HELIOS

List of participants		
MAN Diesel & Turbo	Niels Freese	Niels.Freese@man.eu
University of Erlangen	Thomas Seeger	thomas.seeger@yahoo.de
Germanischer Lloyd	Benjamin Scholz	benjamin.scholz@gl-group.com
Jönköping University	Ingvar Svensson	Ingvar.Svensson@jth.hj.se
Kistler Instrumente Wintherthur AG	Walter Meier	'walter.meier@kistler.com'
Lund University	Mattias Richter	'mattias.richter@forbrf.lth.se'
Sandvik Powdermet	Tomas Berglund	tomas.berglund@sandvik.com
TGE Marine Gas Engineering	Hans-Christian Haarmann-Kuehn	'hans-christian.haarmann-kuehn@tge-marine.com'
Uppsala University	Staffan Jacobson	'staffan.jacobson@angstrom.uu.se'

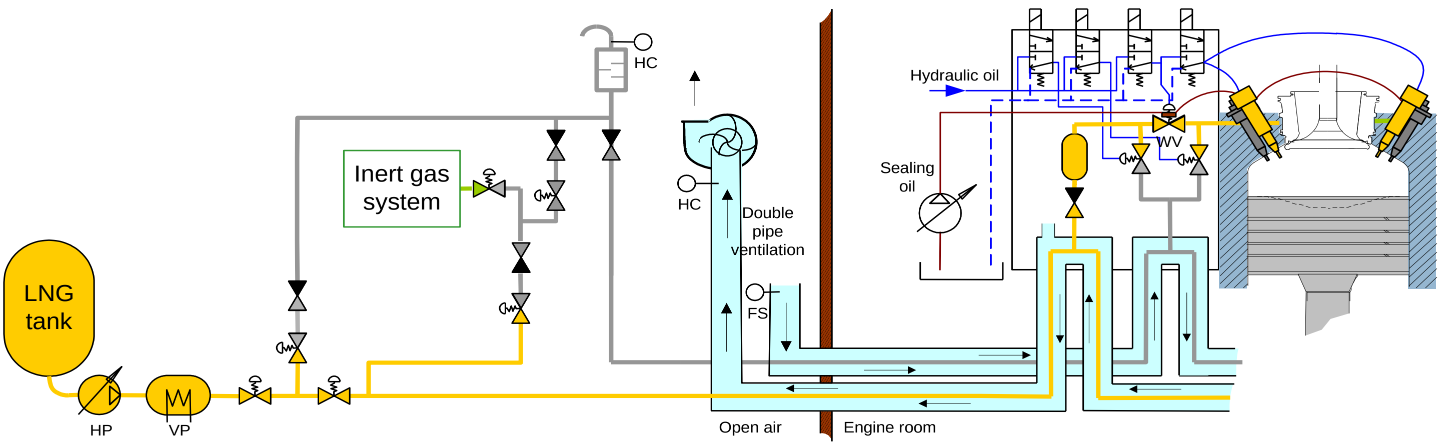
Environmental benefits	
NO_x	24% reduction
CO_2	23% reduction
Methane 'slip':	0.2-0.3 g/kWh
PM	85% reduction
CO	Very low
SO_2	Very low. From pilot oil
Smoke	Almost eliminated
Thermal efficiency	Very high

Running-in and testing of the gas fuelled research engine, 14 April 2011 – 31 December 2013	
Engine operation on gas (1)	420 hours
Consumption of gas	301 tonnes
Consumption of N_2	5.046 m3
Consumption of LIN	143 tonnes

