In Association with Doctor Honoris Causa of The University of Liège
Friday 23rd March 2012

Lessons Learned from Past Accidents:

Why May Accidents Like "*Costa Concordia*" Still Happen in 2012 ?

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Pusan National University, Korea

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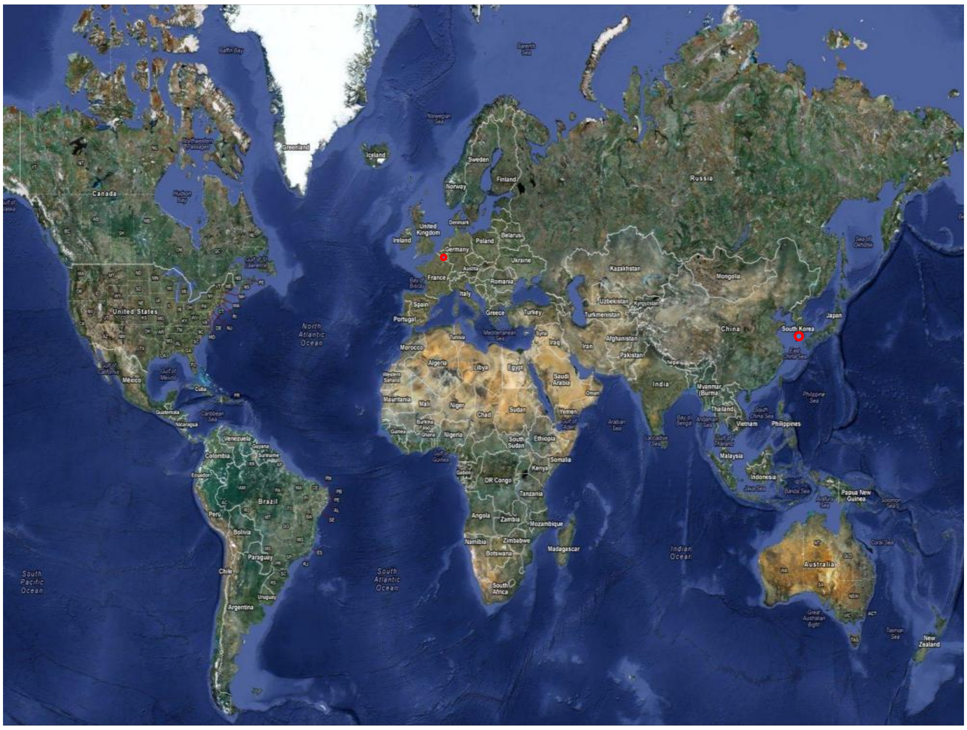

Population = approx. 50million
GNP = 20,000 USD

-Samsung Electronics
-LG
-Hyundai Motors, Kia Motors
-Hyundai Heavy Industries
-Daewoo Shipbuilding and Marine Engineering
-Samsung Heavy Industries
-STX Europe

- South Korea is the world's leading (No.1) ship manufacturer and has been consistently ranked at the top in terms of its order book and building quality and capacity.
- South Korea accounts for more than 40% of the global market for shipbuilding.
- South Korea accounts for more than 70% of the global market for offshore platform construction.

Metropolitan City of Busan, Korea

-The second largest city in South Korea
-Population = 4 million

선박 해양플랜트 기술 연구원
THE SHIP AND OFFSHORE RESEARCH INSTITUTE

DHC ULG, Prof. J.K. Paik, March 23, 2012

Université de Liège

Main Campus of Pusan National University

-Total number of students = 31,000
-Total number of NAOE students = 380(undergraduate)/120(graduate)

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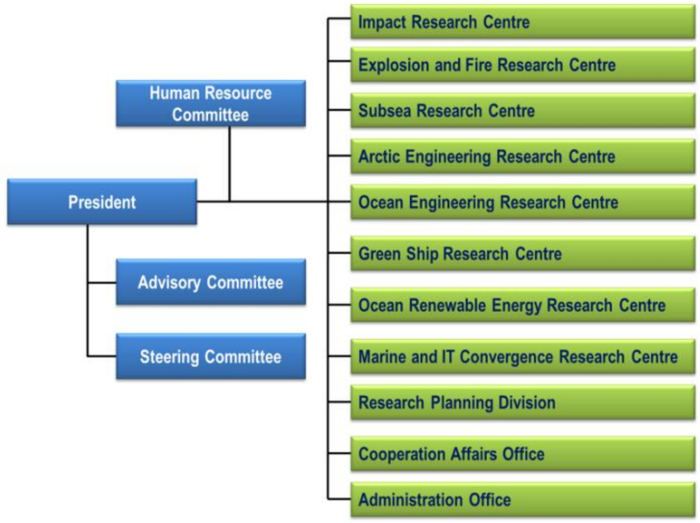
Organization of The KOSORI



Research Staff (as of March 2012)

Research Staff		Number	Remark
Faculty Member		4	
Chair Professor		1	Former Deputy Minister, Ministry of Science and Technology, Korea
Visiting Professor		1	von Karman Chair Professor, University of California at Irvine, USA
Research Professor		2	
Research Engineer		6	
Graduate Student	Master	19	
	PhD	13	
Technician		1	
Administrative		3	
Total		52	

National Advisory Committee Members (as of March 2012)
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- Mr. H.S. Bong, Senor Executive Vice President, Hanjin Heavy Industries
- Mr. T.H. Park, Senior Executive Vice President, STX Offshore and Shipbuilding
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- Dr. K.B. Kang, Senior Vice President, POSCO

