REAL-TIME ENGINE CONTROL UTILIZING EMISSION MEASUREMENT WITH FPGA CONTROLLER

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BACKGROUND

As governments release new emissions requirements which become even more stringent, the pressure to develop new combustion techniques and to use renewable biofuels is growing. To efficiently utilize the biofuels in an internal combustion engine it is necessary to have real-time controllers. In an internal combustion engine the calculation time is extremely limited. Field Programable Gate Array's (FPGA) offer the required calculation speed and low latency required for these advanced engine controllers.

To reduce the overall engine emissions it is important to have real-time models combined with emission readings. The gas exchange model provides a look into the current in-cylinder state but requires sensor input including manifold and in-cylinder pressure. The model can be further improved by utilizing emission measurements.

PROJECT OBJECTIVES

Currently, microprocessor based engine control units require that the gas exchange process is linearized around a desired operating point to simplify the model for real-time implementation. This limits the models' ability to handle disturbances and restricts the flexibility of the model. However, using a FPGA a detailed simulation of the physical gas exchange process has been implemented in real-time. This model will then be used to implement in-cycle control strategies to improve combustion stability, expand the operating range and further reduce HCCI emission levels. This work is being done using state of the art equipment in collaboration with RWTH Aachen Germany.

This real-time capable model will then been supplied with an emission measurement of NOx, NH_3, Unburned hydrocarbons, etc which can be used with closed-loop control strategies to minimize engine emission levels.

PROJECT OVERVIEW

FPGA BASED GAS EXHANGE MODEL IMPLEMENTAION

To have a real-time capable model for engine control the gas exchange process was ported to run on the FPGA hardware. This required the simplification of the gas properties used in the model to support the fixed point arithmetic used on the FPGA and consideration of the limited hardware resources available. The FPGA model was then experimentally tested on a single cylinder engine testbed and the real-time calculated results were compared to the offline reference model. Figure 1, shows the in-cylinder temperature matches the offline calculated values very well. Testing of the model over a range of negative valve overlaps, boost conditions and engine speeds resulted in an accurate calculation of the cylinder state every 0.1 ˚CA.

SENSOR MODEL DEVELOPMENT

A sensor model is developed using normal diffusion as the dominant diffusion mechanism, the model was evaluated at different engine operating conditions with different concentrations of species in the exhaust gas as shown in Figure 2.

The normal diffusion model accurately predicts pumping current for a range of temperatures and for all the operating conditions tested.

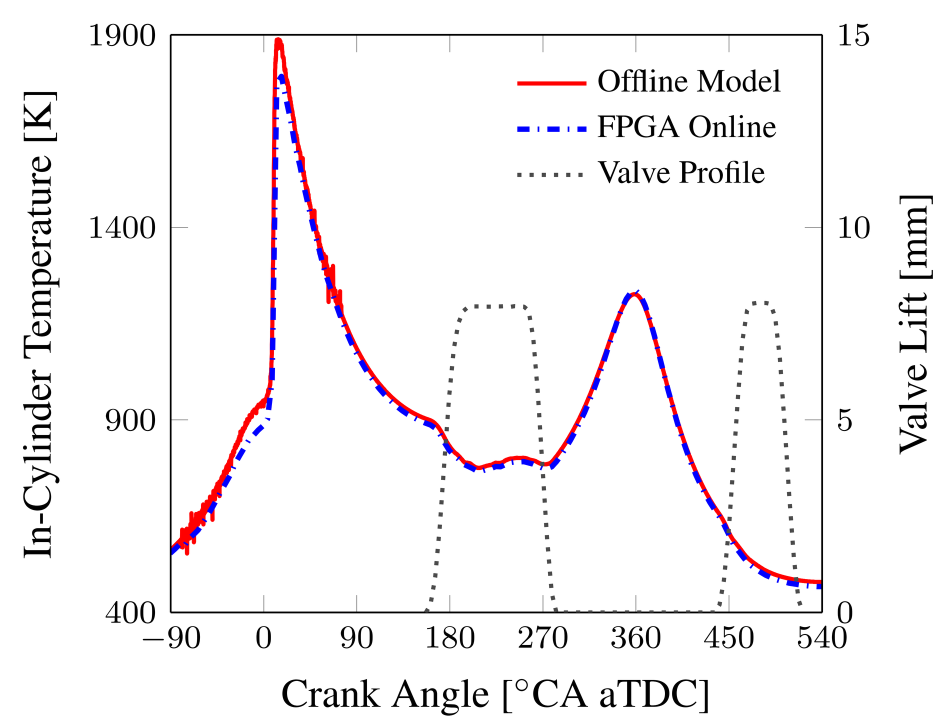

Figure 1 – Comparison of in-cylinder temperature calculated using real-time FPGA model with offline reference model. [1]

