Low- and high-temperature waste heat recovery in internal combustion engines - WP3

1. BACKGROUND

To meet market demands and to comply with existing and future legislation, vehicle manufacturers need to reduce the fuel consumption of their vehicles. Therefore, it is increasingly important to develop highly efficient engines with low operating costs. A promising way of increasing fuel efficiency is by capturing waste heat, since more than half of the fuel energy is lost in the engine as heat. This project is a collaboration between all three Swedish academic competence centers in Internal Combustion Engines (CERC at Chalmers, KCFP in Lund and CCGEx at KTH) and Volvo Car Corporation, with Chalmers having the overall responsibility for the project.

2. METHOD

Simulations and experiments are combined in this project, allowing for investigation of the potential of the selected thermodynamic cycle by using validated models. The thermodynamic cycles are simulated in Modelica coupled to the CoolProp fluid database. Each cycle alternative is evaluated for a number of working fluids and boundary conditions. The experimental setup, shown in Fig. 1, consists of a heavy-duty Diesel engine, which is connected to the waste heat recovery (WHR) system through a plate heat exchanger in the exhaust. The heat exchanger is used to evaporate and superheat the working fluid which then enters the reciprocating piston expander. The goal is to obtain between 5 and 10 % decrease in fuel consumption by including low-temperature heat sources.

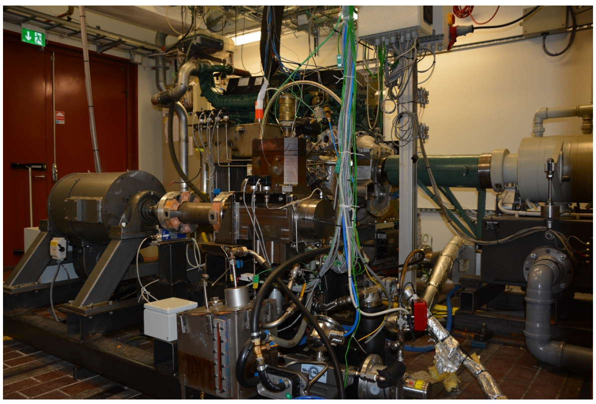

Figure 1: Experimental setup of the heavy-duty Diesel engine coupled to the WHR system.

3. RESULTS

Simulations were used to investigate the working fluid and thermodynamic cycle that yielded the best WHR performance for a heavy duty Diesel engine. As a first step, the maximum power output of the thermodynamic cycles was evaluated for each individual heat source (charge air cooler, engine coolant, EGR cooler, and the exhaust gas), leading to an extra power output up to 5 % depending on the heat source. Then, two configurations of the combined heat sources (including and excluding the engine coolant) were simulated for fifty working fluids and four cycles, with and without a recuperator. Both configurations in the simulations gave similar power outputs (1 to 7 % of the engine power) depending on the working fluid and thermodynamic cycle. The experimental setup was built during the first phase of the project, but since only preliminary experimental results have been obtained, they are not presented here.

4. CONCLUSIONS AND OUTLOOK

The results of the simulations, both with separate and combined heat sources, led to the following conclusions:

- Considering thermodynamic performance and maximum cycle pressures, in most simulations the organic Rankine cycle outperformed the other cycles.
- To obtain feasible cycle power output with the engine coolant as a heat source, the coolant temperature should increase.
- Although using a recuperator does not necessarily increase the power output, it will reduce the load on the condenser, an important consideration for automotive applications.

The next phase of project will focus on the organic Rankine cycle with special consideration for WHR with an increased coolant temperature. Experimental data will be gathered, which can be used to improve and validate the models.