Licentiate-Presentation:

”A Two-Stroke Range Extender Engine for Heavy Duty Battery Electric vehicle applications”

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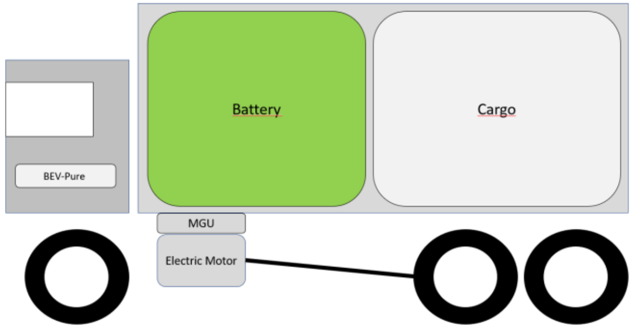
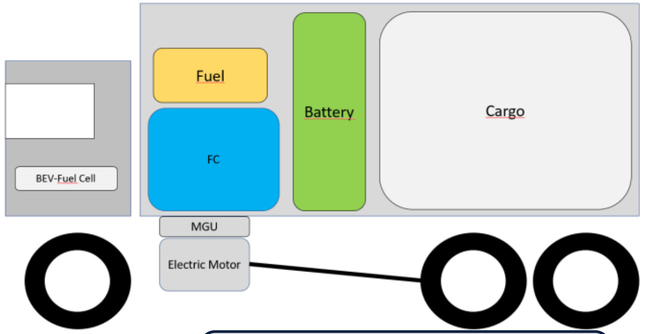
Agenda:

- Introduction
- The idea
- Research questions
- Methodology
- Results
- Conclusions
- Further work
- Aknowledgement

