Damage Stability of Cruise Ships

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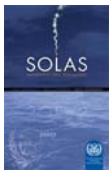
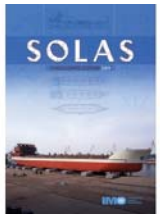
12/04/2016

MEYER WERFT
PAPENBURG 1795

History of SOLAS requirements

- SOLAS 74
  - → 2-compartment standard, margin line and floodable length
  - → A265 equivalent probabilistic method
- SOLAS 90
  - → 2-compartment standard, GZ requirements
- SOLAS 92
  - →Probabilistic damage stability for cargo ships
- SOLAS 2009
  - →Harmonized damage stability
  - →Different required index for cargo and passenger ships
  - →Same safety standard as SOLAS90
- SOLAS2020
  - → New required index





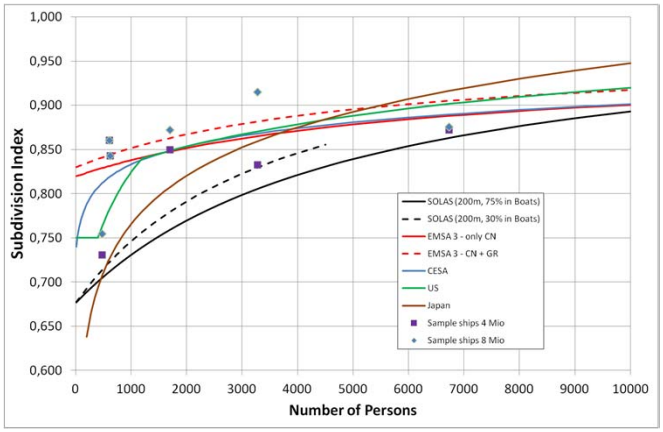
Reasons for revision

- Concerns raised
  - Does SOLAS2009 have the same safety standard as SOLAS90?
  - How to deal with „water-on-deck“?
  - Do we need to raise safety after flooding?
- Research projects
  - EMSA1, Safedor, EMSA2, GOALDS, EMSA3
  - National projects in UK, Denmark, Sweden, Germany
- Accident COSTA CONCORDIA
- Inconsistencies in SOLAS2009

→Decision to revise safety standard
→Revision of SOLAS II-1

Reg.6 Required Index

- Basis for new R index based on EMSA3 results
- Various proposals have been discussed
- Difficult to agree for small ships due to wide variety of ship types and designs



Reg.6 Required Index SCD3

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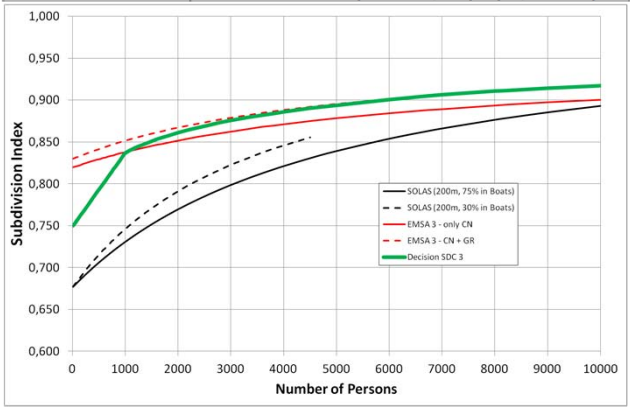
- SDC3 decision → political compromise
  - Only parameter: N = number of persons

Persons on Board	*R*
$N \leq 1{,}000$	$R = 0.000088 * N + 0.7488$
$1{,}000 < N \leq 6{,}000$	$R = 0.0369 * \ln(N + 89.048) + 0.579$
$N > 6{,}000$	$R = 1 - (C1 * 6{,}200)/(4 * N + 20{,}000)$ with: $C1 = 0.8 - (0.25 / 10{,}000) * (10{,}000 - N)$