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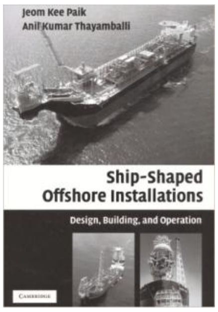
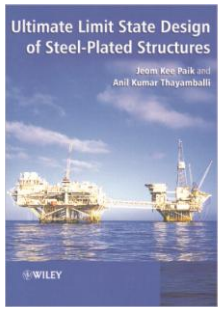
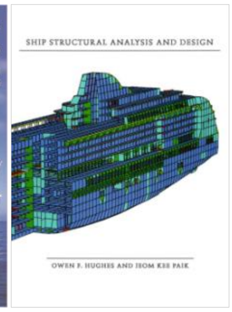
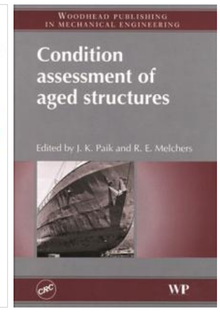
- Emeritus Prof. O.F. Hughes, Virginia Tech., USA
- Prof. R.E. Melchers, University of Newcastle, Australia
- Prof. R. Snell, Oxford University, UK
- Prof. Y. Bai, Zhejiang University, China

Textbooks

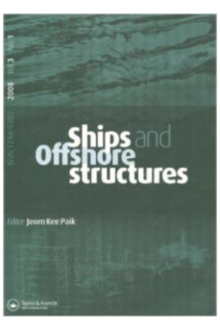


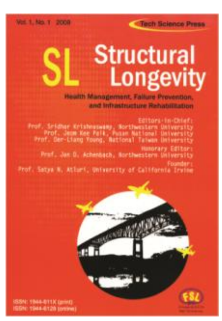






Editor-in-Chief of International Journals



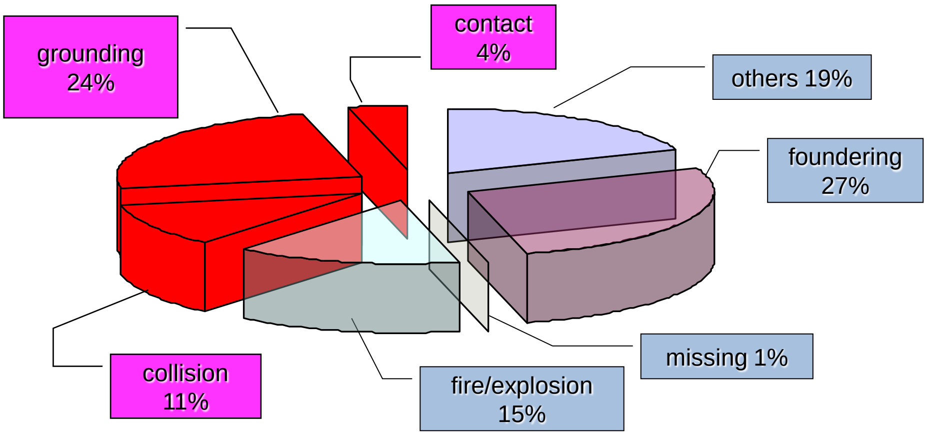


Editor-in-Chief of UNESCO Encyclopedia

Encyclopedia Of Life Support Systems (EOLSS)
6.177 Ships and Offshore Structures
UNESCO, Paris

Editorial Board Members of International Journals

Causes of Maritime Casualties – Ships



Costa Concordia Grounding on January 13, 2012

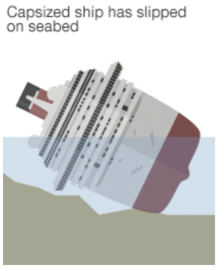
The Costa Concordia, 290.20m long, with a beam of 35.5m and a draught of 8.2m.
Service speed = 19.6 knots (19.6km/h) and maximum speed = 23 knots (43km/h)

Costa Concordia Grounding on January 13, 2012

On evening of January 13, 2012, the Costa Concordia partially sank after grounding off the coast of Italy, while sailing off Isola del Giglio. Of the 3,229 passengers and 1,023 crew Known to have been aboard, seven are missing and 25 are confirmed dead.

Costa Concordia Grounding on January 13, 2012

It is premature to make any conclusions as to the cause of the *Costa Concordia* accident and design lessons to be learned until after a full technical investigation being carried out by the Italian Authorities is completed.



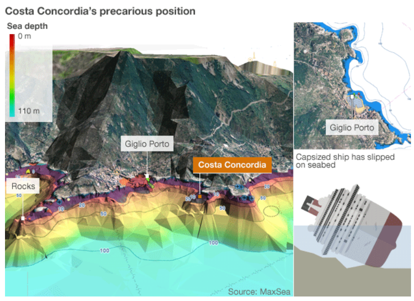
Some maritime safety experts think that the accident is due to the design of the new generation of massive cruise ships, in which their high structures make them prone to tilting, especially in shallow waters and with strong side winds, or when taking in water after damage or in rough seas.

Their large size makes them slow to respond to the controls and when, like the Costa Concordia, they are not equipped with azimuth thrusters they are difficult to manoeuvre. They are also difficult to evacuate because of the crowded outdoor deck space and the old-fashioned lifeboat systems that cannot be lowered when the ship is tilting heavily.

Modern escape capsules or free-fall lifeboats allow safe operation under tilt and are quicker to use.

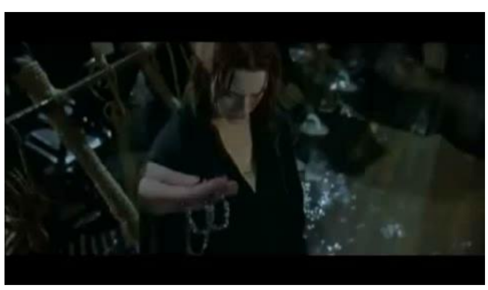
Other experts claim, however, that the design and operation or modern cruise ships are well regulated and that these ships are extremely safe. Since 2005, more than 100 million people worldwide have taken cruises, and until the Costa Concordia disaster there have only been 16 fatalities. (http://en.wikipedia.org/wiki/Costa_Concordia_disaster).

