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Zone damages</td>
<td>0.30311</td>
</tr>
<tr>
<td>2 Zone damages</td>
<td>0.32396</td>
</tr>
<tr>
<td>3 Zone damages</td>
<td>0.11035</td>
</tr>
<tr>
<td>4 Zone damages</td>
<td>0.02775</td>
</tr>
<tr>
<td>5 Zone damages</td>
<td>0.00817</td>
</tr>
<tr>
<td>6 Zone damages</td>
<td>0.00119</td>
</tr>
<tr>
<td><strong>Total A index</strong></td>
<td>0.77454</td>
</tr>
</tbody>
</table>

**Distribution of $s$ factor**

- $s=0$: 50%  
- $0<s<0.5$: 34%  
- $0.5<s<0.8$: 4%  
- $0.8<s<1$: 2%  
- $s=1$: 10%

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**SOLAS 2020**

Attained subdivision index $A$: 0.76410  
Required subdivision index $R$: 0.83414

<table>
<thead>
<tr>
<th>Damages</th>
<th>$W^*P^*V^*S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Zone damages</td>
<td>0.30129</td>
</tr>
<tr>
<td>2 Zone damages</td>
<td>0.31830</td>
</tr>
<tr>
<td>3 Zone damages</td>
<td>0.10783</td>
</tr>
<tr>
<td>4 Zone damages</td>
<td>0.02737</td>
</tr>
<tr>
<td>5 Zone damages</td>
<td>0.00812</td>
</tr>
<tr>
<td>6 Zone damages</td>
<td>0.00119</td>
</tr>
<tr>
<td><strong>Total A index</strong></td>
<td>0.76410</td>
</tr>
</tbody>
</table>

**Distribution of $s$ factor**

- $s=0$: 45%  
- $0<s<0.5$: 10%  
- $0.5<s<0.8$: 12%  
- $0.8<s<1$: 7%  
- $s=1$: 2%
Proposed solution to fulfil SOLAS 2020 requirements
Changing the Initial GM values

- The GM limits values for three loading conditions, at first attempt are usually taken from intact stability limit curve.

- In case when required index R is not met, the GM values may be increased. Increasing GM values should be done ensuring that intact loading condition still met new GM.

- If intact conditions are not meeting the new GM limits it leads to significant loss of cargo or additional ballast.

**Graph: Total A index for different GM values**

GMs is GM value for DS draught
Dividing lower hold by watertight doors

- Additional watertight barriers in case of damages that include lower hold give bigger $s$ factor value.

- This solutions produce extra costs for the vessel owner.
U-deck compartments are designed to increase the survivability of the ship in damage condition.

They are forcing the sea water to flood symmetrically about centerline of the ship.

The higher sea water level in U-deck, the bigger is stabilizer effect, by limiting the volume of water accumulating on the damage side of the ship.
Conclusion
For this ship most of the damage cases already have a higher GZ values and a bigger range than requested by SOLAS2009 resulting in decrease of A index not exceeding few percentage points.

Despite that sample ship calculations shown, that to fulfil requirements of R index, new vessel design approach should change.
Thank You For Your Attention

Katarzyna Malinowska