11th EUROPEAN COMBUSTION MEETING 2023
APRIL 26-28, 2023
ROUEN, FRANCE

11th Combustion Meeting 2023
April 26-28, Rouen France

UNIVERSITY of STRATHCLYDE
MARITIME SAFETY RESEARCH CENTRE

University of Strathclyde

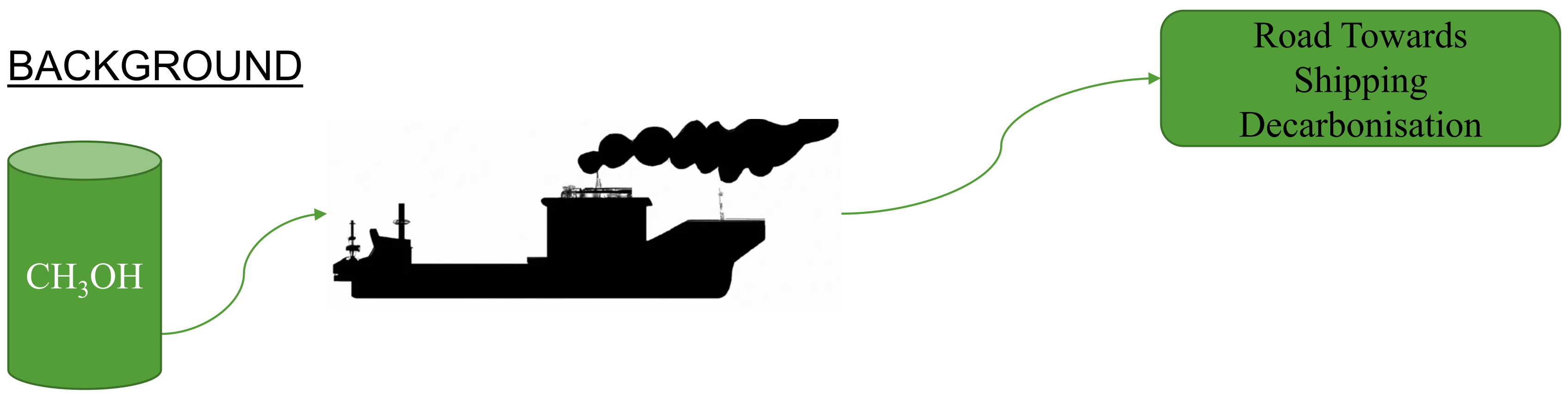
Numerical investigation of diesel – methanol dual-fuel marine engine performance and emissions utilising high methanol fractions.

Karvounis Panagiotis, Gerasimos Theotokatos

Maritime Safety Research Centre, Department of Naval Architecture, Ocean, and Marine Engineering, University of Strathclyde, Glasgow, Scotland, United Kingdom

ABSTRACT

BACKGROUND

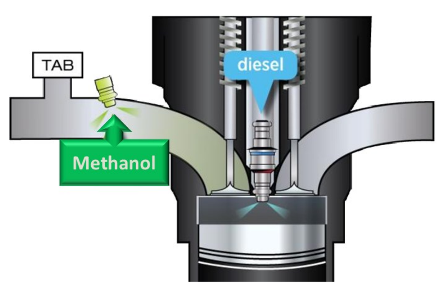


CHALLENGES

- Lack of marine engine studies operating with high methanol fractions
- Knock combustion at high loads with methanol fuel
- Examine limitations of premixed combustion concept under diesel-methanol dual fuel operation

AIM

- Achieving high methanol share knock-free combustion in most frequent operations of marine engines.



