

Heat transfer measurements in a hydrogen fuelled spark ignition engine

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Hydrogen-fuelled internal combustion engines are attractive as they offer the potential of near-zero noxious emissions, high efficiency, and zero greenhouse gas emissions. Computer simulation enables a cheap and fast optimization of engine settings for operation on hydrogen. A quasi-dimensional simulation model (GUEST: Ghent University Engine Simulation Tool) has been developed at Ghent University by Verhelst and Sierens [1]. Up until now the GUEST-code has simulated power output and efficiency of hydrogen engines with good accuracy. The simulation tool has been validated for a varying mixture richness, ignition timing and compression ratio.

In a next step emission calculations will be added to the GUEST-code. Accurate emission calculations are a prerequisite as the control of emissions is an important boundary condition for power and efficiency optimization. In a hydrogen engine, NO_x emissions occur at high loads and are strongly influenced by the maximum gas temperature. To this end it is important to describe the heat transfer from the burning gases to the cylinder walls in a sub-model. Several models exist but they have been developed for fossil fuelled engines and are cited to be inaccurate for hydrogen engines [2]. The heat transfer in an engine operating on hydrogen is expected to be higher when compared to operating on a hydrocarbon fuel because of the shorter quenching distance (thinner thermal boundary layer), higher flame speeds (intensified convection) and higher thermal conductivity. The authors are developing a new model for hydrogen engines and are doing measurements for validation.

Measuring heat transfer inside an internal combustion engine is complex because of the high temperatures, short cycle duration and limited space for sensor mounting. Several measurement methods have been developed since 1950. The authors have selected four sensors to measure the heat transfer inside a CFR-engine (CFR: Cooperative Fuel Research): a coaxial type, an eroding ribbon type and two film types [3]. Measurement results of all the sensors will be compared in order to select the best method for the validation of the heat transfer model.

One of the film type sensors, a thermopile which is commercially available, has already been mounted inside the CFR-engine. Three positions are available for sensor mounting (see Figure 1). The influence of the measuring position, compression ratio, mixture richness and spark timing has been investigated. Measurements were performed on hydrogen and methane for fuel comparison. Less cyclic and spatial variation in the heat flux traces were observed when burning hydrogen, which can be correlated to the faster burn rate. The initial rise of the heat flux occurred when the flame passed the measurement position. The peak heat flux increased with increasing compression ratio and mixture richness, the initial rise in the flux trace occurred earlier. The total cycle heat flux was lowest for the highest compression ratio because of a lower heat flux at the end of the expansion stroke. The plot in Figure 2 shows that increasing spark advance does not only advance the rising of the heat flux, but also generates a higher peak heat flux because of a higher gas temperature. In Figure 3 the heat flux is compared between hydrogen and methane combustion with an equal indicated power output. The peak heat flux and total cycle heat loss are clearly higher for hydrogen.

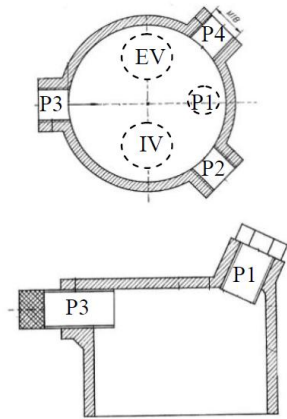


Figure 1: Cross section of the CFR engine, P1: spark plug, P2-P4: sensor positions, IV: intake valve, EV: exhaust valve

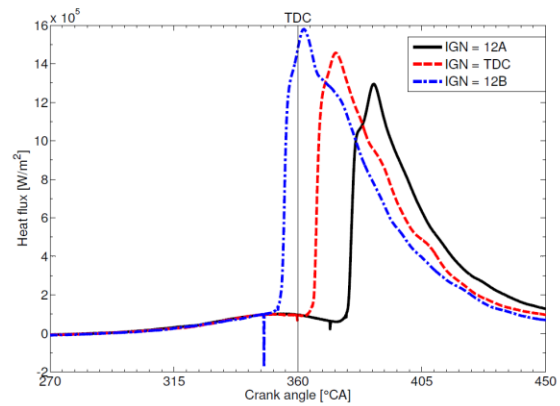


Figure 2: Influence of ignition timing on local heat flux (CR=8, $\lambda=1.5$, P2)

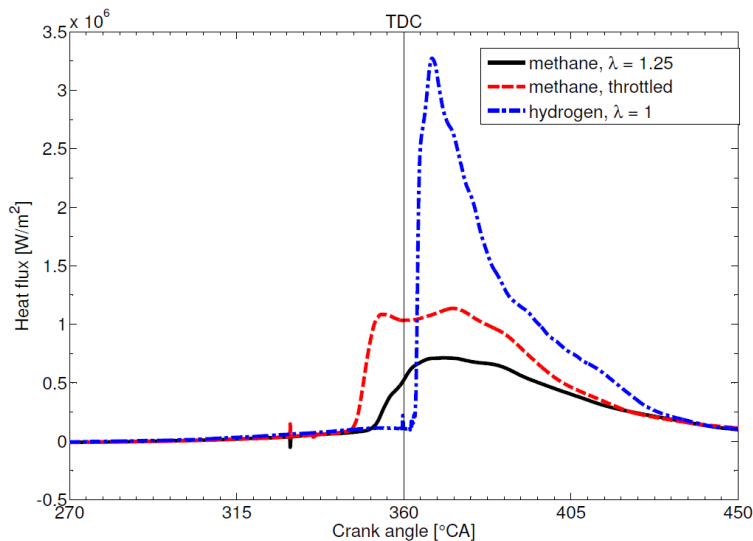


Figure 3: Influence of fuel on local heat flux with equal indicated power output (CR=8, P2)

Conclusion:

The use of a commercially available thermopile sensor for heat flux measurements inside a combustion engine was demonstrated. Local instantaneous heat flux measurements were performed inside a spark-ignited engine. A comparison was made between operation on methane and hydrogen. Due to the unique combustion characteristics of hydrogen, less cyclic and spatial variations, higher peak and total cycle heat fluxes and a smaller lag between ignition and heat flux peak were observed compared to methane.

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3. J. Demuyne, S. Pauwels, S. Verhelst, M. De Paepe, R. Sierens, *Experimental research on the heat transfer inside a hydrogen combustion engine: Evaluation and construction of measurement methods*. in: Proceedings of the FISITA 2008 World Automotive Congress (paper no. F2008-SC-037), 2008.