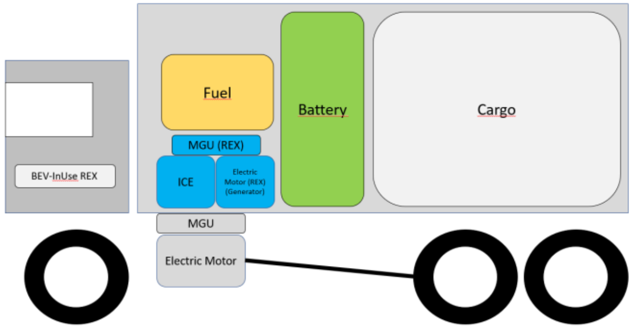
Introduction



Pure-BEV

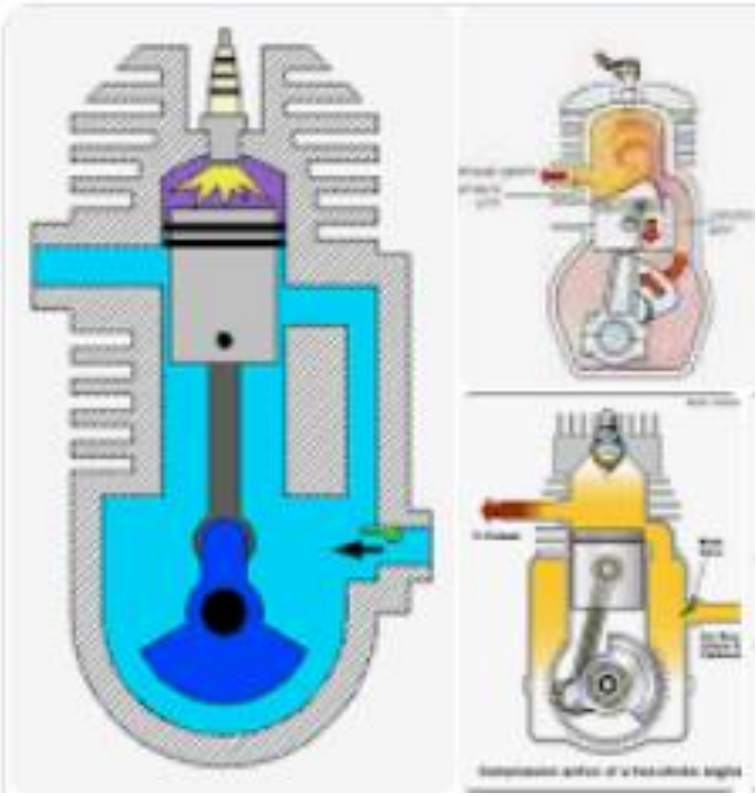


Fuel Cell-BEV

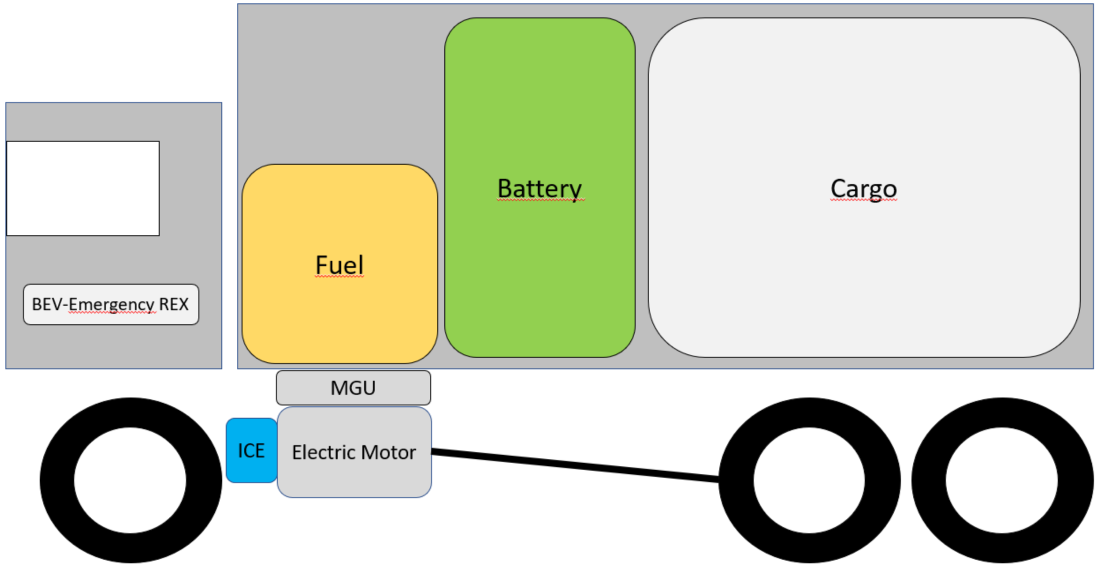


REX-BEV

Introduction

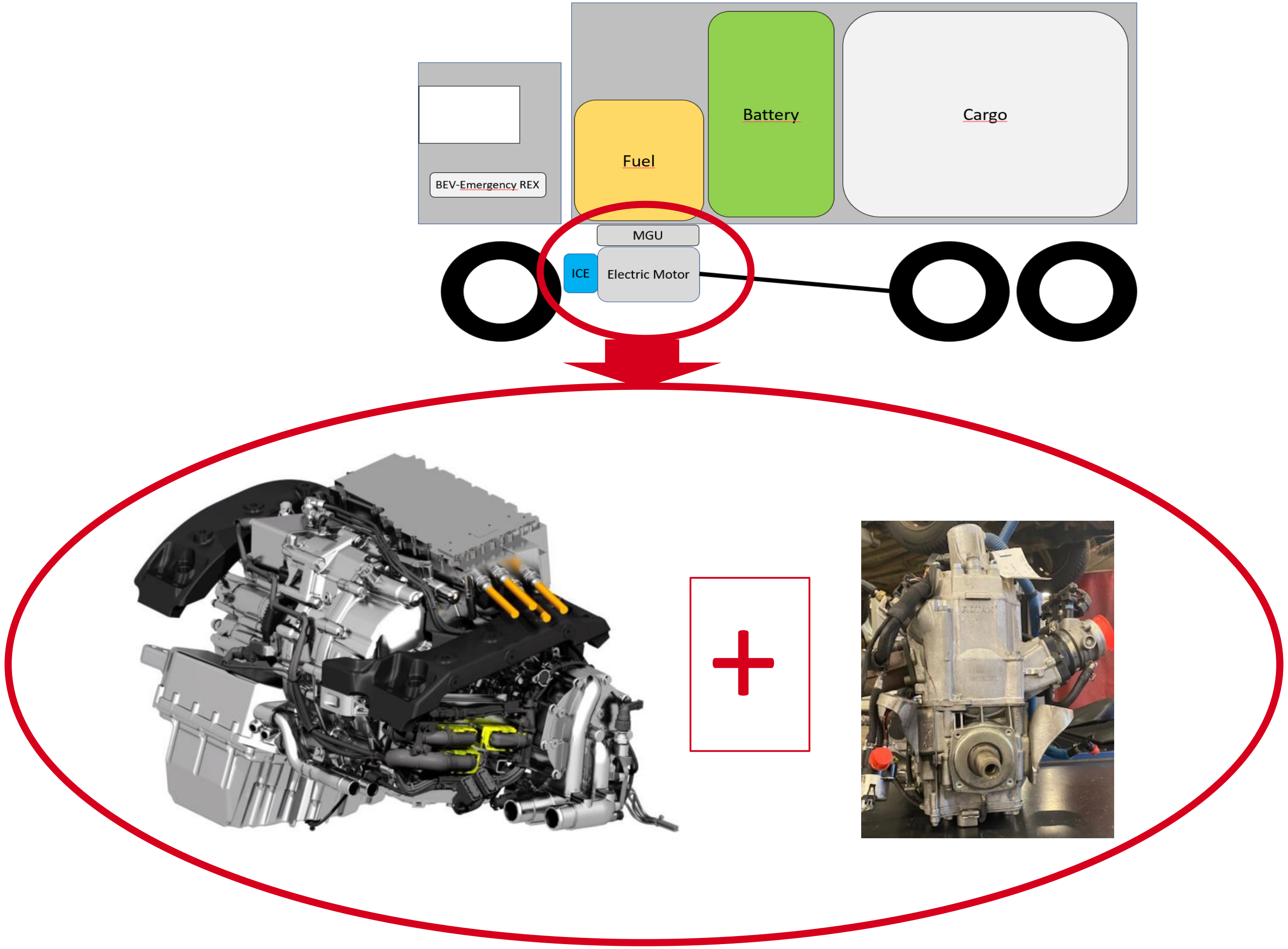


The idea



Two-Stroke Back Up REX-BEV

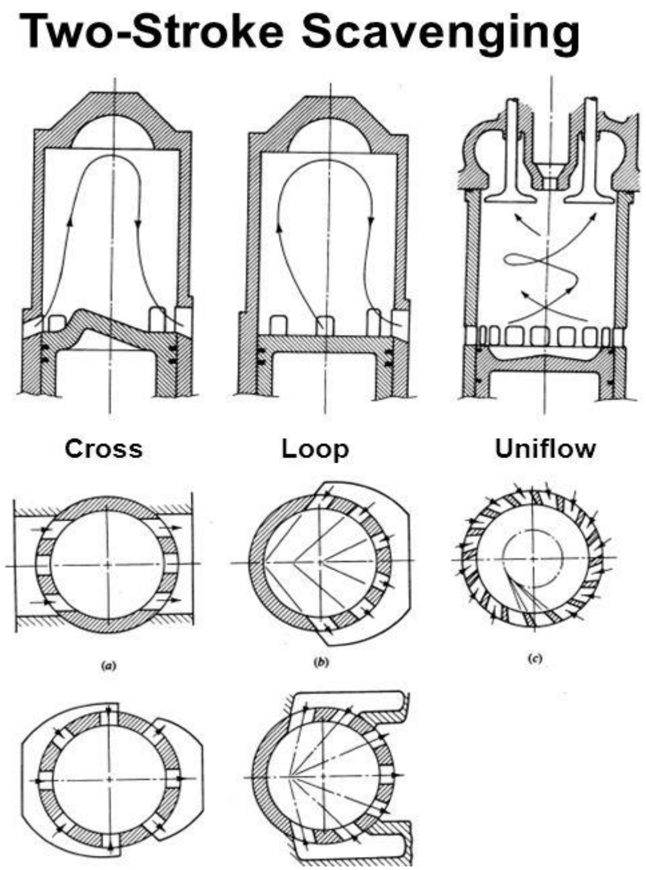
The idea

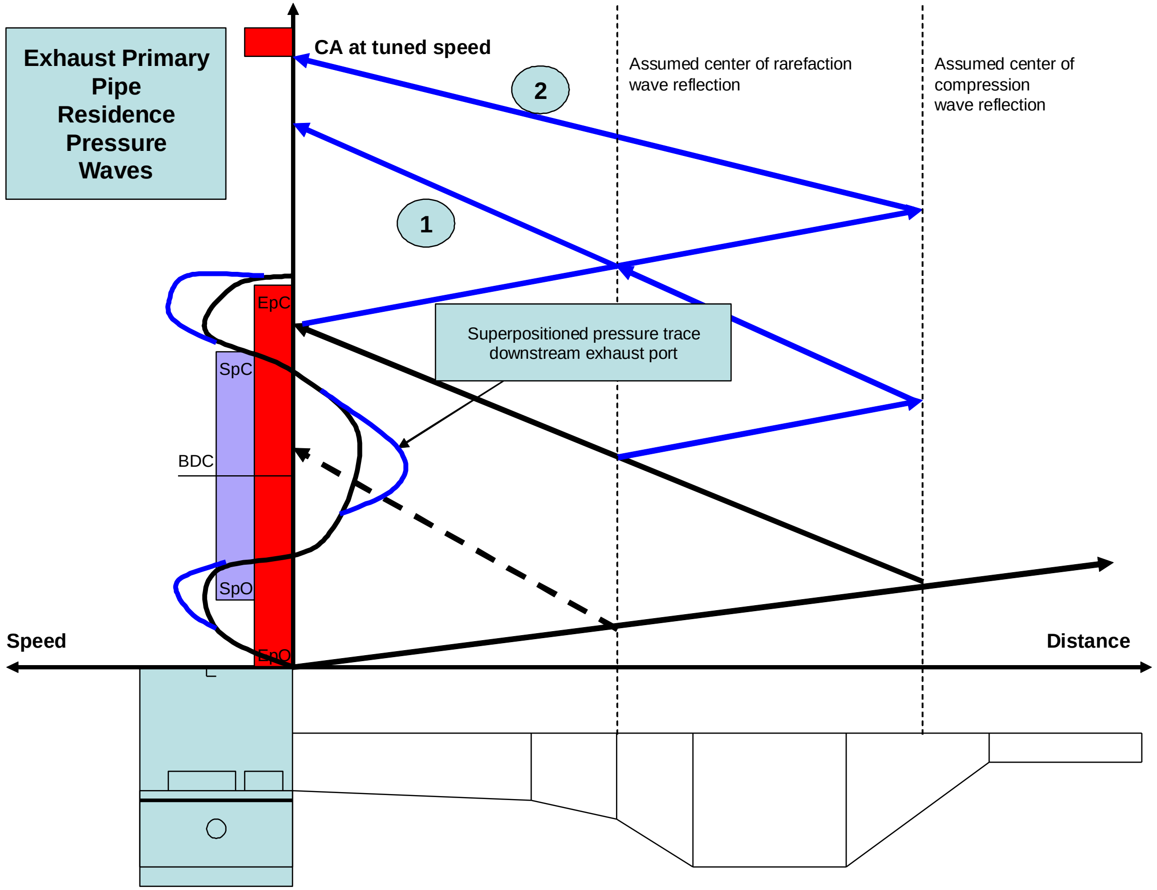

BEV-Emergency REX
Fuel
