frontiers in Mechanical Engineering

EDITORIAL
published: 15 February 2021
doi: 10.3389/fmech.2021.642187

Editorial: Advances in Compression Ignition Natural Gas–Diesel Dual-Fuel Engines

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Keywords: compression ignition engines, diesel engines, natural gas, greenhouse gas emissions, PM emissions

Editorial on the Research Topic

Advances in Compression Ignition Natural Gas–Diesel Dual-Fuel Engines

Natural gas (NG) has been recognized as a low-carbon clean fuel that generates about 20–30% less carbon dioxide (CO_2) and much less particulate matter (PM) emissions than diesel. Replacing diesel by NG in compression ignition diesel engines helps reduce CO_2 and PM emissions. Dual-fuel technology is an effective way to replace diesel by NG in diesel engines. However, there are some technical issues that are limiting the wide application of NG–diesel dual-fuel engines. These include the limited replacement ratio, efficiency deterioration, and especially the low combustion efficiency of NG due to the incomplete combustion of methane. Emissions of unburned methane are also an issue because of its very high global warming potential. This research topic gathers contributions that highlight the advantages/disadvantages and address the existing issues of NG–diesel dual-fuel engines.

The first article (Boretti) reviews the advantages and disadvantages of compression ignition dual-fuel engines compared to those of diesel engines. After a comprehensive literature review, the article indicates that dual-fuel engines allow for comparable or better performances of diesel-only internal combustion engines in terms of steady-state torque, power, and fuel conversion efficiency while dramatically improving the CO_2 and engine-out PM and NOx emissions. Further development of the fuel injection system for the second fuel may lead to novel dual-fuel engine designs with better performance.

The article by Yoshimoto et al. presents an investigation on trade-off improvements by combining exhaust gas recirculation (EGR) and supercharging in a dual-fuel engine using next-generation bio-alcohol–blended FAME as ignition fuel. Instead of conventional diesel, *Pongamia pinnata* methyl ester, which has potential to further reduce CO_2 emissions, was used in the investigation. The infiuence of the ignition fuel on engine performance, combustion characteristics, and emissions is examined and compared for dual-fuel and diesel operation by combining supercharging and EGR in the article.

The third article (Xu and Filipi) presents a quasi-dimensional multi-zone model of methane–diesel dual-fuel combustion. The model is further validated by experimental results. It provides a simplified but practical tool to predict and analyze the performance of dual-fuel engines.

The study by Ichihashi et al. also develops and validates a control model that is able to predict the combustion efficiency for compression ignition dual-fuel engines, and can be used to construct a controller that outputs the diesel injection condition to maximize the combustion efficiency of NG.

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Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Engine and Automotive Engineering, a section of the journal Frontiers in Mechanical Engineering

Received: *15 December 2020*
Accepted: *07 January 2021*
Published: *15 February 2021*

Citation:
Guo H, Li H, Guzzella L and Shioji M (2021) Editorial: Advances in Compression Ignition Natural Gas–Diesel Dual-Fuel Engines. Front. Mech. Eng 7:642187. doi: 10.3389/fmech.2021.642187

The model has the potential to be used to better control and optimize dual-fuel combustion in the real-world applications to improve methane slip, a key technical issue for NG–diesel dual-fuel engines.

An experimental and simulation study on NG–diesel dual-fuel combustion was conducted by Dimitriou et al. for three dual-fuel engines. Their results reveal that an advanced diesel injection timing could significantly reduce NOx formation and improve the engine's thermal efficiency, and hot EGR could contribute to simultaneous reduction of NOx and unburned hydrocarbons dominated by methane while increasing the thermal efficiency of the engine at low-load operation. However, they noted that a multiple pulse diesel injection strategy and intake boosting do not provide any benefits on emissions but increase unburned CH_4 emissions.

Yousefi et al. systematically investigated the effect of the variation of NG fraction on engine performance and the fundamental mechanisms behind the phenomena observed at different engine load conditions by a combination of experiments and numerical simulation. The results of the article indicate that the effect of NG fraction on engine and combustion performance, such as combustion phasing, thermal efficiency, and emissions, depends on engine load, suggesting that different strategies should be adopted to optimize the performance of a NG–diesel dual-fuel engine at different loads. Some strategies that are able to improve the dual-fuel engine performance at different loads are also investigated in this research.

Most previous studies on NG–diesel dual-fuel engines focused on low load conditions at which methane slip is a significant issue, while relatively not enough attention has been paid for high load conditions. Although methane slip is not significant for dual-fuel engines at high load conditions, there are some other issues that need to be addressed. One of these issues is injector tip overheating due to the decrease in diesel flow rate, since diesel also plays the role of coolant to reduce the injector tip temperature for diesel engines. Besides, the effect of NG on engine performance and emissions at high loads is different from that at low loads, as indicated in the article by Yousefi et al. The article by Dev et al. presents an investigation on the high load operation of a NG–diesel dual-fuel engine, including the injection tip temperature performance. Their results reveal that with increasing NG fraction at a given diesel injection timing or advancing diesel injection timing at a given NG fraction, injector tip temperature increases. In addition, combustion phasing is a very critical determinant of dual-fuel combustion performance at high engine loads. Being different from that at low load conditions, increasing NG fraction can advance combustion phasing and cause the combustion duration to decrease.

We hope readers can find from this Research Topic some useful references for better understanding the fundamental mechanisms of dual-fuel combustion and the future development and optimization of NG–diesel dual-fuel engines. Technologies that further decrease and eventually eliminate emissions of unburned methane, and optimize the combustion process at high load are necessary for the wide application of NG–diesel dual-fuel engines.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.