Application of Electric Water Pumps on a Heavy-Duty Diesel Engine

Forschungsgesellschaft für
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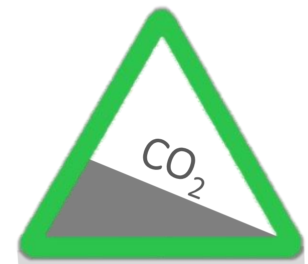
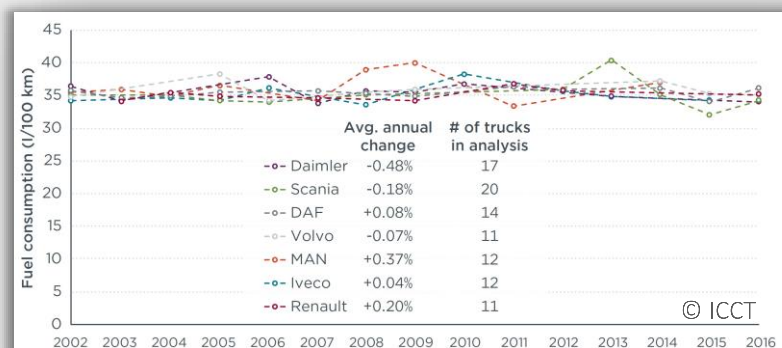
Motivation



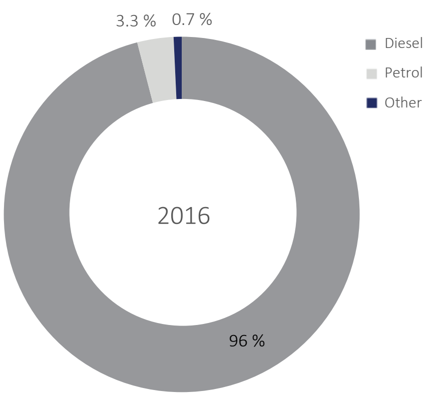
- Environmental aspect → need for CO_2 reduction
- Pollutant emission regulations led to a long period of stagnation of fuel consumption for HDVs
- From 2019: mandatory fuel-efficiency standards for HDVs (VECTO) require 30 % less CO_2 emissions in 2030
- Investigations of potential efficiency increasing technologies



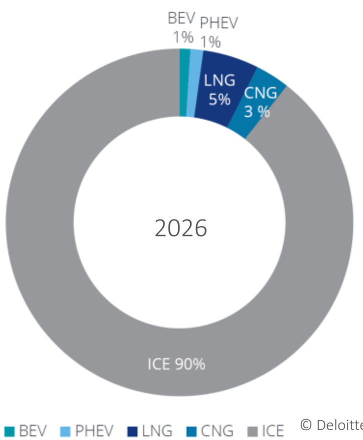
Heavy-Duty Vehicles | Long Haul Trucks

Trends

- 2016: 96 % of all registered trucks and tractor-trailers in Austria have a Diesel powertrain
- 2026: 90 % of long haul trucks still expected to have an ICE powertrain
- Purchase criteria
  - Fuel efficiency
  - TCO
- Investigations of concepts that
  - are short-term technically feasible.
  - have an attractive payback period.
- Electrification of auxiliaries as technology built on robust and well-proven powertrain systems



Quelle: Statistik Austria (Lkw-Neuzulassungen 2017)