METHODOLOGY

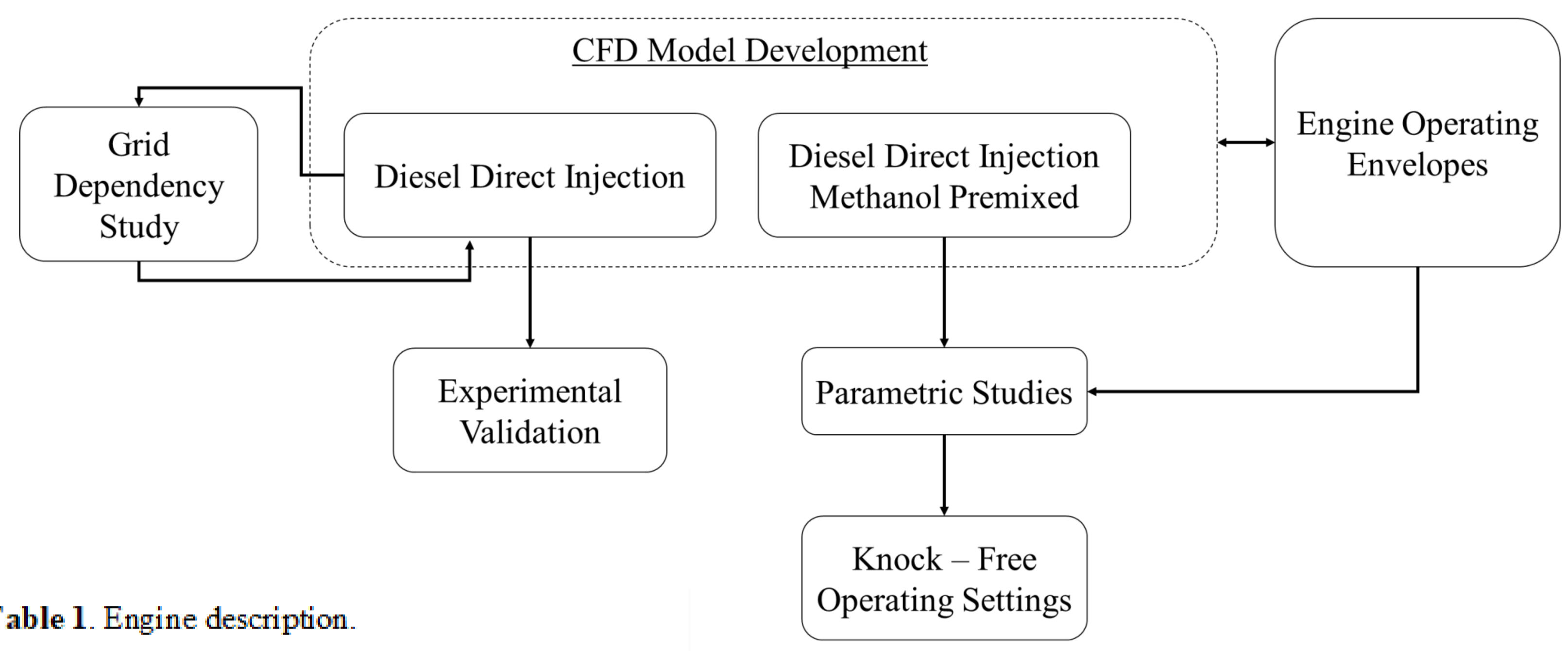


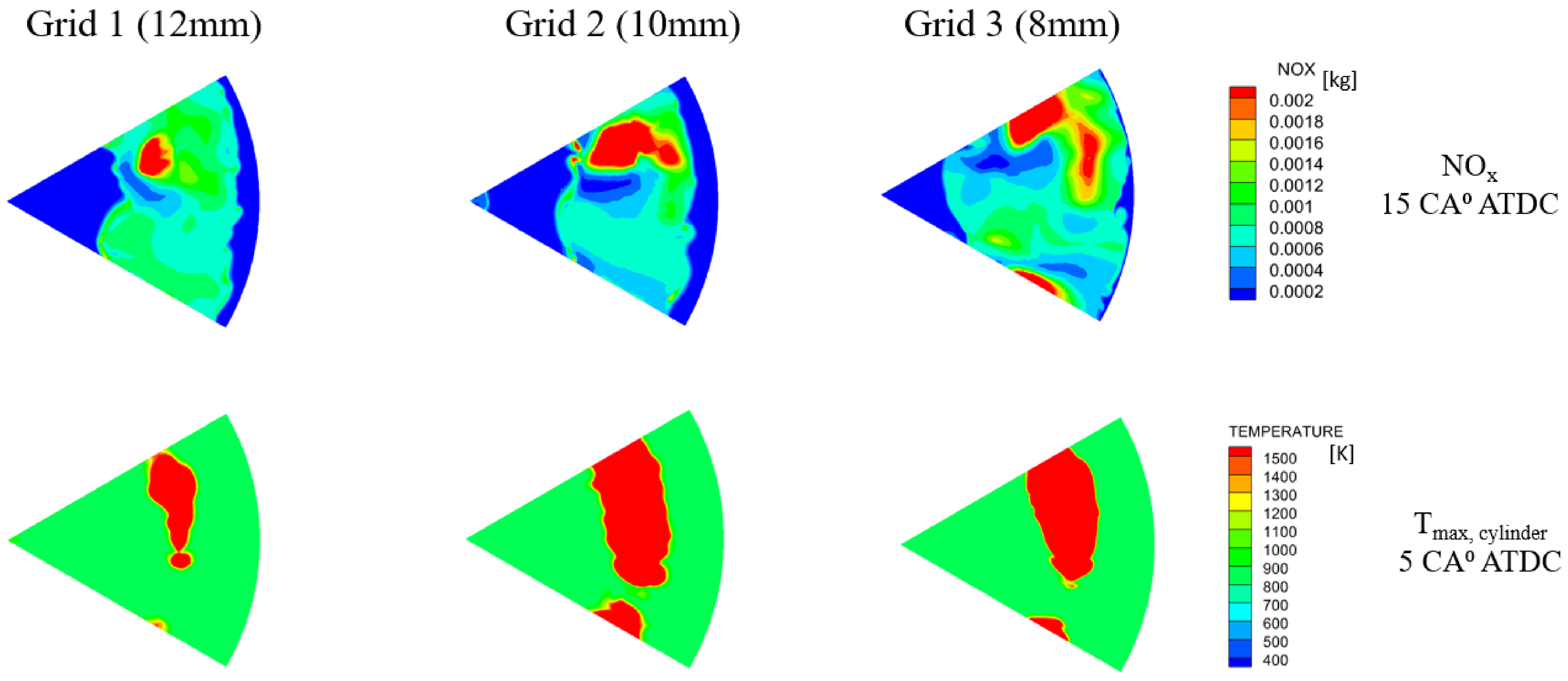
Table 1. Engine description.

Parameter	Value
Type	Wartsila 9L46C
Power Output [kW]	9450
Number of Cylinders	9
Compression Ratio	14.0:1
Bore x Stroke [mm]	460 x 580
Injection Method	Diesel: Direct Injection
	Methanol: Port Injection
Injection Timing	Diesel: -7 °CA BTDC

Table 2. Computational grid data

Parameter	Grid 1	Grid 2	Grid 3
Element size [mm]	12	10	08
Maximum Number of Cells*	10900	18838	36800
Adaptive mesh refinement	On	On	On
Solution duration [h]	3	4.5	9.5

