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NUMERICAL INVESTIGATION OF ENGINE SPEED AND FUEL COMPOSITION EFFECTS ON CONVECTIVE HEAT TRANSFER IN A SPARK IGNITION ENGINE FUELED WITH METHANE-HYDROGEN BLENDS

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ABSTRACT Effects of hydrogen fueling of spark ignition (SI) engines have been investigated in order to quantify the influence on performance and emissions. One general conclusion that emerged was that stoichiometric operation of premixed charge hydrogen engines is associated with high heat losses compared to other fuels such as methane. This was attributed to increased rates of heat transfer from the working fluid to the combustion chamber walls. A confirmation of this phenomenon was obtained through heat flux measurements, that were found to be much higher for hydrogen compared to methane stoichiometric operation. These effects were also corroborated by numerical simulations with 3D CFD codes. Given that quasi-dimensional models offer an acceptable compromise between accuracy and computational requirements, this study employed a three zone simulation in order to study the effects of fuel composition and engine speed on heat transfer rates in a premixed charge SI engine. After an initial validation based on in-cylinder pressure measurements and flame imaging performed on an optically accessible experimental unit, a comprehensive numerical study was undertaken in order to evaluate the effects of engine speed and fuel composition. The latter was considered as the combined use of methane and hydrogen (dual fueling), ranging from one pure fuel to the other. Engine speed was swept in a wide range, that covers the specific case of automotive applications. Stoichiometric operation was considered for all cases, given that this is the closest situation to real-world applications, for which closed-loop air-fuel ratio control is employed. Predicted heat flux is reported in the two distinct zones, namely burned and unburned gas regions. The results suggest that hydrogen addition in its blend with methane increases laminar flame speed (and therefore shortens combustion development), but also results in higher heat losses due to augmented convective heat transfer. Both effects were found to be less evident as engine speed was increased, given that chemical kinetics are mostly dependent on temperature in the unburned gas and the increase in heat transfer rates is not proportional to variations in crank angle rotational speed. These findings can be used for adapting engine control strategies when using methane-hydrogen blends in premixed charge SI engines, in order to optimize efficiency and reduce environmental impact.