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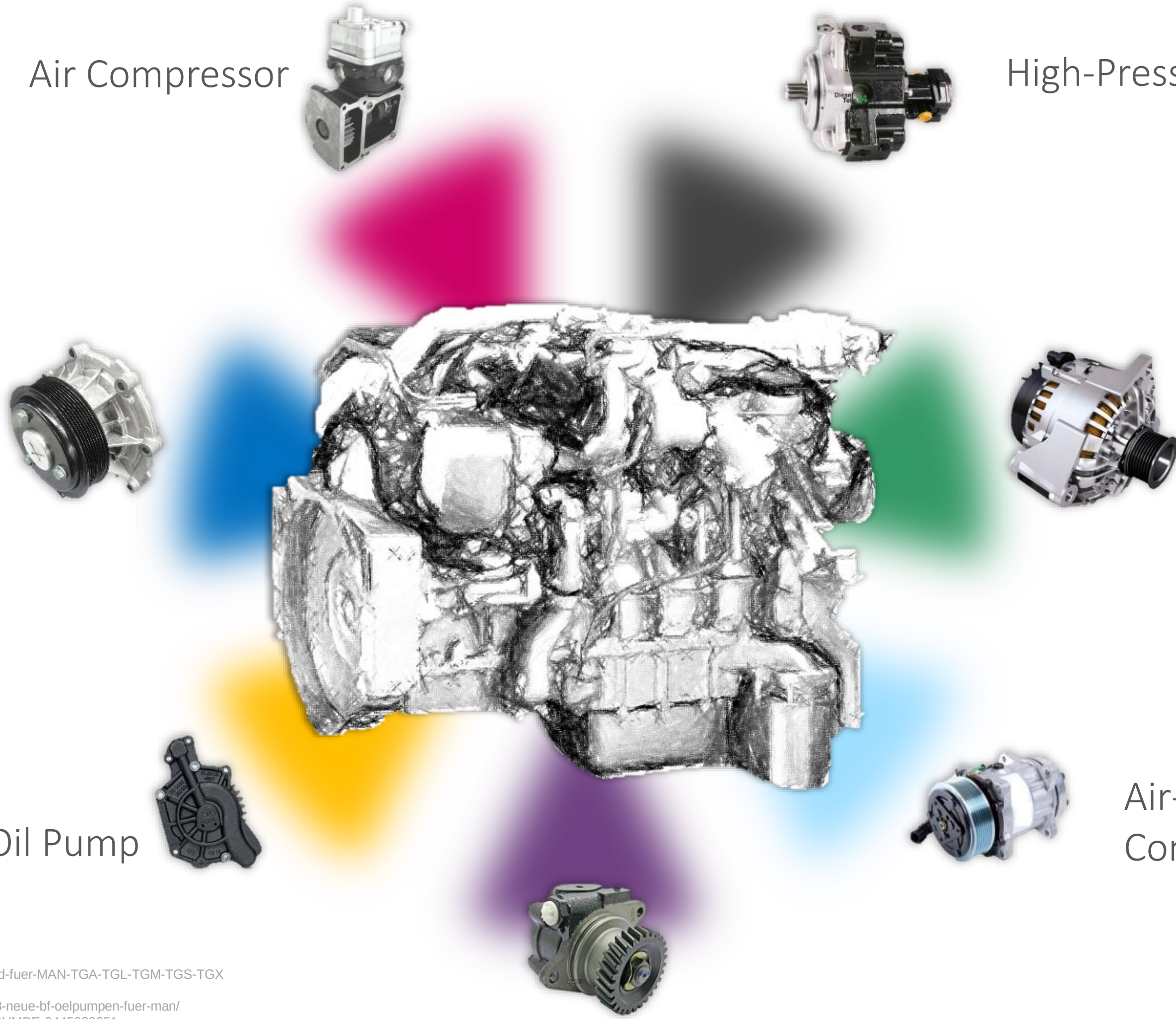
Engine Auxiliaries



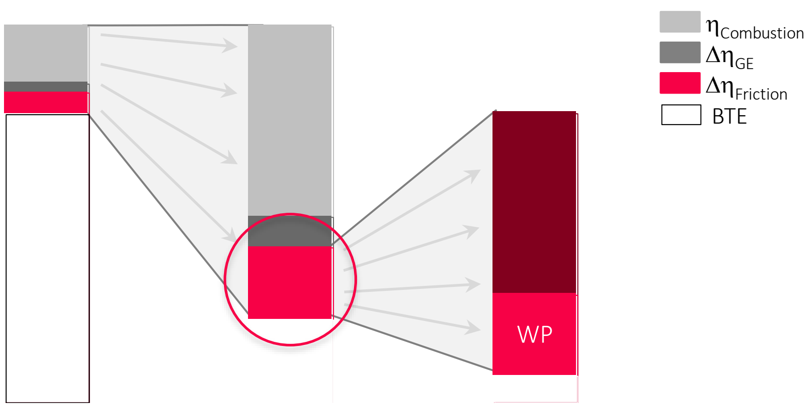
Quelle: https://www.lkw-teile24.de/Klimakompressor-passend-fuer-MAN-TGA-TGL-TGM-TGS-TGX
Quelle: Isuzu Lenkhilfepumpe
Quelle: https://www.ms-motorservice.com/technipedia/post/3-neue-bf-oelpumpen-fuer-man/
Quelle: https://www.dieselpumpen.net/MAN-HOCHDRUCKPUMPE-0445020051
Quelle: http://hesed.info/blog/man-kompressor.abp
Quelle: https://de.bosch-automotive.com/de/parts_and_accessories/specials_1/commercial_vehicle/electrical_system/alternators/alternators_1

