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ความท้าทายและความก้าวหน้าของเทคนิคการเผาไหม้ไบโอดีเซลที่อุณหภูมิต่ำภายในเครื่องยนต์สันดาป

Challenges and Evolution of Low Temperature Combustion Techniques in Internal Combustion Engines for Biodiesel Fuel

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The rising of awareness to global warming situation accelerates the government policy and society action to reduce the release of greenhouse gas by turning to Bio-Circular-Green Economy model to achieve sustainable development [1], [2]. The maximum amount of nitric oxide (NO_x) and particulate emissions are related globally by Compression Ignition (CI) engines running on diesel [3]. Low Temperature Combustion (LTC) technology can reduce the diesel engine emissions and improve the engine efficiency. The LTC include Reactive Controlled Compression Ignition (RCCI), Premixed Charge Compression Ignition (PCCI), and Homogeneous Charge Compression Ignition (HCCI). In all LTC modes, the entire air and fuel mixture is premixed before combustion [4]. The cylinder temperature and predetermined equivalency ratio control the combustion in the LTC mode. The combustion temperature is maintained between 1800 K to 2200 K. LTC enhances pre-combustion, minimizes the locally fuel regions and reduces the peak combustion temperature, resulting in lowest

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NO_x, particulate matter (PM), and soot formation [5]. RCCI technology is currently used instead HCCI and PCCI technology. The premixed combustion phase is increased in the LTC yet the overall cylinder temperature and NO_x are not increased due to longer fuel ignition delay [6]. Higher fuel injection pressure allows for fuel atomization, and a high oxygen level in the biodiesel promotes the soot oxidation. However, due to early and delayed injection timing, hydrocarbon (HC) and carbon monoxide (CO) emissions are varying compared to diesel [7].

In the HCCI strategy, the fuel is thoroughly mixed, similarly to a Spark-ignition (SI) engine, and automatically ignited to the combustion. The fuel is evaporated and properly mixed with air before the combustion starts. The HCCI’s capacity to lower the NO_x emissions, while enhancing the thermal efficiency is possible only by lean-burn combustion [8]. Lower NO_x emissions are produced as a result of the lean-burn combustion, which suppress the combustion temperature. Due to the increase in displacement volume over diesel combustion, HCCI combustion boots the Brake Thermal Efficiency (BTE) up to 50% while emitting less smoke emission. A multi-zone auto ignition and spontaneous combustion of the entire mixture are encouraged by the homogeneous mixture and constant equivalence ratio. Additionally, the flame propagation does not affect the combustion in the HCCI mode [9].

By using a higher-pressure fuel injection system with an advanced injection timing, possible to achieve PCCI combustion by finer atomization of fuel. Early fuel injection increased the period between the start of injection and the onset of combustion, which highly increases the homogeneity of the air-fuel mixture before combustion [10]. For the PCCI, the minimum and excessive lean air-fuel ratios are 34:1 and 80:1, respectively. For the lean combustion, a slightly higher intake charge temperature of 170 °C was maintained. Lean-burn technology is used in the PCCI combustion technology, which operates with higher compression ratio. However, low cetane number fuel tend to be the best burned using PCCI. The improved air-fuel mixing and extended ignition delay period can be accomplished similar to PCCI combustion technique. One way to get a longer ignition delay period in the PCCI combustion is to mix low cetane fuel with diesel. Low cetane fuels have a high resistance to auto ignition and slow air reactivity, which lengthen the ignition delay period [11]. The HCCI and PCCI achieve low-temperature combustion, which increases the engine efficiency and reduces the emissions. However, knocking, misfiring and faster pressure rise rate, these two technologies are not suitable for low load and high load circumstance. Fuel adjustment is necessary for HCCI and PCCI combustion to address the problems [12].

Higher temperature under stoichiometric condition causes more NO_x formation. Additionally, the reduced oxygen availability in the fuel spray periphery resulted in increased soot emissions compared to diesel combustion [13]. Higher compression ratio and piston modification are needed for RCCI, but the higher swirl ratio can be used for HCCI combustion. When compared to diesel combustion, the LTC combustion of NO_x and PM reduced by 85% and 95%, respectively.

Multiple and divided injection efficiently reduce the NO_x and smoke emissions. Without raising the other emissions, the amount of post-injection reduces the smoke emissions. PCCI combustion effectively reduces the HC and CO emissions compared to HCCI, while NO_x and PM emissions were drastically raised with increasing premixed charge fraction. The HCCI combustion shows more cycle to cycle variation due to increased homogeneity, ambiguous auto-ignition zone and unpredictable. The double injection of high reactive fuel lowers the peak pressure and intensity in the RCCI combustion, which lowers the smoke and NO_x emissions. Numerous investigations showed that employing various fuel injection parameters and injection strategies, there is a large and untapped potential for improving low-temperature combustion. The overall study infers that engine combustion, emission, and performance characteristics are more influenced by operating conditions, therefore additional investigation requires in the LTC combustion.

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