

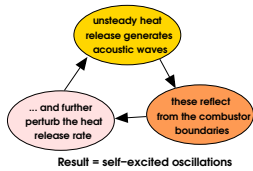
Active Control of Combustion Instabilities

Aimee S. Morgans

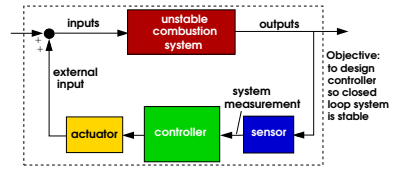
Department of Engineering, University of Cambridge

Background

Lean premixed combustion in gas turbines offers a means of reducing NOx emissions, but is prone to damaging COMBUSTION INSTABILITIES.



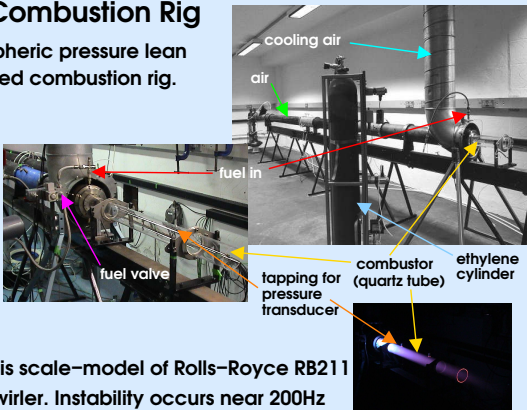
Photograph of damaged gas turbine piece courtesy of F. C. Iannoun



Active control can be used to stabilise combustion instabilities. An external input (usually unsteady fuel addition) is varied in response to a measurement (usually a pressure measurement).

The Combustion Rig

Atmospheric pressure lean premixed combustion rig.

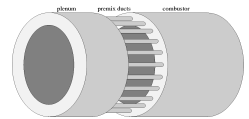


Swirler is scale-model of Rolls-Royce RB211 -DLE swirler. Instability occurs near 200Hz for equivalence ratios 0.7 - 0.9. Sensor for control: pressure transducer. Actuator: fuel valve to modulate fuel supply.

Annular Combustors

Due to circumferential modes, single-sensor single-actuator approach not enough.

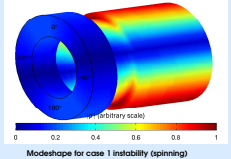
LOTAN (Low Order ThermoAcoustic Network model*) used as computational tool for investigating controller design methodology.



* developed by Slow & Dowling

Annular Combustion Systems Considered

Several systems considered, all with instability in $n=+/-1$ at 520Hz. Some included effects such as non-axisymmetry and other unstable modes. Sensing from pressure transducers around combustor, actuation from valves on some/all pre-mix ducts.

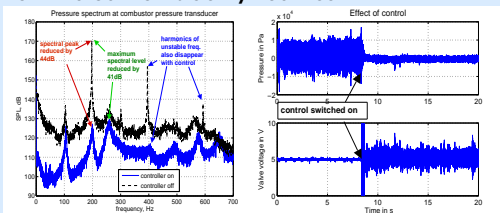


Controller Design

Open loop transfer function measured experimentally by combining control signal (from trial-and-error controller) and wide-band identification signal. Controllers designed using Nyquist techniques.

Results

The controllers were implemented on the combustion rig. All eliminated the instability near 200Hz.



Controller Design

Open loop transfer functions obtained from frequency domain modal heat release forcing in LOTAN.

Two approaches to controller design:

1. Control individual circumferential modes. SISO due to modal decoupling if system is axisymmetric.
2. Stabilise sets of sensor-to-actuator transfer functions. MIMO - useful when very few sensors/actuators used.

Results

Controllers were implemented in the time domain in LOTAN. All stabilised the instability, even from within the limit cycle

