APPLYING ENDOREVERSIBLE THERMODYNAMICS: THE OPTIVENT METHOD FOR SI-ENGINES

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EXTENDED ABSTRACT

All energy transformation processes occurring in reality are irreversible and in many cases these irreversibilities must be included in a realistic description of such processes. Especially the quantification of the losses occuring in technologically relevant processes is an important goal. Endoreversible thermodynamics provides a non-equilibrium approach towards this goal by viewing a system as a network of internally reversible (endoreversible) subsystems exchanging energy in an irreversible fashion. All irreversibilities are confined to the interaction between the subsystems.

Although the performance limits of reversible processes like the Carnot efficiency provide upper bounds for real irreversible processes they are usually not good enough to be a useful guide in the improvement of real processes. Real heat engines, for example, seldom attain more than a fraction of the reversible Carnot efficiency.

The concept of 'endoreversibility' has proven to be a powerful tool for the construction of models with the desired qualities. Endoreversible systems basically are composed of internally reversible subsystems with (irreversible) interactions between them. The losses due to the finite times or rates of processes are located in the interactions alone. A proper modelling of the transport equations between the subsystems allows to quantify the dissipation associated with the energy exchange. The hypothesis of endoreversibility simplifies the expenditure for the analysis essentially. This concept of 'endoreversibility' has been successfully applied to a wide variety of thermodynamic systems and led to remarkable results [1, 2].

An important problem in the analysis of endoreversible systems is how to deal with the time dependence of process variables and parameters, i.e. how the dynamics of a system evolves during a process. This problem has first been investigated in relatively simple models, which lacked the richness in technological detail of sophisticated engine models. However, while it was this approach which made insights into thermodynamic path optimization feasible, endoreversible thermodynamics as a general theory provides a framework to deal with thermodynamical systems *at all levels of detail* and is thus a universal approach also ranging to very elaborate and complex models [3].

We here present an example of such a treatment. It is the analysis of a SI (spark ignition) engine, which is optimized in efficiency under the constraints given by CO_2-emission commitments and legislation all over the world. The goal is to improve the efficiency of the SI engine significantly, while of course the exhaust emissions must not become worse.

One known approach is to reduce the gas exchange losses using fully variable valve trains on the intake side of the combustion engine. OptiVent is another approach [4]. It is a patented new way controlling the mass air flow in the cylinder of a combustion engine using opening valves during the *compression phase* of a four stroke engine, see fig. 1. This technology requires a wider range of variability on the valve train components of the engine especially for opening the valves more than one time during a cycle. In addition it is necessary to combine this technology with direct injection to avoid fuel losses in the exhaust system of the engine. Chemnitz University of Technology and the West Saxon University of Applied Sciences in Zwickau performed numerical investigations on the potential of the OptiVent engine control and combustion system, using a fully variable valve train on the exhaust valves of the engine. We present results from numerical simulations based on the endoreversible description of the OptiVent principle, see figs. 2 and 3. These simulations show the potential of the new OptiVent-way of air mass control, thus enabling us to progress towards developing a running engine and putting it on a test bench.

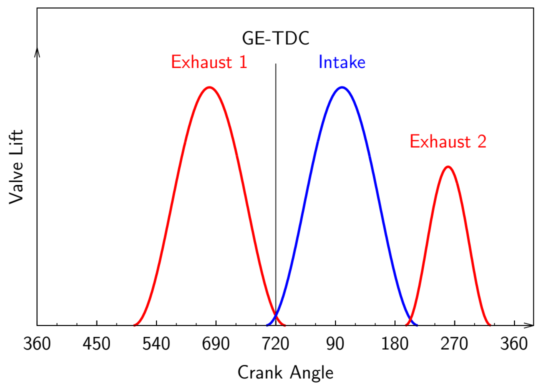

Figure 1. The OptiVent method makes use of adjusting the amount of compressed air in the cylinder by a second opening of the exhaust valve, here shown as "Exhaust2".

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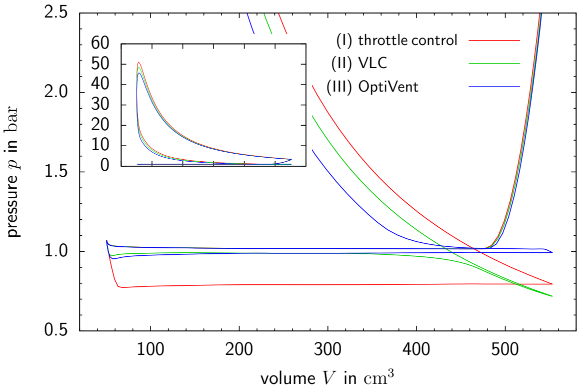

Figure 2. The pressure in the cylinder of a SI engine is shown as a function of the cylinder volume. The lower loops show the exhaust and the intake stroke. The pressure difference is a measure for the so called load exchange losses.

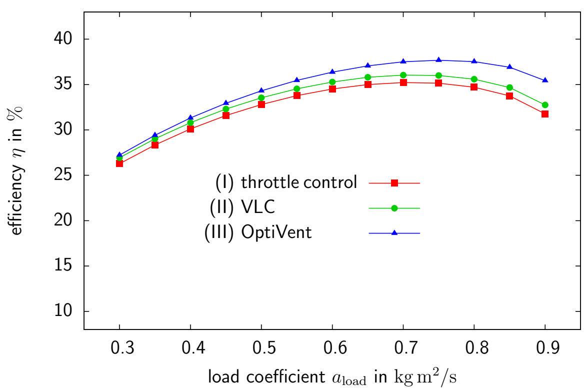

Figure 3. The engines' efficiency as function of the load coefficient at constant (intermediate) accelerator position. Note the efficiency gain of the OptiVent method.

References

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