6th CIMAC CASCADES

Development of a Gas Propulsion System for Harbour Tug Applications

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Power. Passion. Partnership.

Off-Highway Applications Requirements

low cooling demand

good serviceability

stringent emission requirements

high availability and reliability

restricted installation space, high power to weight ratio

high time-between-overhaul (TBO)

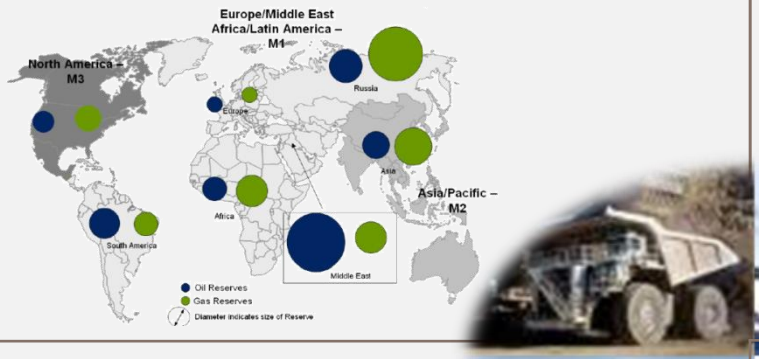
good response characteristic and load acceptance

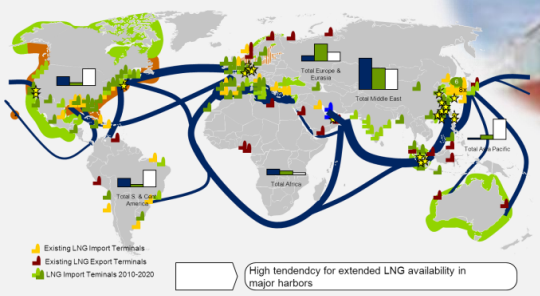
low fuel consumption, low life-cycle-costs (LCC)

➢ **Can a gas fuelled engine meet these requirements?**

Gas for mobile applications
Key Drivers

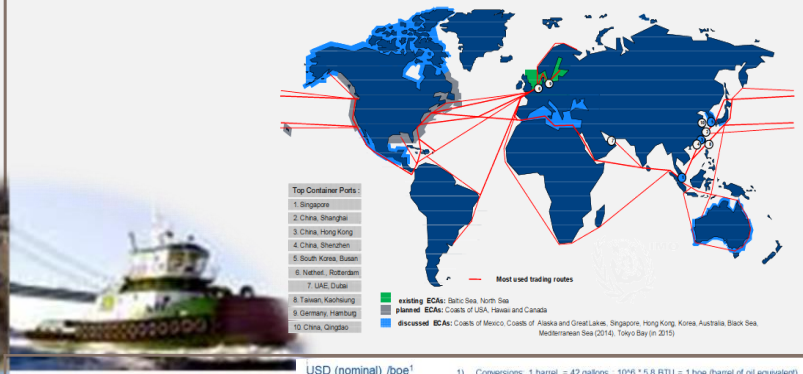
Large Reserves

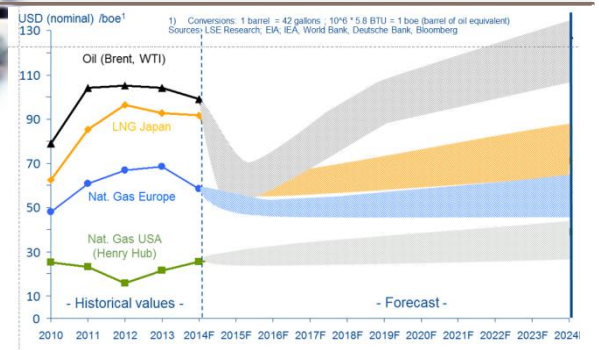




Developing LNG*-Infrastructure

Emission Regulations (ECA**)