The Costa Concordia ran aground, hitting a reef, while operating at forward speed, resulting in the rupture of its bottom structures, water ingress, and eventual capsizing. From the structural design point of view, the lesson to be learnt is that, like in double hull oil tankers, cruise ships must also apply relevant technologies for double-bottom structure designs to increase safety and structural integrity in the event of a grounding accident.

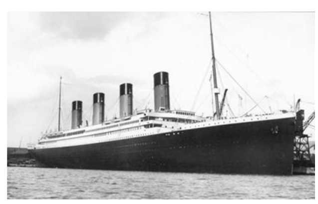


Rock Embedded in Port Side Bottom of Damaged Hull

Titanic Accident on April 15, 1912



Movie directed by James Cameron

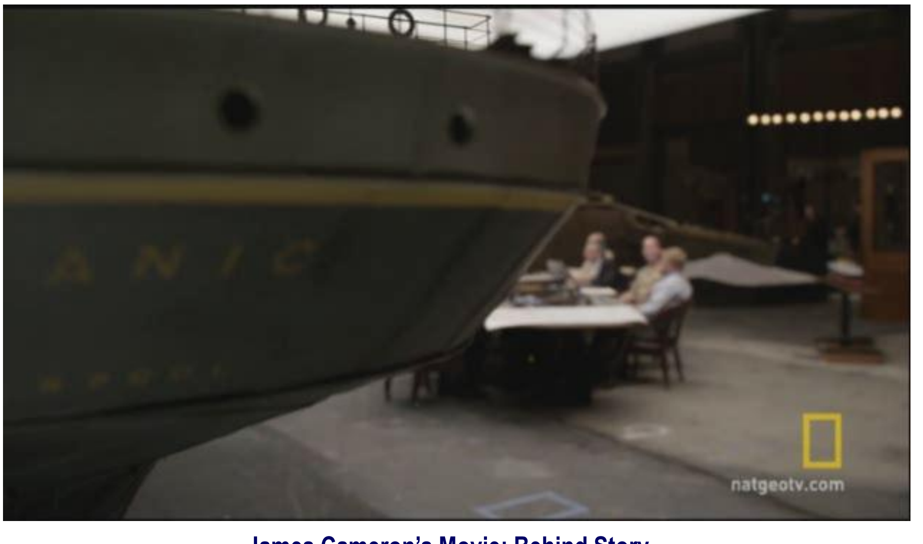


One of the best-known accidents in the history of shipping is the sinking of the *Titanic Liverpool*, 269.1 m long with a beam of 28.2 m. The maximum number of passengers and crew was 2,300 and her maximum speed was 24 knots (44.9km/h). On April 10, 1912, she left the port of Southampton, England, one her maiden voyage to New York City. 2,200 passengers and crew were on the voyage. Four days into her journey, at 11:40pm on the night of April 14, she struck an iceberg on the port-side bow.
The ship's speed at the moment of collision was reportedly 23 knots (43km/h), which is an amazing speed for passenger ships even today. The consequence of the collision with iceberg was catastrophic, because the bow structure was fractured, and icy water soon poured through the ship.
Because of the accidental flooding, the ship was subject to a large bending moment, and when five watertight subdivisions and one boiler room were flooded, her back broke entirely in two.
This year is the 100th anniversary of the Titanic accident.