Reg.6 Required Index

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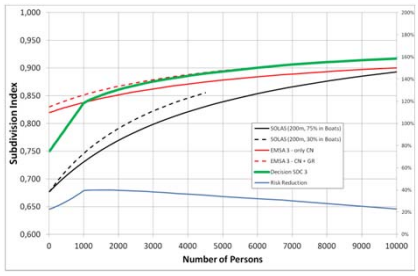
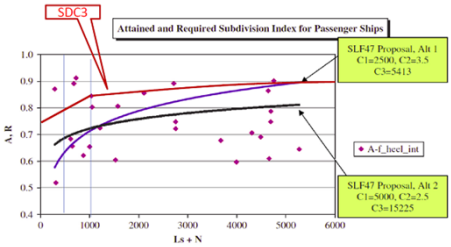
- Huge reduction of risk
  - 200 POB → -25% risk
  - 1000 POB → -40% risk
  - 7000 POB → -30% risk

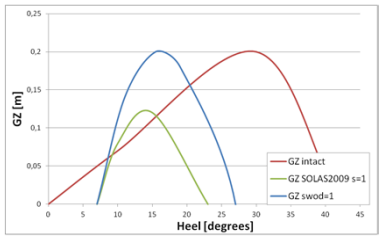


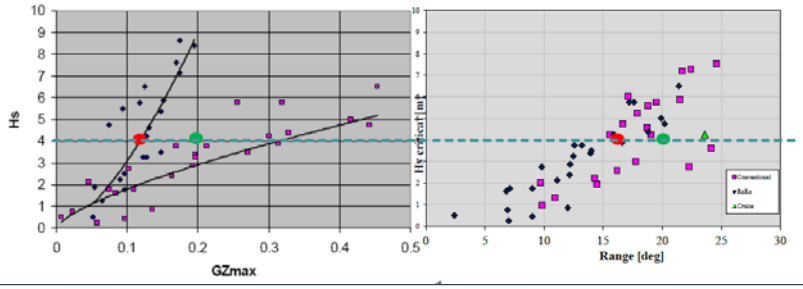
- Previous political decision taken at MSC82 corrected
- Safety level of small ships significant increased



Reg.7-2 s-factor

- Special requirement for RoPax
  - Influence of “water-on-deck” accounted in new s-factor
  - GZ properties based on model tests with conventional ships
  - RoPax require higher GZ and Range to survive
    - GZ: 0.12m → 0.2m
    - Range: 16 deg → 20 deg





Other changes

- No WTD to be kept open during navigation
  - Significant design change for smaller ships
- Principle of Entry into Force changed
  - Keel laying is not relevant anymore
  - 3 dates principle as in MARPOL
  - Entry into force:
    - Contract on/after **1.1.2020**
      - If no contract: Keel laying on/after [1.1.2020]
    - Delivery not later than [**1.1.2024**]

Design Consequences RoPax

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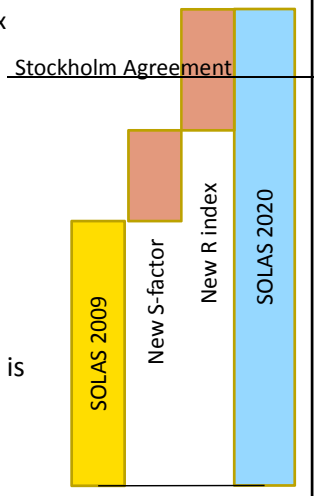
- Safety level most likely higher than 2003/25/EC
- Effect of new s-factor depending on ship design
  - For larger ships 2-6% loss of attained index
  - For smaller ships up to 10% loss on attained index
- For some designs and routes significant changes likely
  - In particular for ships with less 400 POB
  - Maybe no suitable LLH possible
  - Difficult to meet EEDI requirements
  - Modal change to road traffic or pure RoRo ships possible
- Many RoPax are engaged under domestic / EU trade
  - Development of new EC directive uncertain
- Difference between new ships and existing ships is increased, many old ships remain in service with old safety standard



