Meeting the next NOx emission challenges

Direct water injection and selective catalytic reduction systems are among the options available for low speed engines

IMO Tier 2 NOx emission limits are expected from 2011 to impose reductions of 10-30 per cent below the current Tier 1 levels, while Tier 3 under discussion for introduction around 2016 could dictate levels 40-80 per cent less than Tier 2. Such stringent maximum emission limits provide a clear focus for R&D by low speed engine designers.

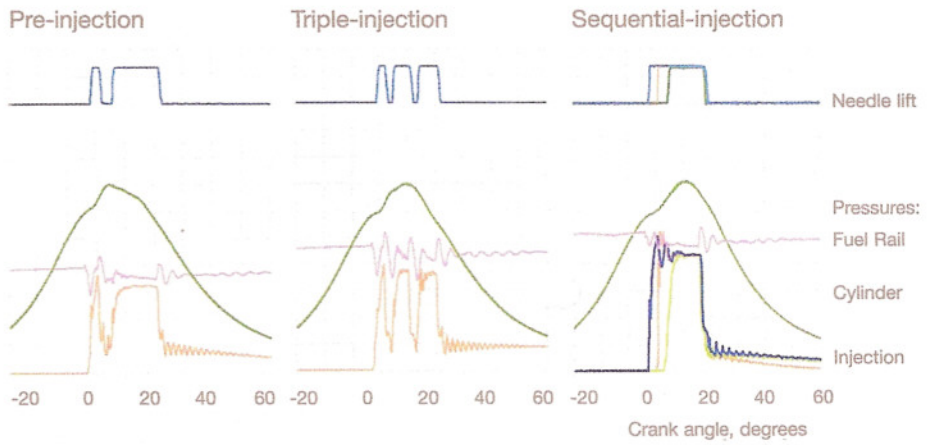
The first approach to reducing NOx emissions, asserts Wärtsilä, is to extend the internal engine measures already implemented to comply with the current IMO Tier 1 limits. These measures include a higher compression ratio, delayed injection timing and adapted exhaust valve timing, along with different fuel nozzles.

Such measures – which can be applied in various combinations according to the degree of NOx reduction necessary for the specific engine type and its rating point – are simple and effective, with no detrimental effect on engine reliability and only minimal impact on fuel consumption.

Extending the established measures as Low-NOx tuning in Wärtsilä RTA low speed engines can yield further reductions in NOx emissions to perhaps five per cent below the IMO Tier 1 limit, while incurring a penalty of some 2 g/kWh in higher specific fuel consumption.

The electronically-controlled common rail fuel injection systems of Wärtsilä RT-flex engines, however, facilitate various injection patterns (see illustration). These patterns can be exploited as a Low-NOx injection option which would be expected to reduce emissions to 15-20 per cent below the Tier 1 limit.

Introducing water into the combustion chamber is another option for NOx reduction, water-fuel emulsions being the longest studied of these 'wet techniques'. Flexibility in setting RT-flex common rail engines eases their adaptation to the requirements of emulsions, the current pumping capacity of the engines making it possible to reduce emissions to some 20 per cent below the Tier 1 limit.

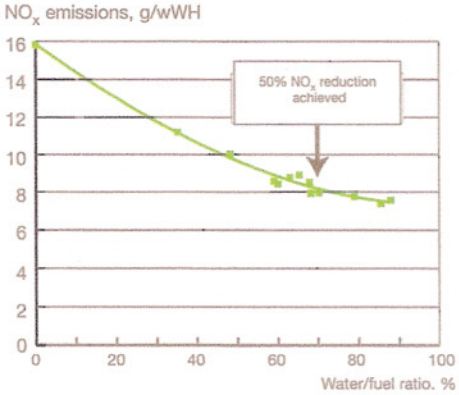


Injection characteristics of three different fuel injection patterns made possible by Wärtsilä's RT-flex common rail system

Alternatively, injecting water directly into the combustion chamber separately from the fuel also lowers NOx emissions. Under development for Wärtsilä low speed engines since 1993, this direct water injection (DWI) technique reduces cycle temperatures and hence NOx formation.

DWI enables the water to be injected at the right time and place to secure the greatest NOx reduction. A fully independent, second common rail system under electronic control is used to inject the water, the quantities injected – if required – being even higher than 100 per cent in relation to the fuel injected.

Water and fuel can also be injected with different timings; for example, the water can be injected in parallel with the fuel or before the fuel during the compression stroke. A DWI-equipped RT-flex engine could be provided with fuel injection that is optimised separately for



NOx emissions measured on the Wärtsilä RT-flex research engine at one load point when using direct water injection with different water-fuel ratios in a common rail system

when water injection is turned on or off.

Tested on Wärtsilä's full-scale low speed research engine in Switzerland, DWI with around 70 per cent water has shown its capability to reduce NOx emissions down to 8 g/kWh (some 50 per cent below the IMO Tier 1 limit). The associated fuel consumption penalty was in the range of 5 g/kWh or less.

Although the DWI system operated for numerous hours on the research engine without problems, even when running on heavy fuel oil, the tests were in no way sufficient for assessing its performance under service conditions, Wärtsilä reports.

Shipboard DWI tests were therefore planned to start this summer linked to one cylinder of an eight-cylinder RT-flex96C container ship engine under normal service conditions. The tests are being carried out as part of the EU-funded HERCULES research project in collaboration with the shipowner. Comprehensive simulation studies for optimising DWI systems formed part of the HERCULES project.

(Whichever 'wet' technique is pursued, Wärtsilä advises, the logistics of providing sufficient fresh water on board have to be considered.)

DWI can be applied alone or in combination with internal exhaust gas recirculation (EGR) as in the WaCoReg (water-cooled residual gas) approach through which Wärtsilä expects to secure up to 70 per cent reductions in NOx emissions below the Tier 1 limit: down to around 5 g/kWh overall.

EGR lowers NOx formation at source by reducing the oxygen available in the engine cylinder and increasing the heat capacity of