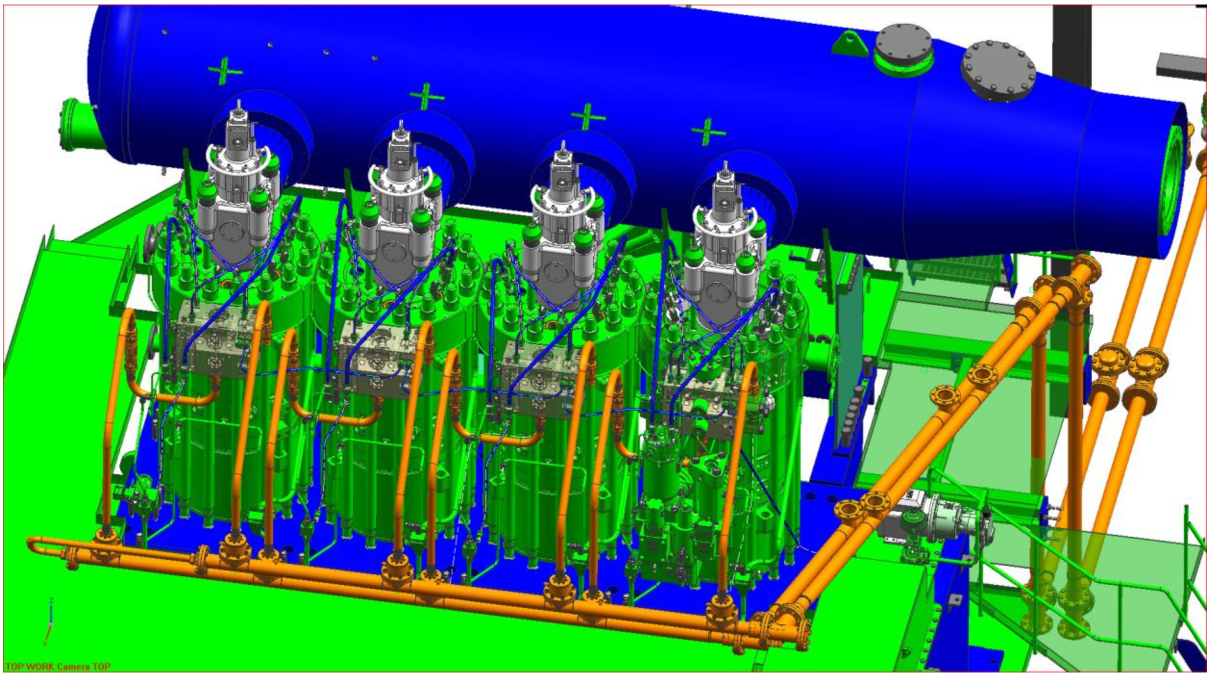
(1): Within WP1 and for testing in WP2, 3, 8 and 9

N_2 is used for purging of the engine, and liquid N_2 is used for purging of the fuel gas supply system.