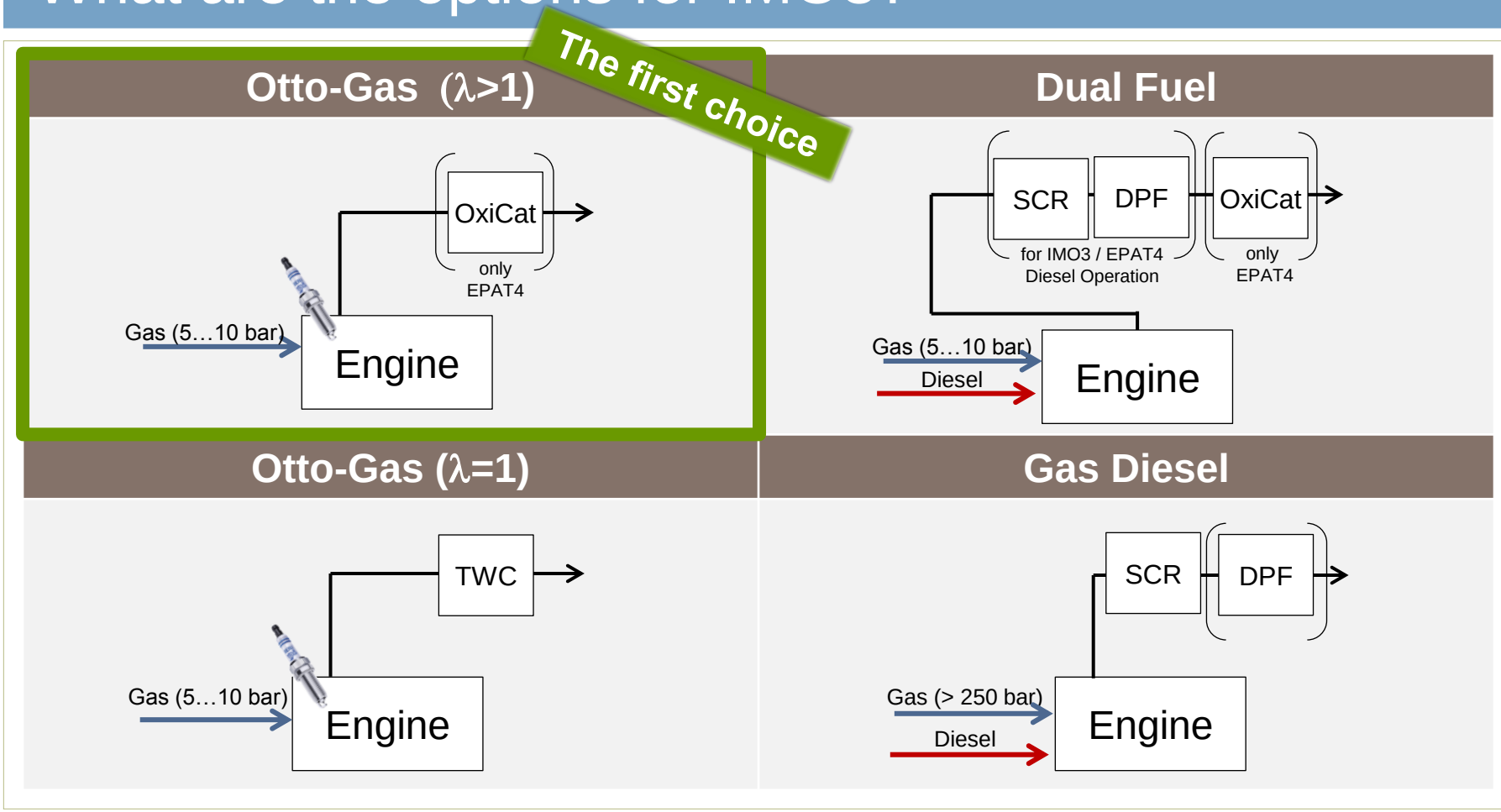




Low Gas Price

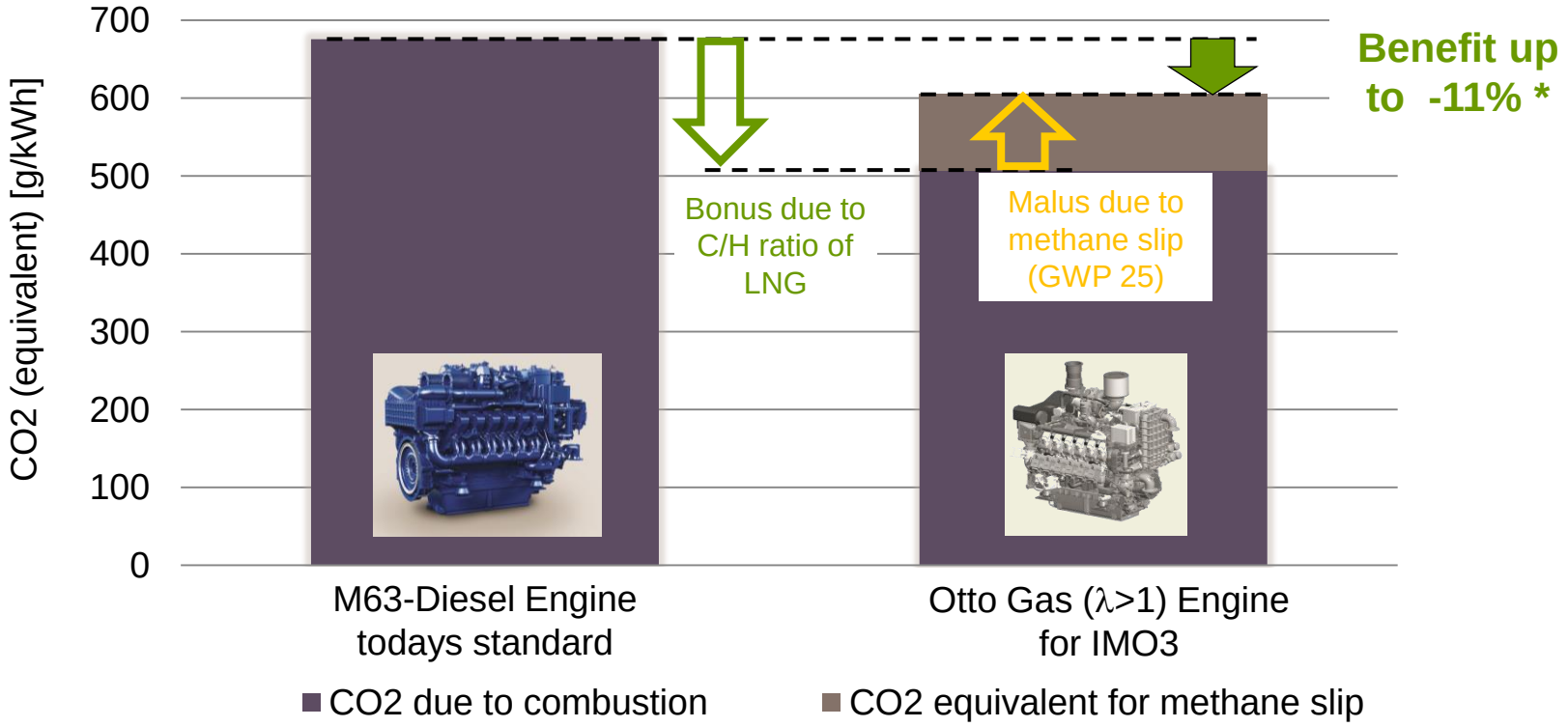
* LNG: Liquified Natural Gas
** ECA: Emission Controlled Area

Engine Concepts for Marine Applications
What are the options for IMO3?



Drivers for Gas – Emissions of Green House Gases Comparison of Gas & Diesel Engines

