Concept Design of LNG Bunkering Ship

~ To meet the growing demand of LNG fuel in the world and in Japan ~

November 2012
Kawasaki Heavy Industries, Ltd.

Contents

1. Introduction of Kawasaki Heavy Industries
2. Growing Demand of LNG as fuel for Ships
3. Concept design of LNG fuel bunkering ship
4. Conclusion
Introduction of Kawasaki Heavy Industries

Kawasaki’s contribution to Small Scale LNG

For domestic distribution of LNG in western Japan

“Shinju Maru No.1” (Delivered in 2003)

“Shinju Maru No.2” (Delivered in 2008)
Introduction of Kawasaki Heavy Industries

Kawasaki’s contribution to Small Scale LNG

“North Pioneer” (Delivered in 2005)

“Kakurei Maru” (Delivered in 2008)

“Akebono Maru” (Delivered in 2011)

For domestic distribution of LNG in eastern Japan
Contents

1. Introduction of Kawasaki Heavy Industries
2. Growing Demand of LNG as fuel for Ships
3. Concept design of LNG fuel bunkering ship
4. Conclusion
Growing Demand of LNG as fuel for Ships

Two main reason for the growing demand

Natural Gas ... Fuel with low CO$_2$, NO$_X$, SO$_X$ emission

Natural Gas ... Reasonable fuel compared with fuel oil

Source: IMF Primary Commodity Prices (WTI), Henry Hub

Price of Crude oil and Natural gas

Coal : 100

CO2
NO$_X$
SO$_X$ (depending on type of main engine)
Growing Demand of LNG as fuel for Ships

Upcoming Environmental Regulations

1. NO\textsubscript{x} emission regulation
   - Stricter regulation in ECA from 2016 (80% reduction)
   - Expected expansion of ECA

2. SO\textsubscript{x} emission regulation
   - Stricter regulation in ECA from 2015
     → Content of sulphur in fuel <= 0.1%
   - Expected expansion of ECA

3. CO\textsubscript{2} emission regulation
   - Energy Efficiency Design Index (EEDI)
     → Entry into force in 2013
   - Emission of CO\textsubscript{2} will be regulated

With LNG...

- Up to 90% reduction of NO\textsubscript{x} (Depending on type of engine)
- No (or reduced) special equipment required for NO\textsubscript{x} reduction other than for LNG
- 100% reduction of SO\textsubscript{x}
- Reasonable cost compared with low sulphur fuel oil
- No special equipment for SO\textsubscript{x} reduction required other than for LNG
- Higher calorific value than fuel oil
  → about 20% reduction of CO\textsubscript{2}
More than 25 LNG fuelled vessels are already operating in Europe now...

Shift from oil to LNG is going ahead in Europe (Due to strengthening of emission control in ECA in Europe is going ahead)

The movement is now spreading in the world...
Growing Demand of LNG as fuel for Ships

Increasing interest in LNG as fuel in Japan

Some recent articles on newspapers in Japan

• Japan to Develop LNG Marine Safety Standards (Nov. 1, 2011)

• Japan To Develop Natural–Gas–Fueled Ships (Nikkei, May 10, 2012)

• Japan and Norway strengthen maritime ties (May 11, 2012; relating to gas fuelled ships)

One of the main topic of a maritime workshop with Japan and Norway government was collaboration regarding to LNG fuel ships.
Growing Demand of LNG as fuel for Ships

Kawasaki’s contribution to LNG fueled ships

2,000 cars type LNG fuelled car carrier

Developed collaborating with “K” Line and DNV

Length overall : 143 m
Breadth : 25 m
LNG fuel tank : 300 m³ x 2 sets

Design Features
• Type C LNG fuel tanks
• Two sets of gas engines
• Mechanical driven
• CO₂ emission reduction by 40%
• NOx emission reduction by 80–90%
Growing Demand of LNG as fuel for Ships