Sketch of the gas fuelled Diesel engine



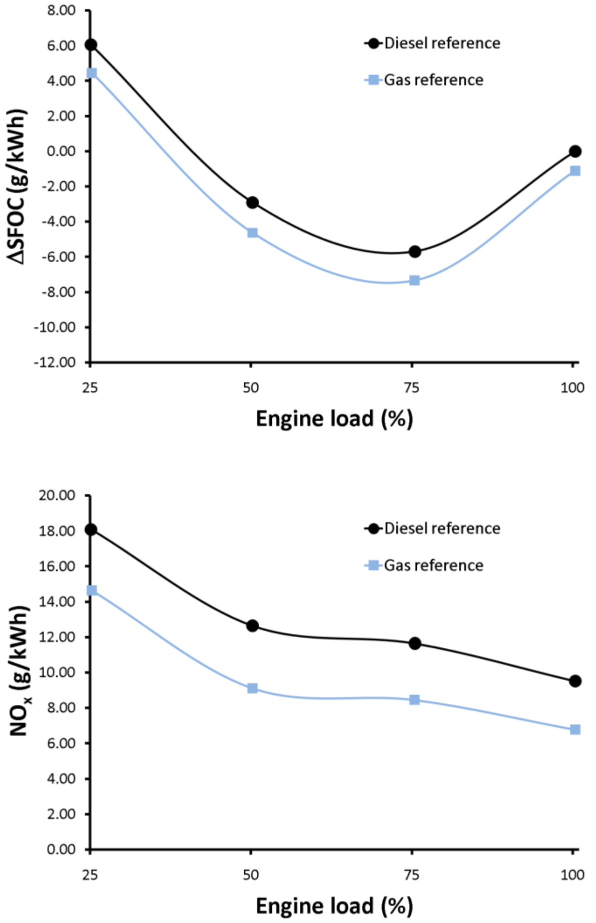
Gas injection valve

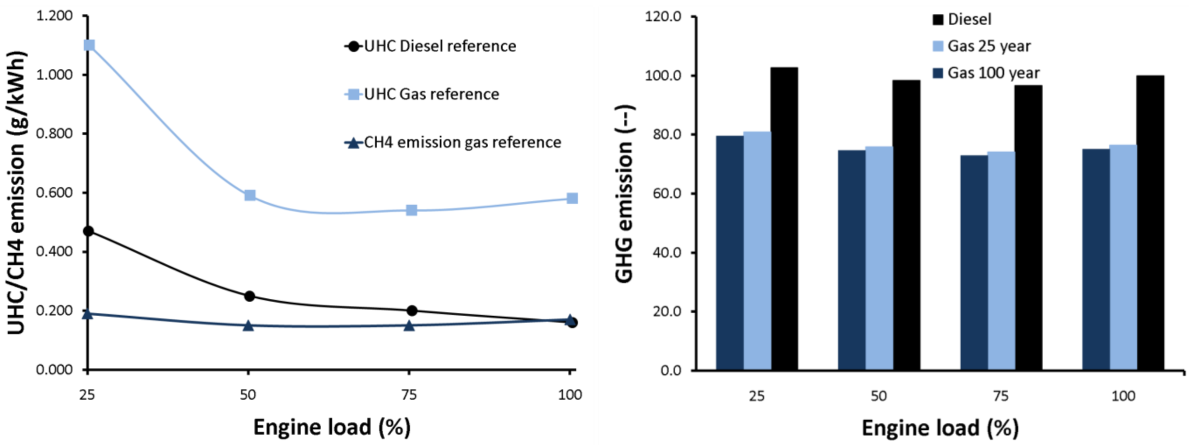


The top of the gas engine

Tests carried out		
Type	**Results**	**Period**
WP1-WP2, Confirmation of basic gas operation and performance. Verification of test set-up	A well functioning engine and positive results compared with diesel operation	April-May 2011
WP2, Gas parameter test, stage I. performance and baseline	Emissions and performance compared with diesel operation	August 2011
WP2, Performance and emissions. Reference test and baseline	Emissions and performance compared with diesel operation	February-March 2012
WP3 Gas+EGR	Compliance to TierIII NOx emission limits demonstrated through use of EGR. Emission and performance compared to diesel operation	September 2013
WP3 Gas pre-injection	Single cylinder tests of early gas injection established limits of stable ignition	October 2013
Type	Results	Period
WP3 High-speed imaging	Ignition and flame development in diesel and gas operation visualized using borescope and high-speed camera	January 2011 May 2011 October 2013
WP3&8 Spectrometer survey	Spectral emission of gas and diesel combustion characterized	March 2012
WP3&8 UV high-speed imaging	UV high-speed imaging of gas ignition attempted, problems with UV borescope performance encountered	September 2012
WP3&8 Thermographic phosphors test	Laser based surface temperature measurements demonstrated	November 2012
WP3&8 Thermographic phosphors via fibre	Fibre based probing of surface temperatures tested	December 2013
WP3&8 Laser induced fluorescence imaging	Laser sheet imaging of gas jet attempted, problems with window failure encountered	December 2013
WP10 Preliminary test of gas sensor	On-line gas composition analysis at medium-pressure demonstrated	March 2012
WP10 Final test of gas sensor	On-line gas composition analysis at high-pressure demonstrated	September 2013

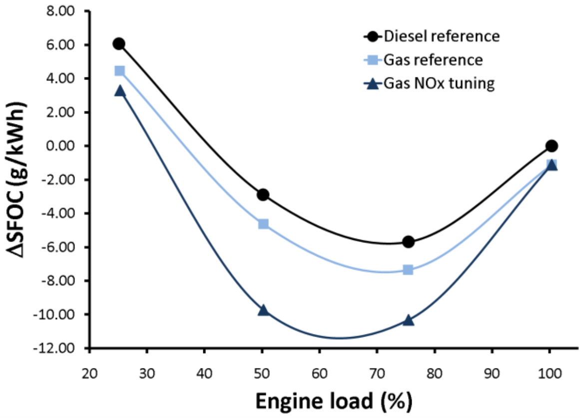
SFOC and specific NO_x emissions for gas and diesel operation