Equivalent CO2 emissions in TUG operating cycle



➢ **Gas engines have the potential to reduce GHG-emissions.**

GWP - Global Warming Potential

assumption: 1A load profile & same efficiency (Diesel and Otto Gas in operating cycle)

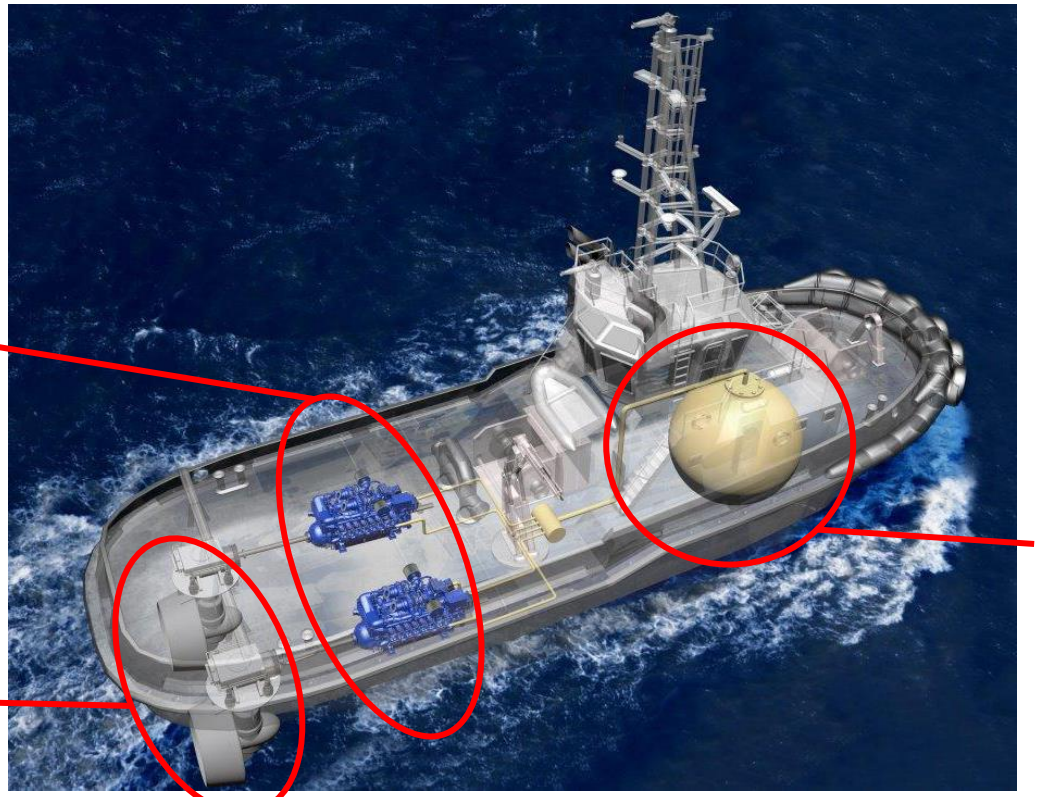
Off Highway Applications
Example: Marine Engine for Harbour Tug

