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Utilisation of 2-stage turbo charging as an emission reduction mean on a Wartsila 4-stroke medium-speed diesel engine

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Abstract: Needs for lower nitrogen oxide (NO_x) and carbon dioxide (CO_2) emissions are some of the major drivers for future combustion engine development. NO_x emissions can efficiently be reduced by cooling down the combustion process with use of a Miller cycle. But high degrees of a Miller cycle (early inlet valve closure timings) demand high boost pressures. One powerful solution for generating this is to use a 2-stage turbocharging (TC) system which is capable of delivering boost pressures of up to 10 bars. With a 2-stage TC system, the engine efficiency is also improved which results in lower CO_2 emissions as well. The higher engine efficiency is a result of higher TC efficiencies with use of 2-stage TC systems as well as the more optimum division between the compression and expansion strokes in the combustion engine with use of a Miller cycle. Due to this, introduction of a Miller cycle in combination with 2-stage TC is efficiently reducing both NO_x and CO_2 emissions. Investigations have been made with 1-D simulation software for finding out the potential gains with a combination of early inlet valve closure timings (IVC) and 2-stage TC systems. For finding optimal IVC timings at different loads, the investigation was also made with variable IVC. Tests with a 2-stage TC prototype system, extreme Miller timings as well as shorter scavenging periods have been made on a Wärtsilä 20 engine. These results are compared against the simulation results and against pre-tests made with a 1-stage TC system for pressure ratios up to 6.2 bars in combination with medium Miller timings. Design of the prototype system, as well as changes needed to the current engine construction due to the considerable increase in boost pressure levels and due to the additional auxiliary technologies needed for operating the engine are also shown and discussed in this paper. Simulations, and assumptions made after the same, were confirmed by tests and the following was achieved with 2-stage TC technology in combination with early IVC timings on a Wärtsilä 20 engine:

- NO_x reduction of up to -50% with extreme Miller timings
- BSFC improvement possibility confirmed
- Thermal load improvement at upper load range due to high air/fuel ratios but worse part load behaviour due to restricted air flows
- Load acceptance and smoke emissions got worse but a Variable Inlet valve Closure (VIC) system offers the solution