World's first ship driven by LH$_2$

Florø 18.09.2019
Norled at a glance

- One of the major Ferry operators in Norway.
- Market leader within Fast Ferries («High speed crafts») in Norway and #4 Globally.
- Major player within Fjord tourism.
- Nationwide operations from Oslo to Tromsø.
- ~300 MUSD (NOK 2.4 billions) in revenue
- 1 200 employees, HQ in Stavanger
- Founded in 1855
- Innovation-driven right for more than 160 years
- Norled aims to operate with low and zero emissions
Different types of new-builds ongoing


From grey to green – the icon

MF Ampere - the first zero-emission ferry in the world
From grey to green – the story

2015:
The el-ferry MF Ampere is launched

2022:
72 siblings in Norway

The entire sector – transformed from predominantly grey to predominantly green in just a few years – huge savings in fuel costs – helps finance a renewal of the fleet
Creating yet another icon for zero emission shipping
World’s first ship driven by LH$_2$

Length 82.40 m  
Beam 16.75 m  
Draught 2.8 m  
Car capacity 80  
Truck capacity 10  
Passenger capacity 299  
LMG80-DEH2
Hjelmeland-Nesvik ferry route

Ryfylke in Rogaland - Riksveg 13:

Hjelmeland-Nesvik  3010 meters
Hjelmeland-Skipavik  4450 meters
Nesvik-Skipavik  3890 meters

Norled operates the route today with two diesel-electric ferries.

The new contract for this route is one battery-electric ferry, as well as the hydrogen-electric ferry, from 2021 to 2031.
Hydrogen supply

- LH$_2$ truck from Europe
- 3,5 tons capacity
- Every three week bunkering operations
- 150 kg daily consumption
Hydrogen arrangement

LH₂ System
Onboard LH₂ System

Process Flow Diagram

- LH₂-inlet
- LH₂-Tank
- Pressure Buildup
- Pressure Control
- LH₂-Vaporizer
- FC System

Safety: all PSV lines are routed to vent mast
Onboard LH₂ System

LH₂ Tank – Key Data

Key Technical Data

<table>
<thead>
<tr>
<th>Insulation:</th>
<th>Multi-Layer &amp; Vacuum</th>
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<tbody>
<tr>
<td>Design Pressure</td>
<td>10 bar(g)</td>
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<tr>
<td>LH₂ capacity</td>
<td>≈3.8 tons (20% ullage)</td>
</tr>
<tr>
<td>Holding time:</td>
<td>15 days</td>
</tr>
<tr>
<td>Standards/Approval:</td>
<td>DNV GL, IGF</td>
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System size: Footprint on the ship quite limited!

Holding Time Requirement:
15 days at operating pressure, but …
- which residual amount at refueling?
- which LH$_2$ temperature is delivered during refueling?
- tank operating pressure during refueling?

(Onshore) Bunkering System & Procedure:
- develop special refueling procedure for maritime application
- minimize or completely avoid GH$_2$ losses during refueling
  ➔ achieve sufficient distribution of subcooled liquid during refueling, and condense vapor
- Special cryogenic coupling is under development
- Safety study of complete bunkering procedure
Onboard LH$_2$ System

Technical Challenges – 2 of 2

- **Stable Operating Pressure:**
  Must be maintained to support continuous vaporization and fuel cell operation. Various options available:
  1. operate tank at low pressure: LH$_2$ pump/compressor necessary
  2. operate tank at higher pressure:
     - necessary time to build up pressure after refueling
     - sloshing effects (low viscosity) could cause undesirable condensation of vapor (loss of operating pressure!)
     ➔ special vessel internals and other measures required!

- **Measurement of LH$_2$ Level:**
  Available types:
  - differential pressure
  - radar, capacity
  - special types: neutron ray, Neon bubble
  ➔ reliability of these measurements under maritime conditions?
Hydrogen arrangement

Fuel cell system
World leading innovative company of electrical propulsion systems
Westcon Power & Automation’s Battery & $H_2$ hybrid laboratory

- Fully integrated energy-system test bench with batteries, fuel cells, drives, switchboards and energy management system
- Dynamic loads
- Facility for testing of next generation hydrogen-hybrid system for future marine projects
- Simulation and optimization of control strategies for hydrogen-hybrid systems
- Hjelmeland ferry testing
400kW fuel cell
OpenBridge Partner

- Harmonising next generation maritime workplaces
- New technologies and open innovation
- Consistent design across vendors
- Cost effective methods, processes and tools
BLUE
Energy optimization

1. Trip info
2. Vessel’s schedule
3. Trip profile
4. Instant consumption
5. Current energy storage
6. Trip consumption
7. Battery charging

Data logged to Cronolog databases with 3rd party interface possibilities
The LH$_2$ vessel is being built at Westcon Yard in Norway, delivery 1Q 2021
Thank you for your attention