25SKSAE_B041

Numerical Investigation of Ammonia Combustion and Emissions with Spark-Assisted Compression Ignition (SACI) Strategies

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Key words: Ammonia combustion, RCEM, Spark assisted compression ignition (SACI), Combustion performance, Engine emission

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Ammonia fuel is one of the most effective hydrogen energy carriers with a greater energy density, providing a path to zero carbon emissions for future combustion engines. However, the laminar flame speed of ammonia is low, which results in poor combustion performance. The purpose of this research was to evaluate the impact of spark-assisted compression ignition (SACI) strategies on the performance and emissions of ammonia combustion using direct injection techniques. The computational results were then confirmed against combustion performance data acquired on an RCEM engine using diesel as a fuel. Through the developed numerical model, the performance of combustion and emission of ammonia direct injection could be further investigated. The result showed an acceptable level of deviation between the computational model and the experimental results of the pressure trace from the RCEM engine. In this study, four SOIs from 40o to 0o BTDC with varied spark timing of spark-assisted methods were investigated at a high compression ratio of 17. The numerical analyses conducted in the current investigation reveal that the utilization of the SACI strategy improves the mass burn rate, advances the combustion phasing, increases engine power output, and reduces unburned NH3 emissions. Ammonia flame propagation is affected by initial temperature and flow field, and increasing spark timing may enhance ignition stability, improve combustion duration and minimize cooling loss. Unfortunately, the emission of NOx gradually rises as the spark timing increases. At longer spark timing, the combustion performance is optimized, and the maximum IMEP and ITE are 4 bar and 38.3 %, respectively. This study provides fundamental insights into ignition techniques for future ammonia engine applications and strongly supports the potential of SACI strategies as a promising direction for developing zero-carbon ammonia engines.

ACKNOWLEDGEMENT

- This work was supported by the National Research Foundation Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2023-00281590).

- This work was supported by Regional Innovation Cluster Development (R&D) by the Ministry of Trade, Industry and Energy (MOTIE, Korea) [Project Name: Open Innovation Project for Convergence Industry of Battery/Fuel Cell for Mobility Electrification and Energy Production/Storage (P0025406)].