Numerical Study on the Effect of Methane Doping in Hydrogen-Air Rotating Detonation Engines for various Temperatures and Pressures

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Rotating Detonation Engines

- Gas turbine (GT) engines are the most popular devices today for transportation and power generation purposes. However, the scientific community looks forward to new technologies that produce energy even more efficiently. In contrast to the Brayton cycle on which GT engines work, detonation cycle operates at constant volume and a static pressure gain. Hence, it produces more work output when compared to the Brayton cycle (Figure 1).

- Detonation cycle is used in devices such as Standing Detonation Engines (SDEs), Pulse Detonation Engines (PDEs) and Rotating Detonation Engines (RDEs). RDEs have gained more scientific interests recently because,
  - of their lower entropy generation and hence higher efficiency when compared to GT engines
  - detonation needs to be initiated only once
  - faster fuel consumption rate and hence higher power output
  - pressure increase from detonation reduces the load on compressors

- The goal of this work is to perform numerical simulations to study detonation and combustion occurring inside an RDE engine.

Numerical Results

Computational domain and boundary conditions

- 3D annular combustion chamber is "unwrapped" to obtain a 2D rectangular domain with discrete, premixed, fuel-air jets with specified upstream total pressure and temperature at the inlets.

Effect of AMR

- AMR resolves detonation and shock zones at increased resolutions to capture fine-scale dynamics
  - Flow field and wave structure
  - Under stable operating conditions, single or multiple continuously rotating wave structures are obtained. Each wave structure consists of a detonation wave, an oblique shock wave, and a slip line.
  - Reaction zones
    - Periodic motion of the detonation front consumes the freshly injected premixed gas. Downstream regions comprise intense mixing of high temperature burnt products and freshly injected fuel-air mixture creating deflagration zones. Negative heat release zones are observed downstream of oblique shocks due to radical species production

Effect of CH4 doping

- Increasing CH4 doping reduces fuel-air mixture reactivity. Lower reactivity leads to delayed detonation transition and hence fewer number of detonation wave fronts. Increasing CH4 doping reduces fuel-air mixture reactivity. Lower reactivity leads to delayed detonation transition and hence fewer number of detonation wave fronts.

References