Battery
Cargo
MGU
ICE
Electric Motor

Research questions

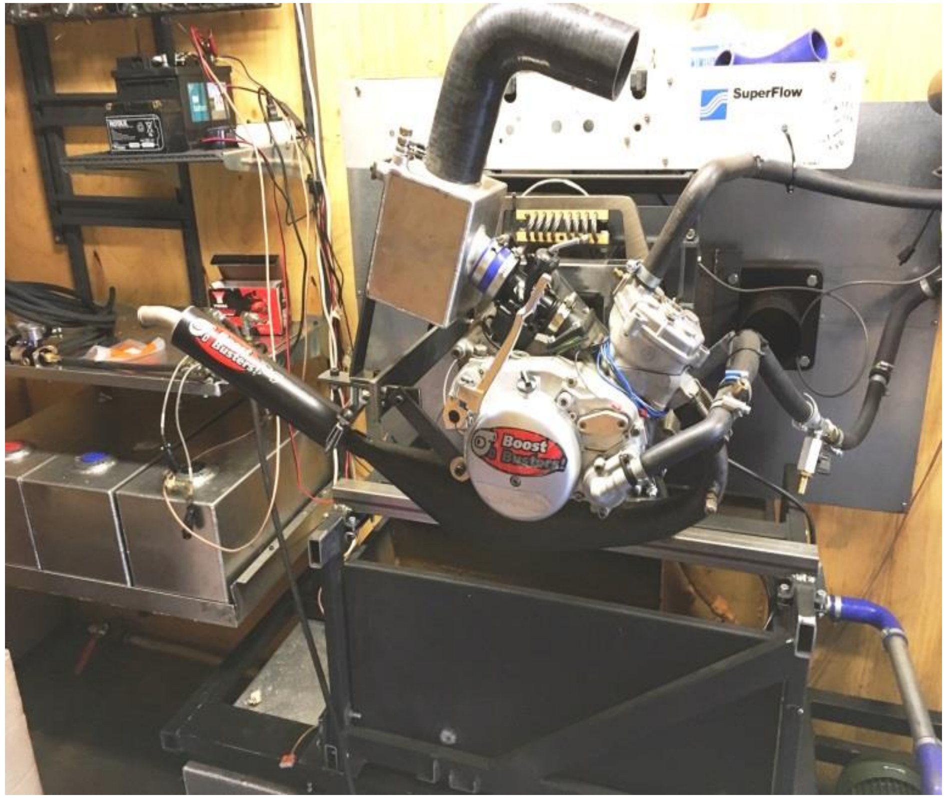
- Back-up Range Extender
- Develop a (turbo) charging system for a single cylinder crank case scavenged two-stroke SI-engine
- Charging system interaction with the two-stroke gas exchange
- Turbocharger fundamentals and selection of concept
- Model- and experimental results for the final concept

