**Utilisation of 2-stage turbo charging as an emission reduction mean on a Wärtsilä 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 scav-}

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