E-Turbo

Challenges and solutions:

Turbo lag affects drivability and Real Driving Emissions. It is addressed, but not completely eliminated, with known compromises in turbo matching and design, that are detrimental to the engine fuel efficiency. Turbo lag is due to a temporary lack of turbine power, caused by too low enthalpy in the exhaust gas, at the begin of load steps.

The issue is addressed in the project by designing the E-Turbo for operation in motor mode: Electric power replaces the missing turbine power input. It is converted directly to compressor shaft power. The so augmented air mass flow, enables a more efficient combustion and faster build-up of fuel injection. The enthalpy in the exhaust gas increases. The supply of electric power is reduced progressively and eventually switched off.

There is always excess enthalpy in IC engines at higher loads, that is wasted by opening a WG or applying the VNT to an opening beyond the optimum efficiency point.

The issue is addressed in the project by designing the E-Turbo for Waste Heat Recovery (WHR) in generator mode: The turbine is operated at its optimum efficiency point, the resulting excess of shaft power is converted directly to electric power by the MGU on the turbo shaft. However, the engine pumping losses increase, with increasing turbo work: The optimum balance between gained electric power and lost gas exchange power is to be found.

Designing the E-Turbo for WHR increases the pressure in the exhaust manifold to values that are higher than the pressure in the inlet manifold. Higher EGR rates can be driven than with a conventionally matched turbo, new optima must be found.

Engine fuel consumption and pollutant emissions must both be reduced further, to achieve the CO_2 reduction targets set by the European Commission for 2025-2030.

IMPERIUM's contributions:

The E-Turbo prototype demonstrates flawless operation in motor mode on the engine dyno. Already with the tested open loop control, there are no overshoots of turbo speed, the increase is perfectly linear function of the electric motor torque only.

The optimum balance between recovered enthalpy and pumping losses is investigated in the project, the optima are identified as minima of BSFC. The tested prototype recuperates up to 25 kW electric power from the exhaust gas. Depleted from the pumping losses, several kW's are dumped in the battery emulator of the test cell.

The BSFC minima are investigated on several NOx emission levels. The engine configuration can be adapted to the capabilities of the After Treatment System (ATS).

Impact / what's next:

The impact of E-Turbo motor operation on RDE emissions and engine efficiency during load steps is to be quantified in test on transient dyno.

1 to 2.5 % BSFC reduction is achieved in engine testing, depending on engine speed and load. BSFC reduction increases with increasing MGU power. The trade-off between BSFC gains and MGU / Inverter size and cost is to be investigated, taking into account all the possible adaptations of the E-Turbo aerodynamic configuration.

The efficiency of EGR driving with the E-Turbo is demonstrated. In a next step the engine EGR configuration and the E-Turbo aerodynamics must be optimized for the expected next generation ATS.

The powertrain must be equipped in the next development step with an MGU-K to recycle the power that is recovered by the E-Turbo from the exhaust gas.

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