Design Consequences Cruise ships

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- Small cruise ships facing severe problems
  - One compartment standard not possible anymore for ships with <400 POB
  - New R level will be determining criterion
  - Higher freeboard and larger breadth required to meet R
  - no passenger below bulkhead deck suitable due to WTD restrictions

→ **significant increase of ship size in particular for ships with less than 400 POB**

Design Consequences Cruise ships

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- Large cruise ships
  - approx 5-6% less capacity due to higher freeboard and breadth or changed subdivision
  - → increase of life-cycle costs and ticket prices
  - No significant influence on design concepts
- Cruise industry supports increase of safety level
- Application scheme may require significant design changes within ship series
  - Delivery 1.1.2024
  - Slots of European shipyards already booked until 2023
- New requirements may already been applied in new projects now

More Research Needed

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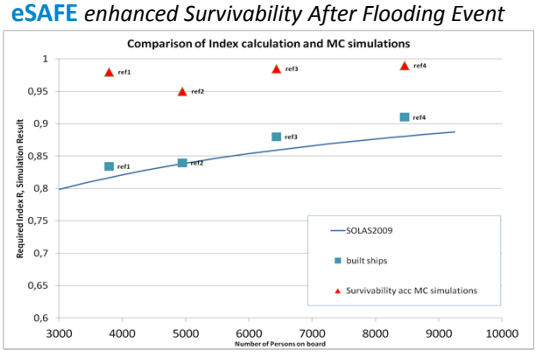
- Safety level as indicated by SOLAS is significantly different to real case experiences and numerical simulations
- e.g. Costa Concordia stayed afloat for many hours, even though she was built to SOLAS90 standard
- Survivability indicated by simulations is >95%

→ **joint industry project under preparation by CSSF**

eSAFE *enhanced Survivability After Flooding Event*



Difference RoPax vs Cruise

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- Damage Stability Regulations are largely based on model tests on RoPax
- Model tests for cruise are complicated and expensive, but:
- Huge difference between RoPax and cruise
  - Different risks and accident frequencies
  - Different sinking behavior (rapid capsize vs slow sinking) due to different internal subdivision
  - Research during the last 20 years focused on RoPax → applicability of s-factor for cruise ships remains questionable
- But:
  - **One level of R defined for all passenger ships**

Simplification of SOLAS

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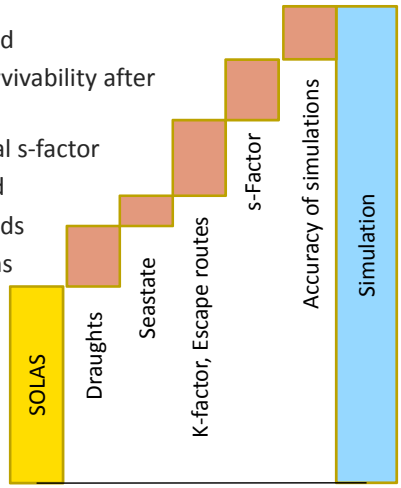
- A number of simplifications are included in SOLAS
  - Grounding not included in attained index
  - Distribution of draughts not realistic
  - Probability of sea state not considered
  - Aspects of evacuation mixed with survivability after flooding
- Complex subdivision not covered by actual s-factor
- Impact of various aspects to be quantified
- Preparation to apply first-principle methods
- Methodology to use numerical simulations



Sample ships

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- Sample ships are As-built ships, no projects
  - Real design environment is used
  - Detailed design information available
  - Onboard data available
- Whole range of CLIA fleet to be considered
- Cover a wide range of size and operational area




