Leading Technology for Next Generation of LNG Carriers

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Overview

- LNG Ship Capacity and Trends
- Leading LNG Technology
- Class Role
LNG Ship Supply-Demand Forecast

In Number of Vessels – Jan. 2005

Deliveries Needed*

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Current Orderbook*

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LNG Trades & Potential Offshore Terminal Locations
Evolution of LNG Carrier Size

- **300,000 m³**
- **200,000 m³**
- **100,000 m³**

Cubic Meters

- 2007: 210/215
- 2009-2010: 250,000

- 2005: 153,000
- 2007: 135,000
- 2005: 133,000
- 1995: 125,000
- 1981: 120,000
- 1975: 87,600
- 1969: 71,500
- 1965: 25,500
- 1964: 27,400

- 1964: Independent Prismatic Aluminum Cargo Tanks
- 1965: Independent Cylindrical Tanks
- 1969: First Membrane Ships
- 1973: First Moss Rosenberg Independent Spherical Tanks
- 1975: Ben Franklin & El Paso Kayser
- 1981: Finima
LNG Transport System Technology

Next Generation of LNG Ships Require Advanced Technology that Addresses the Transport System

- Propulsion Technology
- Containment System Technology
- Pump Tower Analysis
- Structural Integrity Technology
- Ship to Terminal Interface Technology
Larger LNG Carriers

- Technical Considerations
  - Hull Structural Integrity
  - Structural Fatigue Strength
  - Terminal Compatibility
  - Propulsion Systems
  - Strength of Containment System
  - Vibration Performance
  - Pump Tower and Base Support
FULL VESSEL 3D FEM ANALYSIS
for 40 Years Fatigue life

H-V-M Stresses (kg/cm²)
(Port Side View)

GTT MARK III, LNG CARRIER
LC NO. 3NO.25, NO.4 TANK EMPTY, S.G.0.5, DEPARTURE SUB 4
AMERICAN BUREAU OF SHIPPING

ABS
Containment System Strength

• Spot Market Trading of LNG
• Arbitray Filling Condition
  – Sloshing Impact for Membrane System
  – Strength of Insulation System
  – Pump Tower Analysis
  – Ship Motion Coupling
Strength Assessment Procedure

Fig. 3  Strength Assessment Procedure for LNG Containment System
Technical Issues

• Gas Trapping and Cushioning Effect during Sloshing Impact
• Compressibility of Liquefied Gas
• Liquid-Structure Interaction (Hydroelasticity)
• Structural Damping of the Insulation System (Viscoelasticity)
3D Sloshing Animation

Swirling Motion due to Roll (10 deg), Pitch (5 deg) and Surge (1m) combined motion
Sloshing Model Test at Marintek
Sloshing Model Test: MARINTEK
High Filling Level vs. Low Filling Level

High-Filling Level:
Standing Wave

Low-Filling Level:
Progressive Wave

Incident angle is less than 4 degree.
Gas pocket can be found before impact.

Incident angle is greater than 10 degree.
No gas pocket.

DaeWoo/Exmar 138000 m³ LNG Carrier
15% Filling, 4.2 m/9.3 sec Sway
High Filling Level vs. Low Filling Level

High-Filling Level:
Standing Wave

Low-Filling Level:
Progressive Wave

 Incident angle is less than 4 degree.
Highly-localized impact area

 Incident angle is greater than 10 degree.
Wider impact area
Hydro-Viscoelastic Analysis for Mk III System

- Pressure reduction due to Structural Motion
- Stress propagation & dissipation
- Stress concentration on mastic
- Acoustic wave emission
Animations

$S_{yy}$ distribution in LNG and CS

![Diagram showing $S_{yy}$ distribution in LNG and CS](image)
No.96 Insulation System

Primary box

Secondary box

H-Beam and Mastics
Material Test for Visco-Elasticity Model at Univ. of Illinois

Split Hopkins Pressure Bar Test: Plywood and PU Foam

High Strain Rate Mechanics Laboratory, UIUC
Schematics of Split Hopkins Pressure Bar
Drop Test Facility and Model
GTT Drop Test for Corrugation

Picture 1: MARK III corrugated membrane.