Source: Damen – ASD TUG 2810

Gas Propulsion System for Harbour Tug Applications

Example : Design of the RSD TUG 2512 CNG

2 x MTU 16V4000 Gas Engine



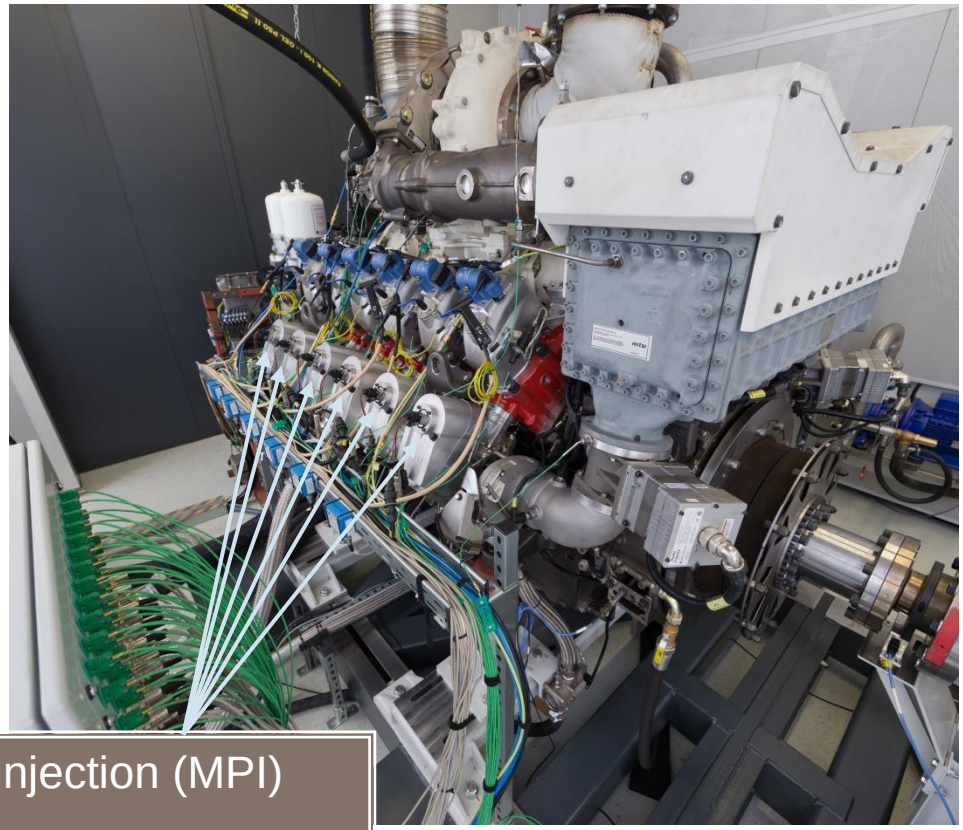
CNG - Tank

2 x Rolls-Royce Thruster

Source: Damen

Engine Design
S4000 Gas Engine for Marine Applications

Engineering Targets:	
Application	Marine Commercial
Emissions	IMO3 / EPA T4 & low Methane Slip
Base-Engine	S4000 M63 Bore: 170 mm Stroke: 210 mm
Combustion	Otto-Gas (λ>1)
Engine Mapping	like M63
Engine Dynamics	like M63
Safety concept	IGF-Code: Gas-safe



Multi Point Injection (MPI)

