Possibilities for LNG Use in Icebreakers

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Outline

- Two main topics
  1. LNG storage tank solutions
     - LNG energy density
     - Available tank options
     - Space allocation to the vessel
  2. Functionality of power plant
     - Means to reduce load variation to power plant
     - Means to tolerate load variation of propulsion
- Items not covered
  - Boil of management
  - Availability of LNG
  - Solution details
  - Operational procedure issues
  - Etc...
LNG as a Fuel for Icebreaker

- First LNG fueled icebreaking vessels in operation
  - Icebreaker Polaris
    - Wärtsilä 34DF type engines, power 22 MW
    - Two 400 m³ LNG storage tank
    - Three ABB Azipod VI1600 (2x6,5MW+1x6,0 MW)
    - Autonomy time with LNG 10 days
  - LNGC Christophe de Margerie -type
    - Wärtsilä 50DF type engines, power 64 MW
    - Membrane type cargo containment system
    - Three ABB Azipod VI2300L (3x15 MW)
    - 10/15 vessels in service

- LNG fuelled icebreaking vessels under construction
  - Le Commandant Charcot – Ponant Icebreaker
    - Under construction at Vard
    - Wärtsilä 31 DF engines, 4x14 cyl + 2x10 cyl
    - Two Mark III membrane tanks by GTT, total volume 4500 m³
    - Two ABB Azipod VI2300L (2x17 MW)
LNG Storage Tank Solutions
Energy density comparison to Diesel fuel

- LNG compared to MDO
  - Higher specific energy +30% (energy in weight)
  - Lower energy density -33% (energy in volume) due to lower liquid density

About 50% more liquid volume required for same autonomy time with LNG fuel compared to MDO
Case study: Icebreaker with 5000 m³ and 10000 m³ storage capacity

- Two solution alternatives:
  1. 2 x Bilobe tanks
  2. 1 x Membrane tank

- Theoretical icebreaking vessel, fixed breadth

- Cross section of Bilobe tanks fixed, length variable
  - Length of tanks may be different

- Height and length of membrane tank variable, beam fixed

- Comparison of space efficiency

<table>
<thead>
<tr>
<th>TANK TYPE</th>
<th>MEMBRANE</th>
<th>MEMBRANE</th>
<th>BILOBE</th>
<th>BILOBE</th>
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</thead>
<tbody>
<tr>
<td>Tank Volume (m³)</td>
<td>5000</td>
<td>10000</td>
<td>5000</td>
<td>10000</td>
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<tr>
<td>Required space (m³)</td>
<td>8200</td>
<td>15000</td>
<td>9900</td>
<td>18300</td>
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<tr>
<td>Space efficiency (%)</td>
<td>61 %</td>
<td>67 %</td>
<td>51 %</td>
<td>55 %</td>
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</tbody>
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Case study summary

- Membrane tank has better space efficiency, improves in bigger volumes
- Bilobe tank provides some arrangement flexibility
  - Two different length tank possible, storage capacity can be located above main deck
  - Some flexibility in form of space
- Space requirement
  - Energy density leads 50% higher liquid volume
  - Space efficiency leads 30-50% higher volume in vessel
  - Double volume in vessel needed compared to fuel oils to achieve same endurance
Power plant functionality with gas fuel
Power plant in icebreaker application – in general

- Icebreaking causes ice-propeller interaction which means either:
  - Torque and rpm variation of propeller if constant power is requested
  - Power and torque variation if constant rpm is requested
- Electric propulsion system has been “standard” in icebreakers already decades:
  - Makes constant power mode possible
  - Makes over torque capability possible
Means to reduce load variation to power plant

- Electric propulsion system is must
  - Propulsion control with constant power mode
    - Filters most of ice loads compared to constant RPM mode
  - Adequate over torque capacity
    - Provides range for constant power mode

- Other electric means
  - Load sharing between propellers
    - Power boost function of ABB
  - Load balancing by resistors
    - Rapid load variation can be slowed down to comply loading ramps of power plant
  - Energy storage system
    - Not sufficient to day for rapid – high power – low energy applications
Means to reduce load variation to power plant

Power Boost Function

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Means to reduce load variation to power plant

Total Dynamic Control of BRUs and Pods

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Means to tolerate load variation of propulsion

- DF engines have slower loading ramps in gas mode compared to diesel mode
  - Tend to change automatically to diesel mode if quicker loading is requested
  - Manual actions needed to change back to gas mode
- Means to secure maximum operation with gas fuel
  - DF engines under heavy development
    - Typical load variation can be maintained by gas fuel with modern technology
    - Pilot boost as a very interesting alternative
      - If extreme loading in gas mode is required, special pilot boost feature can be used, temporarily increasing the share of pilot fuel and void changing to diesel fuel

**Loading rates Constant speed 31DF engines (DE / Aux / CPP)**
Normal loading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)
Source: Wärtsilä
Conclusions

- Currently 11 vessels operating in very difficult ice condition with LNG fuel
- Main technical challenges in ship design point of view
  - How to achieve required autonomy time for remote operations
  - How to get power plant working properly under propeller ice interaction
- LNG tank alternatives exists – requires more space from vessel compared to diesel fuel
- Means to secure LNG as a “only” fuel exists
  - Electric propulsion plant
  - Electric load balancing with resistors
  - Development of DF engines with pilot fuel boost alternative
    - Temporary increasement of pilot fuel in most extreme loading cases and maintain still gas as a primary fuel
Thank you!