Electrification of Auxiliaries

Water Pump

- Energy consumption of the auxiliaries is contained in the friction losses
- Rigid coupling of auxiliary drivetrain with belt-drive of engine → no variability in operating conditions
- Demand-controlled operation as key element to reduce parasitic losses
    - ➢ Decoupling of water pump speed from engine speed

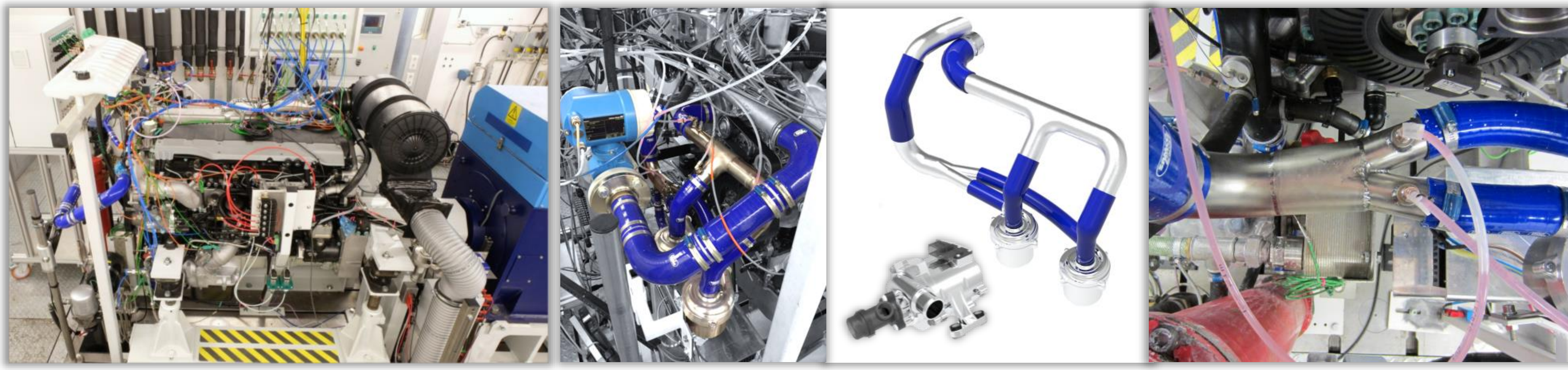
$n = 1200\ min^{-1}$
$p_e = 10$ bar

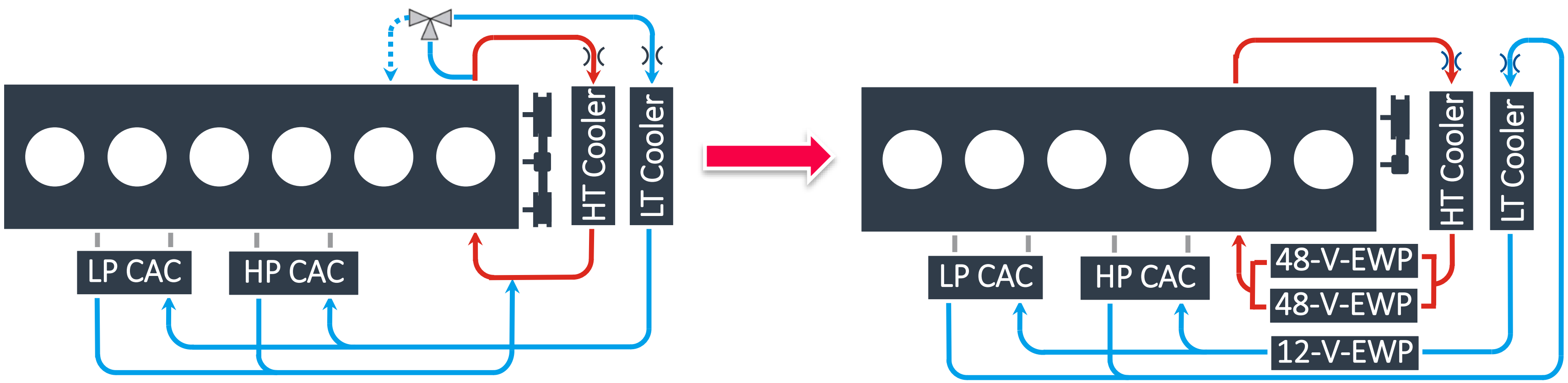


- ➢ Water pump accounts for 21 % of friction losses at $n = 1200\ min^{-1}$
- ➢ Maximum volume flow rate not necessary for part load operation