*At TDC not including embedding and mesh refining

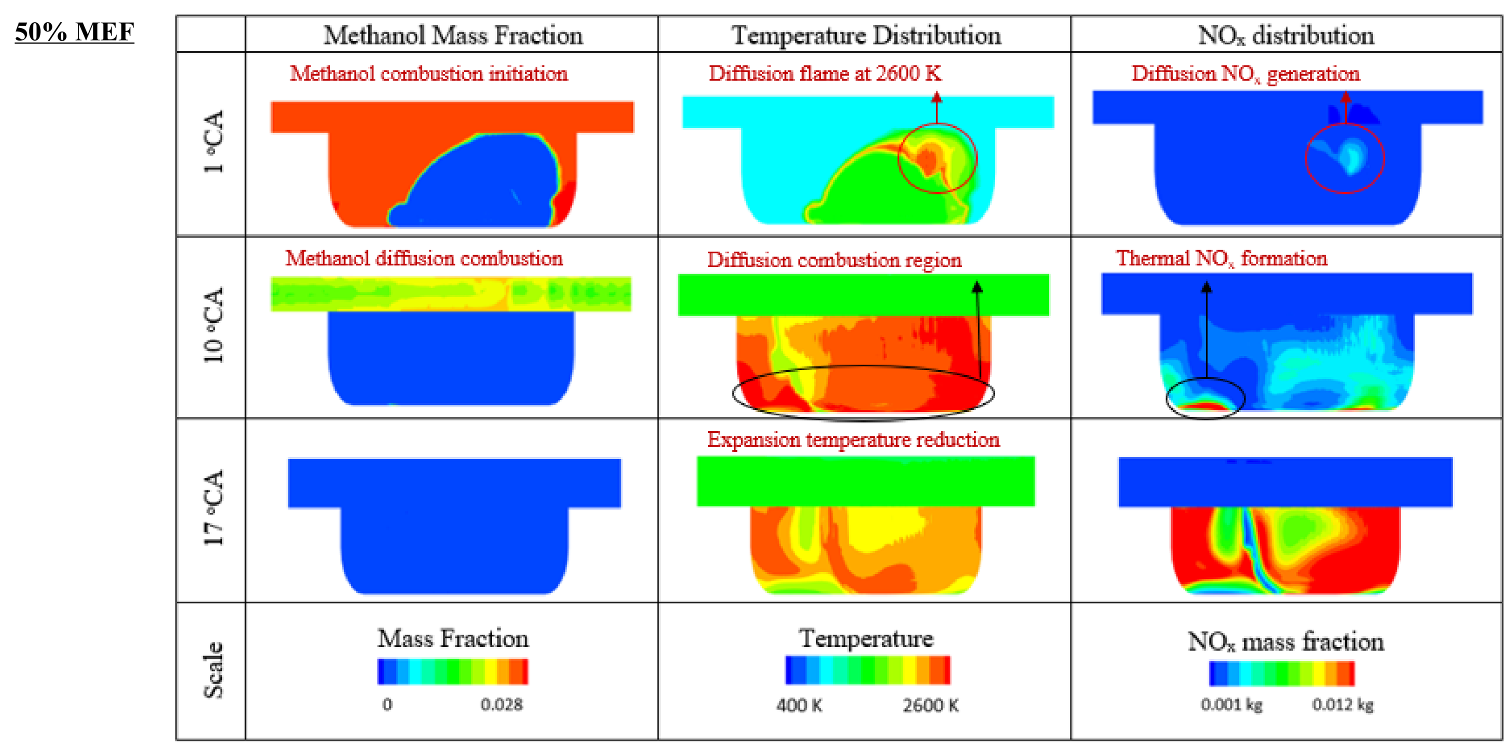


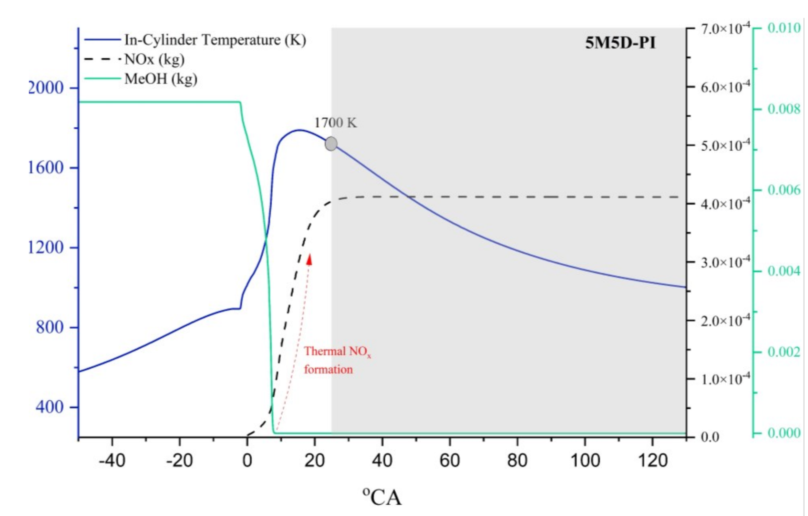
FINDINGS

- The CFD model matches well the experimental in – cylinder pressure and hence is considered validated.
- 50% methanol energy fraction is the upper limit of knock-free premixed combustion.
- NO_x emissions are affected by the methanol high latent heat of vaporisation and the high oxygen content; the former reduces the maximum in-cylinder temperature whereas the latter, would result in increased temperature and hence NOx.
- NO_x emissions reduced by 8% and 37% with methanol energy share of 10% and 50% respectively.
- For higher methanol energy fractions other combustion strategies are required, such as low pressure direct methanol injection at compression stroke.

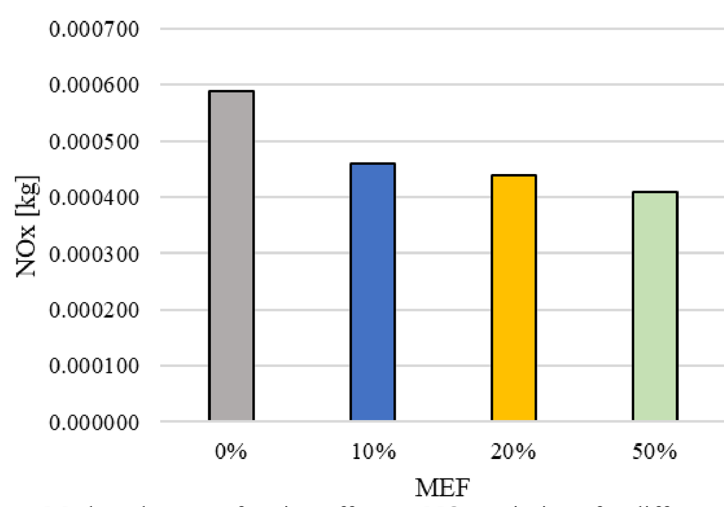
Table 3. Engine parameters for knock – free combustion

Injection Method	Code Name	Diesel Injection	Methanol Injection	Charge Pressure [bar]	Intake Temperature [K]	Equivalence Ratio Φ	EGR [mass %]
	BL	-6 CA° BTDC	-	2.8	360	0.045	30
Port Injection	1M9D-PI	-6 CA° BTDC	Port	2.8	360	0.05	30
	2M8D-PI	-6 CA° BTDC	Port	2.8	360	0.11	30