Kawasaki’s contribution to LNG fueled ships

9,000 TEU type container LNG fuelled ship

- Length overall: 308 m
- Breadth: 48.4 m
- Draught: 14.5 m
- LNG fuel tank: 7,000 m³

Design Features
- Type B LNG fuel tank
- Twin island arrangement
- Two stroke dual-fuel main engine (Electronically controlled)
- Compatible with IMO Tier III NOx standard and SOx standard

Obtained Approval in Principle from DNV in January 2012
Growing Demand of LNG as fuel for Ships

Increasing interest in LNG as fuel in Japan

Some factors for increasing interest in LNG as fuel in Japan

- Sea around Japan to become ECA in the near future?
- Many existing & planned LNG terminals all around Japan
Growing Demand of LNG as fuel for Ships

Issues to be solved for commercial viability of LNG fuelled ships

Issues to be solved:

1. Propulsion system for LNG fuel
2. LNG fuel tank(s)
3. System for supplying LNG fuel to engine(s) and handling boil-off gas
4. LNG fuel bunkering system
5. Sufficient LNG fuel supply chain

Already technically ready or feasible
Growing Demand of LNG as fuel for Ships

Way for sufficient LNG fuel supply chain

Ideas for bunkering LNG fuel:

1. Via LNG fuel bunker station  
   (Similar way for LNG carriers)

2. Via LNG tanker lorries  
   (Currently popular way in North Europe)

3. Via LNG fuel bunkering ship  
   (Ship-to-ship)
Contents

1. Introduction of Kawasaki Heavy Industries
2. Growing Demand of LNG as fuel for Ships
3. Concept design of LNG fuel bunkering ship
4. Conclusion
Technical issues for LNG fuel bunkering ships

Basic idea of LNG fuel bunkering ship

Kawasaki’s small scale LNG carrier + Special equipment onboard (in comparison with small scale LNG carrier)

Technical issues
1. LNG storage
2. Use of LNG on LNG bunkering ship
3. Way to handle BOG from own LNG tank and from LNG receiving ship
4. Way to transfer LNG to LNG receiving ship
Concept design of LNG fuel bunkering ship

Technical issues for LNG fuel bunkering ships

Basic idea of LNG bunkering ship

Kawasaki’s small scale LNG carrier + Special equipment onboard (in comparison with small scale LNG carrier)

Design issues

1. LNG tank
2. Propulsion system and LNG fuel supply system
3. LNG bunkering interface with LNG receiving ships
4. Special equipment onboard
Concept design of LNG fuel bunkering ship

6,000m³ type LNG fuel bunkering ship

Loa : about 120.0 m
Lpp : 114.0 m
Bm : 18.8 m
Dm : 9.5 m
Design draft : 5.6 m
LNG tank : 3,000 m³ x 2
Concept design of LNG fuel bunkering ship

Issue 1: LNG tank for LNG fuel bunkering ship

Requirement for LNG tanks:

1. Flexibility in partial cargo loading
2. Easy boil-off gas management
   (To cope with unfixed bunkering schedule)
3. Low boil-off rate
   (To avoid loss of quality and amount of cargo)
4. Low cost and low weight

IMO Type C cylindrical **aluminum** LNG tank
(Design pressure: 5 barG)
Why Aluminum?

Weight: Al < 9% Ni < Stainless steel
Cost: Al < Stainless steel & 9% Ni

Kawasaki has proven technology and track record for Aluminum tank
Issue 1: LNG tank for LNG fuel bunkering ship

Design pressure: 4 to 8 barG

“Cargo tank weight & cost” vs. “Operational flexibility”

- Design pressure ↗ = Operational flexibility ↗
- Design pressure ↗ = Cargo tank weight & cost ↗

4 to 8 barG

= Good to balance both operational flexibility and weight & cost

Relation between design pressure and lower limit of cargo loading volume

- Tank pressure exceeds safety relief valve set valve within 21 days
- Tank pressure exceeds safety relief valve set valve within 7 days
Concept design of LNG fuel bunkering ship

