Retrofitting a Danish inland ferry with DPF: Reduction in particle emissions, noise, and implication on the ambient environment

Morten Køcks
Danish Technological Institute
mly@dti.dk
+45 7220 2380
IMO regulation for ship emissions

- **Sulphur:**
  - 2015: 0.1% (1,000 ppm) S, SECA
  - 2020: 0.5% (5,000 ppm) S, global

- **NO\textsubscript{x}:**
  - 2011: Tier II, new ships, global
  - 2021: Tier III, new ships, NECA (~80% reduction)

- **Mitigation options:**
  - **Sulphur:** Low sulphur fuel or SOx scrubbers
  - **NO\textsubscript{x}:** EGR, SCR
  - Alternative fuels (e.g. LNG)
  - Battery/hybrid operation
  - DPF
Why reduce ship emissions?

- Pollution from ships in Danish waters accounts for 15-20 % of the total air pollution society costs

- 70 inhabited islands in Denmark
- 67 ferry routes – several with more than one ferry

- Local inconveniences
  - urban movement towards harbor front
  - passenger/crew exposure

1 "Air pollution impact on health in Denmark", DCE 2014
Danish EPA-supported project

“Adaption, integration, demonstration and validation of full-scale solutions for reducing particulate emissions and NOx from existing ships in coastal waters"
Småfærgerne i Danmark har en fælles hjemmeside med henvisninger til hver enkelt færge’s hjemmeside og sejplan.

www.smaa-faergerne.dk
## Ships in the project

<table>
<thead>
<tr>
<th></th>
<th>Case 1 M/F Isefjord</th>
<th>Case 2 Mistral</th>
<th>Case 3 M/S Pernille</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main engines</strong></td>
<td>2 x Cummins QSK19-M 373 kW (MCR rating)</td>
<td>4x Scania D13 405 kW (MCR rating)</td>
<td>2x Volvo Penta TAMD 120 BCC 250 kW (MCR rating)</td>
</tr>
<tr>
<td></td>
<td>2011 IMO Tier II</td>
<td>2013 IMO Tier II</td>
<td>1981 No Tier rating</td>
</tr>
<tr>
<td><strong>Auxiliary engines</strong></td>
<td>2 x Cummins 6CT8.3-D(M) 122 kW (Prime rating)</td>
<td>2x Perkina 29 kW (Prime rating)</td>
<td>2x Volvo Penta 80 kW (Prime rating)</td>
</tr>
<tr>
<td></td>
<td>2012 IMO Tier II</td>
<td>2013 IMO Tier II</td>
<td>1981 No Tier rating</td>
</tr>
</tbody>
</table>
Technologies / installations

- Case 1: M/F Isefjord, Hundested-Rørvig
  - MGO 50 ppm S fuel
  - DPF solution

- Case 2: World Marine Offshore – Mistral
  - MGO/MDO up to 1,000 ppm S fuel – challenge (no standard catalyst solution)
  - DPF+SCR solution

- Case 3: Sundbusserne M/S Pernille
  - MGO 50 ppm S fuel
  - DPF+SCR solution
Instrumentation – emission monitoring

Exhaust

Rotating disc diluter 150°C

PM – ISO 8178

PM – Pegasor Mi3

NOx, NH3, CO, CO2, THC

Catalytic Stripper 350°C

NanoScan SMPS PSD 10-420 nm

DustTrak PM1
## Reference measurements – main engines

<table>
<thead>
<tr>
<th></th>
<th>M/F Isefjord (Built 2013)</th>
<th>WMO Mistral (Built 2013)</th>
<th>M/S Pernille (Built 1981)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x} [ppm]</td>
<td>500-700</td>
<td>900-1400</td>
<td>1700-2200</td>
</tr>
<tr>
<td>PN [number/cm\textsuperscript{3}]</td>
<td>4-5 x 10\textsuperscript{7}</td>
<td>4-8 x 10\textsuperscript{6}</td>
<td>2-3 x 10\textsuperscript{7}</td>
</tr>
<tr>
<td>PM [mg/m\textsuperscript{3}]</td>
<td>25-30</td>
<td>10-15</td>
<td>Not measured</td>
</tr>
<tr>
<td>Technology</td>
<td>DPF</td>
<td>DPF+SCR</td>
<td>DPF+SCR</td>
</tr>
</tbody>
</table>
M/F Isefjord fitted with Exilator DPF
First experiences – M/F Isefjord

- >99% reduction of PM og PN
- The systems are maintenance-free on a daily basis
  - DPF on main engines burns soot in normal operation (passive)
  - DPF on generators burns soot at periodically increased load (controlled automatically)
  - Expected emptying of ash approx. once a year.
- About 22 dB (A) reduction of exhaust pipe noise
  - Effective ambient reduction in combination with existing exhaust muffler
  - Absence of noise has provided positive feedback
Particle size distributions / PN reduction

Main engine - **1500 rpm**

Main engine - **1100 rpm**

> 99.5% PN reduction
PM measurements – how?

- PM measurement with filter collection for short periods of time is very challenging
- PM measurement after DPF is challenging - almost no PM
- Optical measurements provide reproducible results both before and after DPF
- Good correlation between real-time optical measurement and traditional PM filter collection
Ambient air measurements
PN measurements – bridge

- In general, close to background levels measured on the bridge – with and without DPF bypassed.
Particle measurements – passenger deck

- Average passenger exposure similar for periods with/without DPF bypassed (bypassed for 2 hours)
- Lower peak concentrations observed on the passenger deck with filter bypassed
Summary

- Increased Danish and global focus on ship emissions
- DPF is effective on both auxiliary and main engines (>99% reduction of PM and PN) operating with fuel of 50 ppm Sulphur content
- Trouble-free operation with DPF for >1 year
- Significant noise reduction
- Follow-up measurement campaign in autumn 2019 – further validation of performance

Local citizen complained that “the ferry could no longer be used to set the clock”...
Next demo in the project:
Purefi SCR and DPF on World Mistral
Acknowledgements

- Shipping Companies
  - Hundested Rørvig Færgefart
  - Sundbusserne
  - World Marine Offshore
- Technology providers
  - Exilator
  - Amminex Emissions Technology
  - Purefi
- Interest associations
  - Danish Shipping
  - Danish Maritime
- Aarhus University

Financial support from the Danish EPA