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Combustion Sensitivity to Charge Motion in a Dilute Jet Ignition Engine

Though there are multiple viable powertrain options available for the automotive sector, those that contain internal combustion engines will continue to account for the majority of global sales for the next several decades. It is therefore imperative to continue the pursuit of novel combustion concepts that produce efficiency levels significantly higher than those of current engines. Introducing high levels of dilution in spark ignited (SI) engines has consistently proven to produce an efficiency benefit compared to conventional stoichiometric engine operation. However, this combustion mode can present challenges for the ignition system. Pre-chamber jet ignition enables stable, highly dilute combustion by both increasing the ignition energy present in the system and distributing it throughout the combustion chamber. Previous work by the authors have shown that jet ignition produces 15-25% increases in thermal efficiency over baseline SI engines with only relatively minor changes to engine architecture.

Lean combustion in general and jet ignition in particular represent fundamentally different engine operating modes compared to those of conventional stoichiometric SI engines. Therefore, there are some system sensitivities not present in stoichiometric engines that must be investigated in order to fully optimize the jet ignition system. Differing types and magnitudes of charge motion are incorporated in SI engines to aid with mixture preparation but the influence of charge motion over lean combustion performance, particularly in jet ignition engines, is less well understood. This study analyzes the impact that charge motion has on both pre-chamber and main chamber combustion. A 1.5L 3-cylinder gasoline engine is outfitted with multiple intake port configurations producing varying magnitudes and types of charge motion. Pre-chamber and main chamber combustion stability and other burn parameter responses are analyzed at part-load conditions. The results show that there is combustion sensitivity to charge motion, resulting in >1 percentage point spread in peak thermal efficiency for the configurations tested, and that this sensitivity manifests most significantly under low ignitability conditions such as heavy dilution. These results provide guidance for future system optimization of jet ignition engines.