» Wind Propulsion for Cargo Ships «
Performance Parameters and Operational Aspects
Maritime Department Leer

- Founded in 1854 as ‘School of Navigation’
- Incorporated in HS-Emden/Leer (University of applied Sciences)
- Maritime region (shipping, shipbuilding)
- About 350 students: Nautical Studies, Ship Management
- Special competence in ship operation research
Maritime Department Leer

- HS Emden-Leer was/is cooperating in ambitious sail related projects:

  - SkySails-Technology (2002-2008)
    - First full scale ship trials

  - E-Ship of Enercon (2007-2010)
    - First innovative Wind Hybrid Ship

  - Wind Hybrid Coaster (2011-2015)
    - Innovations in sail technology, e.g. light weight materials
Overview

- Introduction and Motivation
- FAQ and answers
- Performance Parameters
- Operational Parameters
- Recent Projects
- Conclusions
Introduction and Motivation

- Fossil fuels are increasingly expensive
  - Depletion of reserves;
  - growing demand (abt. 1.3 % yearly);
  - Combination of above causes is accelerating the rise in prices;
Introduction and Motivation

- **Political pressure**
  - Shipping is a significant air polluter
    - CO2 (abt. 3%)
    - SOx (abt. 7%)
    - NOx (abt. 12%)
    - Particulates
  - This causes damage
    - especially in the future
    - difficult calculations
    - actually not paid for (yet)
Introduction and Motivation

- Summary

- Chances for Wind Propulsion = f (energy prices, political pressure)
FAQ

- How much can you save with Sail Propulsion?

  or

- How long is the „Pay back Time“ on the investment?
FAQ + Answers

- How much can you save with Sail Propulsion?

- You can save „up to“ .... (0 ... 100%)

- (Salesman’s answer)
FAQ + Answers

- You can save „up to“ .... (0 ... 100%) !?

- Researcher’s view:

- This is not necessarily wrong but imprecise!
- A more precise answer:
- You can save approx. ... (%,$) of ... (reference) under the following conditions and assumptions:
  1. ...
  2. ...
  ...
  100. ...
FAQ + Answers

- **Summary:**
  - A precise prognosis of wind power for ships is complex, far more complex than for engine powered ships.

- **Result:**
  - Wind Propulsion as **auxiliary propulsion** for the near future.
    - Reliability of service
    - Innovation needs time to settle

- **Scientific Task:**
  - Find out and quantify all relevant parameters and influences regarding wind propulsion.
  - *(Wind Propulsion Model)*
Performance Parameters

- Basis: Aerodynamic Forces at foils and sails (also other fluids)

\[ F = \frac{1}{2} \rho v^2 c A \]
Performance Parameters

- **Sail Coefficients**

  \[ F_{\text{Lift}} = \frac{1}{2} \rho v^2 C_L A_{\text{Sail}} \]

  \[ F_{\text{Drag}} = \frac{1}{2} \rho v^2 C_D A_{\text{Sail}} \]

  \[ F_{\text{Sail(long)}} = \frac{1}{2} \rho v^2 C_x A_{\text{Sail}} \]

  \[ F_{\text{Sail(trans)}} = \frac{1}{2} \rho v^2 C_y A_{\text{Sail}} \]

Source: T. Fujiwara

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**Performance Parameters**

- **Lift Coefficient**

\[ F_{Lift} = \frac{1}{2} \rho v^2 C_l A_{Sail} \]
Performance Parameters

- **Propulsion:**
  - Lift
  - Drag
  - Lift/Drag-Ratio

- **Overall Objective:**
  - High Thrust in sail direction

Source: T. Fujiwara

Natural Propulsion - Wageningen 20 Jan 2012
Operational Parameters

- Wind speed/direction

\[ F_{\text{Sail (long)}} = \frac{1}{2} \rho \cdot v^2 \cdot c_x \cdot A_{\text{Sail}} \]

