# ACTIVE CONTROL OF COMBUSTION INSTABILITIES USING FUEL INJECTION RATE MODULATION*

Ben T. Zinn

Schools of Aerospace and Mechanical Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0150

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This presentation describes the development of an active control system (ACS) for unstable combustors at Georgia Tech. The objective of these efforts was to develop an ACS that could damp combustion instabilities in a variety of different combustors operating over a wide range of operating conditions. The developed ACS consists of a *sensor*, an *observer*, a *controller* and a *fuel injector actuator*. During operation, the sensor measures the combustor pressure and sends it to the observer, which analyzes this data, using a wavelet-based algorithm, to determine the amplitudes, frequencies and phases of several (the most unstable) combustor modes in real time. The controller then uses these data to determine the optimal phase and gain of the control signal for the actuator. The latter is a fuel injector that uses a magnetostrictive or piezoelectric actuator to periodically modulate the flow rate of *all* or *a fraction* of the fuel supplied to the combustor. The objective of this ACS is to generate combustion process heat release oscillations within the combustor that damp the unstable combustor modes. This could happen in two ways; first, the heat release oscillations could damp the instability by being out of phase with respect to the unstable pressure oscillations and/or they could destructively interfere with the mechanism that drives the instability.

Our initial ACS required the conduct of separate open loop control tests to determine the frequency dependence of the response of the combustor to periodic fuel injection rate modulation. These tests obtain data that are used by the controller to determine the control signal phase and gain. While this approach significantly damped the oscillations (e.g., 40 dB.) in a relatively short time (e.g., 40 msec.), it was problematic because it required the performance of separate open loop control tests to obtain the combustor response data. To overcome this problem, our recent efforts have focused on the development of an *adaptive* active control approach that determines the control signal phase and gain in the course of controlling the instability. The developed approach uses the observer to determine in real time the combustor behavior, thus allowing the controller to determine the optimal control signal phase and gain. While this approach requires a little more time than the previous approach to attain control, it eliminates the need for separate, lengthy and expensive, tests to determine the open loop combustor response.

Our recent studies have investigated the characteristics of the combustion process in the presence and absence of active control in an effort to elucidate the mechanism through which the adaptive ACS damps the instability. These studies have shown that in the absence of control the combustion process drives the pressure oscillations practically all along its length. When control is applied, some of these “driving” regions become “damping” or “neutral” (i.e., they neither drive nor damp) regions because the ACS changed the phase between their heat release and pressure oscillations.

Our present studies seek to further optimize the performance of the ACS by compensating for the detrimental effects of random noise and time delay upon the ACS performance, and demonstrate the effectiveness of our ACS on practical combustors.

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