Titanic Accident on April 15, 1912: 100th Anniversary

James Cameron's Movie: Behind Story

Titanic Accident on April 15, 1912: 100th Anniversary

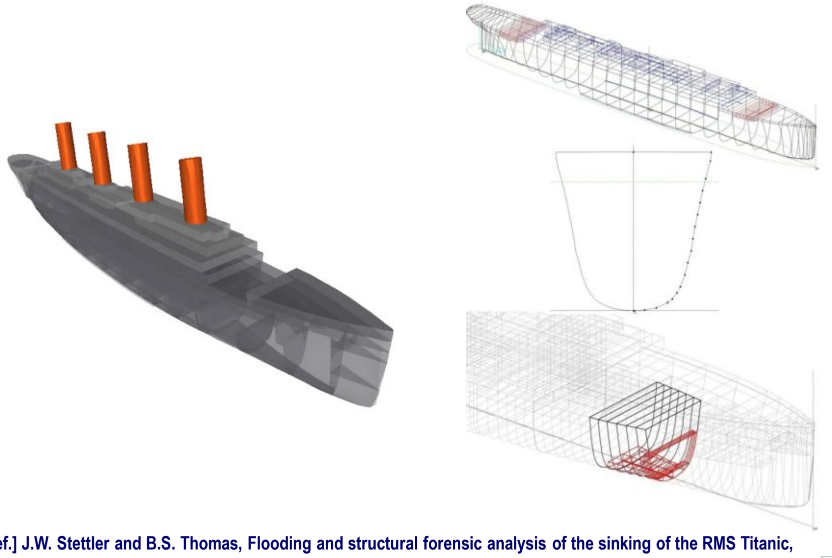


James Cameron's Movie: Behind Story

Titanic Accident on April 15, 1912: 100th Anniversary

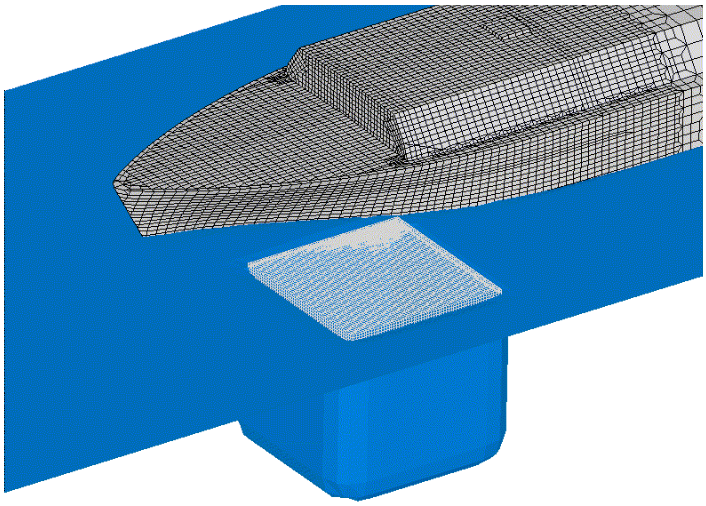
James Cameron's Movie: Behind Story

Hull Form and Compartment Definition of Titanic

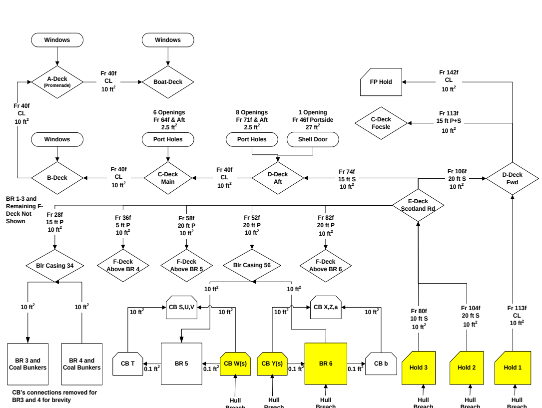


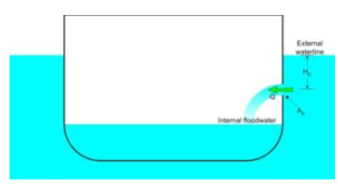
[Ref.] J.W. Stettler and B.S. Thomas, Flooding and structural forensic analysis of the sinking of the RMS Titanic, Submitted for publication in Ships and Offshore Structures, 2012.

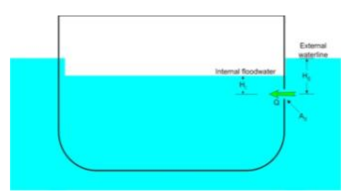
Ship Collision with Iceberg at Port-Side



Progressive Flooding in Compartments (Subdivisions)

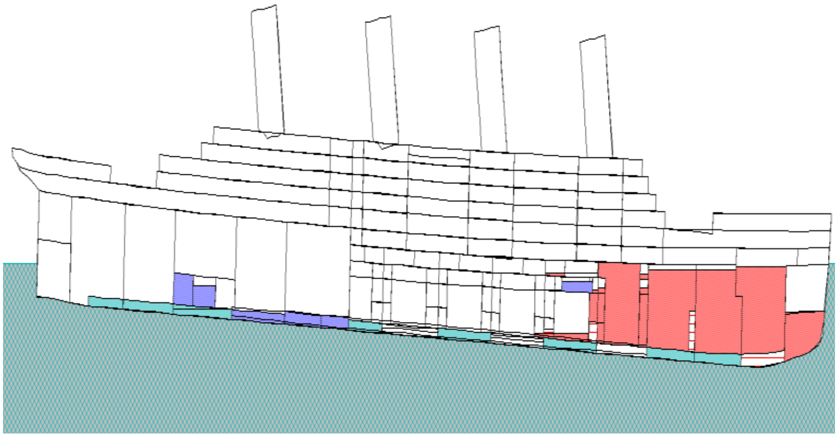






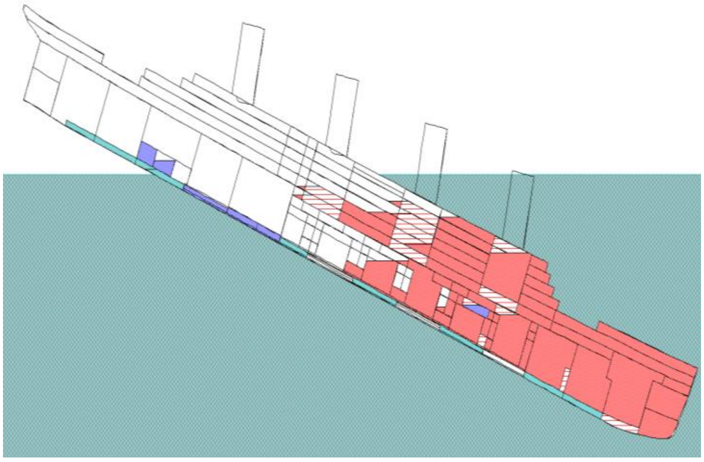
[Ref.] J.W. Stettler and B.S. Thomas, Flooding and structural forensic analysis of the sinking of the RMS Titanic, Submitted for publication in Ships and Offshore Structures, 2012.

Titanic's Condition with Progressive Flooding at 80 Minutes



[Ref.] J.W. Stettler and B.S. Thomas, Flooding and structural forensic analysis of the sinking of the RMS Titanic, Submitted for publication in Ships and Offshore Structures, 2012.

Titanic's Condition at the Point of Maximum Bending Moment, Trim = 23deg.



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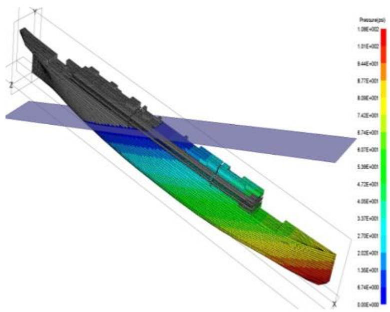

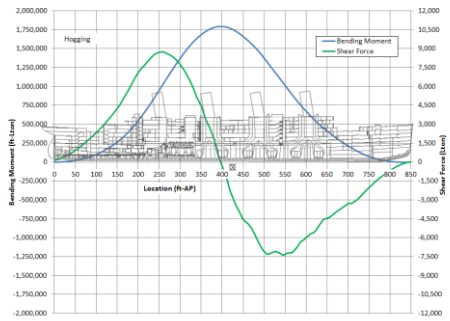

M_{max} = 1,790,000 ft.lton (Boiler Room 2)