- Polar Diagramm
Operational Parameters

- Wind speed/direction

- Interdependencies:
  - Wind conditions in trading area („online fuel“)
  - Route vs. wind direction

\[ F_{Sail\ (long)} = \frac{1}{2} \rho v^2 c_x A_{Sail} \]
Operational Parameters

- **Logistics**
  - New energy efficient liner services following wind patterns

\[
F_{Sail(\text{long})} = \frac{1}{2} \rho \cdot v^2 \cdot c_x \cdot A_{Sail}
\]
Operational Parameters

- **Weather Routing**
- High relevance for savings by wind energy
- **Algorithms**
  - Least time
  - Least fuel
  - Least cost

\[
F_{Sail(\text{long})} = \frac{1}{2} \rho \cdot v^2 \cdot c_x \cdot A_{\text{Sail}}
\]
Operational Parameters

- Side Effects
  - Added resistance by wind drift
  - Added resistance by yawing moments
  - Increased propeller efficiency by reducing propeller load
**Operational Parameters**

- **Side Effects**
  - Added resistance by wind drift
  - Can be minimized by design
    - Shape/Contours
    - Main particulars (L,B,T)
    - Fins, Deadwood, Rudder

Source: MOL
Operational Parameters

- **Side Effects**
  - Added resistance by yawing moments (counter rudder)
  - can be minimized by design
    - Longitudinal position of sail forces (center)
    - Rudder design
      - Area
      - Drag
Operational Parameters

- **Side Effects**
- **Improved propeller efficiency by reducing propeller load**
Operational Parameters

- Compatibility
  - Ship Operation – Sail System
    - Bridge visibility (SOLAS req.)
    - Navigation equipment (nav lights, radar)
    - Space requirements
    - Cargo operations
    - Air draft, bridge passage
    - Crew’s workload / automation
    - Maintenance requirements
    - Crew skills / training
    - Safety: ship stability, traffic, crew
Concepts

- **Concept “SkySails”**
  - System available

- **Concept “E-Ship” (Enercon)**
  - E-Ship 1 in regular service, data collection and evaluation phase
Concept “SkySails”

- Research Project funded by the German Government (BMBF):

  Programme: Climate Protection
  Title: Wind Power Propulsion for Cargo Ships (Low Emission Ship)
  Partners: HS Emden-Leer SkySails
Concept “SkySails”

- **System Advantages:**
  - Re-fit with small space requirements for all ship types available (80, 160, 320 m²)
  - Stowing Position:
    - No disturbing superstructures (cargo operations, bridge crossing)
  - Automatic Operation
    - Challenging task
Concept “SkySails”

- System Advantages:

  - Efficiency
    - Lift coefficient comparatively small
    - But increased lift through dynamic flight mode (down wind to beam wind)
**Concept “SkySails”**

- **System Advantages:**
  - **Efficiency**
    - utilizing stronger and more stable winds in higher altitudes
Concept “SkySails”

- System Advantages:
  - Safety
    - Less load on ship’s stability due to small heeling lever
Concept “SkySails”

- Experimental Platform: Research vessel « Beaufort »
  - September 2006: First Sea Trials of the operational system in the Baltic
Concept “SkySails”

- **Open questions:**
  - Long time overall performance - operational time?
  - System’s robustness (kite material)
  - Kite launch and recovery – (automation? loss of time?)
  - System handling – skilled and motivated crew (incentives?)
  - Flight regulations (international waters only?)
  - Safety items? (not sufficient operational experience yet)

- **Outlook**
  - Market acceptance?
  - Technical progress? (rigid ultra-light kite foils?)
Concept “E-Ship”

- R&D Project “E-Ship”

  performed by

  **Enercon**, Aurich/Germany
  one of the world’s leading wind turbine manufacturers

  Motto:
  “Energy for the World”

  supported by HS Emden/Leer
Concept “E-Ship”