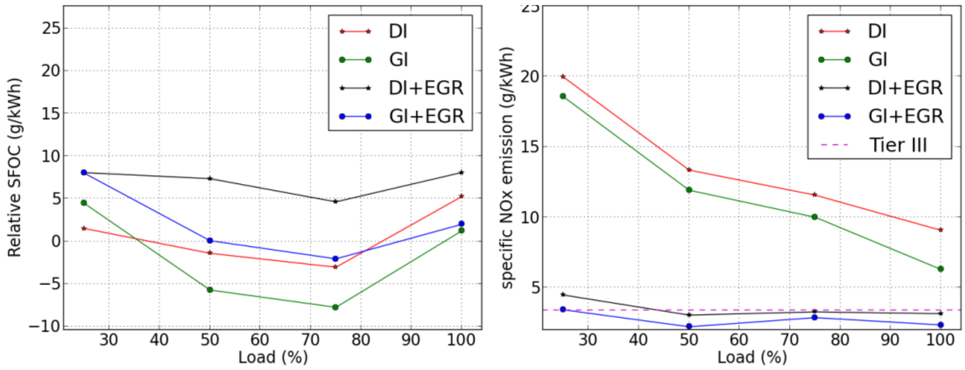




Left: Emission of unburned hydrocarbons for gas and diesel oil operation and methane emission (slip) for gas operation. Right: Green house gas emission from gas and diesel oil operation.

SFOC for gas and diesel oil reference tests and for NOx/SFOC tuning tests.

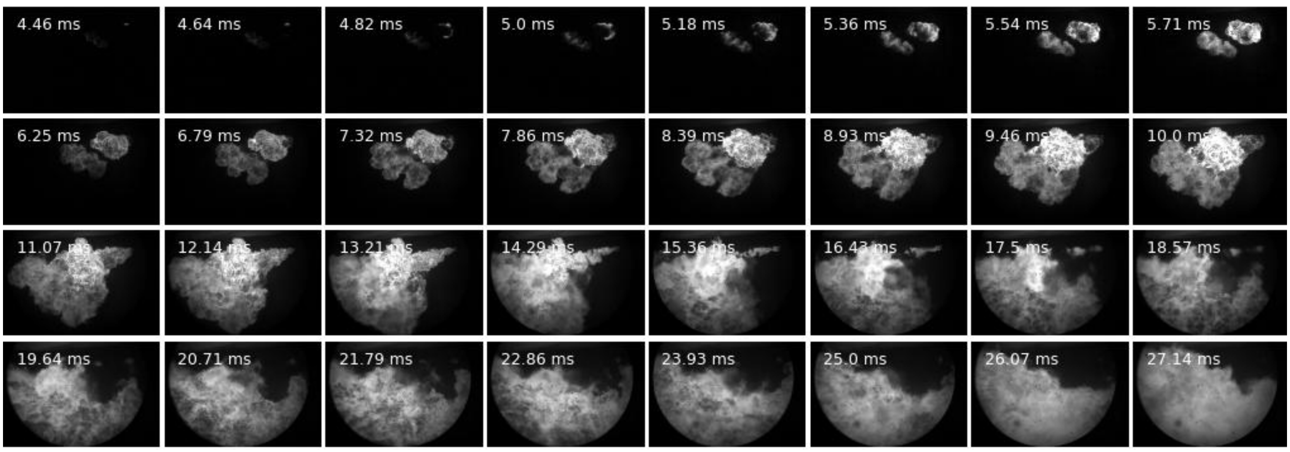




Mode	NO_x g/kWh	SFOC g/kWh
Diesel	11.50	+4.05
Diesel+EGR	3.28	+10.37
Gas	9.60	0
Gas+EGR	**2.68**	+4.16
Tier III	*3.4*	

