Towards fully predictive engine-modelling in Clean Propulsion Technologies

Clean Propulsion Technologies

Clean Propulsion Technologies is a major research project by a Finnish consortium of industry and academia, headed by the University of Vaasa. Its goal is to demonstrate a viable, ultra-clean and efficient marine engine using Reactivity Controlled Compression Ignition (RCCI). Key to this is a novel simulation toolchain using an innovative chemical kinetics-based multizone combustion model (MZM), developed in-house. This runs combustion simulations many times faster than a computational fluid dynamics (CFD) model, while being fully predictive to in-cylinder thermal and turbulence and chemical effects on combustion.

The MZM is coupled to a one-dimensional (1D) simulation framework built in GT-Power. This adds air-path, fuel-path, and aftertreatment sub-systems.

Together, they form a fast, powerful and accurate RCCI simulation tool for cost-effective development of clean, efficient flex-fuel engines. These will be essential in the marine sector – and others – where compression ignition engines remain crucial.

Controlling RCCI

Developing a control and calibration mechanism is a big challenge for RCCI engines. Fig. 1 shows the controller development cycle, which is then validated, along with real hardware. Similarly, the simulation toolchain is used to accelerate calibration of the experimental platform using model-based optimisation of both engine performance and emission.

Find out more

PTNSS — Hautala, S., et al. *"Towards a digital twin of a mid-speed marine engine: from detailed 1D engine model to real-time implementation on a target platform"*, PTNSS 9th International congress on combustion engines, 2021

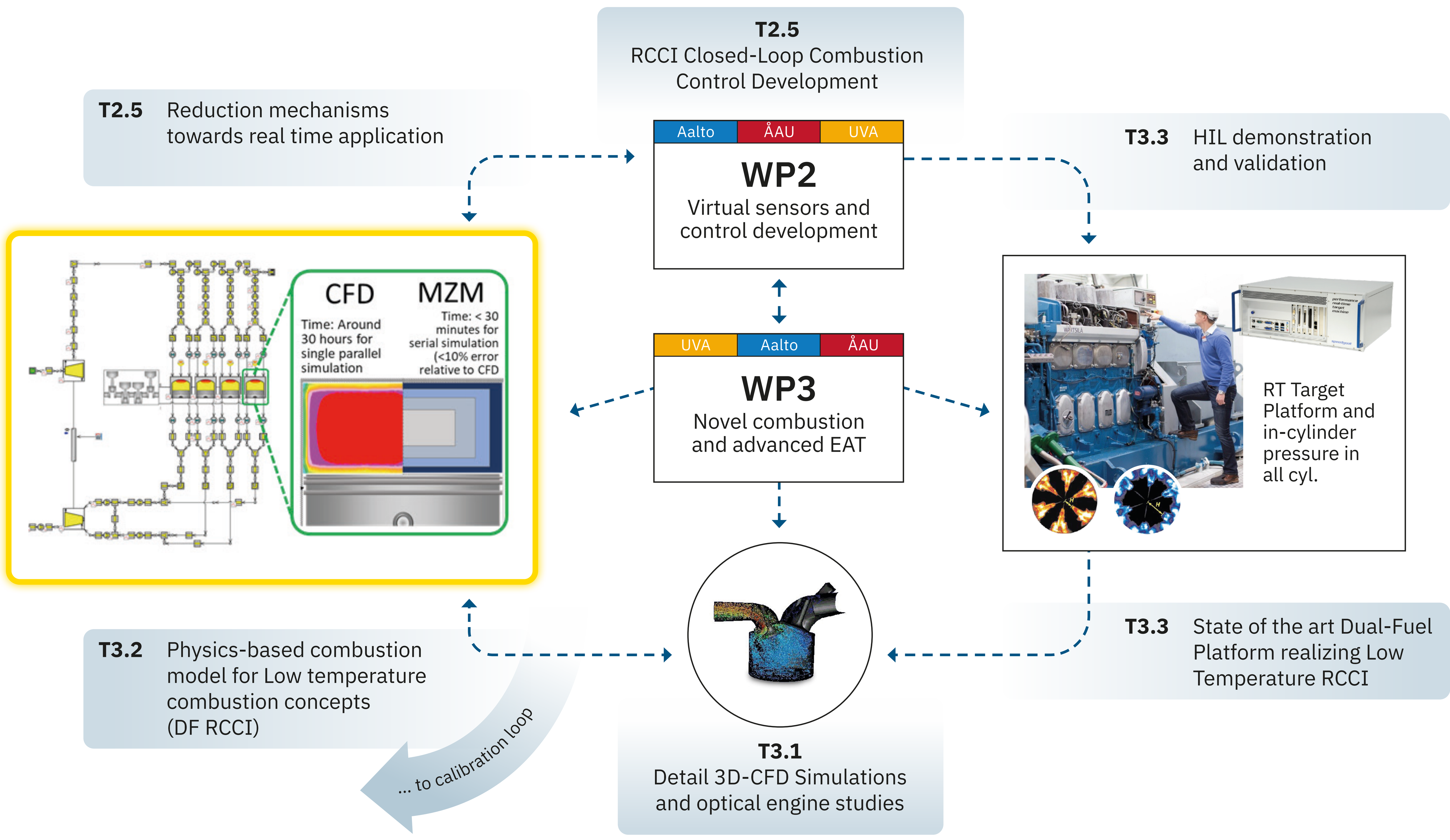
SAE International — Vasudev, A., et al. *"Towards next generation control-oriented thermo-kinetic model for reactivity controlled ignition marine engine"*, SAE Powertrains, Fuels & Lubricants Conference, 2022 *

