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Editorial

Special Issue on "Advanced Combustion and Combustion Diagnostic Techniques"

Zhihua Wang

State Key Laboratory of Clean Energy Utilization, Zhejiang University, Hangzhou 310027, China; wangzh@zju.edu.cn; Tel.: +86-571-8795-3162

1. Introduction

Our world still greatly relies on the combustion process to convert fuel into power and heat for purposes such as gas turbines, internal combustion (IC) engines, jet engines, rockets, boilers, and furnaces. However, with the consumption of fossil fuels, i.e., coal, oil, and natural gas, emissions of CO_2 have become an urgent problem in controlling global warming and climate change. At the same time, emissions such as particle matter (PM), NO_x, SO_2, etc., arising from the traditional combustion process, also create troubles for our environment. Therefore, the development of advanced combustion technology has become an urgent issue, with the ambition of creating techniques with high-efficiency and low-emission characteristics. The combustion of new carbon-free or carbon-neutral fuels, such as H_2, NH_3, and methanol, as well as the development of new models to optimize the combustion performance, have also become important. To address the detailed chemical kinetics and turbulent–combustion interaction, advanced combustion diagnostic techniques for flow velocity, species, and temperature measurement are essential tools for the development of new concepts and new combustion technologies. This Special Issue entitled "Advanced Combustion and Combustion Diagnostics Techniques" showcases the recent technological developments and applications in the area of combustion and combustion diagnostics. It is available online at: https://www.mdpi.com/journal/processes/special_issues/Combustion_Diagnostic_Techniques (accessed on 31 October 2022).

2. Advanced Combustion in Engines

IC engines provide reliable driven power to cars, ships, trains, etc., through the combustion process. Improving the performance of IC engines can involve either employing new control methods or combining new type of fuels. Through the optimization of the compression ratio and intake or exhaust valve closing time control method, the engine thermal efficiency and NO_x emissions can be improved. Oh Jungmo et al. [1] analyzed the thermodynamic performance of the Otto–Miller cycle. The results show that the theoretical thermal efficiency can be improved by approximately 18.8% compared to the Otto cycle. In order to reduce CO_2 emissions, methanol, considered as a new type of e-fuel, has become an attractive alternative fuel that can be used in IC engines. Zhang Zhao et al. [2] investigated the combustion of pure gasoline and methanol blended fuels (10%, 20%, 30%, 50%, and 75%) in a direct injection (GDI) turbocharged engine using the steady-state, new European driving cycle (NEDC), and acceleration approaches. The results show that when methanol was blended with gasoline, the emissions of CO increased, while the NO_x, total hydrocarbon (THC), and PM emissions decreased. With the increasing methanol blending ratio, the acceleration time was shortened.

3. Combustion Optimization by Artificial Intelligence

The application of artificial intelligence (AI) to optimize the combustion process has attracted high interest in recent years. Different models, such as artificial neural network (ANN), support vector regression (SVR), and back-propagation neural network

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(BPNN), were developed and applied for the optimization of the combustion process. Yang Ruomiao et al. [3] developed an ANN model to predict the combustion of gasoline IC engines. The power, emissions, and combustion phasing were all considered. The proposed models can be used for combustion optimization in engines. Zhang Yu et al. [4] applied an SVR method to predict the fuel combustion rate, UHC, CO, and NO_x emissions of a spark-ignition engine. Zhang Hanlin et al. [5] proposed a combustion regime identification method based on the BPNN method. The results were also verified by large-eddy simulation (LES) results based on two types of turbulent non-premixed flames. The different combustion regimes, i.e., the combustion zone, preheat zone, co-flow, pure fuel, and air region, were all efficiently detected by the BPNN model. With five-scalar data for training, the identification accuracy could reach more than 98%.

4. New Concepts for Combustion Technology

Oxy-combustion replaces the N_2 in the air stream with recycled flue gas, which can generate a high concentration of CO_2 in the final combustion products, thus benefiting subsequent CO_2 capture and the sequestration (CCS) process. With a high combustion efficiency, low NO_x emissions, and enriched CO_2, the Oxy-combustion technology has become an attractive new combustion technology. Wang Chaoyang et al. [6] investigated the thermal radiation performance of both gas and soot particles in several counter-flow Oxy-combustion flames. On the air side with a stoichiometric ratio of 0.3~0.6, the soot formation decreased with the reducing fuel concentration when the same adiabatic flame temperature was maintained. Decreasing soot particle radiation shifted the main radiation zone ~0.04 cm toward the fuel side.

