Achieving Near-Zero Tailpipe Pollutant Emissions in Lean-Burn Ammonia–Hydrogen Co-Fuelled Spark-Ignition Engines via Selective Catalytic Reduction

MariNH3 — Clean, green ammonia engines for maritime

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CONTEXT

NOx → SCR → Unburned NH_3

$$\text{Alpha ratio} = \frac{NH_3}{NOx} = 1$$

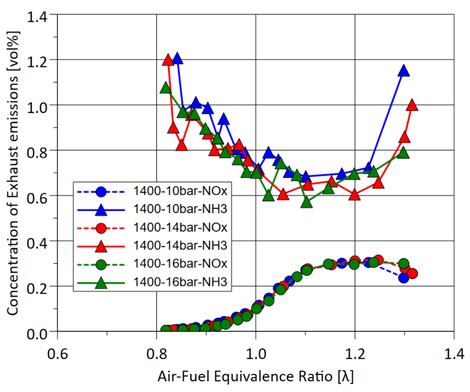
Ammonia engines produce NO_x , Unburned NH_3, N_2O etc as exhaust emissions

SCR- Mature Aftertreatment system uses NH_3 to reduce NO_x

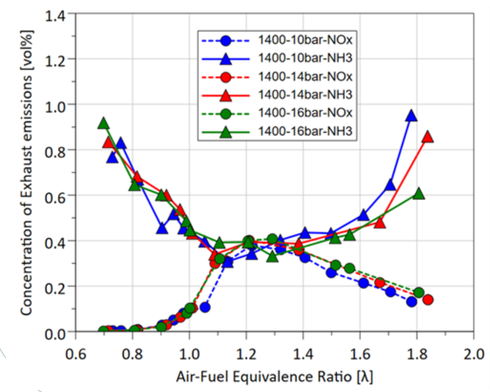
→ Nitrogen & Water Vapor

For the SCR to be most effective, composition of Ammonia to NO_x fed into the SCR often called **Alpha ratio should be =1.**

OPTIMUM OPERATING CONDITIONS TO ACHIEVE ALPHA RATIO =1



Stochiometric Operation on bottled gas leads to high **unburned NH_3** emissions leading to an **Alpha ratio >7**



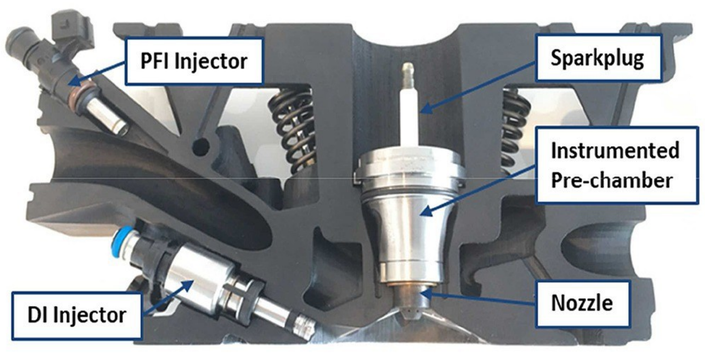
Alpha Ratio =1 operation requires slightly lean conditions **(λ=1.2)**

AIMS AND OBJECTIVES

1. Can this **Alpha =1** approach bring down the unburned ammonia and NOx emissions to below regulatory levels using a SCR?

2. How does this operating strategy along with **SCR impact the N_2O** in the exhaust?

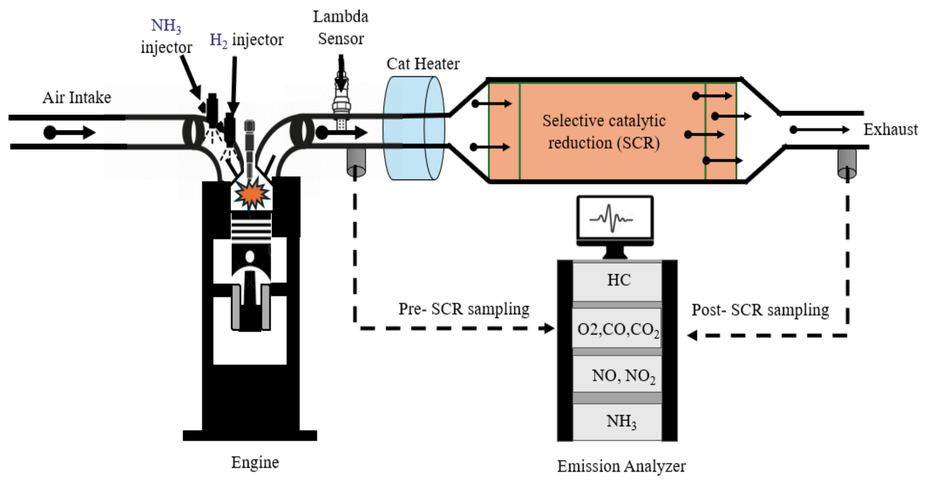
ENGINE HARDWARE



- Long stroke Spark Ignited engine
- High Tumble flow
- Port Fuel injection of NH_3 and H_2
- Capable of operating in SI, Active and Passive Jet Ignition configuration

