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Thermoacoustic dynamics and premixture properties

Experimental Study in a Turbulent Swirl Stabilized Combustor

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Motivation: Study of Limit Cycle Bifurcations



- Sas turbine combustors: <u>limit cycle</u> thermoacoustic instabilities
- Rolls Royce Model Gas Turbine Combustor: <u>two</u> limit cycle dynamic states
- Link between <u>fundamental premixture properties thermoacoustic dynamics</u>

Structure

- Description of the Rolls Royce model gas turbine combustion and diagnostics.
- Limit Cycle: Flow and Flame Structure.
- Global Dynamics in the Thermal and Acoustic Fourier Spectra.
- Identification of Aerodynamic Coherent Structures.
- Link between Mixture Properties and Observed Dynamics.

Experimental Configuration Swirler and Optically Accessible Combustion Window



Unstable Premixed Flame

Topology of attraction of dynamic pressure signal in phase space

Operational Conditions Premixed Combustion State

Case ID	φ	Dynamic State	K _{ext} [1/s]
Ν	0.50	Intermittent	85
А	0.55	Period-1	236
В	0.60	Period-2	608
С	0.65	Period-2	1138



Limit Cycle: Flow and Flame Shape





Limit Cycle: Dynamics in Flames A, B and C

Global Dynamics



1 × 10⁴ 0.03 0.5 0.02 ÷ Α 0.0 p(t-27) 17.02 T[s] 17 17.02 17.04 T[s] 17 0.4 0 0 500 f [Hz] 1000 500 f [Hz] 1000 0

Global Dynamics













Identification of Aerodynamic Coherent Structure

DMD on Flame B: Link between f_i and coherent structures



DMD Modes Amplitude

DMD Modes Growth Rate

400

500

DMD: Link between f_i and coherent structures Nature of the subharmonic frequency



Precessing Vortex Core





[1]: N. Syred, "A review of oscillation mechanisms and the role of the precessing vortex core (PVC) in swirl combustion systems" Progress in Energy and Combustion Science, 32-2 2006



Link between Mixture Properties and Observed Dynamics







Conclusions

- The period 2-limit cycle featured contribution by the unstable acoustic eigenmode and the PVC which induced resonance at the subharmonic frequency.
- The PVC introduced an azimuthally skewed heat release rate disturbance. This introduced resonance at the frequency of interaction between the fundamental and the aerodynamic modes.
- It was observed that if at the moment of maximum dynamic pressure the flow imposed strain rate is able to locally extinguish the flame close to the z = 0 mm section, the helical instability will be excited leaving a subharmonic signature on the heat release rate power spectra. However, on increasing the equivalence ratio, the flame is able to sustain increased stretching at the same topology and may flash back.