CFD Analysis of Turbulent Flow Characteristics of Charge Inside the Combustion Chamber of a Dual–Fuel HCCI Engine under varying Swirl ratios

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ABSTRCT

The effect of swirl ratio on turbulent kinetic energy (TKE) distribution and its consequent impact on combustion and emissions characteristics of a dual-fuel HCCI engine fed by n-dodecane and ethanol is investigated in this work. Computational fluid dynamics (CFD) simulations utilizing the ECFM-3Z compression combustion model within STAR-CD are used to study the engine's performance at various swirl ratios. Furthermore, the study found that swirl ratio effects combustion phasing, in-cylinder pressure, and NOx and soot emissions. Increasing the swirl ratio causes the combustion phasing to advance, the in-cylinder pressure to decrease, and the NOx emissions to decrease. The results of this study provide important insights into optimizing the swirl ratio for enhanced performance and lower emissions in a dual-fuel HCCI engine. These findings can help to influence the design of more efficient and less polluting IC engine

1. INTRODUCTION & OBJECTIVE

Dual-fuel combustion (DFC) has emerged as a potential solution for meeting the rigorous emission standards imposed on internal combustion engines (IC). It provides a diverse strategy to reducing nitrogen oxides (NOx) and soot emissions, both of which are substantial contributors to air pollution. Within a single combustion cycle, the DFC idea involves the simultaneous burning of two fuels with differing ignition properties. The pilot fuel is a high cetane number (CN) fuel, often diesel or a diesel-like fuel, while the main fuel is a low CN fuel, such as natural gas, propane, or ethanol. The pilot fuel ignites first, creating a confined flame kernel that ignites the main fuel later. This two-stage combustion technique has a number of advantages over single-fuel combustion.

The pilot fuel's early ignition enables a more controlled and slow combustion process, resulting in lower peak in-cylinder temperatures and pressures. Lower temperatures and pressures reduce the generation of NOx, which is largely created at high temperatures by the Zeldovich mechanism. Furthermore, the pilot flame offers a confined heat source that improves main fuel combustion, resulting in more complete combustion and lower soot emissions.

The primary goal of the investigation is to provide insight into the effect of swirl ratio on the turbulent kinetic energy (TKE) distribution and how it affects the combustion and emissions characteristics of a dual-fuel HCCI engine that runs on n-dodecane and ethanol. The study's goal is to find the best swirl ratio for maximizing engine performance while avoiding hazardous emissions.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Fig 1 indicates that as the swirl ratio increases, correspondingly increases the peak in-cylinder pressure. This is due to the fact that swirl improves the mixing of the air-fuel mixture, resulting in a more thorough and efficient combustion. With an increased swirl ratio, the peak in-cylinder pressure also occurs slightly earlier. This is due to swirl increasing turbulence in the cylinder, which speeds up the combustion process. Fig 2 demonstrates that as the swirl ratio increases, correspondingly reduces NOx emissions. This is due to the fact that swirl improves the mixing of the air-fuel mixture, resulting in a more thorough and efficient combustion. This minimizes the quantity of unburned fuel that can react with nitrogen to produce NOx.

Fig 3 demonstrates that when the swirl ratio increases, the piston work reduces. This is due to the increased heat transmission from the combustion gases to the cylinder walls caused by a swirl. This reduces the available energy to drive the piston down. A further reason for the decrease in piston work, as the swirl ratio increases, is that the swirl causes turbulence in the cylinder. Because of the turbulence, part of the combustion gases may escape from the cylinder before transferring their energy to the piston.

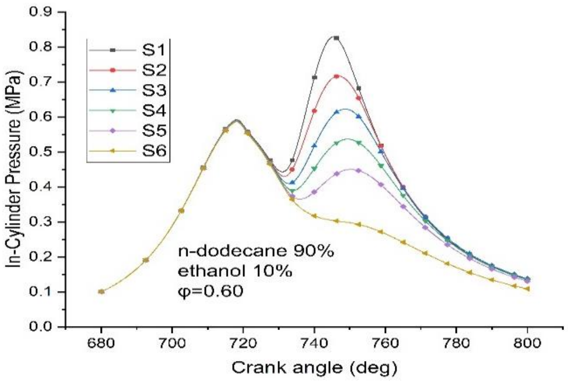

Fig 1. In-cylinder pressure vs Crank angle

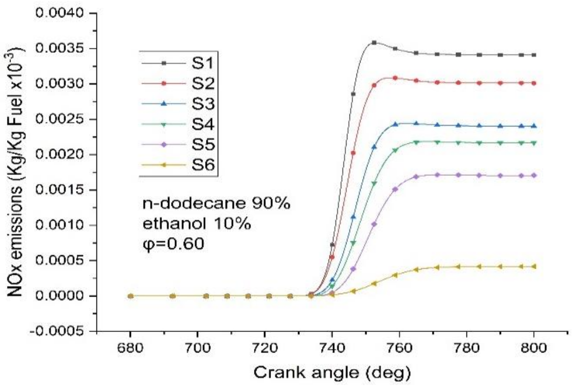

Fig 2. Nox emissions vs Crank angle

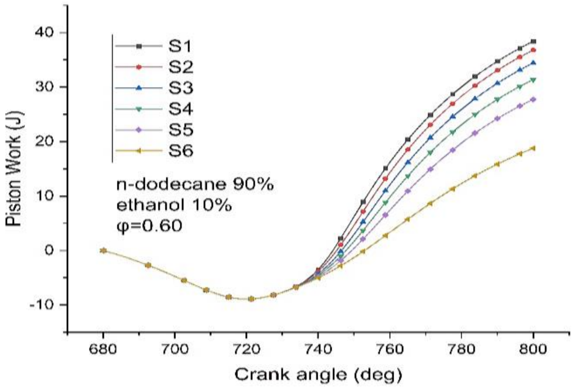

Fig 3. Piston Work vs Crank angle

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