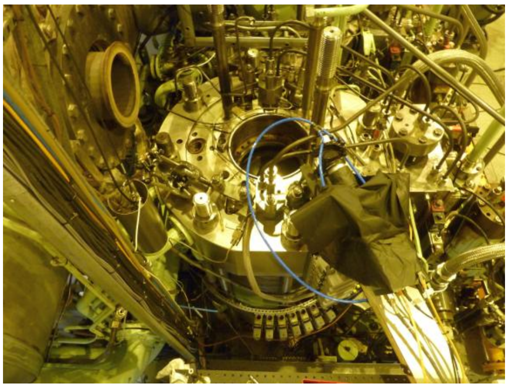
Cycle weighted NOx and SFOC

SFOC and NO_x emissions for gas and diesel operation, with and without EGR



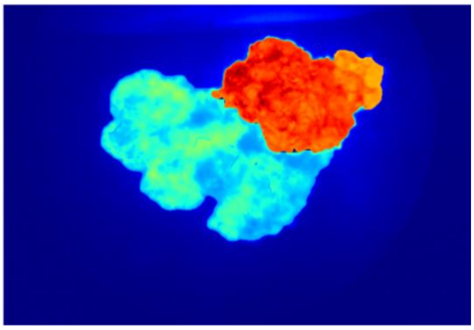
High-speed sequence of pilot ignited gas combustion.

Gas cover

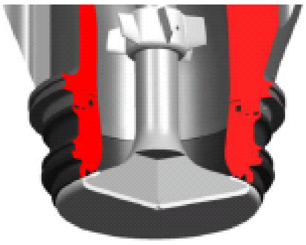


Camera insert

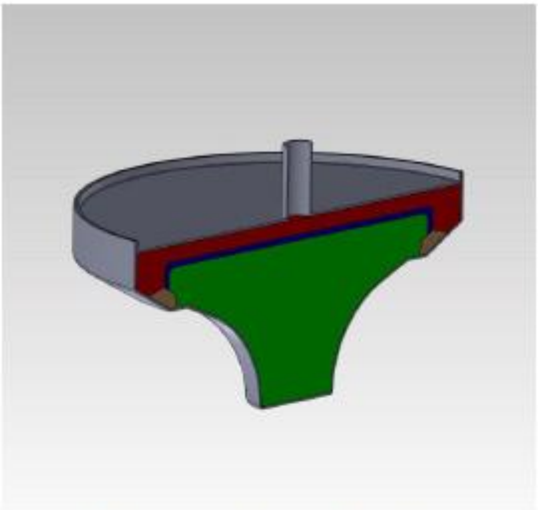
Mounted laser and camera inserts



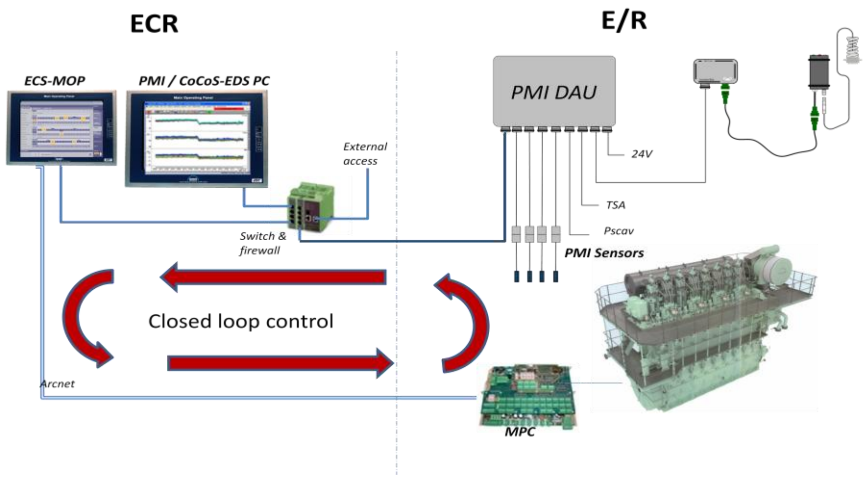
Diesel pilot (red), gas flame (cyan)



