Proceedings of the Canadian Society for Mechanical Engineering International Congress 2022
CSME Congress 2022
June 5-8, 2022, Edmonton, AB, Canada

Alternative combustion mode to minimize methane slip in a dual-fuel natural gas diesel combustion engine

Mohammad Taghi Zarrinkolah[1], Vahid Hosseini[2,*]
[1] Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran
[2]School of Sustainable Energy Engineering, Faculty of Applied Sciences, Simon Fraser University, Surrey, BC, Canada
*v_hosseini@sfu.ca

ABSTRACT

Methane slip in dual-fuel compressed natural gas-diesel (CDF) engines is a severe hurdle preventing commercialization due to the negative balance of greenhouse gas potentials between CO_2 and CH_4. In this paper, the methane slip of a CDF combustion engine was numerically studied and compared with an alternative mode of reactivity controlled compression ignition (RCCI) combustion with late (LIRCCI) and early (EIRCCI) direct fuel injections. In all combustion modes, methane was injected as the premixed fuel into the port, and diesel was used as the directly injected fuel. The start of direct fuel injection (SOI) and spray angle (SA) were used as strategies of combustion management, swiping from misfiring to knock limits at part loads.

Results showed that, by advancing SOI, NOx emission was increased in CDF, decreased linearly with the same but negative slope in LIRCCI, and reduced exponentially in EIRCCI mode. EIRCCI had 3.1%, and 3.5% higher thermal efficiency than CDF and LIRCCI combustion, respectively. Compared to CDF, LIRCCI and EIRCCI averagely (SOI averaged base) have 417% and 97% more soot, 140 and 14% more CO, and 10 and 76% lower NOx emission, respectively. Also, results showed that high levels of methane slip in CDF can be reduced to some extent without any geometry modification by SOI management. The averaged methane slip was decreased by 10.5% and 36% by switching combustion from CDF to LIRCCI and EIRCCI modes, respectively. At too early injection timings (EIRCCI), the combustion regime resembled a homogeneous charge compression ignition (HCCI), and as a result, methane slip was significantly decreased. At late diesel injection timings (CDF and LIRCCI), there was not enough time for diesel to be mixed well in the combustion chamber. Therefore, in regions far away from diesel spray plumes, methane flame front did not propagate well, and much more methane remains unburned.

Three diesel spray angles of 60 $^\circ$, 90 $^\circ$, 120° were examined. Minimum methane slip was obtained when spray angle was towards squish area, and maximum methane slip was obtained when spray angle was towards piston bowl. Increasing SA from 60 $^\circ$ to 90 $^\circ$ and 120° resulted in a 27% and 50% reduction of methane slip.