➔ Double walled gas supply

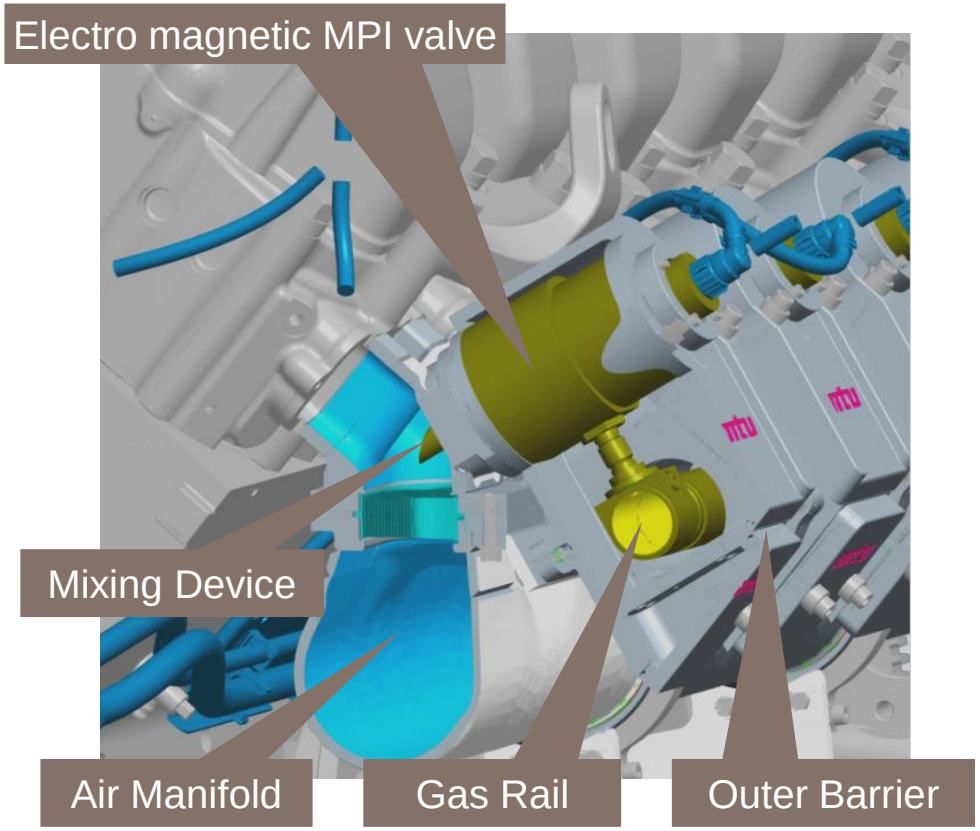
Engine Design
Multi Point Injection with Electric Valves

High flexibility to influence
the air / gas mixture with MPI-valves:

- Begin of injection
- Gas rail pressure

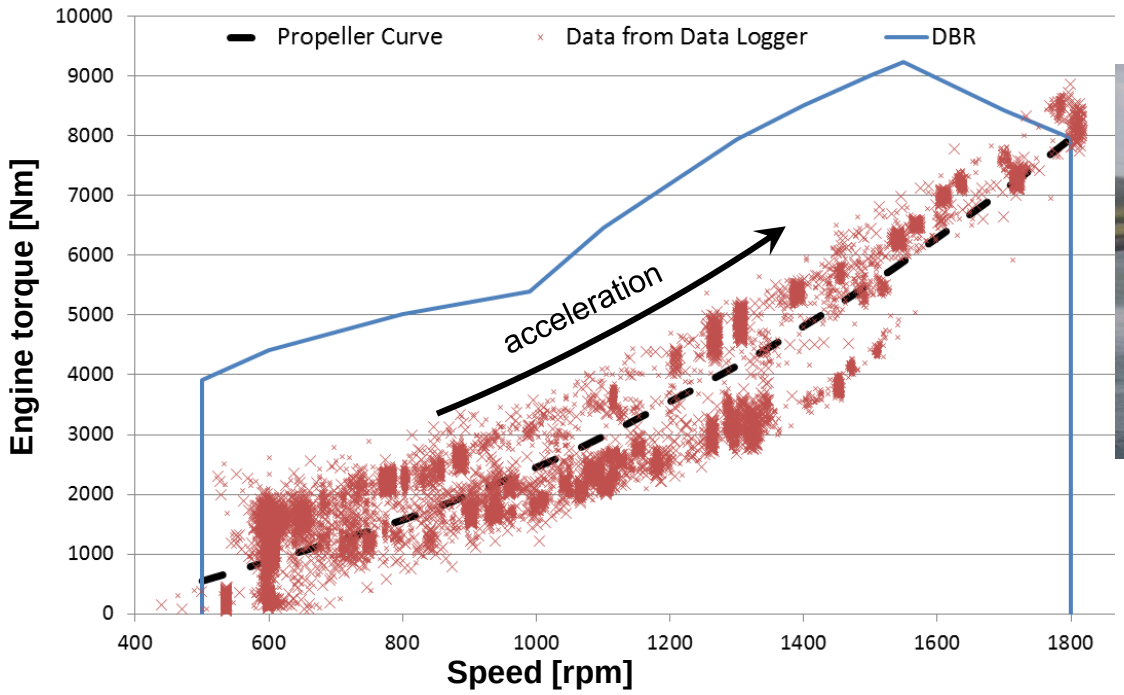
Flexible injection strategy:

➢ **Opportunity to optimize mixture quality for combustion stability at each engine operating point from cycle to cycle**