Issue 2: Propulsion system and LNG fuel supply system

Requirement for propulsion system and LNG fuel supply system:

1. Utilize LNG at propulsion system
2. Driven also by fuel oil  
   (To flexibly select suitable fuel in accordance with fuel market)
3. Handle boil-off gas from LNG tank
4. Redundancy
5. Low fuel oil/gas consumption
6. Reasonable initial cost

DFD mechanical driven propulsion system
+ 
BOG compressor & heater/vaporizer as LNG fuel supply system
Concept design of LNG fuel bunkering ship

Issue 2: Propulsion system and LNG fuel supply system

DFD mechanical driven propulsion system

Mode B
(by DFD generators)

SGM : Shaft generator motor
Concept design of LNG fuel bunkering ship

**Operational mode**

**During voyage:**
- Mode A: Propeller shaft output + Shaft generator

**Berthing/Unberthing**
- Mode B: Onboard electricity + Thruster

**Unloading**
- Mode B: Onboard electricity + Cargo equipment

**Docking**
- Mode A (DO mode DFD)

**Emergency navigation**
- Mode B: SGM shaft output + Onboard electricity

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**Issue 2: Propulsion system and LNG fuel supply system**

**Mode A** (by DFD engine)

**Mode B** (by diesel generators)

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SGM: Shaft generator motor
Concept design of LNG fuel bunkering ship

Issue 3: LNG bunkering interface with LNG receiving ships

Ideas for LNG bunkering interface with LNG receiving ships:

1. By loading arms
   - Similar concept to LNG terminals, but specialized modification for ship-to-ship use is necessary

2. By flexible hose
   - Some actual cases already done by Ship-to-Ship using flexible hose
   - Most feasible way at this time
An instance of ship-to-ship LNG transferring
~ Executed for the first time in Japan ~

- At Tomakomai, Japan
- From Nov. 2011 to Feb. 2012, total 34 times
- To fulfill the region’s temporary demand
- LNG transferred;
  - A 126,000m$^3$ LNG carrier
  - A 3,500m$^3$ LNG carrier
- The region’s small scale LNG terminal

Important milestone for LNG fuel ship-to-ship bunkering

Concept design of LNG fuel bunkering ship

Issue 3 : LNG bunkering interface with LNG receiving ships
Concept design of LNG fuel bunkering ship

Issue 3: LNG bunkering interface with LNG receiving ships

Case study of bunkering LNG
~ from LNG bunkering ship to LNG fuelled oil tanker ~

Ship-to-ship arrangement

- Liquid line
- Vapor line
Concept design of LNG fuel bunkering ship

Issue 3: LNG bunkering interface with LNG receiving ships

Two typical bunkering conditions

Case 1

- Oil Tanker (Ballast condition)
- LNG fuel bunkering ship (Full loaded)

Case 2

- LNG fuel bunkering ship (Ballast condition)
- Oil Tanker (Full loaded)
Issue 4: Equipment for LNG fuel bunkering ship

Necessary additional equipment
~ in comparison with small scale LNG carrier for domestic distribution ~

For transferring boil-off gas to main engine(s)
- BOG compressor
- Vaporizer
- LNG Heater

For bunkering LNG fuel to receiving ship
- LNG bunkering interface (manifold)
- Return gas compressor
- Gas combustion unit
- BOG re-liquefaction plant

For providing service for pre-docking
- Inert gas generator

Necessity depends on receiving ships’ specifications
Contents

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2. Growing Demand of LNG as fuel for Ships
3. Concept design of LNG fuel bunkering ship
4. Conclusion
Conclusion

• Demand of LNG fuel for ships is increasing in the world and in Japan, and LNG fuel bunkering ship would play an important role to back-up the trend.

• Adding special equipment for bunkering function on a proven small scale LNG carrier can make a basic concept of LNG bunkering ship.

• Necessary equipment for bunkering function needs to be determined considering LNG fuelled ship’s specifications.
Thank you for your attention!