Initial conditions and environment

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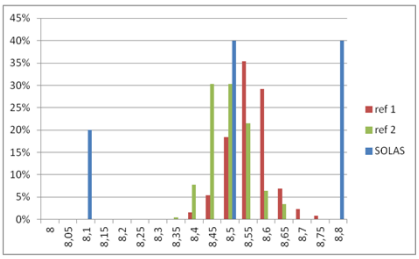
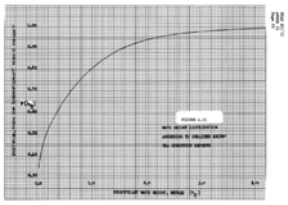
- Collection of onboard data for 1 month of at least 10 different ships operated by CLIA members
- Weighing factors for DL, DP and DS to be checked
  - $A = 0.2*A_{DL} + 0.4 * A_{DP} + 0.4*A_{DS}$

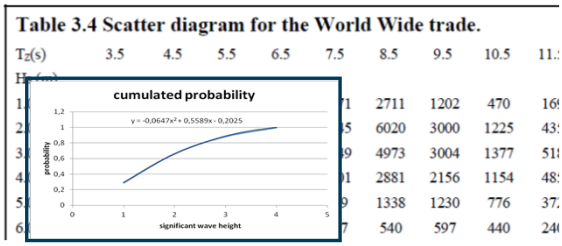


- Calculation of A Index using real loading conditions, including tank fillings
  - Significant impact due to
    - Actual tank fillings
    - Behaviour of free surfaces
    - Actual GM

Effect of wave heights

- SOLAS s-factor is based on probability to survive flooding accident up to 4m wave height
- 4 m wave height based on old damage statistics (Stab15, HARDER)





- Probability of sea state not included
  - 90% are less than 3m, 60% are less than 2m
- Ship size may have significant influence
- More damage cases are survived in smaller waves

Effect of SOLAS parameters

- Influence of other parameters on attained index A to be verified
  - Immersion of escape routes and emergency stations
  - K-factor using 7 and 15 degrees as heel limits
  - External moments
  - Permeabilities may be wrong
- Calculation methods to be reviewed for handling of openings
  - Downflooding points not considered to stop GZ curve but calculation including progressive flooding through the opening

Non-zonal Approach for collision

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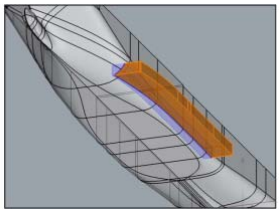
- Develop a non-zonal approach for collision damages
- Geometrical and probabilistic model of collision damage in accordance with SOLAS2009 to generate hull breaches
- Probabilistic description of lower limit of damage is missing in SOLAS2009 (presently worst case for s-factor): update needed
- Reference data from GOALDS
- Continue work from EMSA3



Combined collision and grounding

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- Survivability assessment considering "all" types of damages
- Source of breach not relevant
  - Collision
  - Bottom grounding
  - Side grounding
- Determination of relative frequencies of different type of accidents (analysis of EMSA3 database)
- consider risk models developed in EMSA3 as a basis for the combination

Derivation of s-factor

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- Current s-factor based on RoPax modeltests
- Special behaviour of cruise ships to be considered
- Flow of water is randomly process
- Use the results from the simulations, confirmed by validation to propose a modified s-factor appropriate for the cruise ship design
- Based on work done in GOALDS
- No model tests, but numerical simulations

Numerical simulations

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- Enhance numerical simulations as an alternative method for assessment of survivability
- Guideline to be developed to approve software and results
- Common guidance how to deal with probabilities, sea states, initial conditions
- Strategy to be developed to consider escape routes, external moments, max heel for LSA etc
- Comparison with updated static calculations

Conclusion

- **New SOLAS2020 increase the safety level significantly**
- **Combination of new requirements may change some ship designs**
- **Some routes may suffer from modal change**
- **Gap between existing ships and new design will increase**
  - **Delay of introduction of improved safety level**
  - **Economic advantage of old ships**
- **Difference between RoPax and cruise ships to be further studied**
- **Quantification of real safety level for cruise ships needed**

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