- Objectives:
  - Hybrid Propulsion
    - Innovative product – huge market
  - Optimized cargo carrier for the transport of wind turbine plants (own cargo)
  - Reduction of transportation costs
  - Environmental protection
Concept “E-Ship”

- Sailing Technology:
  - 4 Magnus Rotors (25 m x 4.30 m)
  - Functional principle: “Magnus Effect”
Concept “E-Ship”

- Historical Background:
  - The German engineer Anton Flettner developed an innovative wind propulsion system in the 1920’s – Flettner Rotors
  - Flettner had no economical success – The age of “Dieselization” had just started!
Concept “E-Ship”

- **System Advantages:**
  - High lift – about 10x higher than conventional square sails
  - Right: Lift Coefficient of Sail Systems in comparison
Concept “E-Ship”

- System Advantages:

  ➢ Small Sail Area (space requirements)
Concept “E-Ship”

- **System Advantages:**
  
  - Less load on ship’s stability:
    - smaller heeling lever
    - nearly constant heeling moments in squally winds (right + below)
    - no (nearly) impact on stability after ‘shut down’

\[
F_{Sail\,trans} = \frac{1}{2} \rho v^2 c_y A_{Sail}
\]
Concept “E-Ship”

- System Advantages:
  - Fully automated operation
    - no sail handling
    - automatic switch on/off
    - integrated power management and propulsion control (Diesel-electric)
  - automatic RPM-control
  - ‘routing’ for optimal efficiency (under construction)
Concept “E-Ship”

- First Sea Trials – North Sea 2010
Concept “E-Ship”

- Economic Potentials:
  - A ship of this size (130 m) and speed consumes about 30 tons fuel oil per day
  - i.e. about 6 Mio USD p.a. (IFO 380)
  - i.e. about 8.7 Mio USD p.a. (SECA)
  - You can save up to ....
Concept “E-Ship”

- Environmental Protection:
  - … less CO2
  - 90% less NOx (SCR-technology)
  - 97% less SOx
    (Diesel-electric main propulsion with low sulphur fuel oil)
  - No sludge
  - Clean ballast
  - “Foul release coating” under water
    (no poison)
  - Garbage segregation and recycling/disposal ashore only
  - Organic food for crew
  - Sailing incentives
Concept “E-Ship”

- **Outlook:**
  - First results after test and evaluation phase
  - Continuous optimization will increase savings, e.g. system settings, routing, cargo logistics
Conclusions

- All technical requirements can be handled;
- Technological developments in start up phase;
- A skilled and motivated crew will be more successful;
- Volatile markets with rising energy prices to be expected;
- Climate change will increase political pressure;
- “Good Seamanship”
- means to be prepared for all possible scenarios!
**Conclusions**

- **Our task: to be prepared (political) and to take chances (economical)!**

### Table 1-2 – Assessment of potential reductions of CO₂ emissions from shipping by using known technology and practices

<table>
<thead>
<tr>
<th>DESIGN (New ships)</th>
<th>Saving of CO₂/tonne-mile</th>
<th>Combined</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept, speed &amp; capability</td>
<td>2% to 50%⁺</td>
<td>10% to 50%⁺</td>
<td>25% to 75%⁺</td>
</tr>
<tr>
<td>Hull and superstructure</td>
<td>2% to 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power and propulsion systems</td>
<td>5% to 15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-carbon fuels</td>
<td>5% to 15%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renewable energy</td>
<td>1% to 10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust gas CO₂ reduction</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OPERATION (All ships)**

| Fleet management, logistics & incentives | 5% to 50%⁺                | 10% to 50%⁺  |
| Voyage optimization                     | 1% to 10%                 |              |
| Energy management                        | 1% to 10%                 |              |

* Reductions at this level would require reductions of operational speed.

* CO₂ equivalent, based on the use of LNG.
Outlook (for universities and institutes)

- Innovation begins in the minds …
- Innovation requires innovative people
  - open minded
  - motivated
  - special competences:
    - Sail Technology
    - Energy Management
    - Routing

Thank you!