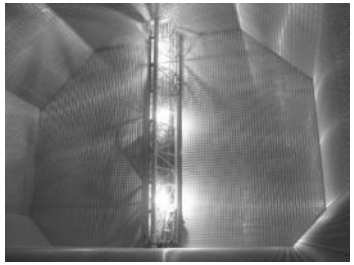
Expert in LNG

Tenue des technologies de confinement GTT à la collision par essais, simulations et retour d'expérience

114ème Session de l'ATMA







1ier Juin 2016

Safety | Excellence | Innovation | Teamwork | Transparency

Disclaimer

Introduction

- **With the new applications of membrane tanks (LNG fueled ship, bunker barge), the risk of collision must be addressed**
  - No dedicated shipping routes for LNG fueled ship
  - Crowded routes
  - No dedicated terminals

Marc Van de Velde, July 2009

- **What is GTT's return of experience of collision cases?**

Introduction - GTT's return of experience

- **1979, El Paso Paul Kayser's grounding**
  - Outer hull torn over nearly 180m
  - Inner hull warped about 30cm

Outer hull deformation

NO96 membrane deformation due to grounding

- **Despite deformation, no loss of LNG tightness!**

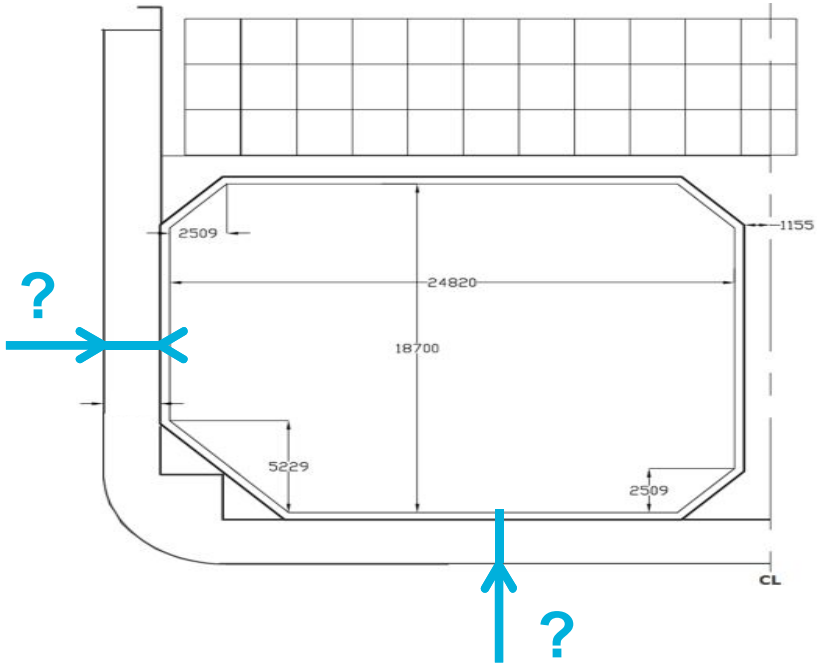
Introduction - GTT's return of experience

- **1983, Mark I membrane**
  - Over-pressure in the primary insulation space
  - Equivalent deformation of a 2.5m of displacement of the inner hull

- **No loss of LNG tightness**

Introduction - IGF code requirement

- **For LNG as a fuel application: LNG tank design must respect IGF code requirements**
  - Requirements on the distance between the tank and the outer hull to face collision risk



- **Two approaches suggested**
  - Deterministic approach
  - Probabilistic approach

Introduction - IGF code requirement

- **Deterministic approach**
  - Referring to paragraph 5.3.3.1 of the IGF code:

5.3.3 The fuel tank(s) shall be protected from external damage caused by collision or grounding in the following way:

.1 The fuel tanks shall be located at a minimum distance of B/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught;

where:

B is the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

Introduction - IGF code requirement

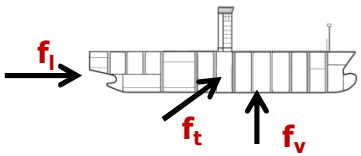
- **Probabilistic approach**
  - Referring to paragraph 5.3.4 of the IGF code:

5.3.4 As an alternative to 5.3.3.1 above, the following calculation method may be used to determine the acceptable location of the fuel tanks:

.1 The value f_{CN} calculated as described in the following shall be less than 0.02 for passenger ships and 0.04 for cargo ships. [5]

.2 The f_{CN} is calculated by the following formulation:

$$f_{CN} = f_l \times f_t \times f_v$$



- f_l : collision damage extension in longitudinal direction
- f_t : collision damage extension in transverse direction
- f_v : collision damage extension in vertical direction

Introduction - IGF code requirement

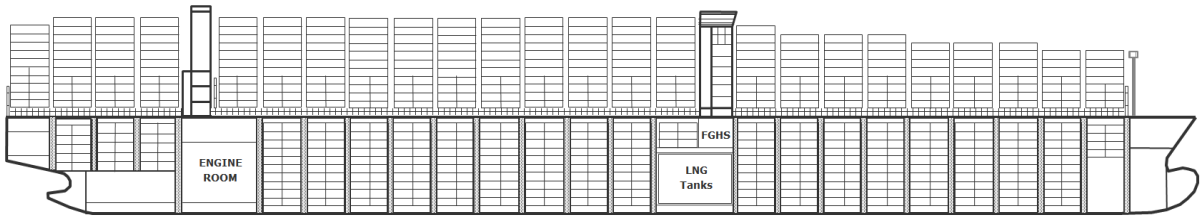
- **In each approach, the membrane CCS and its interaction with inner hull is not taken into account…**

How should be validated the membrane CCS with regard to ship to ship collision ?