Two-stroke gas exchange basics

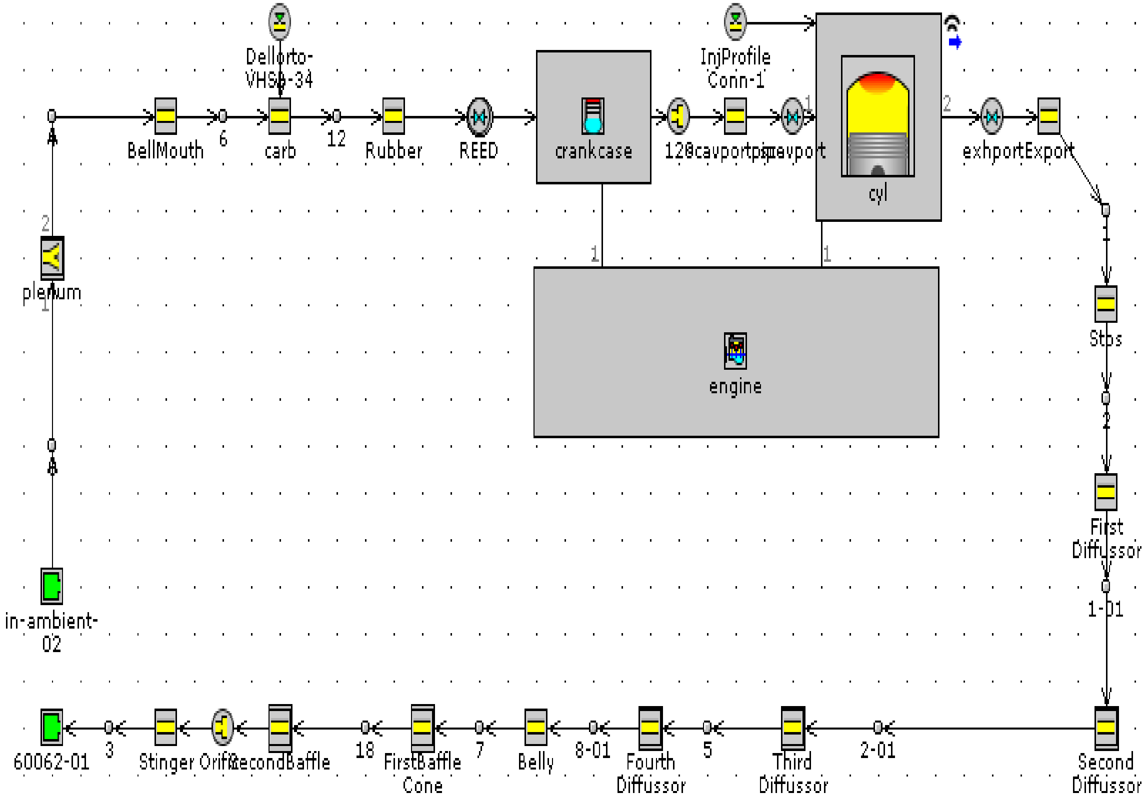




Methodology:
Experimental engine and dyno testing and 1D engine simulation



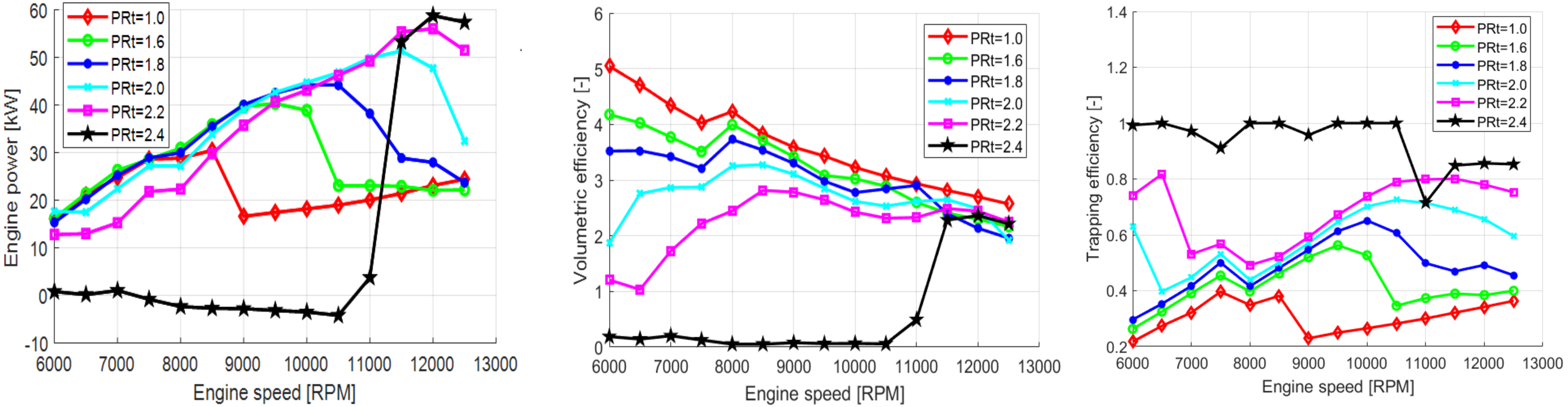
A single cylinder motorbike engine at 125cc swept volume and 30 [HP] was used in the engine dyno experiments



Engine experiments were utilized to calibrate a 1D engine model equiped with variable pressure boundaries to simulate different supercharger and turbocharger system

Results

Exploring the optimum boost- and exhaust pressures for the two-stroke engine with the help of 1D engine simulations