METHODOLOGY

Schematic of engine integrated with SCR

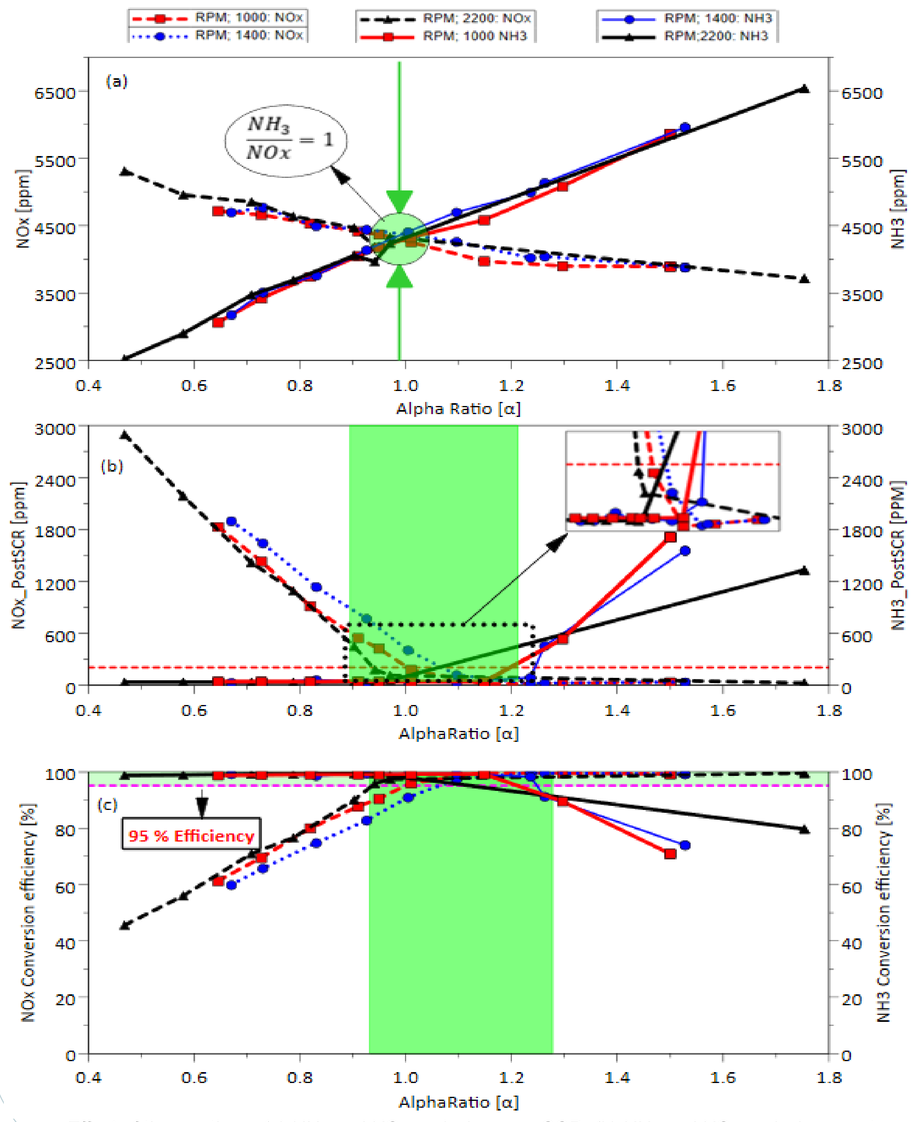


TEST CONDITIONS

Parameters	Value
Engine Temperature	90^{0}C
SCR Temperature	>300^{0}C
Spark Timing	MBT
Lambda	1.2

- Engine-out emissions were sampled both upstream and downstream of the SCR to quantify raw exhaust and tailpipe emissions.
- Gas-phase species were measured using a suite of dedicated exhaust gas analysers.

RESULTS: VALIDATION OF ALPHA=1 WITH SCR



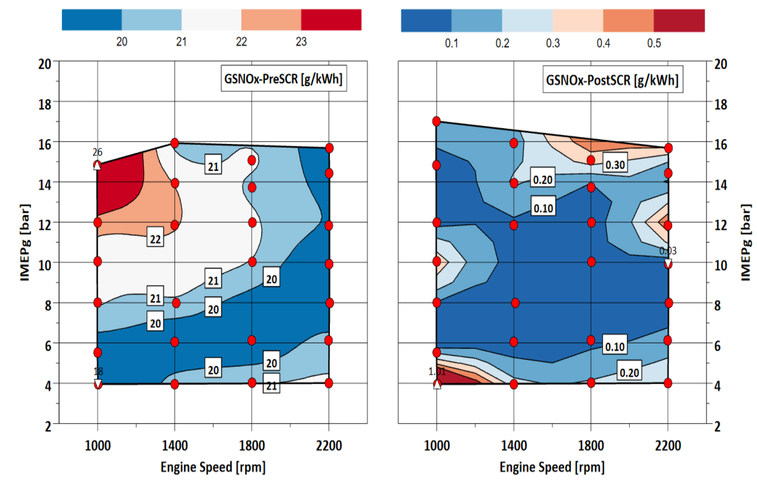
Effect of the α ratio on (a) NH_3 and NOx emissions pre-SCR, (b) NH_3 and NOx emissions post-SCR, and (c) NOx and NH_3 conversion efficiencies under different engine speed conditions.