- **TUHH - DNV GL - GTT cooperation program**
  - **Study on a 18,000 TEU LNG powered container ship**
  - Equipped with Mark III containment system
  - Experimental campaign & numerical developments

DNV·GL

TUHH
Technische Universität Hamburg-Harburg



Cooperation Program

DNV·GL

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1. Ship to ship collision probability analysis

2. Numerical analysis on a 18,000TEU container ship

3. Tests performed on the Mark III membrane

4. Perspectives

DNV·GL

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Ship to ship collision probability analysis

Performed by TUHH & DNV GL

Ship to ship collision probability analysis

- **Focus on :**
  - The route for a round-trip from Europe to Asia
  - Collisions involving a container ship
- **IMO GISIS and DNV GL databases, reference period 1990 to 2014**
  - 813 collisions
  - Fleet of 4330 container ships
- **Collision probability:**

  7.82×10^{-3}

Thea Glaser, 2015

Ship to ship collision probability analysis

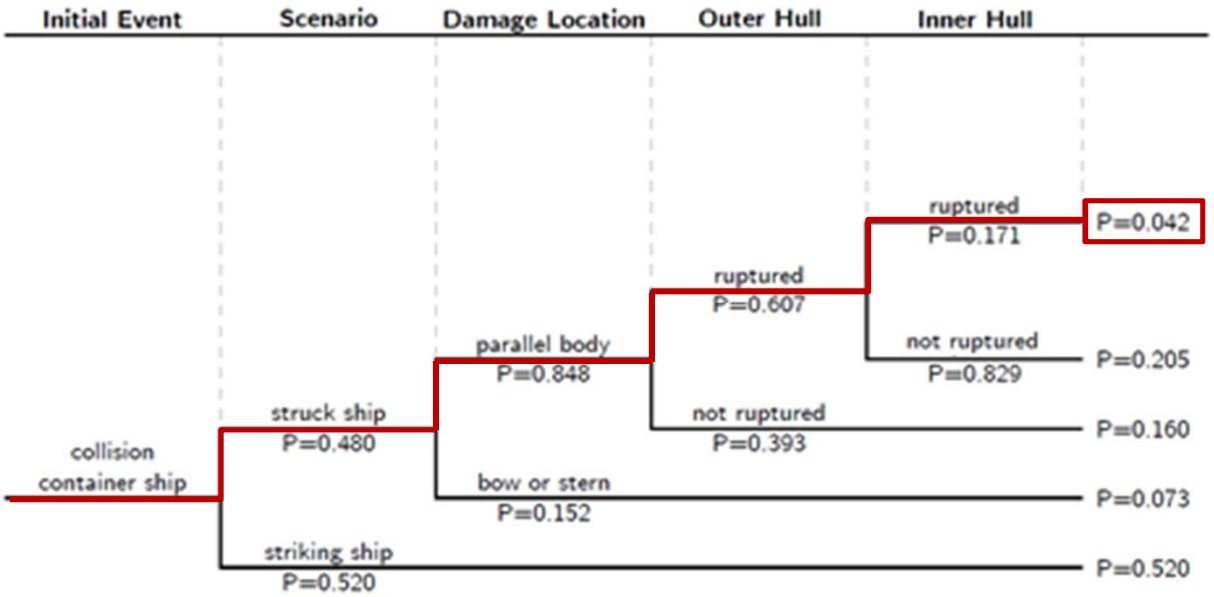
- **Example of ship to ship collision in the Singapore Strait:**

MAIB, 2013

Damage to the bow of ACX HIBISCUS and to the side of HYUNDAI DISCOVERY

Ship to ship collision probability analysis

- Probability of inner hull rupture:

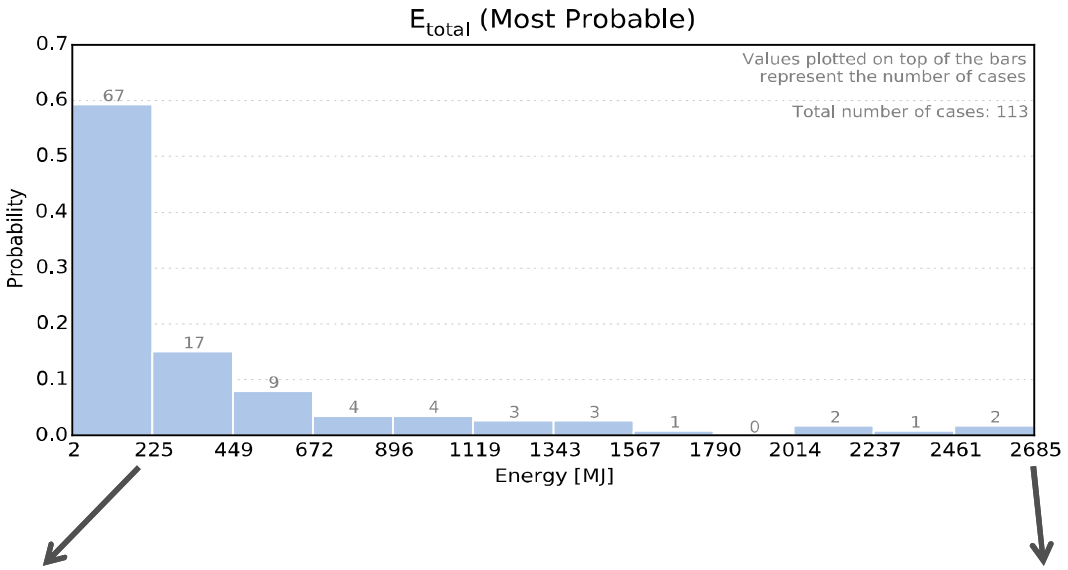


- Collision probability: **7.82×10^{-3}**

- **Probability of inner hull rupture for container ships in a collision: 3.28×10^{-4} per ship year**