Thermodynamic Design
Required Engine Dynamics

Data logging in a TUG boat - „Standard“ - TUG Manoeuvers



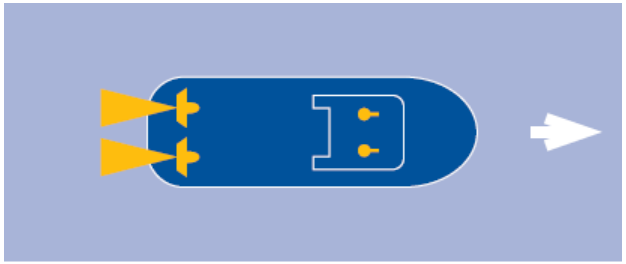
data logging: engine runtime approximately 6h

➢ **Typical TUG manoeuvre: acceleration along propeller curve**

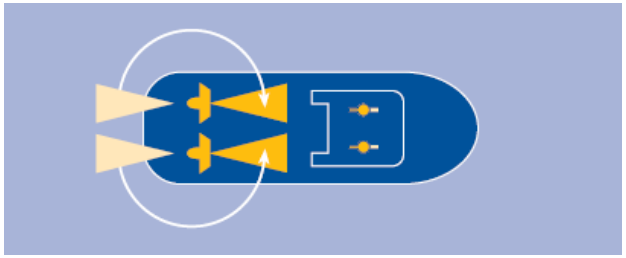
Source: Damen

Thermodynamic Design
Required Engine Dynamics

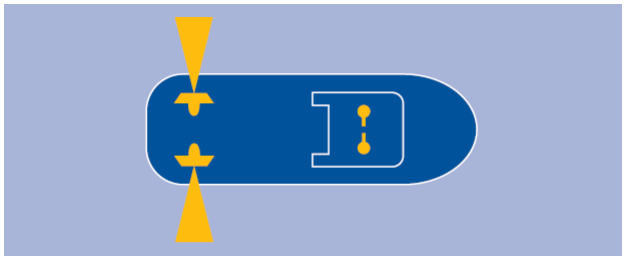
“Worst Case“ TUG Manoeuver - Emergency Crash Stop



1. Start condition: Sailing full speed ahead
   - Engine Speed: maximum
   - Engine Torque: high



2. Emergency Stop: Turn the thrusters 180° against original direction
   → thrust reversal
   - Engine Speed: high
   - Engine Torque: maximum



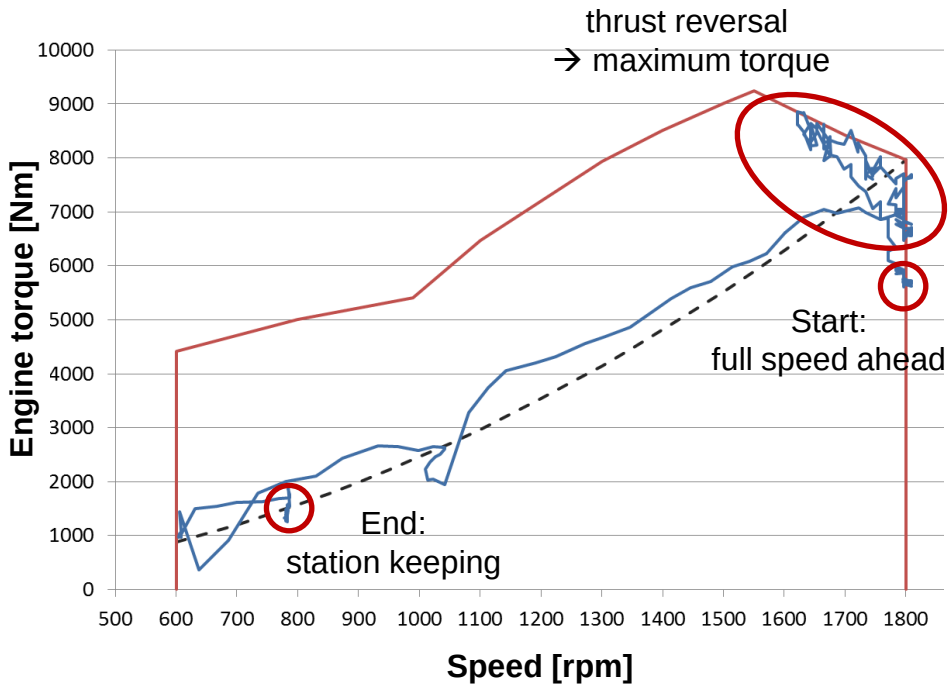
3. Station keeping: Thrusters in neutral position
   - Engine Speed: low
   - Engine Torque: low