Engine Dynamometer

Electric Water Pump

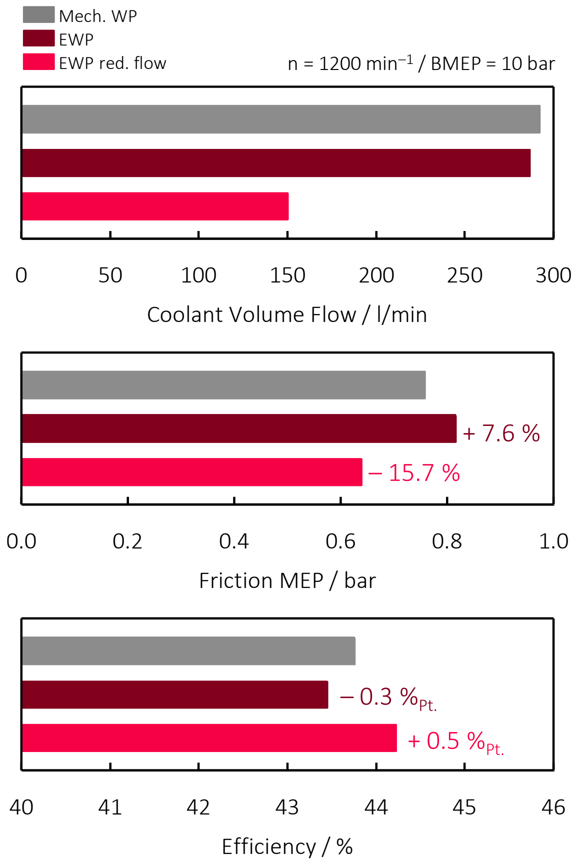




Experimental Investigations

Mechanical vs. Electric Water Pump

$n = 1200\ \text{min}^{-1}, p_e = 10\ \text{bar}$



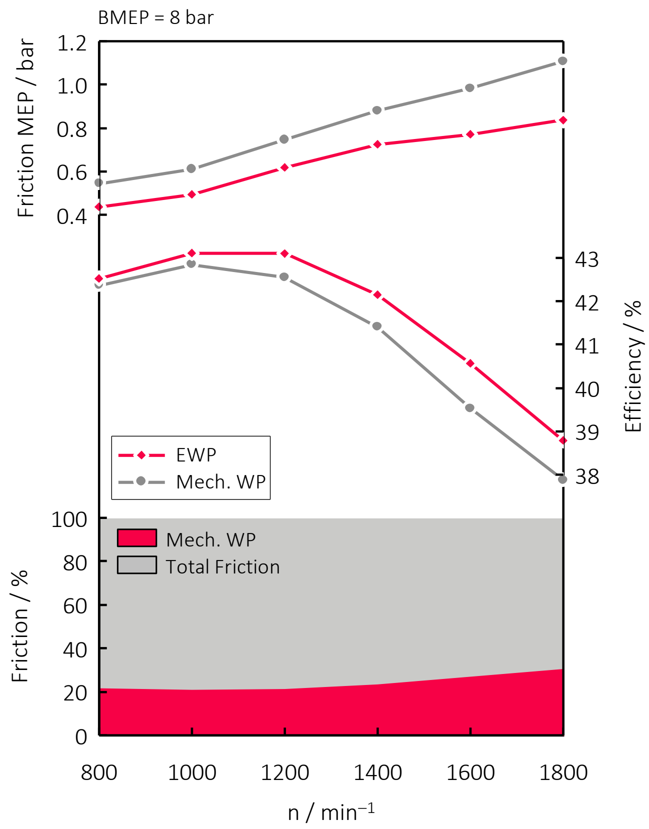
- Cooling system designed for worst case conditions
  - Low speed with full load and high ambient temperatures
  - Rated power at high ambient temperatures
- Unnecessary high flow rate for part-load operation due to rigid coupling to engine speed
- EWP offers full variability in operating speed
  - Demand-controlled coolant flow rate
- Operation at same conditions as mechanical WP is unfavourable