Ship to ship collision probability analysis

- **Collision energy vs probability of occurrence:**



100,000T at 4.1 knots

100,000T at 14.2 knots

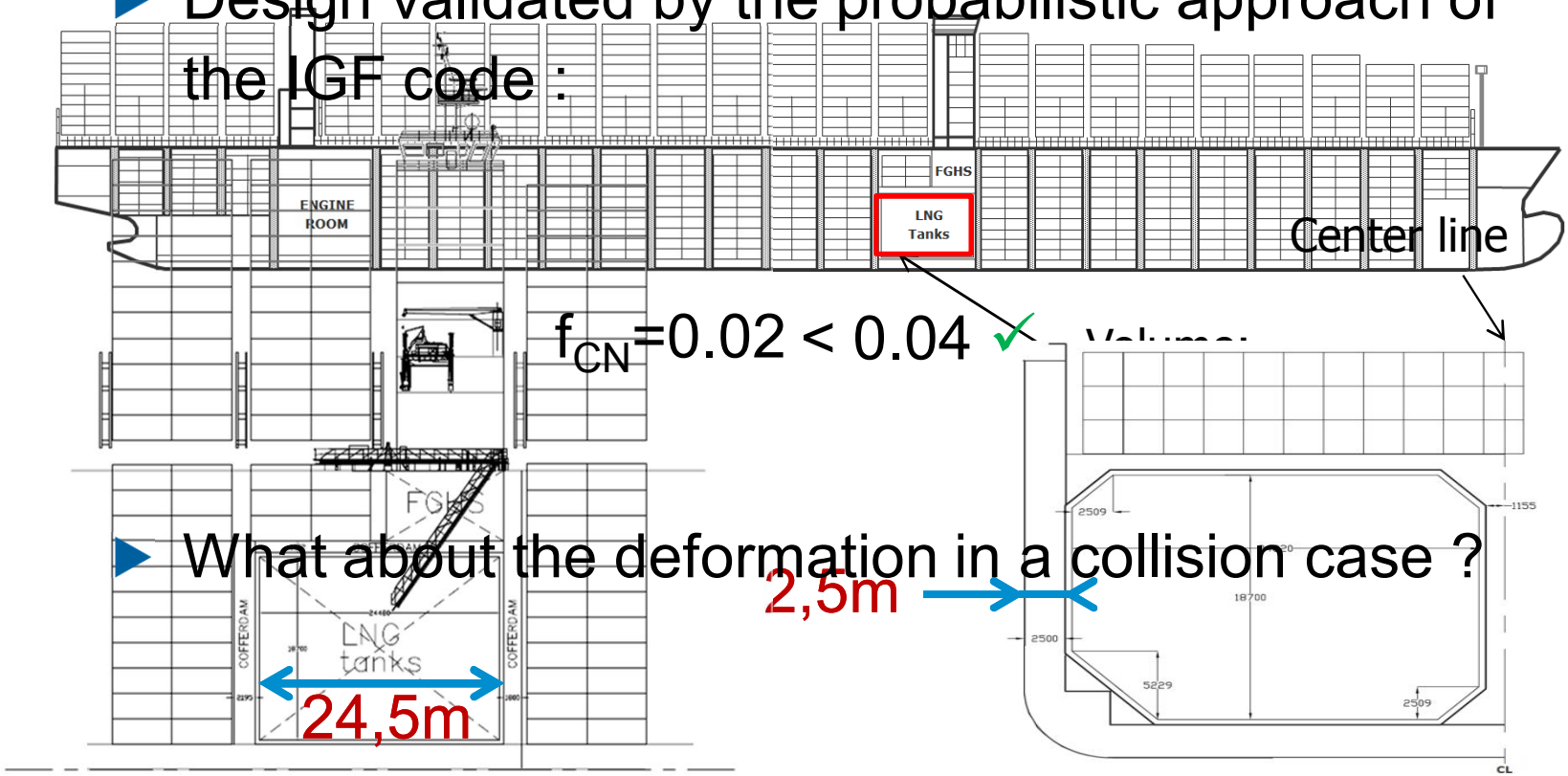
- **Equivalent kinetic energy**

2 Numerical analysis on a 18,000TEU container ship

Performed by DNV GL

Numerical analysis of a collision case

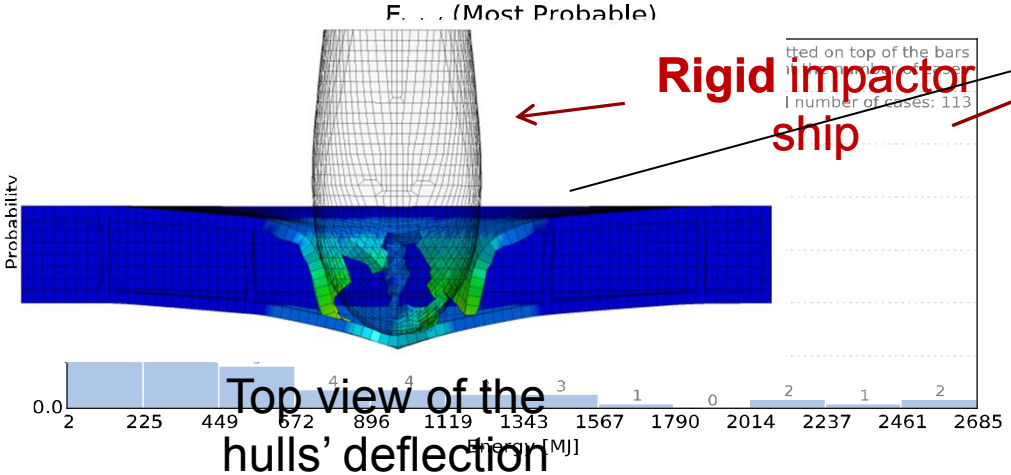
- **Application on a 18,000 TEU LNG fuelled ship:**
  - Design:
  - Design validated by the probabilistic approach of the IGF code :
  - What about the deformation in a collision case ?

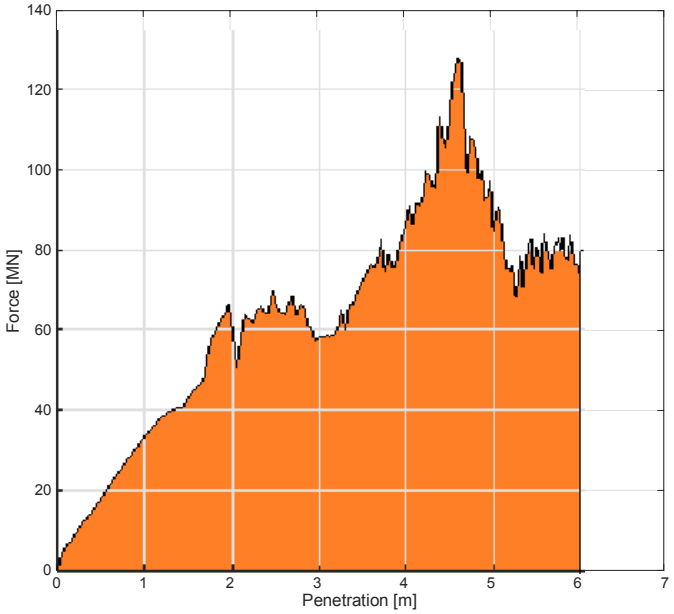


Numerical analysis of a collision case

- **Collision simulation**
  - More severe collision case parameter (rigid impactor, 90°)
  - Inner hull deformation calculation

