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Boundary layer flow measurements in a motored IC engine at engine speeds up to 2500 rpm

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Near-wall processes in internal combustion engines play a crucial role for engine efficiency and emissions. With the current trend of engine downsizing, near-wall heat transfer will continue to gain importance. Engine boundary layers have been shown to differ from canonical steady-state turbulent boundary layers [1] which are the basis for wall models in numerical simulations. To improve the predictive power of engine simulations, a comprehensive understanding of the structure of engine boundary layers is required [2].

In this study, the boundary layer flow over the piston surface is investigated by means of high-resolution, high-speed particle tracking velocimetry in an optically accessible spark ignition engine. Measurements were performed with a vector resolution of up to 5 µm perpendicular to the wall to resolve the phase-averaged viscous sublayer for technically relevant engine speeds up to 2500 rpm. Relative to the piston surface, the phase-averaged flow during compression resembles canonical flows over a flat plate. However, in extension of previous studies, results show that no logarithmic layer is present even at higher engine speeds and corresponding Reynolds numbers. The viscous sublayer was found to be as thin as 30 µm ($y^+ = 5$). Relevant for the application of wall models in numerical simulations are also the outer scales, with the bulk flow already starting at a wall-scaled distance of $y^+ = 30\text{-}90$.

Flow modes that differ substantially from conventional phase averages were revealed by conditional analysis. The boundary layer’s structure was found to be strongly impacted by the temporal flow evolution and horizontal position. Even in the case of wall-parallel flows, regions with strong acceleration and deceleration exist, which impact the adherence of boundary layer profiles to the law-of-the-wall. Another dominant mode is an impinging flow, where the degree of boundary layer development increases with the distance from the stagnation point. These results resemble classical channel flows with impinging wall jets [3].

REFERENCES

[1] C. Jainski, L. Lu, A. Dreizler, V. Sick, *High-speed micro particle image velocimetry studies of boundary-layer flows in a direct-injection engine*, Int. J. Engine Res. 14 (3) (2013) 247–259.

[2] C. D. Rakopoulos, G. M. Kosmadakis, E. G. Pariotis, *Critical evaluation of current heat transfer models used in CFD in-cylinder engine simulations and establishment of a comprehensive wall-function formulation*, Appl. Energy 87 (5) (2010) 1612–1630.

[3] H. Hattori, Y. Nagano, *Direct numerical simulation of turbulent heat transfer in plane impinging jet*, Int. J. Heat Fluid Flow 25 (5) (2004) 749–758.