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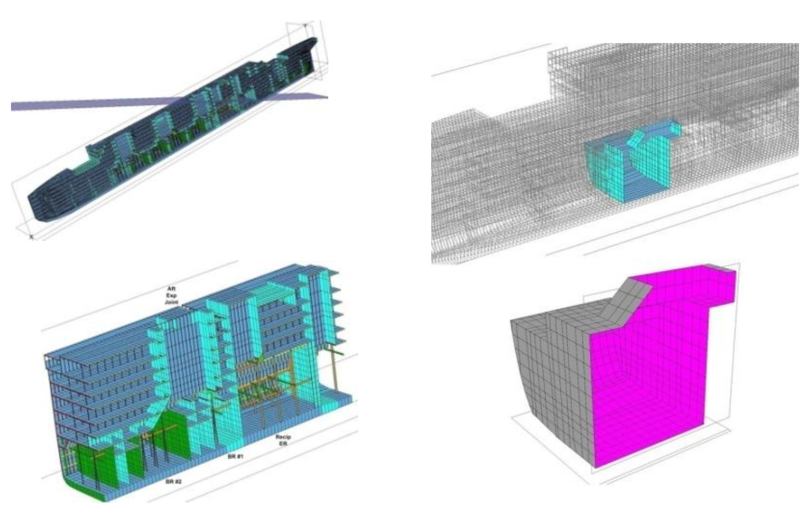

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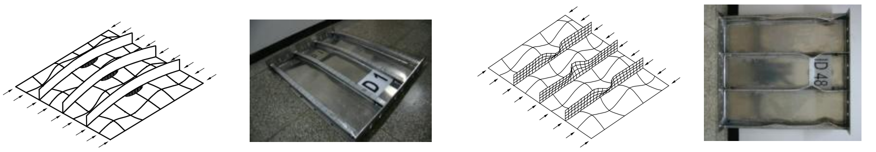
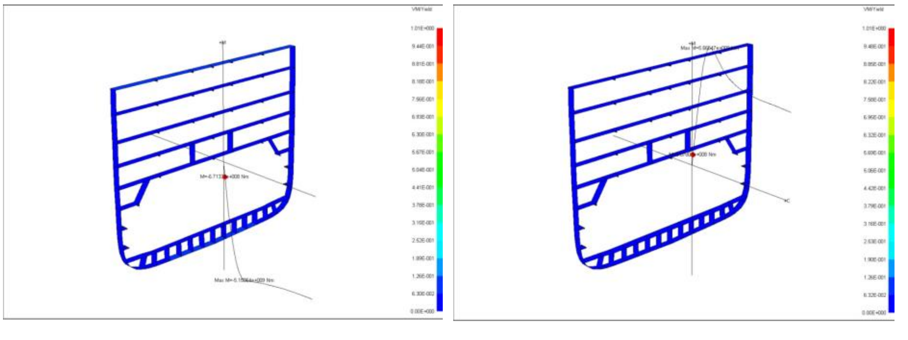
Buckling Phenomenon



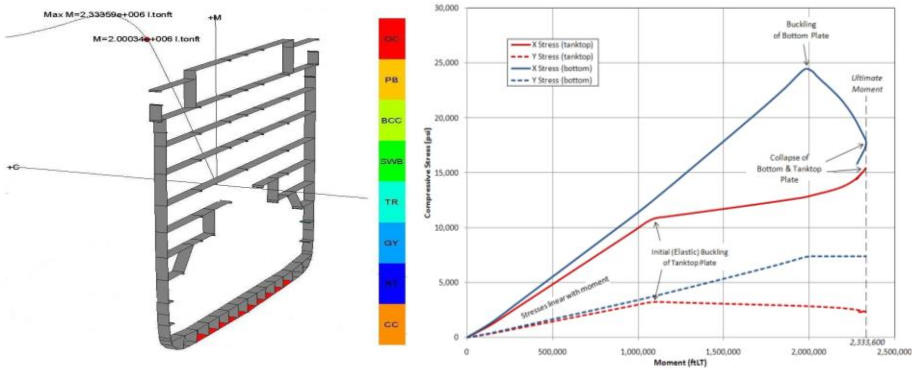
Progressive Collapse Analysis of Titanic's Hull at Boiler Room 2



Sagging Hogging

ALPS/HULL Simulations

Collapse of Titanic's Hull – ALPS/HULL Simulations



M_u = 2,333,600 x (1.0-0.28) = 1,680,192 ft.lton (Effect of riveting)

M_{max} = 1,790,000 ft.lton

M_u/M_{max} = 1,680,192/1,790,000 = 0.94

[Ref.] J.W. Stettler and B.S. Thomas, Flooding and structural forensic analysis of the sinking of the RMS Titanic, Submitted for publication in Ships and Offshore Structures, 2012.

Lessons Learned from the Titanic Accident

1. Steel tends to become brittle at low temperatures.
2. The impact velocity at the moment of the Titanic's collision with the iceberg is reported to have been 23knots (or 11.8m/s).
3. Accidental flooding most likely altered the hull girder load distribution and amplified the maximum hull girder bending moments.
4. Because the water ingress following the collision with the iceberg subjected to the ship to the bending moment in the boiler room, the large axial compressive loads bearing on the structures led to their buckling and collapse.

Hull Collapse of Anonymous Capesize Bulk Carrier at Harbor

The back of an anonymous Capesize bulk carrier broke at the harbor during the unloading of cargo. This photo shows the ship after the breakage of her hull girder.
Because of the shallow depth of the harbor, she did not disappear beneath the water after breaking into two, but her mid-section reportedly touched the bottom of the pier.
Evidently total loss was the outcome.