Striken ship mesh



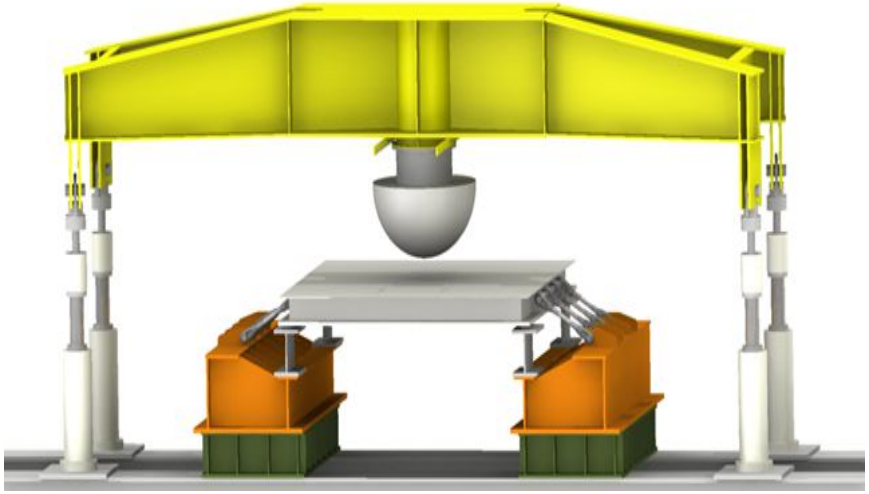


- **No consideration of the containment system**

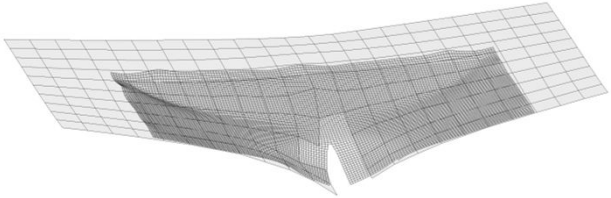
3 Tests performed on the Mark III containment system

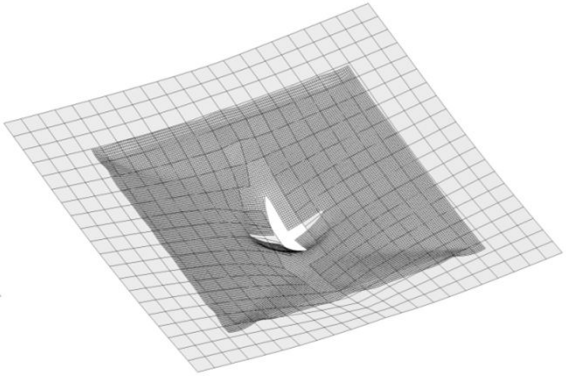
Tests performed on the Mark III containment system