➢ Reduction of coolant flow rate

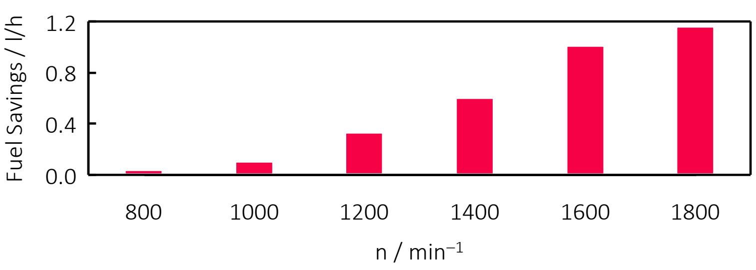
Experimental Investigations

Mechanical vs. Electric Water Pump

Speed Sweep $p_e = 8$ bar



- Share of mechanical WP on total friction losses rises with speed
- Volume flow rate in EWP configuration is half of series value
- Reduction in friction losses up to 24 %
- 0.9 $\%_{Pt.}$ benefit in brake thermal efficiency η_e



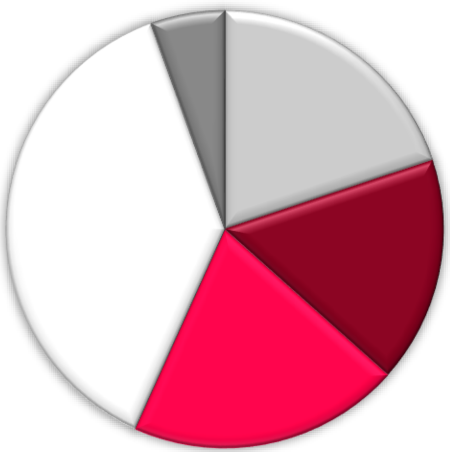
Experimental Investigations

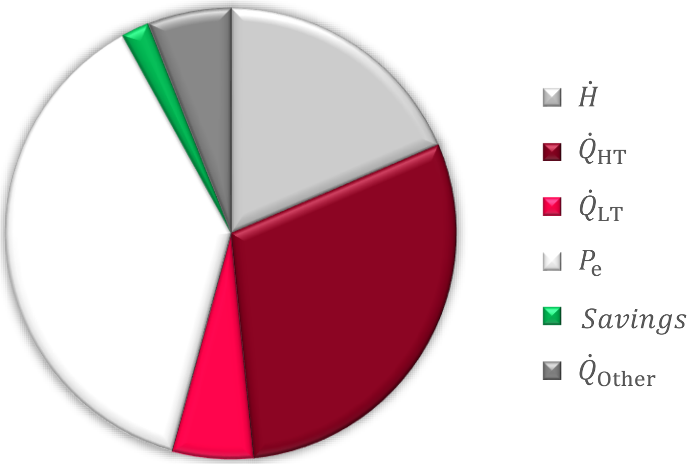
Separation of Cooling Circuits

$n = 1800\ \text{min}^{-1}$, $p_e = 8$ bar

- Basis configuration with two linked cooling circuits
  - High temperature (HT) circuit as main cooling circuit
  - Low temperature (LT) circuit for charge air cooling

- Modified configuration with EWP and separated cooling circuits
  - One 12-V-EWP in LT circuit
  - Two 48-V-EWPs in HT circuit
- Total heat dissipation is equal
- ➢ 2 % less fuel consumption

