Jet Ignition in Pressure-Gain Wave-Rotor Constant-Volume Combustor

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Motivation

Today’s combustors, boilers, and furnaces guzzle fuel continuously, creating high temperatures, but no direct power output. IC engine combustion generates work output, but only with heavy piston machinery. Jet engines and gas turbine plants allow continuous constant-pressure gas expansion during combustion, thus reducing work availability and efficiency. In contrast, the Wave Rotor Constant Volume Combustor (WRCVC) employs constant-volume combustion that improves work availability and engine efficiency, reducing fuel consumption, engine weight and emissions. This innovative combustor enables a new thermodynamic cycle. The technology is being developed at IUPUI and Purdue University with the participation of Rolls-Royce North American Technologies.

Wave Rotor Constant Volume Combustor

WRCVC enables super-efficient gas turbine power generation using pressure-wave compression and confined combustion in multiple rotating channels. Mechanical confinement of combustion gas in a constant-volume cell allows relatively uniform pressure rise by deflagrative combustion.

Combustion Model Validation

WRCVC simulation models use knowledge from wave rotor, IC engine, and jet ignition studies to predict combustion and engine performance. Simulations are compared with data measured from the WRCVC test rig. Static pressure and flame location (ionization) data are measured at multiple locations in the channels.

Fluid dynamic process in WR channel

WRCVC test rig

Comparison of predicted and measured static pressure values

Predicted fuel concentration, temperature, pressure profiles and ionization data

Inflow duct

Inlet Seal Plate

Rotor

Cell combustor

Outflow duct

Combustion

Torch igniter

Fluid dynamic process in WR channel

Schematic of WRCVC rig

Comparison of pressure traces at PT2

Comparison of predicted and measured static pressure values

Predicted fuel concentration, temperature, pressure profiles and ionization data
Jet Ignition in WRCVC

Jet ignition is studied using a wave rotor ignition test rig. It consists of two combustion chambers. A pre-chamber with slightly rich mixture is ignited using a spark. The partially combusted transient jet from the pre-chamber is injected through a converging nozzle to ignite the main chamber lean mixture, in multiple locations. Chemically active radicals and fast turbulent mixing in the jets create an explosion much more energetic than a spark. Jet ignition offers the advantage of fast ignition and complete combustion of leaner mixtures. This enables the channel to discharge a more uniform temperature gas, mitigates heat losses to the walls, and reduces pollutant emissions.

Reference:

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