Thesis subject: Automotive waste heat recovery system behavior in degraded operations.

With the reinforcement of CO_2 emission legislations, waste heat recovery systems are considered as possible solutions to further improve truck fuel consumptions. The organic Rankine cycle is considered as one of these promising solutions.

A high amount of literature exists on the subject and several works have been well described in the literature from the initial thermodynamic modeling, 1D transient system simulation up to demonstration trucks ([1]-[7]). Among all those works, the system performance, its impact on the vehicle (cooling, size), its control over the vehicle application have been well established ([8] – [11]).

Such a system will have to be safe and reliable as the rest of the truck and comply with a continuous On board Diagnostic (OBD) monitoring, with a limited amount of sensor and high level of quality (low fault frequency level allowed) as well as a limited software complexity. It is thus of high importance to better understand the system behavior in degraded operation.

In that context, a thesis subject is proposed.

In a first part, PhD student will make a deep analysis of the Rankine system behavior and its various failure modes (fluid leakage, component failures, component manufacturing variability). The literature review shall allow him (her) to understand what kind of diagnostic algorithm exists in the Rankine system field and various applications to evaluate analogies (automotive air conditioning, gas driven powertrains, fuel cells, industrial, marine, etc). A deeper understanding of subjects (not exhaustive) like fault detection, diagnostic levels, system sensor uncertainties, component production and performance variability shall be evaluated in the literature review.

The thesis student will then participate in improving further Failure Mode Examination and Effect Analysis (FMEA), and structuring and developing on board diagnostics algorithms to better understand trade-offs existing between fault detection, accuracy level of diagnostics and measurement sensitivity. Identification of the system and its internal state variables in normal and degraded operation must be evaluated. Degraded operations could result from failure modes of any component and sub-components, ageing of the complete system, fluid leakage, safety protection and production variability. Improvement of existing modeling, detection algorithms, control algorithms are example ways of doing that and must be proposed. As main contribution, the candidate shall bring innovative algorithms that enable to better distinguish and identify various failure modes that could arise (during system standby and/or truck moving). The assessment of the computational time in the Volvo platform Environnement will be assessed. Also diagnostics in end line assembly chain system checks are to be considered.

A Rankine system bench already developed by Volvo can be considered as a way to validate the most promising algorithms. Modification/ adaptation of the existing bench are considered as the most plausible way of validating experimentally models/ algorithms. The candidate is expected to participate actively in these experimental validations.

In the end, the thesis student will contribute to a scientific work that is novel in field of automotive Rankine cycle waste heat recovery.

A candidate of engineering skills in automatism (control algorithms), mathematics, energetics and thermodynamic field is expected for the subject.

Motivation, strong autonomy and open mind are a must for the success of that PhD work.

The position is based in Saint-Priest (69), within Volvo Group Trucks Technology. Fluent English is a must.

[1] Heavy duty on road waste heat recovery, F. Coccocetta, FPT, 3- internationaler Motoren Congress, BadenBaden, 2016
[2] Waste heat recovery for the long haul. Off Highway engineering.2015.
[3] S. Singh. SuperTruck Program: Engine Project Review Recovery Act – Class 8 Truck Freight Efficiency Improvement Project, 2014.
[4] J. Gibble, SuperTruck Powertrain Technologies for Efficiency Improvement. 2016 Annual Merit Review.
[5] L. Tornqvist. The waste heat is on. Volvo group magazine, 2015. Available at www.volvogroup.com.
[6] R. Cipollone, D. Di Battista, F. Bettoja, Performances of an ORC power unit for Waste Heat Recovery on Heavy Duty Engine, Energy Procedia, 129, 770-777, 2017
[7] T. Engel, M. Fritsch, J. Kurz, H. G. Schmitz, Evaluation of Waste Heat Recovery in a Close to Reality Environment, Bosch Engineering
[8] Seitz et al. Model-based control of exhaust heat recovery in a heavy-duty vehicle. Control Engineering Practice. 2018
[9] V. Grelet and P. Dufour and M. Nadri and T. Reiche and V. Lemort, Modeling and control of waste heat recovery Rankine based systems for heavy-duty trucks, IFAC International Symposium on Advanced Control of Chemical Processes (ADCHEM), 569-574, 2015.
[10] B. Michael, J. Swoboda, K. Christian, I. Thomas, G. Wachtmeister, Institute of Internal Combustion Engines, Technische Universitat Munchen, Germany; MAN Truck & Bus AG, Dept. ERV, Germany, Dynamic Vehicle Model for the System Engineering of Thermal Management and Waste Heat Recovery Concepts on Commercial Vehicles
[11] T. Reiche, F. Galuppo. EORCC 2017. Waste Heat Recovery Potential Analysis for Heavy Duty Truck Applications Based On Transient Road Cycle Simulations.