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EFFECT OF SPLIT INJECTION TIMING ON COMBUSTION AND EMISSIONS OF A DISI OPTICAL ENGINE UNDER LEAN BURN CONDITION

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ABSTRACT

Lean combustion has proven to be an effective way to improve the efficiency and emissions of the direct injection spark ignition (DISI) engine. However, one of the main problems at the lean stability limit is the major decrease in flame temperature due to dilution, resulting in a low laminar flame speed, especially under low-speed engine operating conditions. The split injection is a potential technology to realize proper air-fuel mixing and achieve different spray distribution that can help in solving such problems. In this study, split injections with different secondary injection timings were tested to achieve homogeneous and homogeneous-stratified modes in a DISI optical engine under lean-burn mode. The split ratio of each strategy was 1:1. The engine was operated at 800 rpm, and a high-energy ignition system was utilized to realize lean combustion at a lambda of 1.55. Engine combustion performance and emissions were tested while performing high-speed color recording to study the characteristics of flame chemiluminescence through a quartz piston combined with a 45-degree mirror installed below. Flame structure during various combustion phases was compared under different selected conditions based on a digital image processing technique. The results show that the pressure and emissions vary with the second injection timing. Proper control of the split injection timing can improve lean combustion performance, including faster flame speed, increased indicated mean effective pressure (IMEP), and lower harmful emissions. Poor fuel evaporation and soot generation from spatial hot spots in the combustion process of split injection are the major challenges for further improvement.

INTRODUCTION

Direct injection spark ignition (DISI) technology has become the mainstream technology of passenger car engines due to the improved fuel economy, lower emissions and flexible control strategies [1-3]. However, many DISI technical problems should be solved, such as poor fuel-air mixing, super knock, and wall wetting, which leads to lower thermal efficiency and higher emissions. Lean combustion has been considered as a promising method to limit the heat transfer losses by lowering the combustion temperature, thereby further improving the thermal efficiency [4-7]. Additionally, this combustion mode reduces the pumping losses under low-load conditions [8-10] and reducing in-cylinder harmful emissions (such as CO, THC, NO_x [11], and soot [12]). However, some challenges are facing lean combustion mode, such as after-treatment systems for NO_x [5]. Also, lean combustion at same load means increased density which tends to increase heat transfer losses, so net heat transfer losses are not necessarily lowered. Additionally, it has been shown that a high excess air ratio may pose a significant challenge in igniting lean mixtures, which will exacerbate combustion variations between cycles and even lead to engine misfire [13]. Besides, slower flame propagation was reported for lean condition compared to stoichiometric combustion, which results in worse engine performance [14].

To address these challenges in lean combustion, stratified mode and high-energy ignition are used to enhance the stability of combustion by enriching the gas mixture around the igniter and establishing a more energetic plasma. However, it should be noted that in the case of lean combustion, the stratified mode may require modifications to the combustion chamber. Meanwhile, the late injection may also worsen the combustion emissions due to the short mixing time and possible spray-wall interaction [15]. Therefore, stronger in-cylinder turbulence intensity is needed to enhance the crossflow on the spark plug so that the plasma