Progress in Energy and Combustion Science — Vasudev, A., et al. *"Thermo-kinetic multi-zone modelling of low temperature combustion engines"*, Progress in energy and combustion science, 2022 *

International Journal of Engine Research — Hautala, S., et al. *"Towards a digital twin of a mid-speed marine engine: from detailed 1D engine model to real-time implementation on a target p/atform"*, International Journal of Engine Research, 2022 *

* Submitted, under review

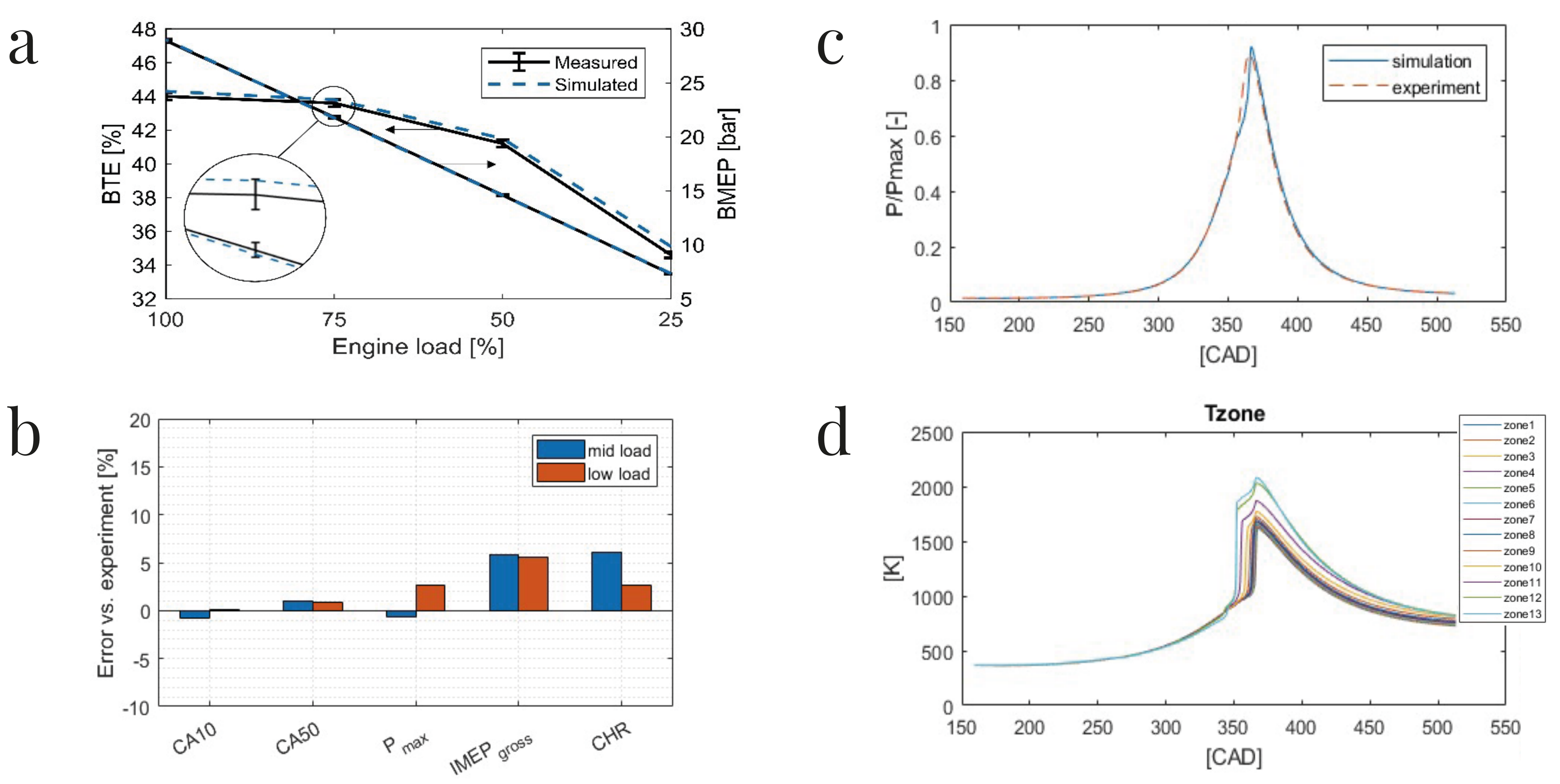
Figure 1. Model-based controller development cycle, using the engine simulation toolchain (MZM + 1D model)



The results so far ...

- Individual components of the simulation framework have been validated against experimental data (Fig. 2)
- Dynamic coupling of the MZM and 1D model is being de-bugged and checked for stability of numerical simulation
- The 1D model captures gas dynamics within error margins of 5% for all load cases (Fig. 2a)
- All combustion indicators have the same order of accuracy as 1D model (Fig. 2b)
- Target execution time for fully predictive coupled simulation is below 5 min/cycle
- Based on 1D model inputs, the MZM reproduces detailed in-cylinder pressure evolution and mixture thermal stratification (Fig. 2c & 2d)

Figure 2. Selected validation results of 1D engine model (a) and MZM – combustion indicators (b) in-cylinder pressure (c) and in-cylinder thermal stratification (d)

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