CONCLUSION

1. Operating the engine at Alpha ratio of **0.9-1.2** results in the **>95%** simultaneous reduction of engine out NOx and Unburned NH_3
2. Emission optimised operation of the engine leads to post SCR emissions of NOx and Unburned ammonia significantly lower than IMO Tier III limits and close to Euro 7 WSHC emission limits in most of the map.
3. N_2O emissions higher than regulatory limits proposed by Euro 7 WHSC and EPA Tier 4 regulations in tested region and isn't affected by SCR.

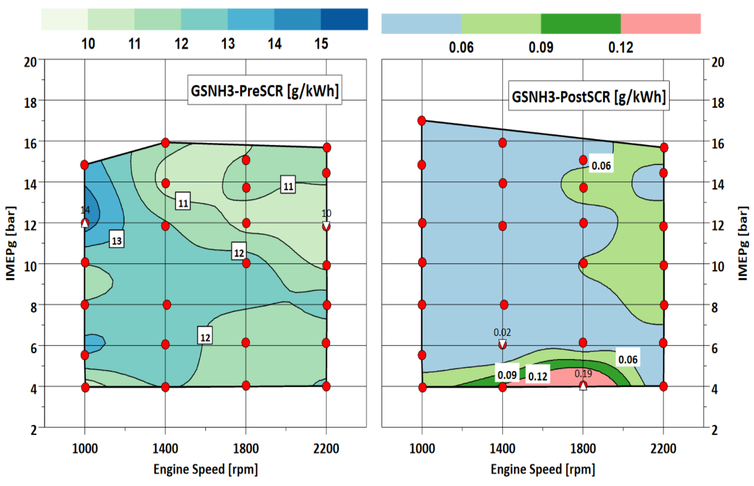
PRE AND POST NO_X EMISSIONS

IMO Tier III	Euro 7 WHSC	EPA Tier 4
2.0 g/KWh	0.2 g/KWh	0.4 g/KWh

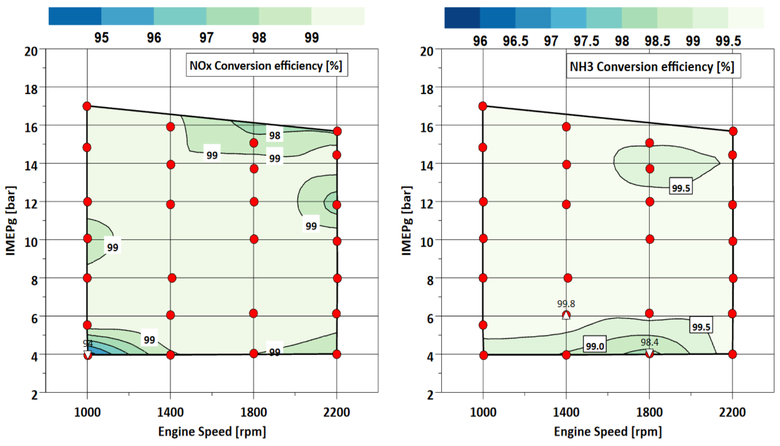


PRE AND POST NH_3 EMISSIONS

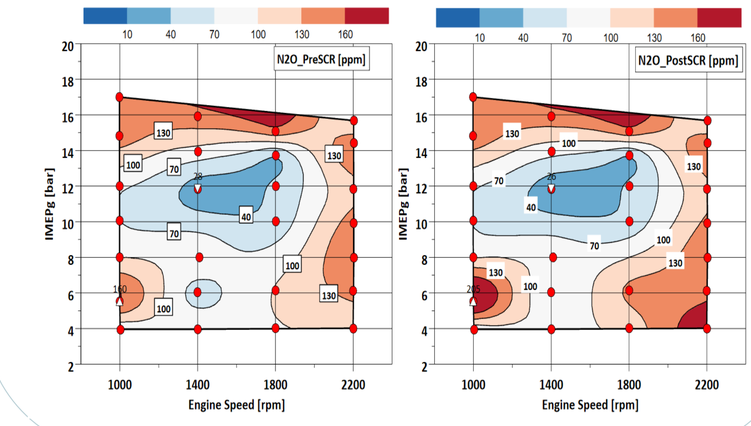
IMO Tier III	Euro 7 WHSC	EPA Tier 4
NA	0.06 g/kWh	10ppm*



NO_X and NH_3 CONVERSION EFFICIENCY



PRE AND POST N_2O EMISSIONS



ACKNOWLEDGEMENT

This work was supported by the Engineering and Physical Sciences Research Council, grant number EP/W016656/1.

The partnership — University of Nottingham UK | CHINA | MALAYSIA — Science and Technology Facilities Council — University of Birmingham — University of Brighton — Cardiff University / Prifysgol Caerdydd

Funded by Engineering and Physical Sciences Research Council

MAHLE Powertrain — HYAMTEC — clean air power — Johnson Matthey