Picture 5: Liquid Nitrogen test installation.
Dry Drop Test by GTT

- Full-Scale Mark III Insulation Model
- Failure Mode of Insulation System
- Fracture and Crack Propagation

Impact Strength in terms of
- Measured Impact Pressure
- Impact Strength Simulation by Visco-Elastic Fracture Analysis
ABS Sloshing Analysis: Pump Tower

Load considered:

- Inertial Load due to ship motion
- Thermal Load
- Sloshing Load

Sloshing Load

- Morrison force
- Nonlinear time-domain simulation
- Instantaneous maximum load

Structural analysis & Code check

NASTRAN, SACS, API Code
ABS SLOSH

ABS SLOSH v1.0
Sloshing and Pump Tower Analysis
2014 American Bureau of Shipping

Seakeep Analysis using PRECAL v5.0
Sloshing Analysis using SLOFE2D
Pump Tower and Base Structure Analysis
SALT-JIP: Model Test for Coupling Effect
Coupling Effect of Ship Motion and Sloshing

- Strength of the Containment System, Pump Tower and Base Support at Certain Limit of the Sea State
- Extension to the Severe Sea State Condition
  - Nonlinear Ship Motion
  - NLOAD3D
- Three-Dimensional Effect
- Arbitrary FLVL Combination
Propulsion For Next Generation LNG Carriers

- **Alternative Propulsion**
  (Existing fleet is all steam turbine)
  - Propulsion efficiency
  - New technology developments
    - Dual fuel - Natural Gas & Fuel Oil
    - Slow & medium speed diesels & gas turbine
    - Shipboard re-liquefaction plants
  - Class societies offering technical guidance for alternative propulsion.
Global FE Model for Vibration Analysis
Containment system in Global Finite Element model

Containment System was represented in Global FE model as idealized homogeneous elements.
Analyzed Locations

- AFTBHD at Tank 5 After Bulkhead
- FWDBHD at Tank 5 Forward Bulkhead
- BOTTOM at Inner Bottom of Tank 5
- DECK at Inner Deck of Tank 5
- SIDESHELL at PS and SB Inner side skin of Tank 5
Containment System
Finite Element Model

Layer 1 – Mastic
Layer 2 – Plywood
Layer 3 – Secondary Foam
Layer 4 – Triplex Membrane
Layer 5 – Primary Foam
Layer 6 – Plywood
Layer 7 – Steel Membrane.
Dynamic Shaft Alignment Analysis

Information to be Investigated

• Bearing reaction loads
• Misalignment at the aft stern tube bearing
• Bending curvature
• Stresses in shafting
Considering the Effect for

- Hull deflections
- Thermal displacement
- Buoyancy
- Bearing wear down for existing vessel
- Propeller thrust
Shafting Alignment Measurements
Approval in Principle (AIP) of ConocoPhillips Prism Tank Ship 225,000 m³
New Configuration of Cargo Tank
Prism Type by ConocoPhillips

138K: 42.6 (m)  
Convn225K: 51 (m)  
Prism225K: 51 (m)
Artic Route Operation

• Murmansk (Russia) to GOM via Arctic seas (Iceland)
Artic Route Operation

• Sloshing Impact Calculation and Model Test in the Arctic Environmental Condition
• ICE Class LNGC including Sideshell & Propulsion Requirement
• Containment System Assessment in Ice Breaking Operation for Arctic Class LNGC
LNG Core Technology

• Membrane Fatigue Analysis
• Pump Tower Vibration and Fatigue Analysis
• Multi Tanks and 3-D Sloshing Calculation
• Hull Temperature Distribution Analysis
• Offshore Loading & Offloading System
• Ice Breaking Impact Analysis for Hull and Containment System
Class Role for LNG Transportation

- Develop and Set Standards (Ex: ABS Guide for Membrane Tank LNG Vessels, Offshore Terminals)
- AIP and Third Party Independent Verification Agent
- Enabling LNG Designers and Operators to meet the New Technical Standards
- Enhancing Safety of the Handling of LNG with Integrated Approach that considers Production, Storage, Transportation, Discharge and Regasification
Thank You