May 24, 2022

Technology Collaboration Programme on
Advanced Motor Fuels

The Progress of Advanced Marine Fuels and the Specific Role of Dual-Fuel Technology in Decarbonising Shipping

German Weisser
Winterthur Gas & Diesel Ltd

© 2020 WinGD
WIN GD

Setting the stage

AMF Task 60 (formerly Annex 60)

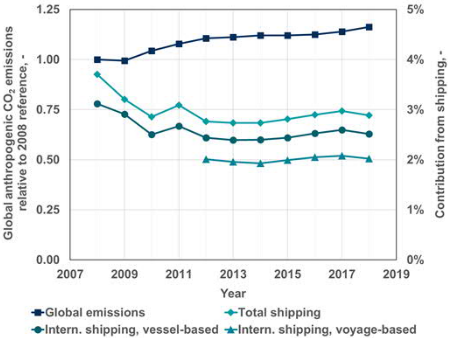
Technology Collaboration Programme on Advanced Motor Fuels

Purpose: Assessment of fuel options that have emerged or significantly developed since the 2013 report (AMF Annex 41).

Table 13. Summary of Evaluation of Propellant Systems

	IFO	LSFO	MGO/GTL/ BTL	HVO/SVO/ FAME	MeOH	DME/LPG	LNG/LBG
Engine and fuel system cost	Drop in	Drop in	Drop in	Drop in	Dual fuel	Gas tank	Dual fuel Cryo tanks
Projected fuel cost		Refining	Refining	Land use		Infra structure	Infra structure
Emission abatement cost	SOx, NOx, PM, CO_2	NOx, PM, CO_2					
Safety related cost					Flash point	Ventilation	Press/temp
Indirect cost				Ethics	Cargo space	Cargo space	Cargo space

Serious impediment
Significant cost
Feasible solution available



© 2020 WinGD
WIN GD

Setting the stage

Technology Collaboration Programme on Advanced Motor Fuels

AMF Task 60 (formerly Annex 60): The Progress of Advanced Marine Fuels

Purpose:	Assessment of fuel options that have emerged or significantly developed since the 2013 report (AMF Annex 41).
Coordination:	Kim Winther, Danish Technological Institute, Denmark
Timeframe:	November 2019 to November 2022
Participants:	Canada, Denmark, Finland, Korea, Sweden, Switzerland, USA, China, Austria
Co-sponsor:	Methanol Institute

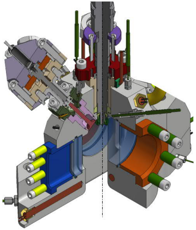
Swiss contribution:

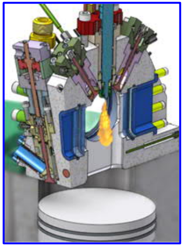
Assessment of the state of the art of dual fuel technology for large two-stroke engines (WinGD)

Investigation of ignition and combustion properties of mixtures of methane and gases with lower carbon intensity at conditions relevant for large two-stroke dual-fuel engines (FHNW, WinGD)

© 2020 WinGD

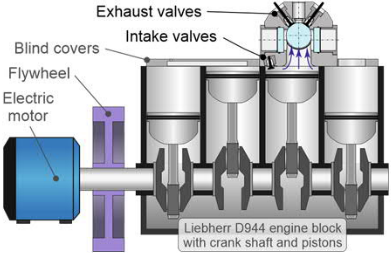
Principle, specifications and features



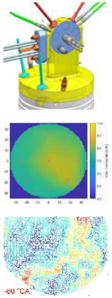


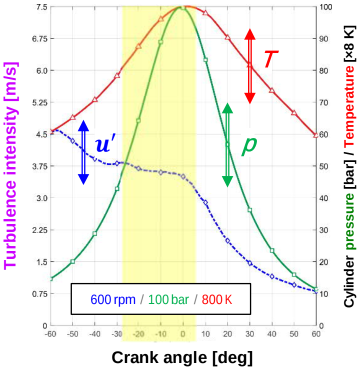
Optical combustion chamber

- Optical access: 4 windows optical chamber ⦰ 60×20 mm
- Engine-like compression/combustion pressure / temperature
  → up to 160 bar max. 240 bar / 700 ... >1000 K
- Variation of flow/turbulence by speed: u'≈ 3...6 m/s (300...1000 rpm)