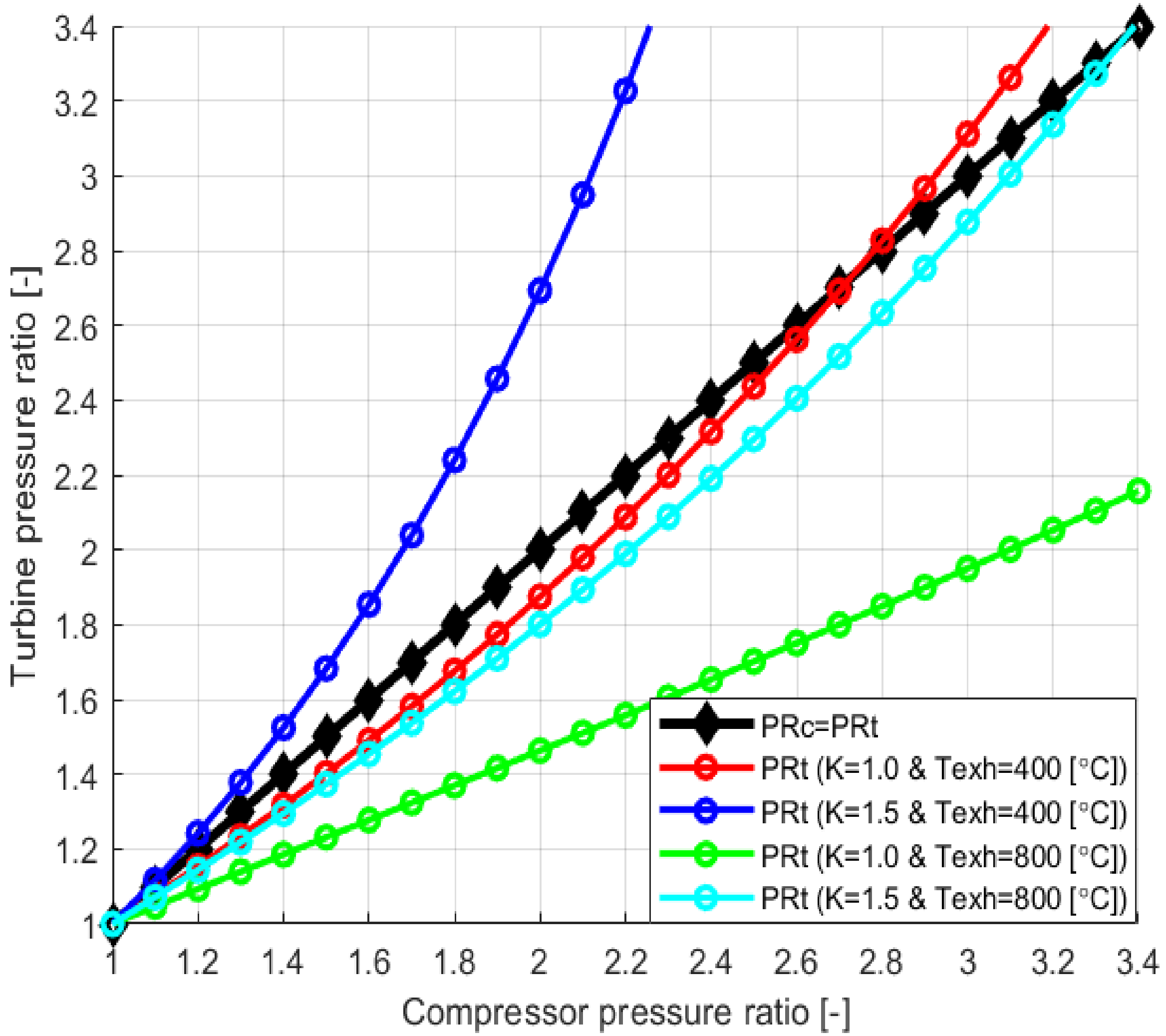


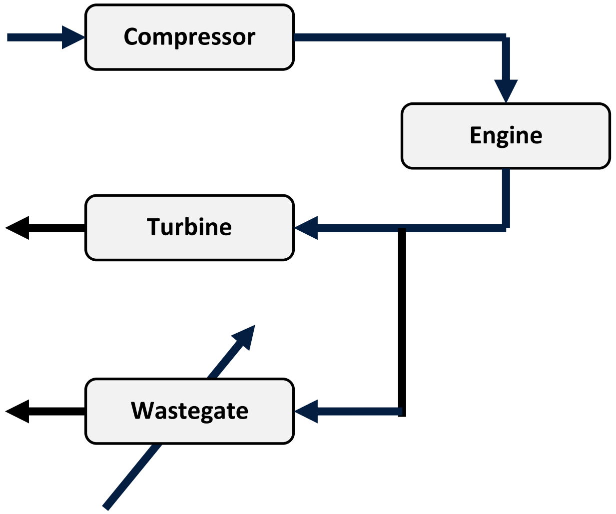
Engine simulations were carried out with a boost pressure of 2.0 [bar a] and the exhaust pressure was varied between 1.0–2.4 [bar a]. The pressures were applied independent of engine speed.

A boost pressure of 2.0 [bar a] in combination with an exhaust pressure of 2.0–2.2 [bar a] was considered to optimize the gas exchange.

This pressure balance will not be achieved with a mechanical driven compressor (supercharger) but can be achieved with an optimized turbocharger system.

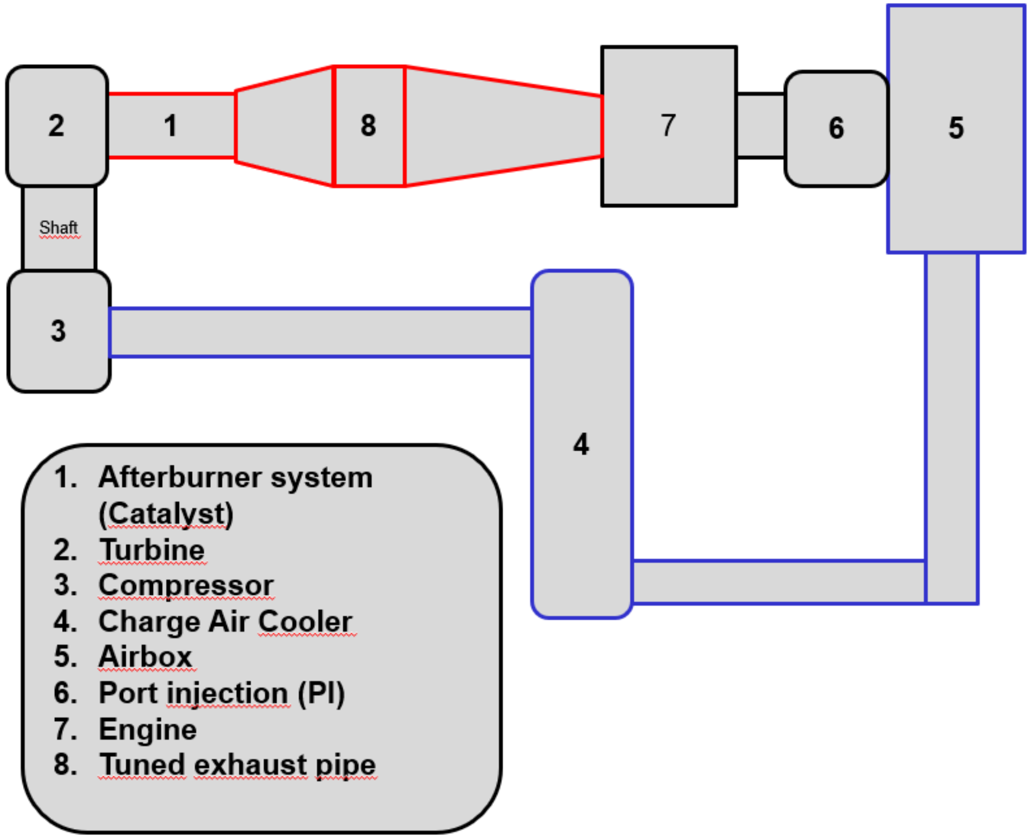
Turbocharging challenges to obtain the desired pressure balance





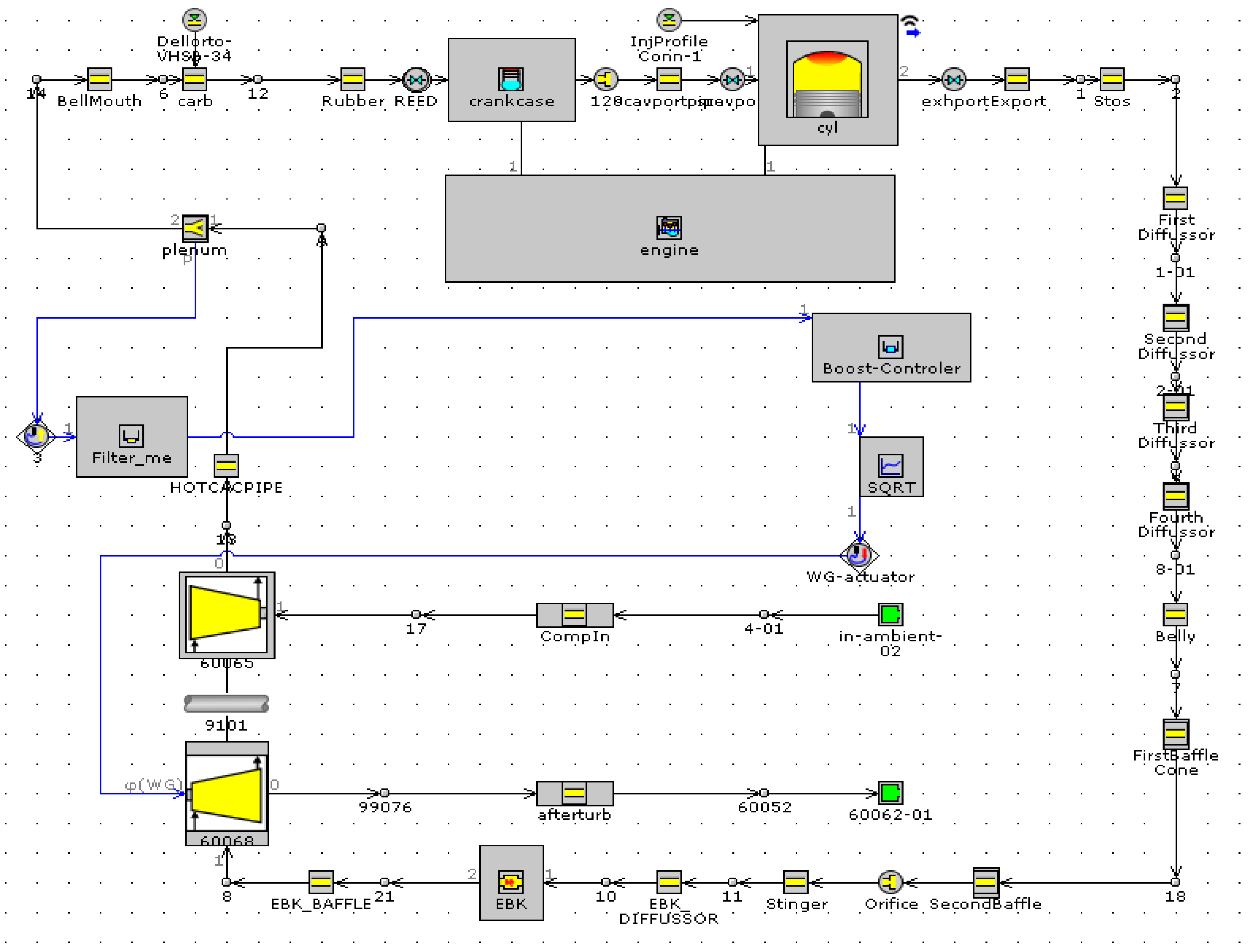
Power equilibrium over the turbocharger and isentropic assumptions can be utilized to express the turbine pressure ratio as a function of the boost pressure
.
The different efficiencies, wastegate-ratio and exhaust temperature have a strong impact.

