

Jet Ignition Research for Clean Efficient Combustion Engines

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Abstract

Ignition by a jet of hot gas has application in lean-burn pre-chamber internal combustion engines and in innovative pressure-gain combustors for gas turbine engines. Jet ignition offers the advantage of reliable fast ignition and complete combustion of leaner mixtures. Fast burn rates due to the energetic ignition source produce multiple, distributed ignition zones, which consume the fuel-air mixture rapidly. Chemically active radicals and fast turbulent mixing in the jets create an explosion much more energetic than a spark. This high energy ignition results from the partially combusted gas from the pre-chamber products initiating combustion in the main chamber mixture.

IC engines using low-cost, low-carbon natural gas need improved methods for ignition of lean mixtures to avoid nitrogen oxide emissions. This usually requires a richer mixture in the pre-chamber which is spark-ignited using a little additional gas fuel or compression-ignited with diesel fuel, possibly with a glow plug. A jet of hot reactive gas then ignites the main chamber lean mixture. Novel approaches for gas turbine engines using constant-volume, pressure-gain combustion include the multi-chamber wave rotor combustor. A wave rotor combustion chamber is best ignited with a jet of hot gas that may come from a small separately fueled pre-chamber or from a previously combusted chamber.

Experiments on traversing and stationary jets have been conducted using the constant-volume wave rotor combustor established at combustion and propulsion research laboratory, IUPUI. The ignitability limit and ignition delay time for various hydrocarbon fuels (methane, ethylene and propane) have been investigated. Ignition characteristics have been analyzed using the high speed camera images and pressure data. Numerical simulations have been carried out using a hybrid eddy-break-up combustion model including finite-rate chemistry and two-equation $k-\omega$ turbulence model. Numerical and experimental results showed similar trends, with the modeling results illuminate the jet ignition process.