Numerical study of Rotating Detonation Combustion (RDC) for Stationary Power Generation

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Abstract
Recently pressure gain supersonic combustion has received renewed interest among the combustion researchers as it offers higher efficiency and lower emissions. Among the possible technology concepts that employ this mode of combustion Rotating Detonation Combustion (RDC) is thought to be most suitable for stationary power. However, most research on RDC is focused on propulsion applications. The overall objective of this study is to assess, through computational modeling, the feasibility of RDC for power generation.

A commercial Computational Fluid Dynamics (CFD) code is used for the simulations along with several custom built sub-models to emulate the chemical reactions and boundary conditions of the RDC. The complex supersonic flow and combustion phenomena in an RDC are captured in these simulations. Future simulations will be performed using the model to evaluate the efficiency and emissions for RDC and to estimate the design specifications for a stationary gas turbine to be used in conjunction with the RDC.

Methodology
- Initial simulations were performed for inert and reacting shock tubes.
- Domain simplification.
- Treatment of Boundary Conditions (B.C.):
  - Vertical faces: Periodic boundary.
  - Outlet Pressure Outlet with static pressure < critical pressure
  - Inlet: Muro Laval nozzles injecting premixed fuel and oxidizer [1].

Implementation of inlet B.C. performed through user defined function (UDF).
- Chemical reactions for H2 - O2 - N2 mixture modeled using chemical mechanism with 14 species and 43 reactions [2] including NOx chemistry.
- Solution Strategy:

Results
-Transient behavior is observed up to 0.4 ms.
-Pressure distribution for at periodic operation [Pa].
-Outlet and chamber pressure, and wall temperatures.
-NO mass fraction.

Conclusions
-Transient simulations of RDC are performed using commercial solver ANSYS Fluent to the extent of our knowledge, for the first time.
-Tailored sub models are implemented to emulate RDC injection system using FLUENT UDFs.
-Periodic solution achieved for hydrogen oxygen mixture.
-Qualitative comparison with experimental data shows that general aspects of the detonation phenomena are appropriately captured.

Future Work
-Quantitative comparison of outlet and chamber pressure, and wall temperatures between simulations and experiments.
-Simulation of coal syn-gas operation.
-Characterization of outlet condition and its implications on the design of turbine stage.
-Development of detonation simulation capability for in house CFD code.

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References

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