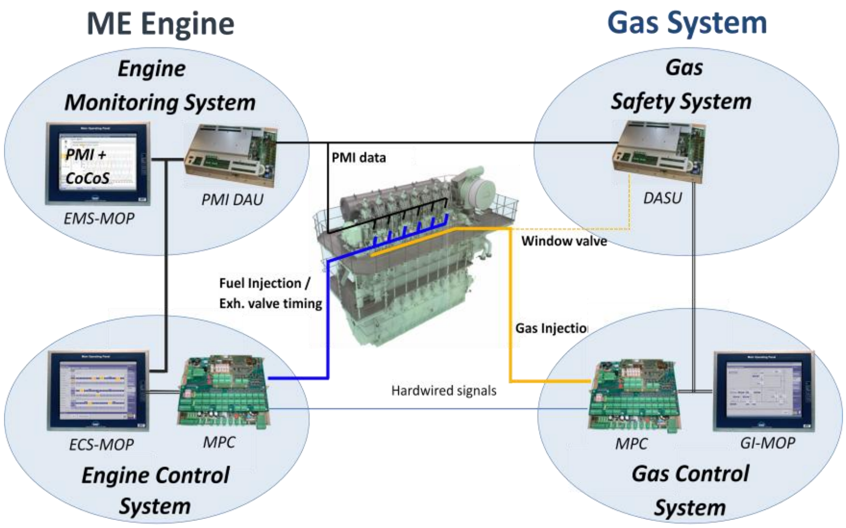
2-stroke exhaust valve



HIP compound spindle disc capsule

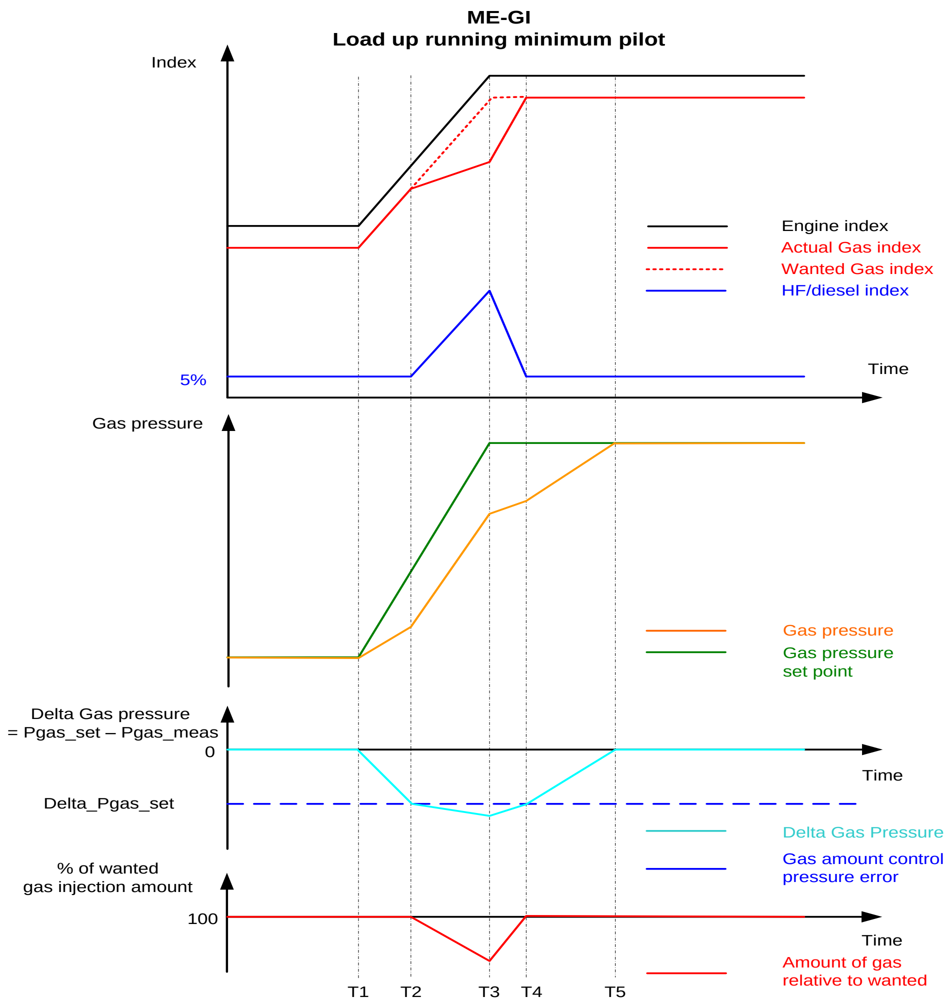


Control system



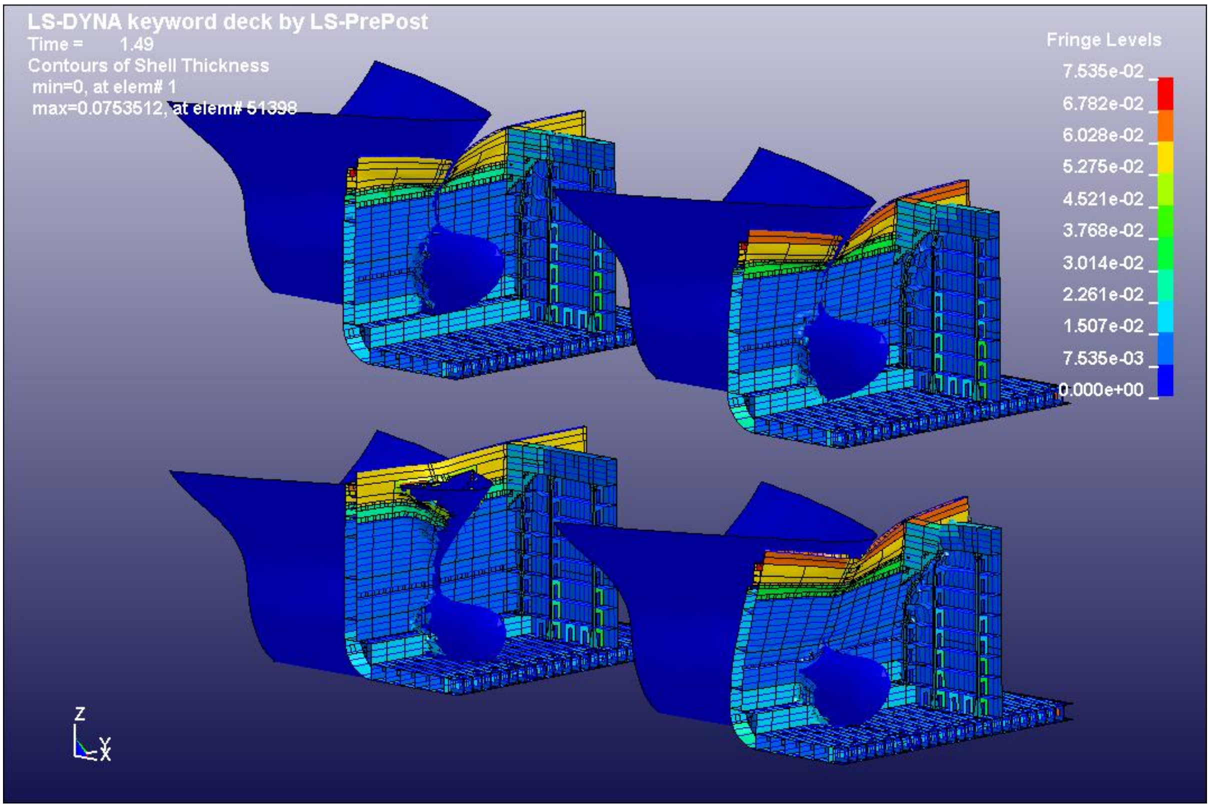
Gas control strategy

Fuel Oil Compensation for Gas Principle During Engine Load Up



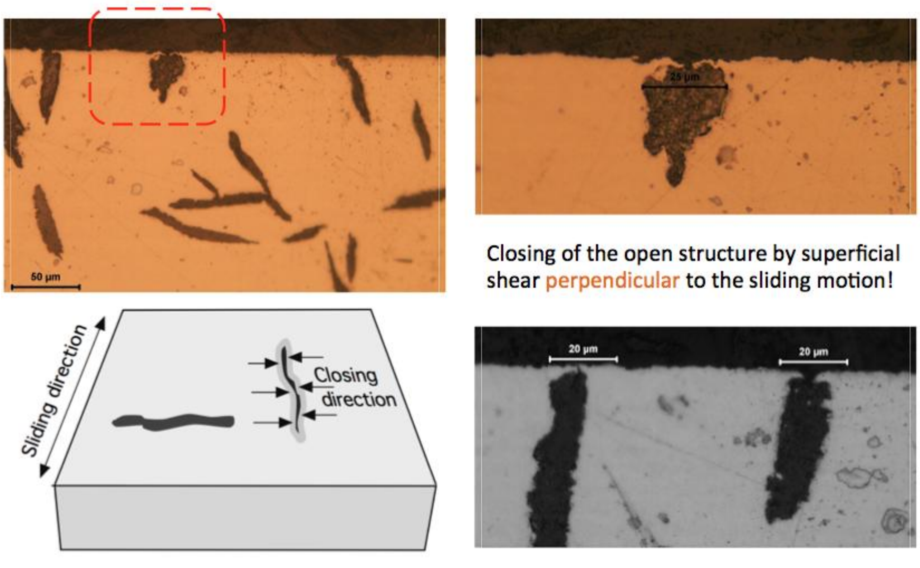
With auto-intermittent gas operation the gas amount is being fast-ramped

Reference Sensor & HCD