Turbocharging supported by an afterburner system (EBK)



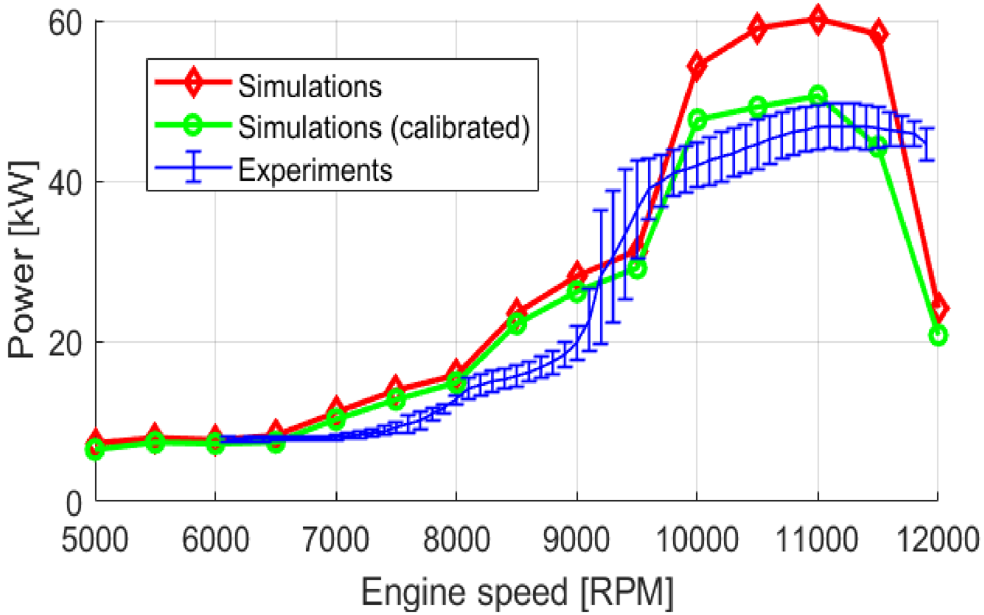
The two-stroke engine is exhaust temperature limited because of the piston controling the exhaust port and great heat losses over the large tuned exhaust pipe. But the exhaust gases contain both air- and unburned fuel (HC) which can be converted to heat upstream the turbine using an oxidation catalyst hereby aso named afterburner.

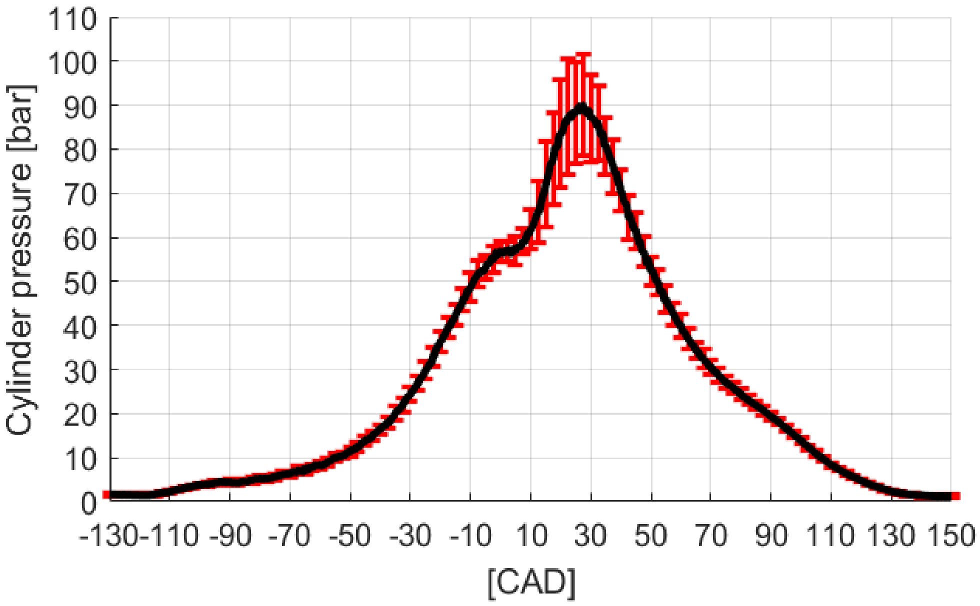
The 1D engine simulation is expanded…

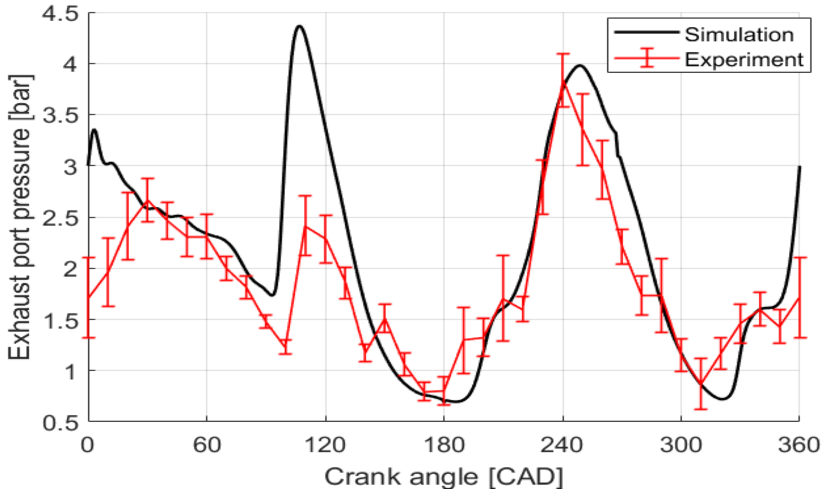


The 1D engine model is now developed with turbocharger- and heater object to come closer to a real afterburner assisted turbocharger system.