Lessons Learned from the Bulk Carrier Accident

1. The poorly executed unloading of cargo can amplify the maximum hull girder bending moments to the extent that exceed the maximum load-carrying capacity of the hull structures.
2. Deck panels or bottom panels should be designed using ultimate limit state design methods so that the ultimate hull girder strength is able to withstand unintended scenarios of cargo loading and unloading that cause uncertainties and subsequently affect the structural design process.

Oil Tanker Erika Accident on December 12, 1999

24-year-old oil tanker Erika broke up on December 12, 1999, causing the spillage of some 7,000 to 10,000 tons of oil. Immediately before the accident, she was forced with structural problem in very rough sea condition, which was reportedly a wind of force 8 to 10 with a 6m swell. This photo shows the Erika as she sank.

Lessons Learned from the Erika Accident

1. Rough sea conditions can amplify hull girder loads to the extent that they reach or even exceed the corresponding design values.
2. Such age-related damage as corrosion wastage and fatigue cracking damage can decrease hull girder strength.
3. An increase in applied hull girder loads, a decrease in hull girder strength, or both, can result in the collapse of the hull girder.

Oil Tanker Sea Prince Accident on July 23, 1995

The oil tanker Sea Prince grounded as she attempted to leave the port of Yosu in South Korea to a safety bay to shelter from an incoming typhoon, causing the spillage of 5,000 tons of oil of the 85,000tons that had been loaded. The engine room caught fire as shown in this photo, and presumably the bottom structures suffered grounding damage. The remaining oil in the cargo tanks was transferred to barges when the fire was eventually put out on July 24. When the weather conditions further improved on July 25, lighterage and recovery operations were started and continued for 19 days. The ship was eventually refloated and towed out of Korean waters, but sank during towing. It is believed that the ship sank possibly due to hull girder collapse initiated by the failure of the damaged bottom structures.

Lessons Learned from the Sea Prince Accident

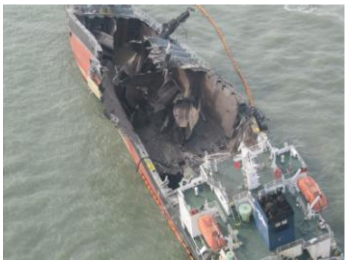
1. Accidents such as grounding or collision can cause structural damage to the bottom or side structures.
2. Hull girder strength can be decreased due to accidental damage, which means that the residual strength of damaged hull may be lower than the applied hull girder loads, causing hull girder collapse.

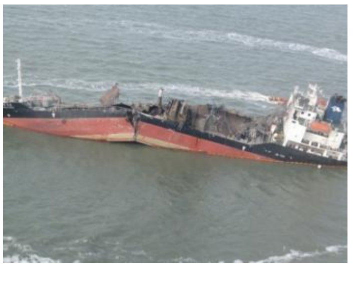
Oil Tanker Doola No.3 After an Explosion on January 15, 2012

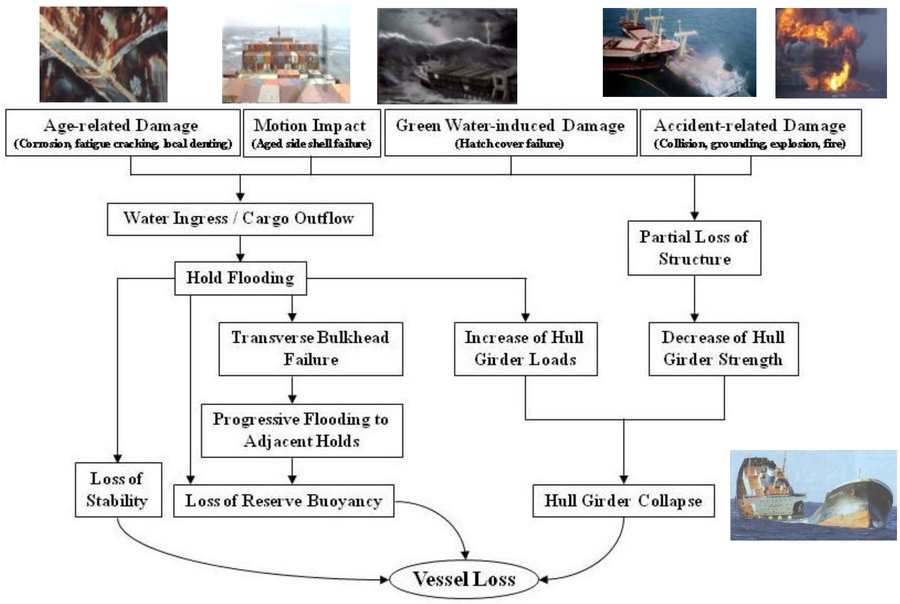
On January 15, 2012, the oil tanker Doola No.3 broke in two after an explosion in its cargo tank during gas-free operation off the west coast of South Korea.

Lessons Learned from the Doola No.3 Accident

1. This accident was the result of blast loads arising from vapor cloud explosion, which caused significant structural damage.
2. Whipping exceeded the limits of the design bending moments, resulting in hull girder collapse.







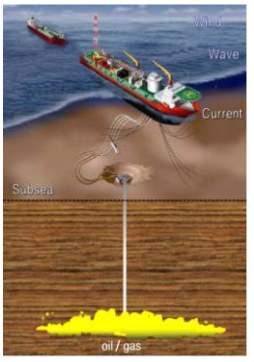
Total Loss Scenarios for Ships

Exploration of New Ocean Energy Resources in Deep Waters

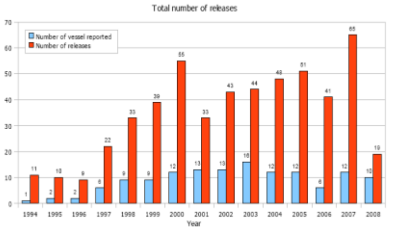
- The deep sea is a treasure house of energy resources such as oil, natural gas, gas hydrate, minerals (rare materials).
- Renewable energy sources such as wind energy and current energy are available.
- World market size is growing with more than 500billion US$ in 2030.