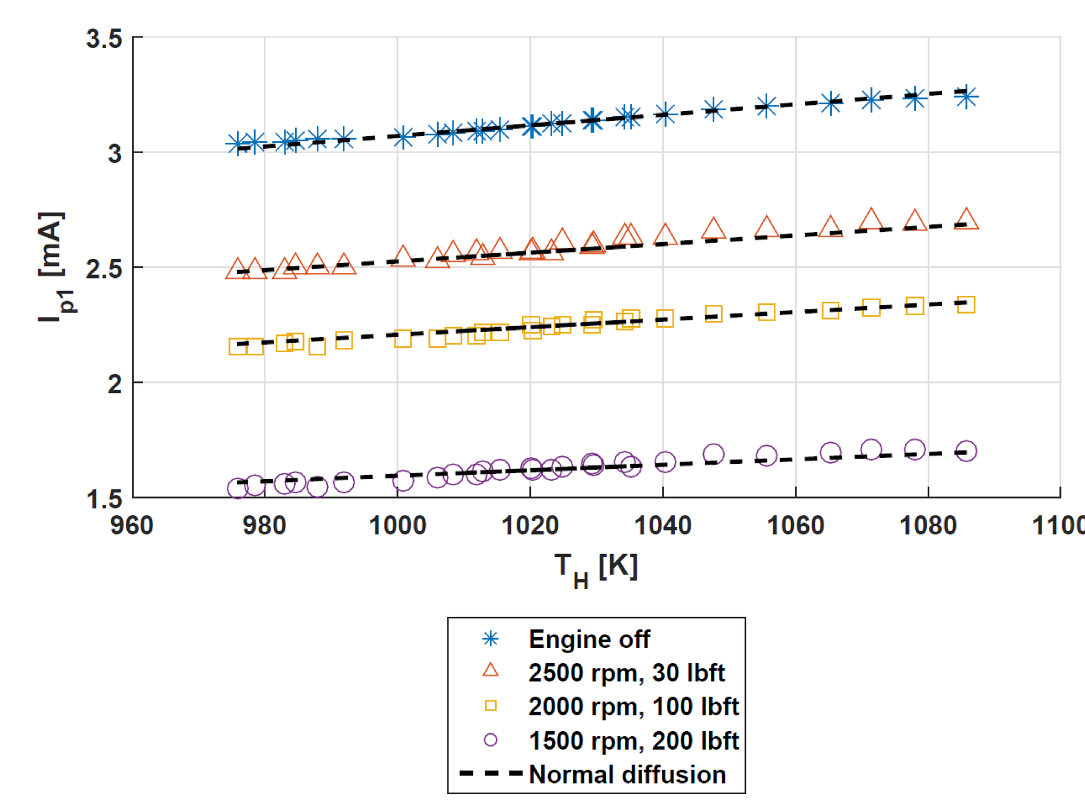

Figure 2 – Oxygen pumping current (IP1) vs sensor temperature for normal multi-component diffusion mechanism [2]

THEME OVERVIEW

T01-P04: Control of CI engines for efficient and robust biomass utilization

Utilizing the biomass derived fuel in CI engines in the most efficient manner is the focus of this work. Since the fuel can dramatically change the combustion characteristics and the biomass conversion process is for a specific fuel, both aspects must be examined. How tailor made fuel properties can be used to optimize engine and exhaust gas aftertreatment efficiency and reduce harmful pollutants will be studied, and feedback and learning control methods developed. The properties of promising fuels and how this affects the biomass to fuel conversion will be considered through collaboration with our partners.

EXPECTED OUTCOMES

The current gas exchange model has shown its ability to accurately calculate the cylinder state during the gas exchange process in real-time. This model will now be coupled with the emission sensor data to provide closed loop control of the combustion process.

The developed sensor model can be used to reduce the effect of manufacturing deviations on the sensor output signals and the measurement error without re-calibrating the sensor. The diffusion model is an essential element of the sensor model and will be used in the future to develop more complex sensor models.

Finally, the effect of using biofuels with the developed model will explored and experimentally validated. The impact of these biofuels on combustion stability and emissions output will be examined.

REFERENCES

[1] D. Gordon, C. Wouters, M. Wick, F. Xia, B. Lehrheuer, J. Andert, C. Koch, S. Pischinger. Development and experimental validation of a real-time capable field programmable gate array–based gas exchange model for negative valve overlap. International Journal of Engine Research 930 (2018)

[2] M. Aliramezani, C.R. Koch, R.E. Hayes, R. Patrick, "Amperometric solid electrolyte NOx sensors – The effect of temperature and diffusion mechanisms", Solid State Ionics, Vol. 313, pp. 7-13, (2017)

EXTERNAL PARTNERS

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