Battery-Hybrid Propulsion for a RoPax Concept Study
Hamburg / Leer
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# Vessel data for concept comparison: RoPax

## MAIN DATA

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Conventional</th>
<th>Battery-hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWT</td>
<td>6 500 t</td>
<td></td>
</tr>
<tr>
<td>Design speed</td>
<td>19 kt</td>
<td></td>
</tr>
<tr>
<td>LOA</td>
<td>190 m</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>550 vehicles / 750 passengers</td>
<td>19,2 MW + PTO/PTI</td>
</tr>
<tr>
<td>Battery Storage System</td>
<td>Battery Storage System</td>
<td></td>
</tr>
<tr>
<td>Installed power</td>
<td>21,6 MW + PTO</td>
<td>3,84 MW</td>
</tr>
<tr>
<td><strong>Conventional</strong></td>
<td>3,96 MW</td>
<td></td>
</tr>
<tr>
<td><strong>Battery-hybrid</strong></td>
<td>19,2 MW + PTO/PTI</td>
<td></td>
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</tbody>
</table>

- **Installed power**
  - Conventional: 2 x 9L48/60CR, 3 x 6L21/31
  - Battery-hybrid: 2 x 8L48/60CR, 2 x 2000 kWh, 2 x 12V175D-MA
Commercial and technical goals

**Commercial goals**

- **Lowest possible life cycle costs** for a **reliable** and **flexible** propulsion system

**Design targets for the propulsion system**

- Achieve a **high efficiency** of the propulsion system at each operation mode
- **Less installed engine power** necessary due to support by battery power
- **Less running hours** on gensets due to battery supply
- **Increased system performance** via electric boost & E-spinning reserve
- **Increased hydrodynamic efficiency of the propeller** by operation on an optimal combinator curve (EcoControl)
- **Mitigate smoke** during manoeuvring
Operation modes, hours and propulsion power demand

Annual operational profile and operation modes

- Harbour and high speed modes dominant
- Hotel load is approximately 1000 kW at sea and 250 kW at port
Battery-Hybrid Plant Layout
Combination of combustion engines with electric machines and an energy storage system
Power supply via batteries

Harbour mode

Benefits

- Zero emissions: Batteries
  (Gensets are started if minimum State-of-Charge is reached and no shore power is available)

(Gensets in standby / Shore connection for long berthing)
Power supply via batteries
Manoeuvre / Slow speed mode

Benefits
- Batteries are used as primary source of power supply
- Gensets are in standby

12V175D-MA 1.920 kW
12V175D-MA 1.920 kW

440 V AC, 60 Hz

2.000...2.500 kWh DC/DC

PTI

Bernd Friedrich – Hybrid RoPax 20/03.2019
Power supply via main engines

Sea mode

Benefits

- Optimal loading of main engines at normal conditions
- Batteries are available for load fluctuations / peak shaving and for performance boost / spinning reserve

(Gensets in standby)
Reference propulsion system for a RoPax

“Conventional” propulsion system for RoPax with L48/60CR engines

Usually one additional auxiliary engine and two additional cylinders at the main engines are required in the conventional propulsion system.
Example route

“Mini Cruise” (4 trips / day)

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>50.2 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAVEL TIME</td>
<td>3.25 h</td>
</tr>
</tbody>
</table>

Bernd Friedrich – Hybrid RoPax
Mini Cruise – typical day profile (calm sea)

Conventional layout (9L48/60CR + 6L21/31)

Power Demand

Propulsion Power
Hotel Power
Engine Power

Loading of M/E and number of M/E’s running (9L48/60CR)

Loading
Number

Loading of A/E and number of A/E’s running (6L21/31)

Loading
Number

AVG. LOADING

Hotel load provided by PTO

1 A/E in Harbour
Mini Cruise – typical day profile (regular sea)

Conventional layout (9L48/60CR + 6L21/31)

AVG. LOADING

Bernd Friedrich – Hybrid RoPax 20/03/2019
Mini Cruise – typical day profile (extreme sea)

Conventional layout (9L48/60CR + 6L21/31)

M/E’s are fully loaded with the propellers
A/E supplies the hotel load

1 A/E in Sea Mode

Hotel load provided by A/E

1 A/E in Harbour

Bernd Friedrich – Hybrid RoPax

20/03.2019
Mini Cruise – typical day profile (calm sea)

Hybrid layout (8L48/60CR + 2 x 2000 kWh)

Only one M/E is running @ High Loading
Surplus power is taken from battery
When battery is at low SOC → 2nd M/E

-16.4 % OPEX

-8.0 % fuel consumption
-65 % lube oil consumption
-57.1 % engine RH

8497 cycles / 10 years

Bernd Friedrich – Hybrid RoPax
Mini Cruise – typical day profile (regular sea)

Hybrid layout (8L48/60CR + 2 x 2000 kWh)

-7.0% fuel consumption
-56% lube oil consumption
-47.8% engine RH
8924 cycles / 10 years

Less RH’s of the A/E at port
Power is taken from battery
When battery is at low SOC → Start A/E

-13.2% OPEX
Mini Cruise – typical day profile (extreme sea)

Hybrid layout (8L48/60CR + 2 x 2000 kWh)

-1.5 % fuel consumption

-32 % lube oil consumption

-32.5 % engine RH

6292 cycles / 10 years

As higher the AVG loading of the engines is, as lower is the benefit of batteries
EcoControl (Optimal combinator curve)

Example for a Battery-Hybrid CPP plant
Business case

CAPEX (Mini Cruise: 2 x 2000 kWh)

+35.5%
Business case

OPEX (Mini Cruise)

-74.6% (ca. 6.2m USD)

< 3.2 years

+35.5% CAPEX
MAN in partnership with AKA provides complete system solutions

Medium Speed Engines and Gensets
(Common Rail & Dual Fuel)

SCR Systems
Fuel Gas Supply Systems

Propellers & Gearboxes, incl. Propulsion Control System

CPP’s and FPP’s
Alphatronic 3000
MAN in partnership with AKA provides complete system solutions

Switchboards, incl. Power Management System

E-Motors and Variable Speed Drives, incl. Control System


DC Switchboards / DC Grids

MV & LV Switchboards (AC)

E-Motors
Variable Speed Drives
Hybrid Control Systems

Battery Storage Systems
SuperCap Systems
Summary

In a Q&A manner

1.) Q: What are the key findings of this study about battery-hybrid systems?
   A: For ferry applications we see three major learnings:
   - The OPEX can be reduced for all operation modes mainly due to a reduction of the running hours of the auxiliary gensets and a better (= higher) loading of the main engines. This pays especially at low load operation (i.e. low sea states).
   - Due to the fact that the running hours of the auxiliary gensets are very low, it is worth to think about the use of high speed gensets (instead of medium speed gensets). The lower CAPEX outweighs the higher OPEX (= higher SFOC) of a high speed genset. Additional there are savings in weight and size.
   - A project-specific business case needs to be evaluated, because of the higher CAPEX of a battery-hybrid system.

2.) Q: Does a battery-hybrid concept make sense for all ferry applications?
   A: No. A battery-hybrid propulsion system is always a project-specific solution. The system layout and the business case have to be evaluated. Also the availability of a shore connection plays a role.
   In principal there is a favour for a battery-hybrid solution if the operational profile of the vessel is diversified, means there are running hours with high propulsion and hotel load demand as well as with lower.
   Also the performance of the propulsion plant (i.e. boost capability) is often decisive.
   Side effects are often smoke mitigation, zero emission and reduced methane slip (in case of DF engines operating at part load).
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Thank you very much!