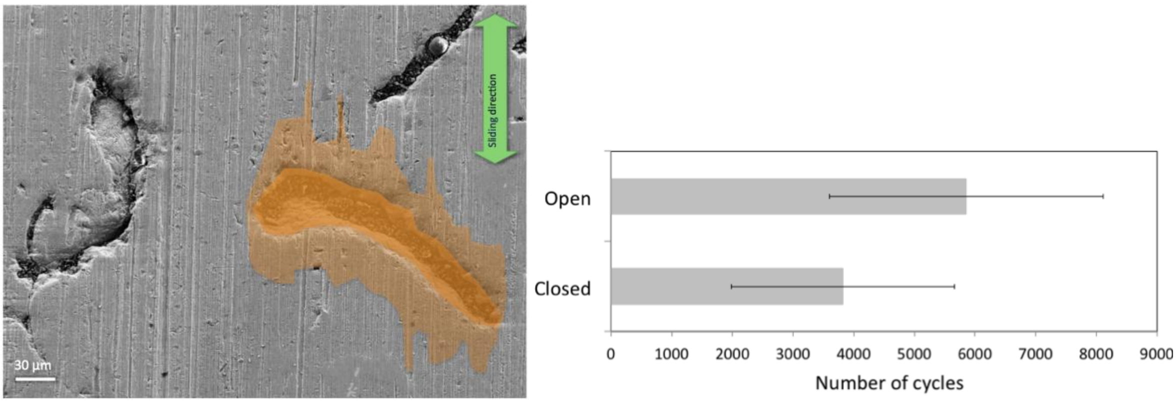


Safety: collision scenario

The Helios lab scale test rig, allowing two simultaneous reciprocating sliding tests (left) and a close up of one of the two the sample fixtures (right). Letter A) corresponds to the stationary ring and B) to the reciprocating cylinder sample. The arrow shows the movement of sample B.

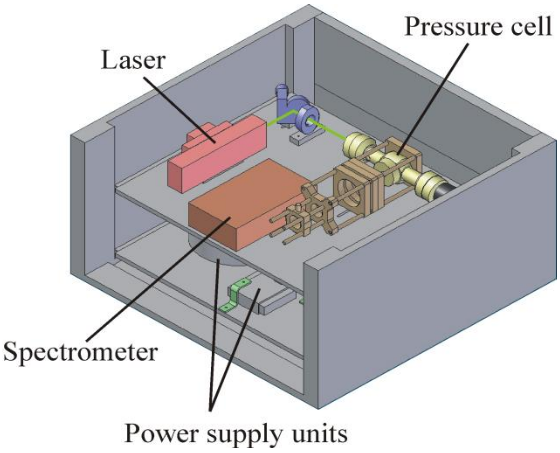


Graphite lamella closing mechanism studied in cross section.



a) *b)*

a) Illustration of the reservoir mechanism of open graphite. These reservoirs may appear small but our tests have shown that initial addition of a 1 µm oil film (≈ 1 g/m2) is enough to prevent scuffing for thousands of cycles in the test rig. b) Reduction in number of cycles to scuffing caused by only a low degree of closing graphite.



Scheme of the sensor system