- TUHH laboratory – Scale 1:1 test



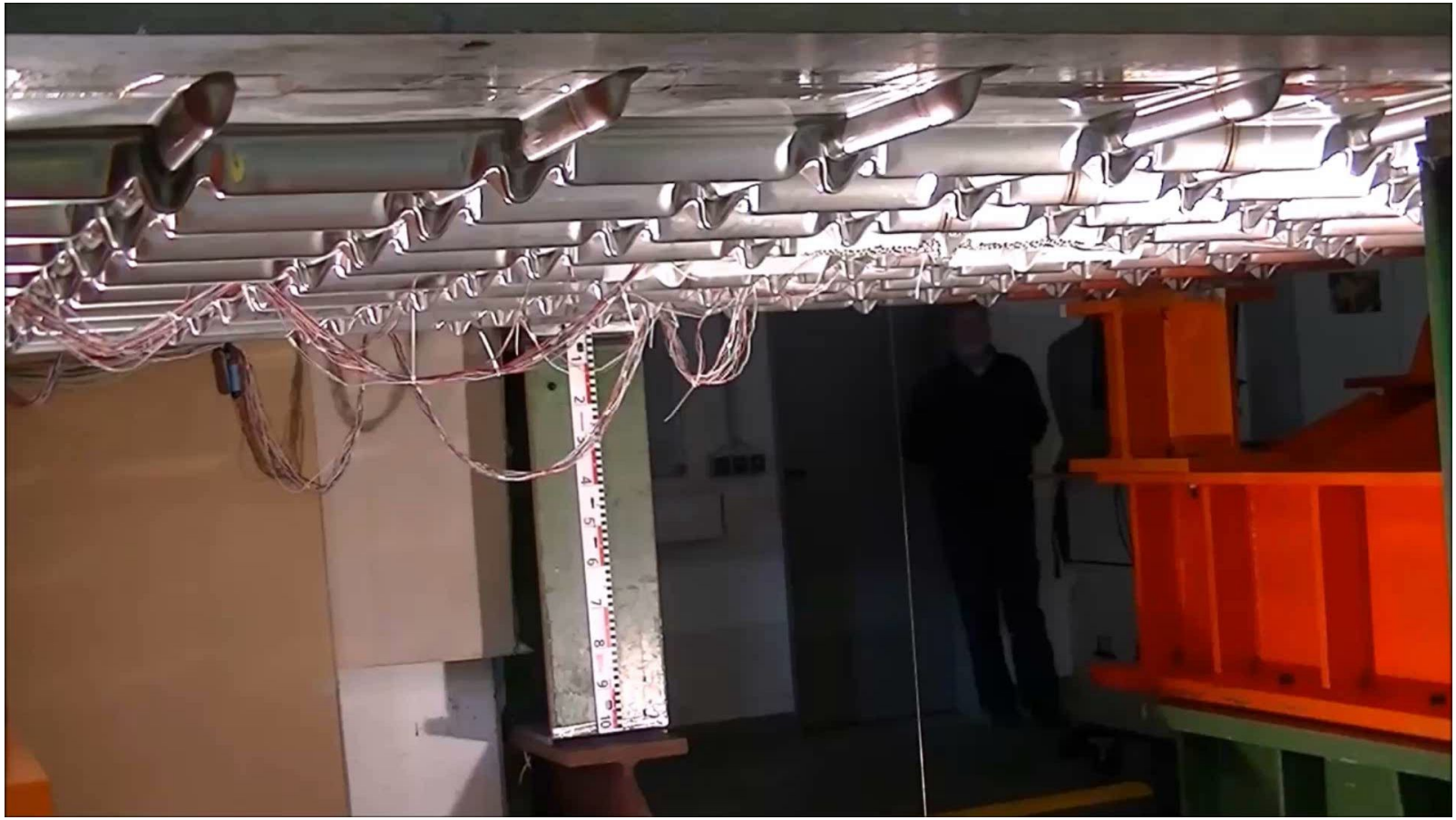
- mock-up and collision simulation





Tests performed on the Mark III containment system

- **Test :**

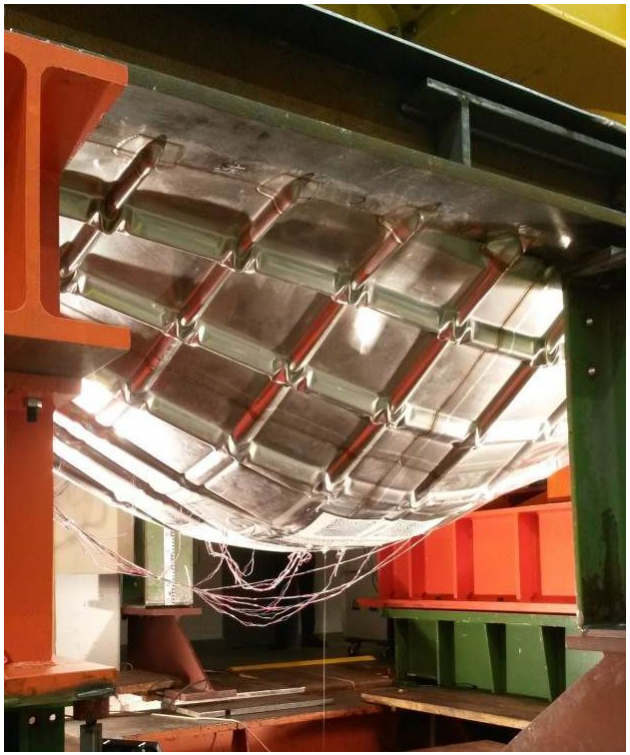


Tests performed on the Mark III containment system

- **Test results:**

- **Bulb displacement of 1m on 3m of Mark III membrane**

- **Small corrugations completely unfolded**



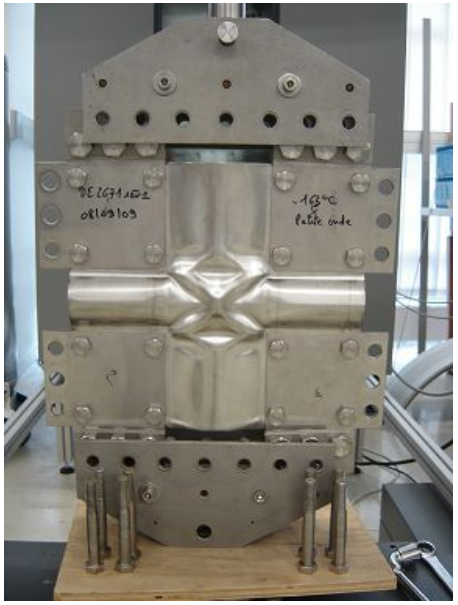
- **Obtained at ambient temperature**
  - What about cryogenic condition?

Tests performed on the Mark III containment system

- **Unfolding tests performed at cryogenic temperature :**

Along large corrugation

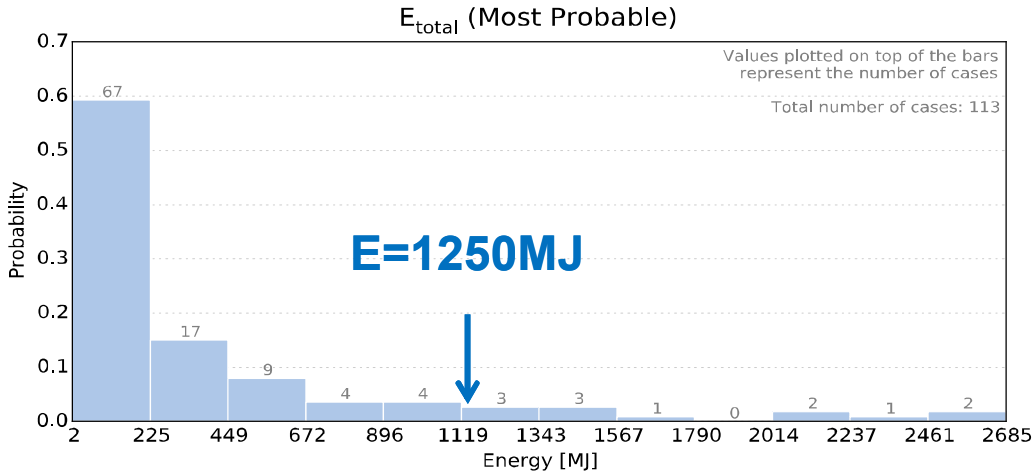
Along small corrugation



- **Results: corrugations completely unfolded without any crack**

Tests performed on the Mark III containment system

- **Test interpretation :**
  - With **24m** span, this would be **equivalent to validate a 8m penetration** of the inner hull
    - In term of collision energy: ~**1250MJ**
    - Equivalent to a vessel of 100,000T at 9.8knots