Prove of concept

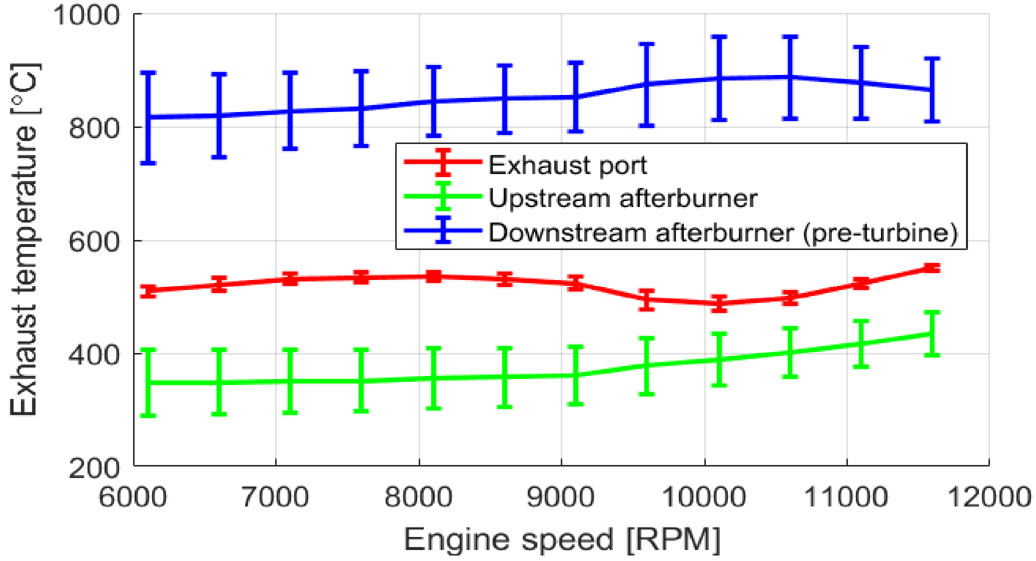


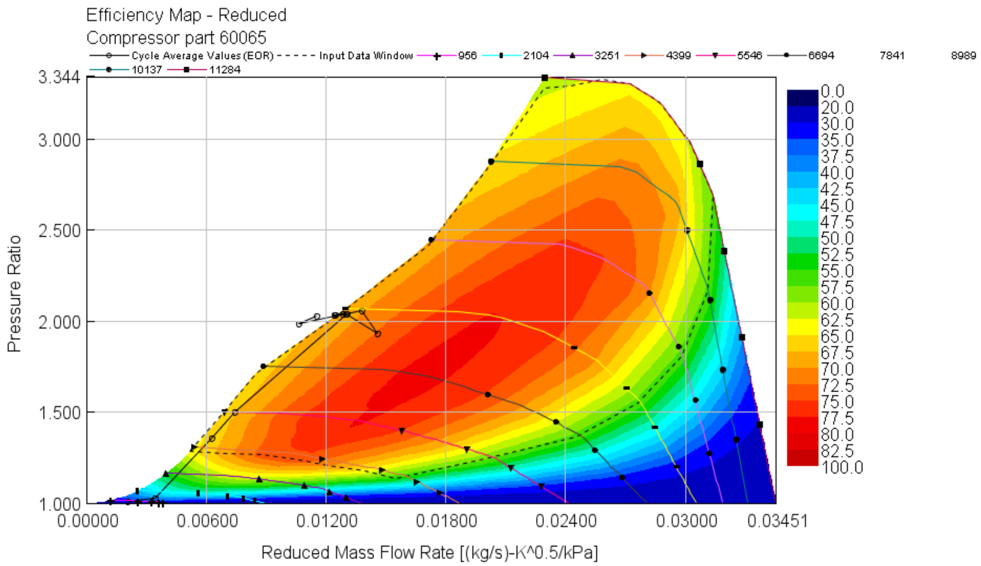




Once the heat release model was calibrated using cylinder pressure traces the correlation was acceptable to indicate that the concept works. Also exhaust pressure traces was collected to calibrate the tuned effects from the exhaust pipe.
The power level is increased from 22 [kW] to 50 [kW] or 400 [kW/L]

