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A Computational Investigation of Knocking Tendency in a Hydrogen-Fueled SI Engine

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Abstract : Hydrogen is a promising future fuel to support the transition of the energy sector toward carbon neutrality. The direct utilization of H2 in Internal Combustion Engines (ICEs) is possible, and this technology faces mainly two challenges; high NOx emissions and severe knocking at mid to high loads. In this study, we numerically investigated the potential of H2 combustion in a truck-size engine operated in SI mode. To mitigate the knocking nature of H2 combustion, we have focused on studying the effects of three primary parameters; the compression ratio (CR), the air-fuel ratio, and the spark time. The baseline case was set using a CR of 16.5 and an equivalence ratio of 0.35. In simulations, the auto-ignition tendency was evaluated based on the maximum pressure rise rate and the local pressure fluctuations at the monitoring points set along the wall of the combustion chamber. To mitigate the auto-ignition tendency while enabling a wider range of engine operation, the effect of lowering the compression ratio was assessed. The results indicate that by lowering the compression ratio from 16.5:1 to 12.5:1, an indicated thermal efficiency of 47.5% can be achieved. Aiming to restrain the auto-ignition while maintaining good efficiency, a reduction in the equivalence ratio was examined under different compression ratios. The result indicates that higher compression ratios will require lower equivalence ratios, and due to practical limitations, a lower equivalence ratio of 0.25 was set as the limit. Using a compression ratio of 13.5 combined with an equivalence ratio of 0.3 resulted in an indicated thermal efficiency of 48.6%, that is, at a fixed spark time. It is found that under such lean conditions, the incomplete combustion losses and exhaust losses were high. Thus, advancing the spark time was assessed as a possible solution. The results demonstrated the advantages of advancing the spark time, where an indicated thermal efficiency exceeding 50% was achieved using a compression ratio of 14.5:1 and an equivalence ratio of 0.25.

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