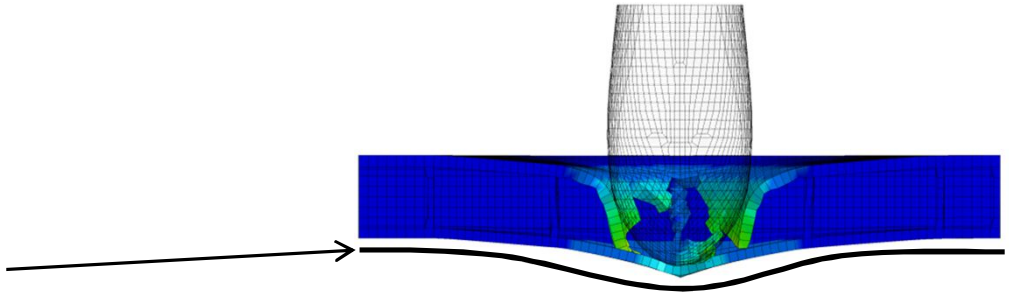
→ **91%** of collision cases **approved**

4 Perspectives

Perspectives

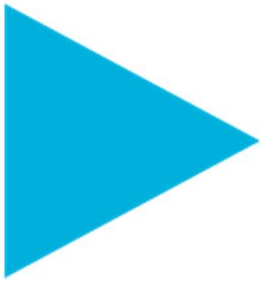
- **Direct approach to validate the membrane**
  - Using a Finite Element Method
    - Possibility to assess the level of strain

Membrane element



  - Developping collisions scenarios

- **Optimization of hull scantling with regard to collisions**



Conclusion

Conclusion

- The membrane's flexibility is very large
- Therefore the membrane can adapt to very large deformation which would occur during a collision case without loss of tightness
- Another demonstration of the Mark III membrane's flexibility and strength with the *Tellier* dismantling

Papers, Conferences…

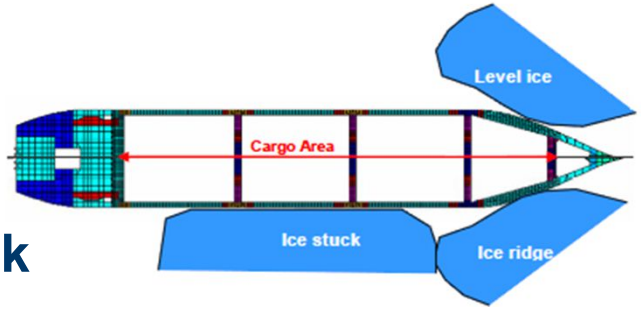
- LNG18

- International Conference on Ships and Offshore Structures (ICSOS), Hamburg University of Technology, from 31.08.2016 to 02.09.2016

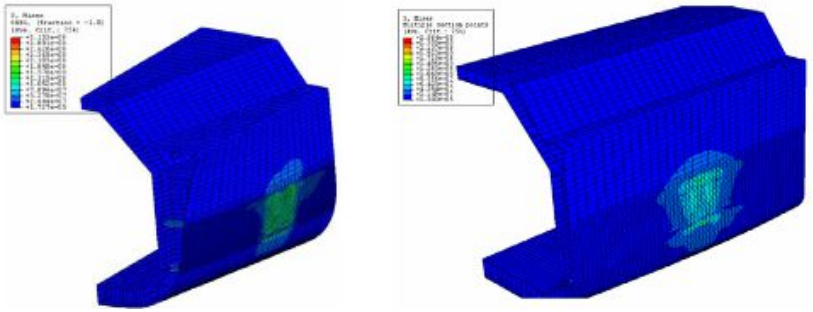
Thank you for your attention

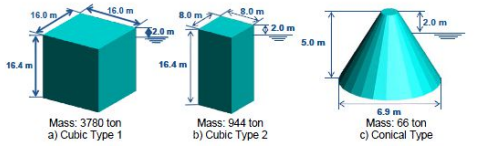
Chapot • kchapot@gtt.fr

Iceberg collision

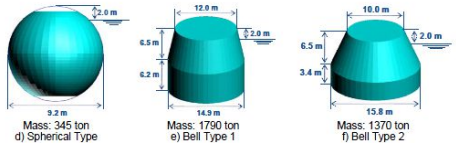


- **Iceberg collision with an Ice Class 1A 170k**
  - Study with different impact locations





  - Study with several shapes of ice bergy



- **With different ice characteristics, no significant damage on the inner hull or NO96 cargo containment system**