Offshore Production Systems in Deep Waters

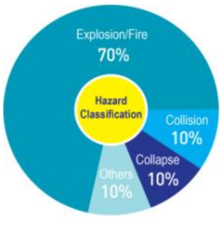
- Fixed type in shallow waters → Floating type in deep waters
- Ship-shaped offshore unit, Semi-sub, Spar, TLP
- Pipeline infrastructure → Multiple functions such as production, storage and offloading



Oil/Gas Leak Resulting in Explosion and Fire



Source: Health and Safety Executive, UK

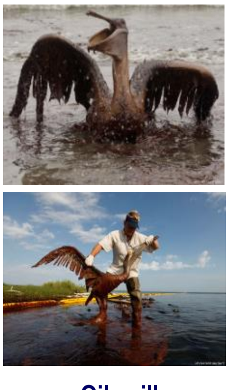


Pipe Alpha Accident

- July 7, 1988, North Sea
- 167 people killed
- Property damage of 1.4billion US$
- Risk based engineering became mandatory since the Pipe Alpha accident

Deepwater Horizon Accident

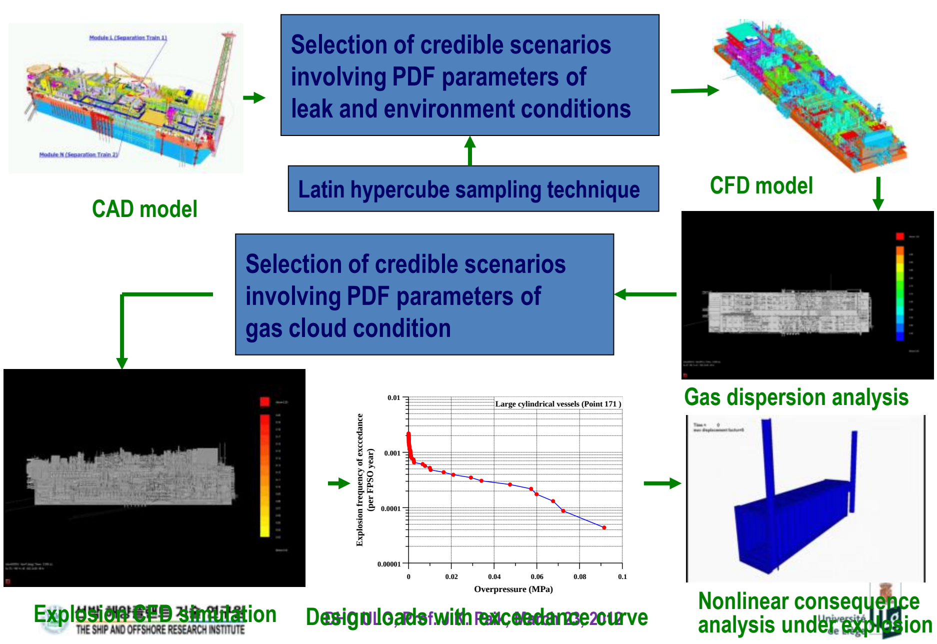
- April 20, 2010, Gulf of Mexico
- 11 people killed, 17 people wounded
- Environmental damage of approx. 30 billion US$



Oil spill

Deepwater Horizon Accident on April 20, 2010

EFEF JIP Procedure for Explosion Risk Assessment and Management (

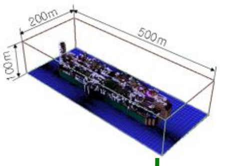


EFEF JIP Procedure for Fire Risk Assessment and Management (2

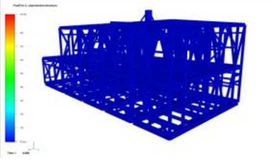
CAD model

Selection of credible scenarios involving PDF parameters of leak and environment conditions

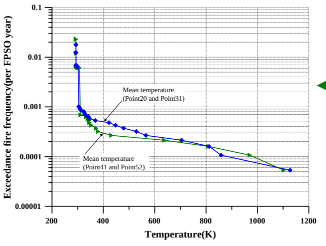
Latin hypercube sampling technique



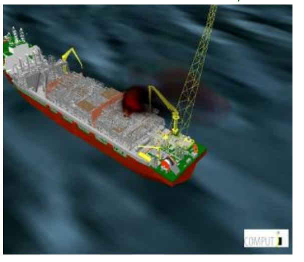
CFD model



Nonlinear consequence analysis under fire



Design loads with exceedance curve

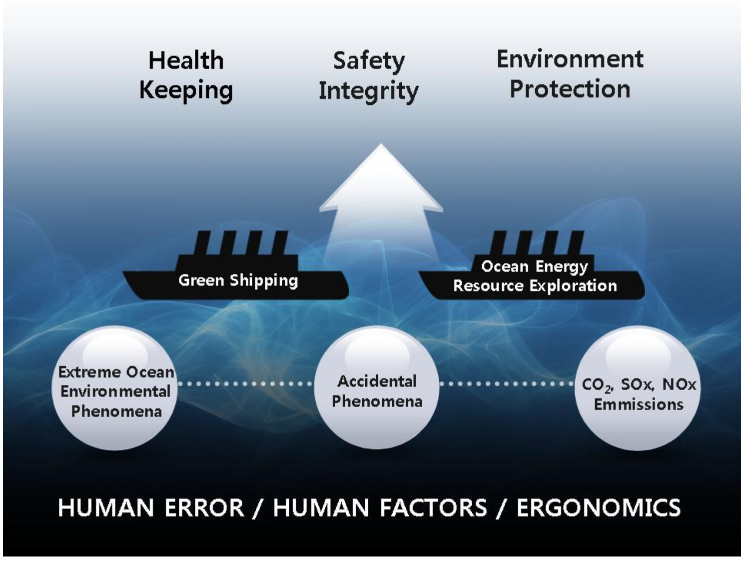


Fire CFD simulation

Most of accidents are the result of a long chain of human error, with such error responsible for
- 65% of all airline accidents,
- 80% of all maritime casualties,
- 90% of all automobile accidents, and
- 90% of all nuclear facility emergencies.