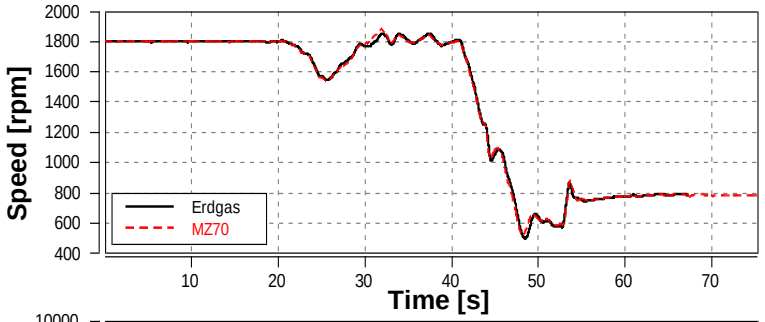
➢ **Manoeuver Goal: Realization of minimal stopping distance to avoid crash!**

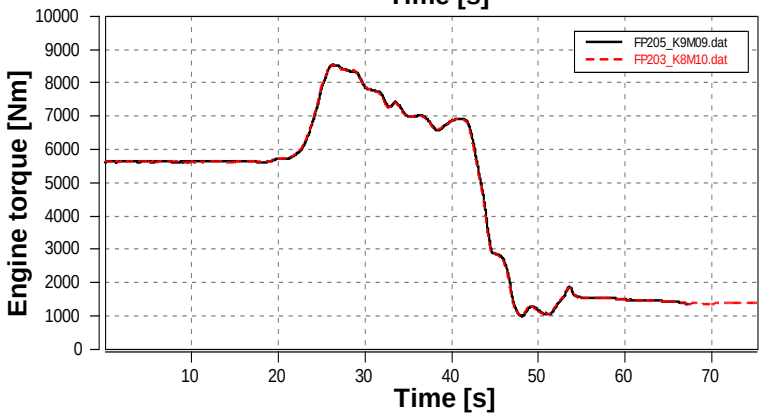
Source: Damen

Thermodynamic Design
Required Engine Dynamics

Data logging in a TUG boat - „Worst Case“ - TUG Manoeuver *





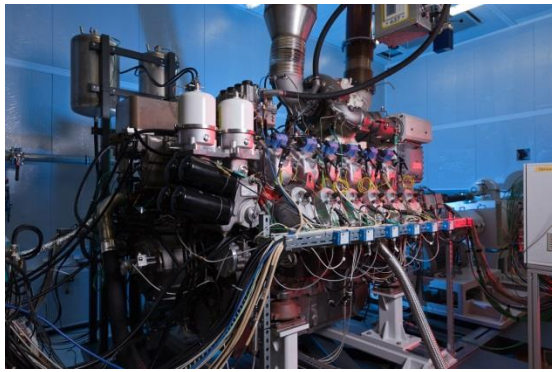


➢ **„Worst Case“ TUG manoeuvre: Emergency crash stop**

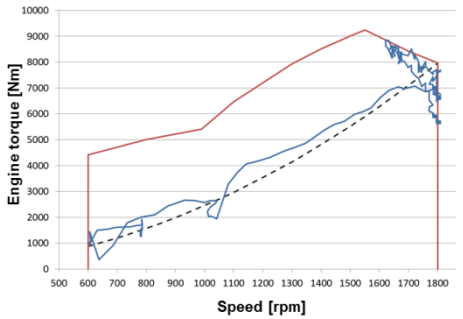
* Data from crash stop manoeuvre with DAMEN ASD Tug 2411

Engine Dynamics
Investigations of Real Vessel Operation on Test Bed

Simulation of TUG maneuver with ship model → Hardware in the Loop



engine @ high transient test bed



resulting driving curve

engine torque

engine speed

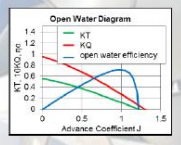
Gearbox
Clutch
Transmission ratio
Transmission efficiency

propeller torque

propeller speed

real time ship model @ test bed

Propeller
Open water diagram



Propulsion parameters
(Wake fraction, thrust deduction, relative rotative efficiency)