NO96 membrane behavior in collision case

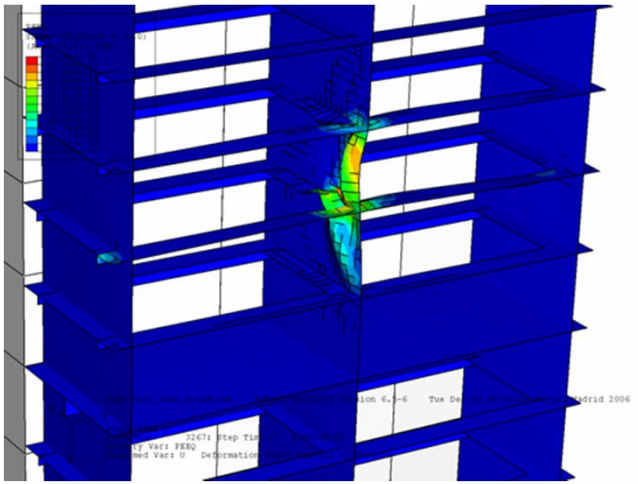
- **Collision with ice may induce outer hull deformation**
- **Double hull structure of LNGC will limit deformation of inner hull**

Example : 1m^2 ice loading condition

Double hull stiffeners start to see high damages at >90bars

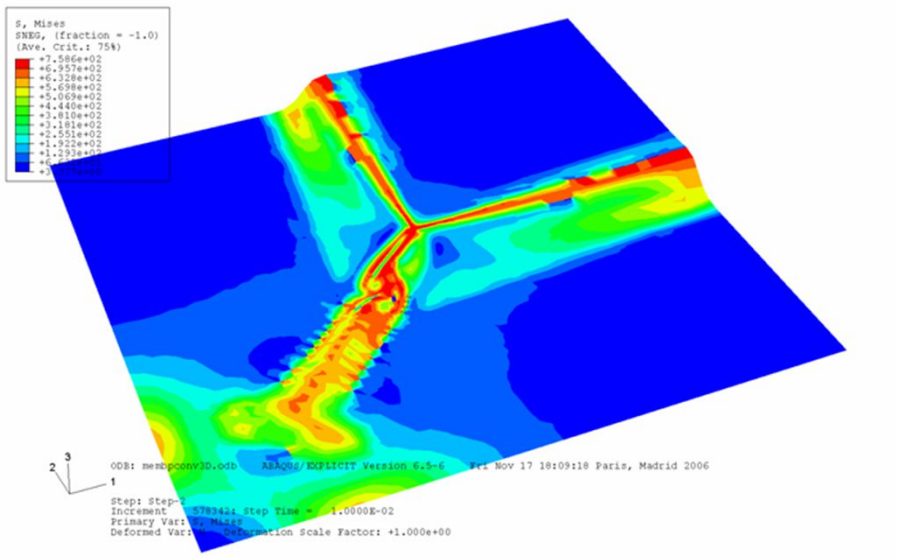
Local buckling of transverse stiffeners

Deformations not transferred to the inner hull



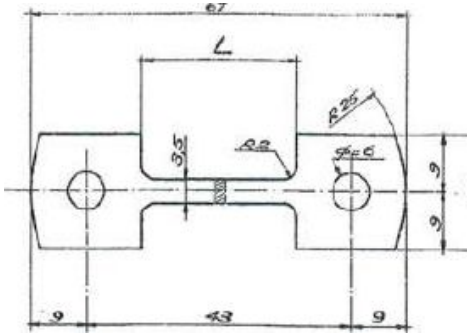
NO96 membrane behavior in collision case

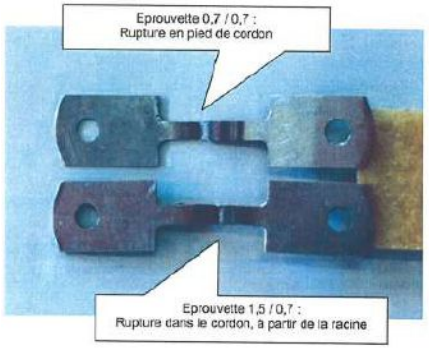
- Membrane CCS is anchored to inner hull
- Flexibility of NO96 membrane (40mm/m maximum elongation in longitudinal direction) allows for large inner hull deformation (i.e. more than 1.2m deep for 10m in diameter)

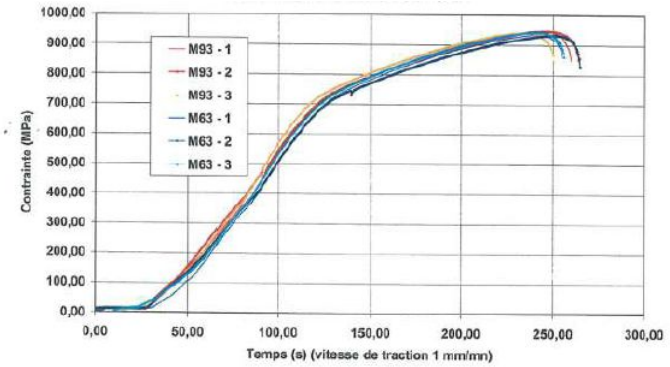


LARGE HULL DEFORMATION

- Invar tensile properties of both NO96 barriers







- Strain is not an issue (>20% at failure for Invar)

- Membrane flexibility is such that 100 mm vertical displacement does not affect membrane tightness