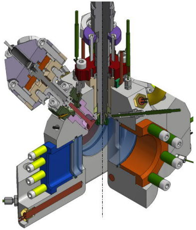


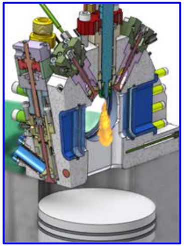
Operating conditions:





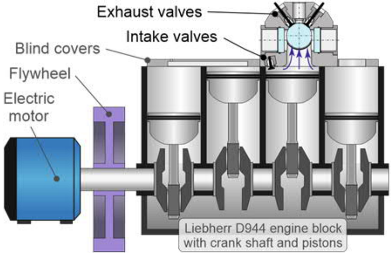
Principle, specifications and features





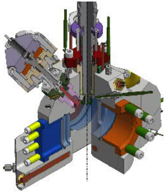
Optical combustion chamber

- Optical access: 4 windows optical chamber ⦸ 60×20 mm
- Engine-like compression/combustion pressure / temperature
  → up to 160 bar max. 240 bar / 700 ... >1000 K
- Variation of flow/turbulence by speed: u'≈ 3...6 m/s (300...1000 rpm)
- Flexible operation: mixture charge, injection parameter, timing, ...
- Variability to adapt test rig to a variety of DF combustion processes

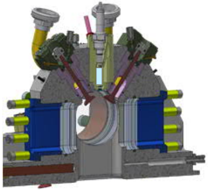


low pressure

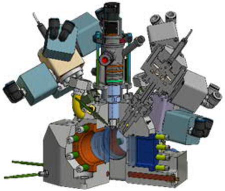
high pressure



pilot spray



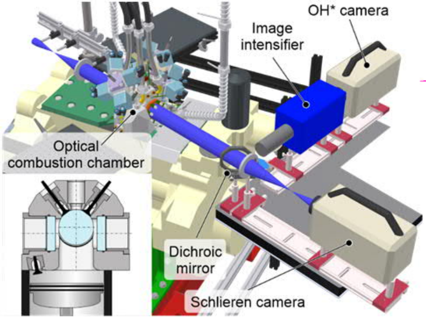
prechamber jet



gas injector

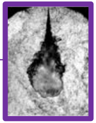
Characterization DF Combustion Processes

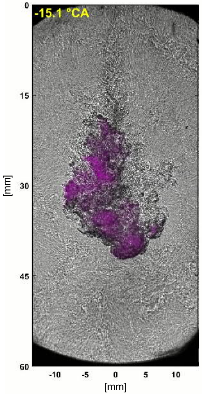
Lean-premixed pilot fuel ignited dual-fuel combustion