Accidents – Result of a Chain of Human Error

- Human error results from ignoring human factors and ergonomics.
- Ignorance of human factors is either the root cause of or a major contributing factor to many maritime accidents.
- Ignorance of engineering factors is primarily due to a lack of knowledge and guidance at the design, building and operation stages.



Importance of Human Error Minimization to Protect Human Health and the Environment and Ensure Safety

New Paradigm for Engineering and Design

Various Types of Phenomena Causing Structural Failure

Traditional

- Design Formula
- Past Experience
- Deterministic
- Allowable Stress

Future

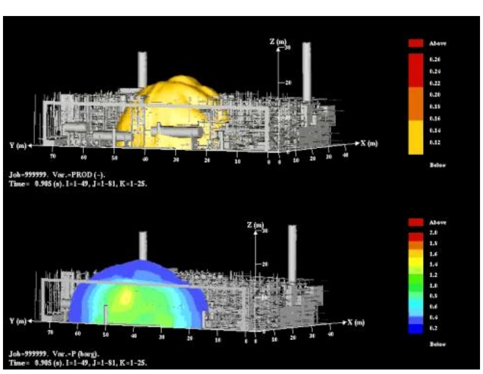
- Engineering
- First Principles
- Probabilistic
- Limit States/Risk

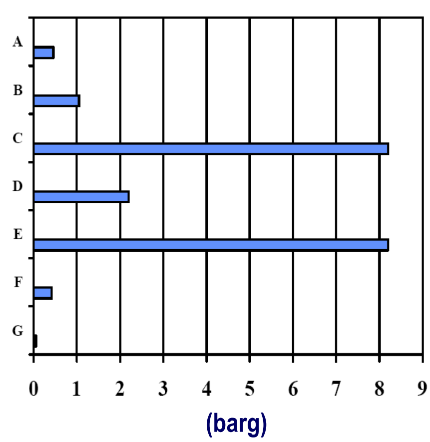
Mathematical Algorithm

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\phi\alpha\beta\gamma\lim_{x\to\infty}\frac{\zeta}{\sqrt{x^2-\varepsilon x+\eta}}\frac{n!}{r!(n-r)!}$$

Experimental Investigation

CFD Explosion Simulations





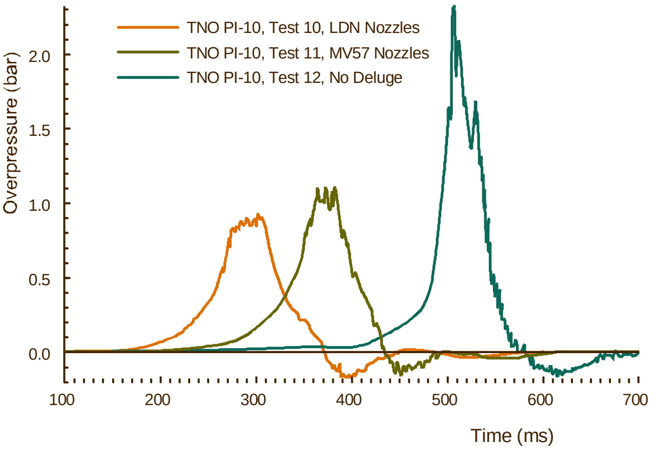
Gas Explosion Tests with or without Water Sprays
- Importance of Risk Management

Without water sprays

With water sprays

Source: © The Steel Construction Institute, Fire and Blast Information Group

Gas Explosion Tests with or without Water Sprays (2/2)
- Importance of Risk Management



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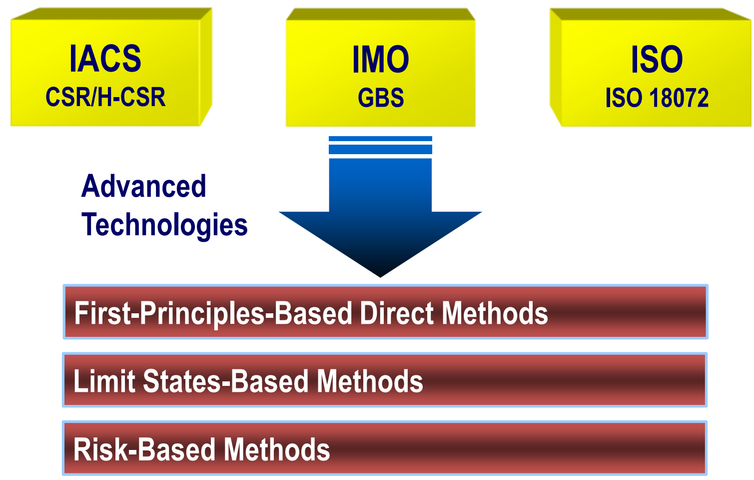
International Rules and Guidelines

HSE & E – Health, Safety, Environment & Ergonomics



Paradigm Change for Reduction of Human Error

- Over the last decade, the likelihood and consequences of marine casualties have certainly declined, in part due to technological improvements.
- However, accidents continue to occur while ships and offshore installations are in service, regardless of the significant efforts exerted toward eliminating them.
- Furthermore, the public's growing concerns and intolerance for safety, health and environmental risk suggest that more has to be done going forward.
- The best way of achieving this goal is to reduce human error by better understanding ocean environmental phenomena and then apply human factor and ergonomic best practices to vessel design, engineering, construction, and operation.

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SNAME = The Society of Naval Architects and Marine Engineers, USA

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