Plasma-assisted combustion is considered as a useful method to control the combustion process, improving the combustion performance under critical conditions. Nilson Elna J.K. et al. [7] investigated the laminar burning velocity of lean methane/air flames with pulsed microwave irradiation. The laminar burning velocities could be enhanced by 1.8~12.7% in a microwave environment. The enhancement of the burning velocity magnitude was dependent on both the strength of the electric field and the pulse sequence.

Micro-combustion is acquiring an increasingly important role in the driving of micro-electromechanical systems (MEMS) systems such as drones, robots, and aerospace systems. Due to its small size, a micro-combustor is usually affected by serious heat loss, combustion instability, and low combustion efficiency. Wang Fei et al. [8,9] investigated the influence of a porous media aperture arrangement on a CH_4/air micro-combustor by experimental and numerical simulation methods. The results showed that the porous media embedded in the inner and outer layers benefited the combustion process. The center and wall temperature distribution in the micro-combustor was also studied.

Liquid fuels play important roles in the aerospace and aviation industry. The ignition and combustion behavior of liquid fuels under high or sub-atmosphere pressure are important under reignition conditions during flight. Zhang Hongtao et al. [10] investigated the combustion behavior of RP-3 kerosene droplets under sub-atmospheric conditions. The results showed that the flame propagation time was proportional to the normalized droplet distance and pressure. During the combustion process, both puffing and micro-explosion phenomena were observed. The two processes both had significant impacts on the secondary atomization, ignition, and extinction processes. Thongsri Jatuporn et al. [11] investigated the gas flow and ablation phenomenon in a 122 mm supersonic rocket nozzle through the conjugate heat transfer analysis (CHTA) method. The method and results could be used to improve the design of new-type rocket nozzles with less ablation and a higher combustion efficacy.

Metal fuels are already widely used in rocket propellants. Lin Chengyuan et al. [12] investigated the combustion of magnesium microparticles under natural convection conditions. Based on experiments and SEM, XRD, XPS, and EDS analyses, a combustion model for Mg microparticles was developed to help researchers to understand the combustion process.

5. Combustion Diagnostic Technology

Advanced combustion diagnostic techniques are very important for understanding the details of the combustion process. In recent years, techniques such as laser diagnostic technology have been playing an increasingly important role in the field of combustion diagnostics due to their advantages of a high sensitivity, high spatial and temporal resolution, real-time application, and non-invasive nature. Li Ming et al. [13] developed a new method based on femtosecond laser filamentation in CH_4/air gas flames for equivalence ratio measurements. By measuring the spatially resolved spectra of the femtosecond laser-induced filament, the equivalence ratio in the flow field can be obtained. The equivalence ratio was calibrated using the spatial positions of C_2 at 516.5 nm and N_2 at 337 nm.

Liu Siyu et al. [14] conducted a thorough review of the surface temperature measurement method in combustion environments. Their paper summarizes and compares the main surface thermometry techniques from their basic principles, current state, and development to their applications. Two categories are summarized: contact-based thermometry and non-intrusive thermometry. Techniques ranging from conventional thermocouples and thin-film thermocouples to radiation thermometry, temperature-sensitive paint, liquid crystal thermography, and laser-induced phosphorescence were described.

Yang Li et al. [15] investigated the dilution effect and hydrogen content of a syngas/air premixed flame using OH planar laser-induced fluorescence technology (PLIF). Weng Wubing et al. [16] developed an infrared tunable diode laser absorption spectroscopy technology (IR-TDLAS) for the quantitative measurement of HCN and C_2H_2. The technique was applied to measure the release process of HCN and C_2H_2 in a nylon 66-strip flame in a hot environment of 1790 K. This advanced diagnostic technology can provide new insight into the combustion process, helping is to understand the physical–chemical phenomena as well as the development of new combustion technology.

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