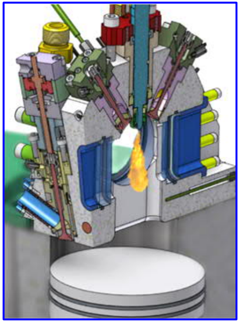


OH* CL

Schlieren

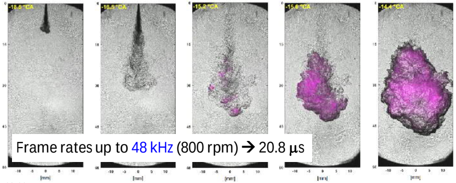






D. Humair, et al.: "Characterization of dual-fuel combustion processes", 6th Rostock Large Engine Symposium 2020

Simultaneous Schlieren / OH* chemiluminescence



Frame rates up to 48 kHz (800 rpm) → 20.8 µs

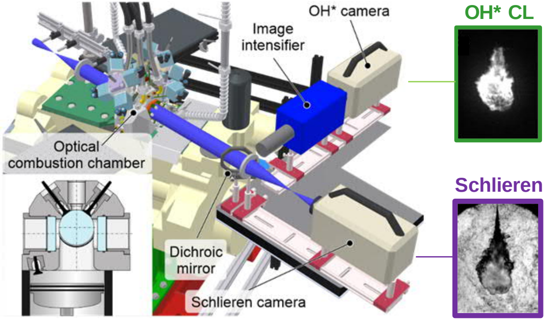
Investigations

→ Ignition delay (location): OH* chemiluminescence

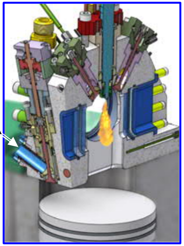
→ Flame propagation: Schlieren

→ Heat release/cyclic stability: pressure measurements

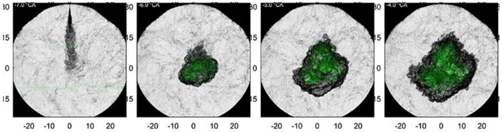
Experimental setup / operation parameter variation



- Gaseous NH_3/air charge
- Pilot fuel ignition (dodecane)
- Operation parameter variation:
  - ➢ air/fuel ratio
  - ➢ pressure
  - ➢ temperature
  - ➢ flow conditions
  - ➢ start/duration of injection



Simultaneous Schlieren / OH* chemiluminescence



NH_3 combustion characteristics

→ Ignition delay (location): OH* chemiluminescence

→ Flame propagation: Schlieren

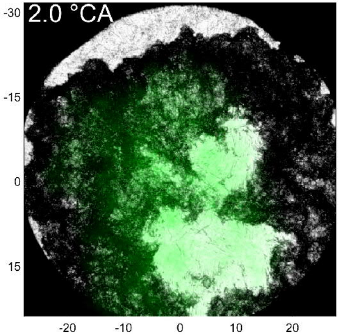
→ Heat release/cyclic stability: pressure measurements

Initial NH_3 Combustion Tests

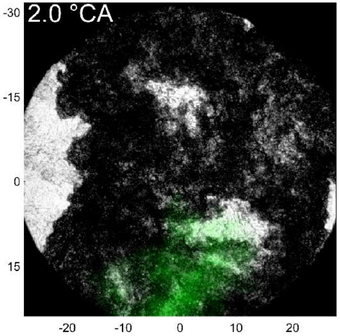
Variation of air/fuel ratio λ (mixture charge)

p_{comp} = 70 bar / T ≈ 810 K / SOI = -10 deg / ET = 500 μs

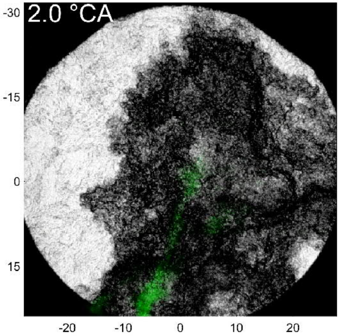
λ = 1.0



λ = 1.5



λ = 2.0



Low-speed engine DF technology state of the art

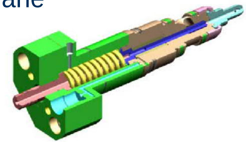
Variants of dual-fuel engine concepts applied on two-stroke engines

The MAN ME-GI concept:

- Diesel-type combustion of a gas jet
- Injection pressure in the range of 150 to 315 bar, depending on engine load
- Ignition by means of pilot fuel via backup fuel system

Fuel varieties covered by the concept and derivatives:

- LNG, bio-methane, synthetic methane
- Ethane (ME-GIE)
- LPG (ME-LGIP)
- Methanol (ME-LGIM)
- VOC (LNG/VOC blends ME-GIE)



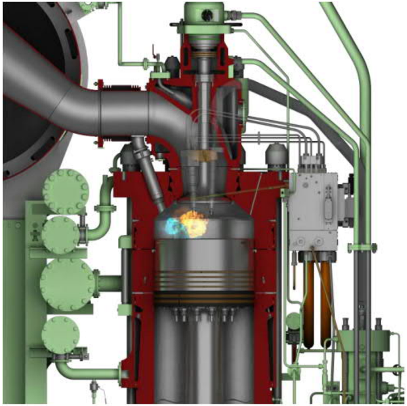


Illustration of ME-GI working principle (right) and gas injector (left) as key system feature, from L. Ryberg Juliussen et al, 2013, The MAN ME-GI engine: From initial system considerations to implementation and performance optimisation, CIMAC