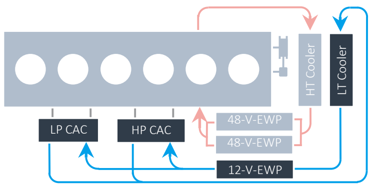


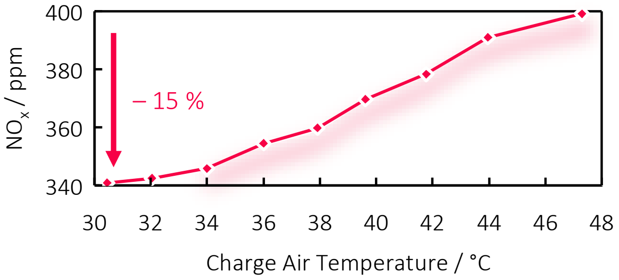


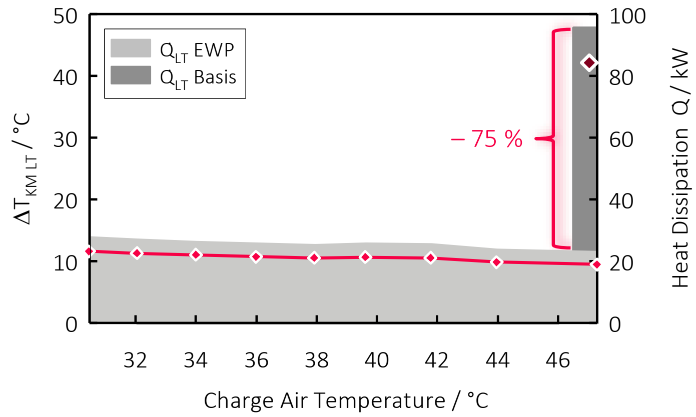
Experimental Investigations

Low Temperature Circuit

$n = 1800\ \text{min}^{-1}, p_e = 8\ \text{bar}$



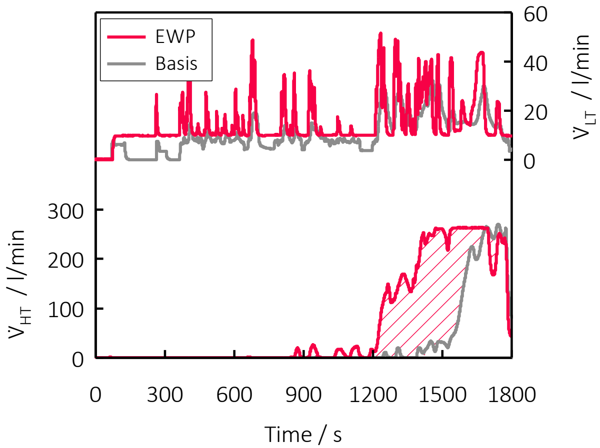




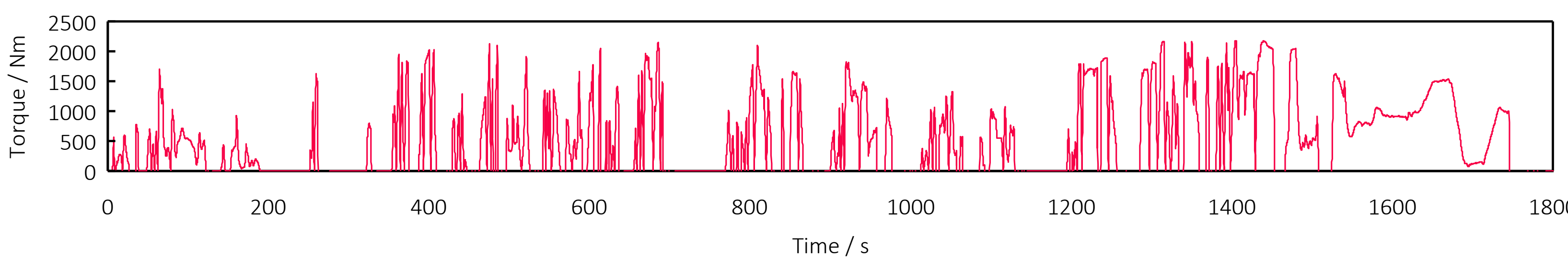
- CAC integrated in low temperature (LT) circuit
- Basis configuration: LT and HT circuit mixed before LT outlet
  - Higher temperature spread over LT cooler
  - Maximum possible heat dissipation in LT cooler as limiting factor
- Separation of cooling circuits leads to a 75 % reduced load of LT cooler
  - Charge air temperature T_{CAC} can be decreased
  - ➢ Reduction in temperature facilitates 15 % savings of NO_x engine-out emissions

Experimental Investigations

Transient Operation



- Evaluation of warm-up behavior in WHTC
- Coolant flow in HT circuit represents opening of thermostats.
- Separation of cooling circuits leads to an elimination of support in heat dissipation of HT cooler.
  - Coolant in HT circuit heats faster
  - Faster warm-up of engine



Summary

- A heavy-duty diesel engine has been set up on an engine dynamometer with electric water pumps.
- LT- and HT-circuit have been separated and operated with different EWPs.
- In the highway load point a benefit in η_e of 0.5 $\%_{Pt.}$ was obtained.
- Friction losses can be reduced by 24 % at rated speed.
- Heat dissipation is shifted from LT- to HT-cooler.
- Reduced thermal load in LT-cooler facilitates possibility to reduce charge air temperature level.
- Improved thermal management with regard to demand-controlled operation of EWP (faster warm-up in transient operation)

Thank You.