

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

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IMO regulation for ship emissions

- <u>Sulphur:</u>
 2015: 0.1% (1,000 ppm) S, SECA
 2020: 0.5% (5,000 ppm) S, global
- <u>NO_x:</u> 2011: Tier II, new ships, global
 2021: Tier III, new ships, NECA (~80% reduction)
- Mitigation options:
 - <u>Sulphur:</u> Low sulphur fuel or SOx scrubbers
 - <u>NOx:</u> EGR, SCR
 - Alternative fuels (e.g. LNG)
 - Battery/hybrid operation
 - DPF







Why reduce ship emissions?

- Pollution from ships in Danish waters acounts for 15-20 % of the total air pollution society costs¹
- 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

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Danish EPA-supported project



"Adaption, integration, demonstration and validation of fullscale solutions for reducing particulate emissions and NO_x from existing ships in coastal waters"





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Ships in the project

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



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





Reference measurements – main engines



	M/F Isefjord (Built 2013)	WMO Mistral (Built 2013)	M/S Pernille (Built 1981)
NO _x [ppm]	500-700	900-1400	1700-2200
PN [number/cm ³]	4-5 x 10 ⁷	4-8 x 10 ⁶	2-3 x 10 ⁷
PM [mg/m ³]	25-30	10-15	Not measured
Technology	DPF	DPF+SCR	DPF+SCR



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

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> 99.5% PN reduction

PM measurements – how?

35 30

25

20 15

10

5 0

- 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 realtime optical measurement and traditional PM filter collection

DustTrak vs. ISO 8178 – before DPF

average Filter mg/m^3

Average DT mg/m^3

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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



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Next demo in the project: Purefi SCR and DPF on World Mistral







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