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The Effects of Turbulent Jet Characteristics on Engine Performance Using a Pre-Chamber Combustor

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ABSTRACT

Increasingly stringent US fuel economy regulation has emphasized the need for automotive engines to achieve greater levels of efficiency. Lean operation in spark ignition engines has demonstrated the ability to increase thermal efficiency, but this is typically accompanied by increased nitrogen oxides (NO_x) emissions. Ultra-lean operation ($\lambda > 2$), however, has demonstrated increased thermal efficiency and the potential for significant reductions in NO_x. Turbulent Jet Ignition (TJI) enables ultra-lean operation by utilizing radical turbulent jets emerging from a pre-chamber combustor as the ignition source for main chamber combustion in a spark ignition engine. This study seeks to better understand the interaction between the pre-chamber and main chamber combustion events, specifically the effect that particular TJI design parameters have on this interaction.

Engine data is acquired first on an optical engine and then on a single-cylinder metal engine, with both engines intended to emulate existing production designs. This common architecture basis adds a degree of confidence and validity to efforts to synthesize data between the engines. This synthesis enables engine performance data to be correlated with observed trends derived from image-based measurements of TJI jet characteristics.

TJI is shown to perform as anticipated, enabling ultra-lean operation and consequently increasing thermal efficiency and reducing NO_x. Analyzing data from both optical and metal engines, it is determined that jet velocity and penetration exhibit sensitivities to certain design parameters. Furthermore, controlling jet velocity and targeting chamber penetration is imperative to optimizing TJI effectiveness in efficiently igniting the main chamber charge. The effect of nozzle design on engine performance, specifically thermal efficiency, is explored and discussed within the context of jet characteristic differences.