	5M5D-PI	-6 CA° BTDC	Port	2.8	360	0.27	30
	8M2D-PI	-6 CA° BTDC	Port	2	380	0.5	45





NOx formation tendency for 50% MEF



Methanol energy fraction effect on NO_x emissions for different cases.

Table 4. MEF effect on engine parameters comparing to baseline case

Parameter	P_{max}	T_{max}	HRR_{peak}	CA50	CA90	NO_x	RI	ITE
Case	%	%	%	%	%	%	%	%
1M9D-PI	+1.6	-1.3	+5%	-4.11	+1.62	-22.03	+41	-
2M8D-PI	+8.1	-2	+23%	-19.18	-0.65	-25.42	+120	-
5M5D-PI	+35.5	-3	+390%	-51.30	-41.88	-30.51	+594	+5%

REFERENCES

-Karvounis, P., Tsoumpris, C., Boulougouris, E., Theotokatos, G. Recent advances in sustainable and safe marine engine operation with alternative fuels. Frontiers in Mechanical Engineering, 8, 994942, doi: 10.3389/fmech.2022.994942
-Datta, A., Mandal, B.K., Impact of alcohol addition to diesel on the performance of combustion and emissions of a compression ignition engine. Applied thermal engineering, 98, 670-682, 2016

Acknowledgements
This study was carried out in the framework of the i-HEATS project, which is funded by the Innovate UK Smart Grants under the grant agreement No 99958. Authors would like to acknowledge CONVERGE CFD company for providing the CFD software.