thrust

vessel speed

Vessel
Resistance diagram

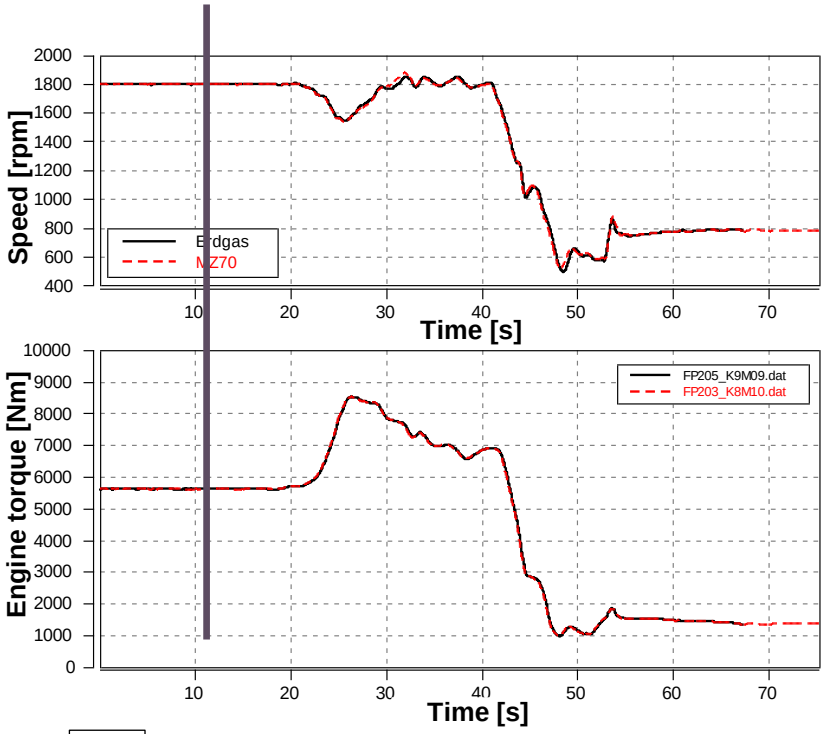
Displacement

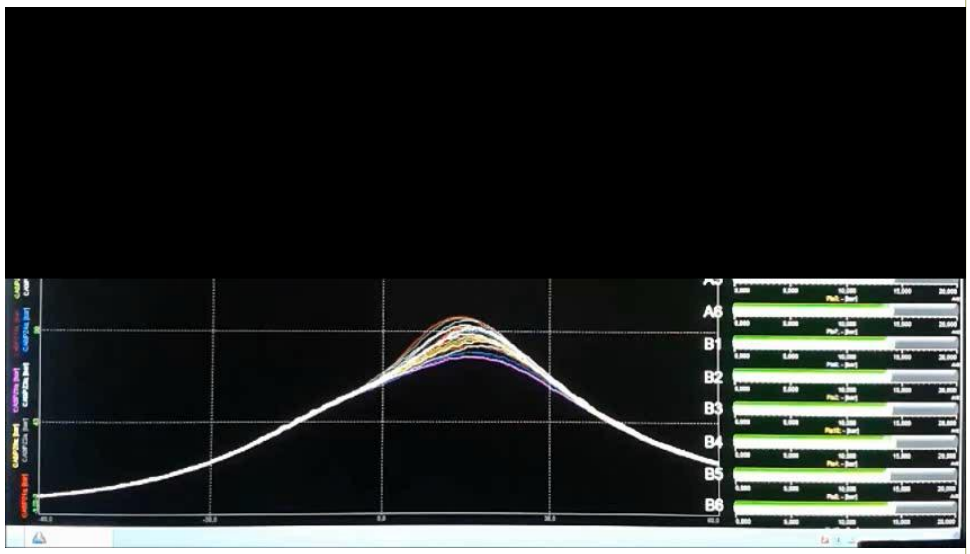
➢ **Real engine operating in a vessel can be tested.**

Source: Damen

Engine Dynamics
Investigations of Real Vessel Operation on Test Bed

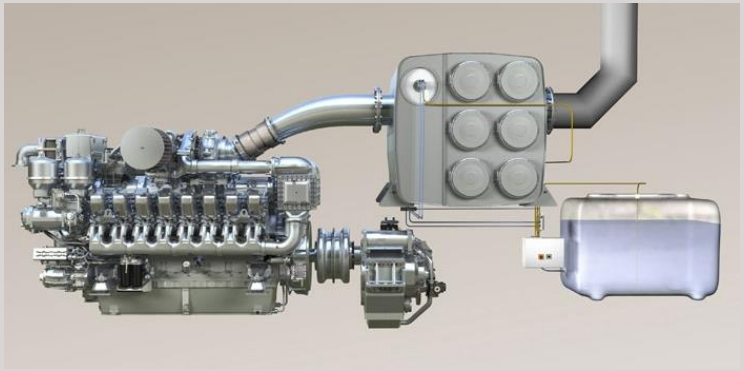
Results: Hardware in the Loop Emergency Crash Stop





- **HIL testing offers significant advantages in engine and software development!**

MTU´s options for future Marine Applications Diesel and Gas Engines for IMO3

Diesel + SCR	Natural Gas
	
+ proven, established + fuel logistics and handling - complexity: SCR - operational cost - limited oil reserves	+ operational costs + engine complexity: lean burn no EAT + global gas reserves - gas infrastructure - gas storage system

➢ **Diesel and Gas Engines are future fuel options for marine applications!**

Thank you very much for your attention.

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