© 2020 WinGD

Low-speed engine DF technology state of the art

Variants of dual-fuel engine concepts applied on two-stroke engines

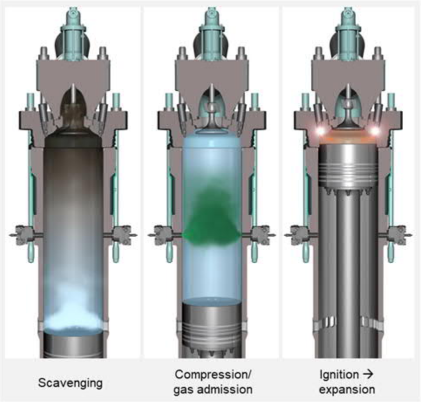


Illustration of WinGD X-DF working principle, from I. Nylund I., M. Ott, 2013, Development of a dual fuel technology for slow-speed engines, CIMAC

The WinGD X-DF concept:

- Engine operating according to the Otto process
- Pre-mixed 'Lean burn' technology
- Low pressure gas admission at 'mid stroke'
- Ignition by pilot fuel in prechamber
- Combustion in main chamber initiated and enhanced by hot jets

Largely similar approach used on MAN ME-GA engines

Fuel varieties covered by the concept:

- LNG, bio-methane, synthetic methane
- VOC (LNG/VOC blends)

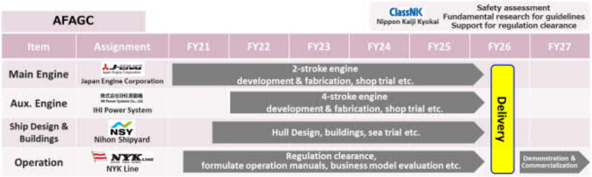
© 2020 WinGD

Low-speed engine DF technology state of the art

Future fuel development plans of large two-stroke engine developers

Fuel types	MC	ME-B	ME-C	ME-GI	ME-GA	ME-GIE	ME-LGIM	ME-LGIP
0-0.50% S VLSFO	Design	Design	Design	Design	Design	Design	Design	Design
HFO	Design	Design	Design	Design	Design	Design	Design	Design
Biofuels	Design	Design	Design	Design	Design	Design	Design	Design
LNG	-	-	Retrofit	Design	Design	Retrofit	Retrofit	Retrofit
LEG (Ethane)	-	-	Retrofit	Retrofit	-	Design	Retrofit	Retrofit
Methanol / Ethanol	-	-	Retrofit	Retrofit	-	Retrofit	Design	Retrofit
LPG	-	-	Retrofit	Retrofit	-	Retrofit	Retrofit	Design
Ammonia	-	-	Retrofit	Retrofit	-	Retrofit	Retrofit	Retrofit

Fuel Type	Drop-in capable	X-engines	X-DF engines
0 – 0.5%S VLSFO	n/a	Available	Available
HFO	n/a	Available	Available
Bio-diesel	✓	Available	Available
LNG	n/a	Retrofit	Available
Bio-methane	✓	Retrofit	Available
Synthetic methane	✓	Retrofit	Available
Ammonia	Dual- / Tri-Fuel	In Development	In Development
Methanol/ Ethanol	Dual- / Tri-Fuel	In Development	In Development
Lignin- derived biofuel	(✓)	Available	Available



3D-view of hydrogen-fueled engine

Image of hydrogen-powered ship

Top row: Overview of fuel types and their applicability / retrofit ability on different engine design variants, MAN (left) from R. Bidstrup, 2021, MAN B&W Ammonia fueled engine development status, 42. Informationstagung zur Schiffsbetriebsforschung, WinGD (right), from D. Schneiter, S. Goranov, P. Krähenbühl, D. Schäpper, M. Spahni, G. Weisser, 2021, WinGD's X-act initiative: A holistic approach towards sustainable shipping, 18th Symposium „Sustainable Mobility, Transport and Power Generation"
Bottom row: JEng devlopment plans: Ammonia-fuelled ammonia gas carrier demonstration project (left) ,Agreement for Trial of Hydrogen-fueled Engine equipped Onboard (right), Illustrations from press releases retrieved from https://www.j-eng.co.jp/en/news (last accessed November 18, 2021)

© 2020 WinGD

Thank you!