Prove of concept

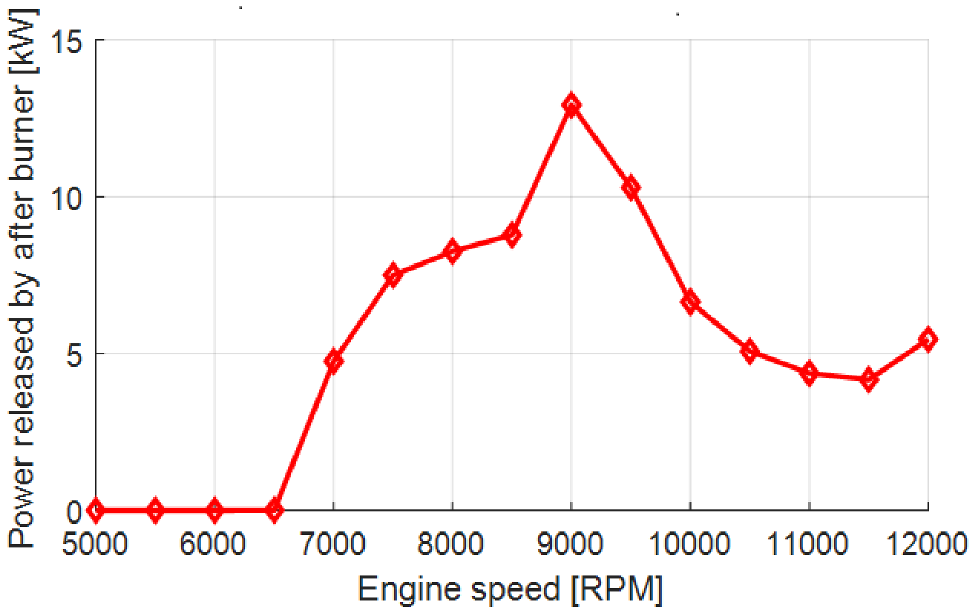


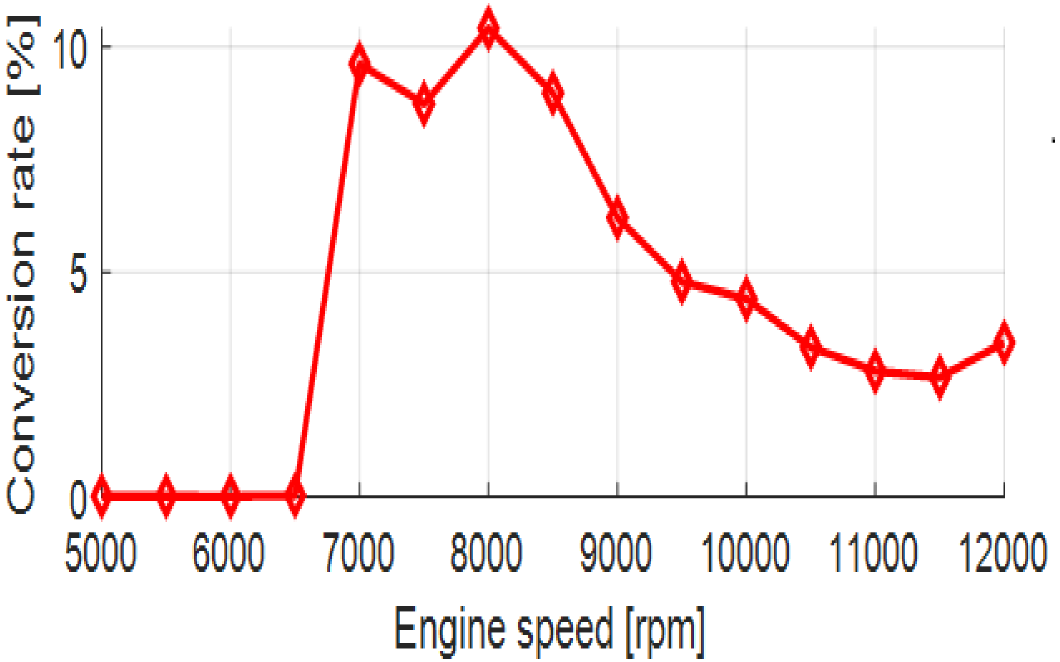


The afterburner assisted turbocharger system makes it possible to ”over scavenge” the engine to lower the exhaust port temperature while the pre turbine temperature can be maintained at a decent 800 degC temperature. Not bad for an engine putting out around 50 [kW].

The turbocharger needs to be selected based on the turbine swallow capacity. Since the turbocharger used in the experiments was intended for a four-stroke engine in combination with larger wastegate-ratios, the compressor is operated to close to the surge line.

Prove of concept





Only a fraction of the available air and HC needs to be utilized in the afterburner system to obtain the desired exhaust temperatures into the turbine.

Conclusion

- A single cylinder two-stroke engine is small enough to install directly onto the existing electric mahine in a heavy duty battery electric vehicle as a back up range extender.
- This thesis have shows that an afterburner assisted turbocharger system can be optimized to increase the specific power to 400 [kW/L] indicating that a 400-425 [cc] engine can deliver the 150 [kW] needed to recharge the batteries on a heavy duty battery electric vehicle.
- A supercharger is not a good charging system for a two-stroke engine.
- The afterburner turbocharging system will create lower exhaust port temperatures in combination with higher exhaust temperatures upstream the turbine which will be a benefit for the engine structural stresses.
- The afterburner system will also reduce the HC exhaust emissions.

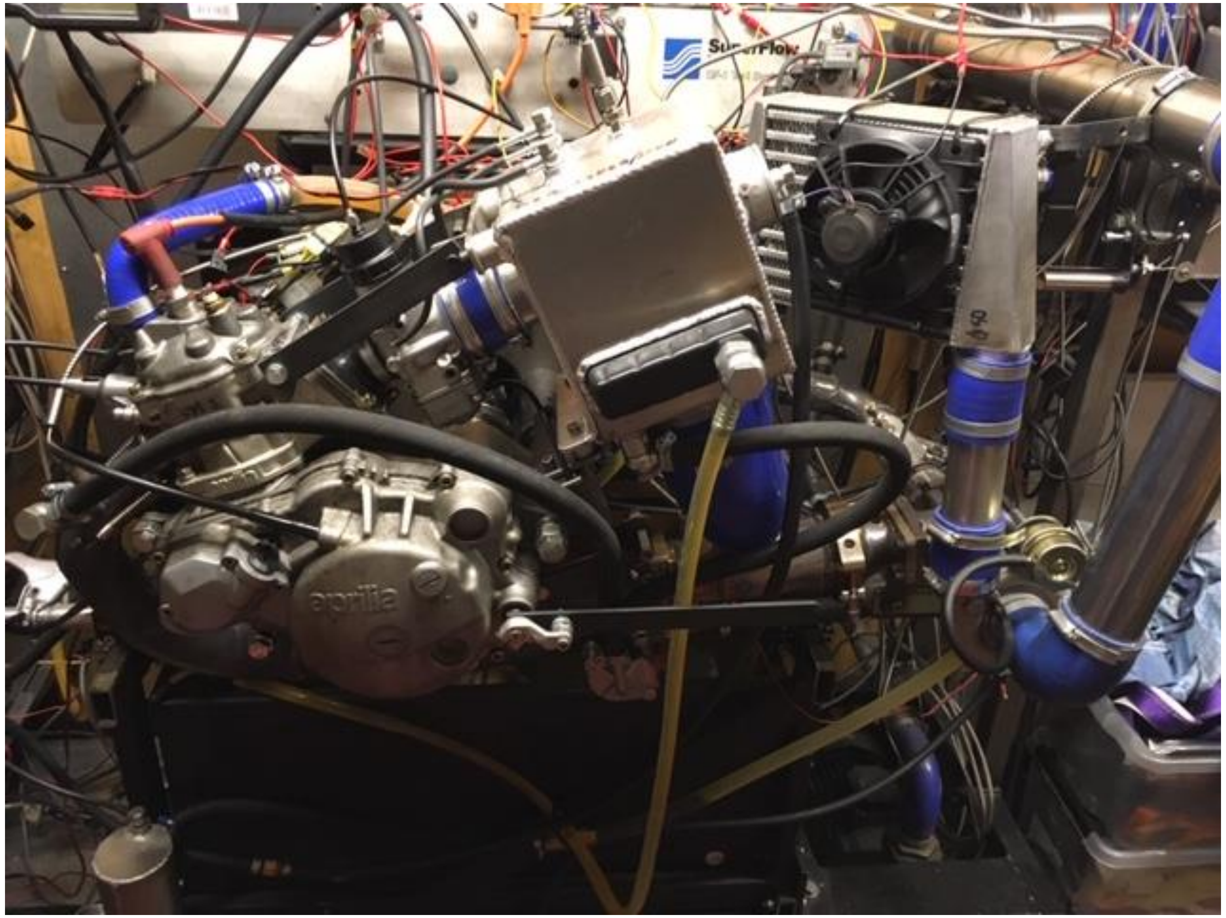
Further work

- A simulation study can be carried out on a scaled-up engine with 400-425 [cc] swept volume to reach the desired 150 [kW].
- A scaled up engine shall use direct injection (DI) and not port injection (PI) as the experimental engine in this thesis.
- The DI technology will create lower HC emissions and a higher conversion catalystrate can be used for improved exhaust emissions and improved control of the afterburner.
- The turbocharger system can also be optimized to suit the two-stroke engine better.

Aknowledgement

- Thanks to CERC for financial support!
- Thanks to Scania for making it possible to combine work and studies!

Thanks for your kind attention!



The turbocharged Rotax 122 engine in the dyno