✿ Active Suppression of Instabilities in Engine Combustors

Fuel flow would be modulated to generate pressure fluctuations opposing those of instabilities.
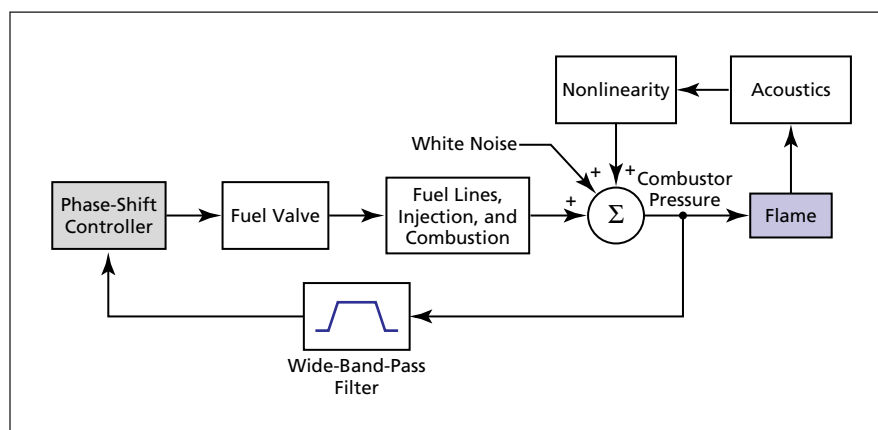
John H. Glenn Research Center, Cleveland, Ohio

A method of feedback control has been proposed as a means of suppressing thermo-acoustic instabilities in a liquid-fueled combustor of a type used in an aircraft engine. The basic principle of the method is one of (1) sensing combustor pressure oscillations associated with instabilities and (2) modulating the rate of flow of fuel to the combustor with a control phase that is chosen adaptively so that the pressure oscillations caused by the modulation oppose the sensed pressure oscillations.

The need for this method arises because of the planned introduction of advanced, lean-burning aircraft gas turbine engines, which promise to operate with higher efficiencies and to emit smaller quantities of nitrogen oxides, relative to those of present aircraft engines. Unfortunately, the advanced engines are more susceptible to thermo-acoustic instabilities. These instabilities are hard to control because they include large dead-time phase shifts, wide-band noise characterized by amplitudes that are large relative to those of the instabilities, exponential growth of the instabilities, random net phase walks, and amplitude fluctuations.

In this method (see figure), the output of a combustion-pressure sensor would be wide-band-pass filtered and then further processed to generate a control signal that would be applied to a fast-actuation valve to modulate the flow of fuel. Initially, the controller would rapidly take large phase steps in order to home in, within a fraction of a second, to a favorable phase region within which the instability would be reduced. Then the controller would restrict itself to operate within this phase region and would further restrict itself to operate within a region of stability, as long as the power in the instability signal was decreasing.

In the phase-shifting scheme of this method, the phase of the control vector would be made to continuously bounce back and forth from one boundary of an effective stability region to the other. Computationally, this scheme would be implemented by the adaptive sliding phaser averaged control (ASPAC) algorithm, which requires very little detailed knowledge of the combustor dynamics. In the ASPAC algorithm, the power of the instability signal would be calculated from the wide-band-pass-filtered combustion-pressure signal and averaged over a period of time (typically of the order of a few hundredths of a second) corresponding to the controller updating cycle [not to be confused with the controller sampling cycle, which would be much shorter (typically of the order of 10^{-4} second)]. If the power were found to be decreasing, the direction of change in control phase would be maintained. If the power were found to be increasing, the direction of change of the control phase would be reversed.

A large portion of the algorithm is devoted to quickly recognizing loss of control (equivalently, growth of instability) and re-establishing control within a region of stability before the instability at-tains an unacceptably large amplitude. The algorithm also includes provisions for discontinuous exponential gain modulation and adaptation of control parameters to further reduce the instability.

In a computational simulation, this method was demonstrated to be effective in reducing instability, characterized by a frequency of about 550 Hz, in an aircraft-engine-type combustor. In addition, in two separate tests conducted during 2002 this control algorithm has been shown to be effective in reducing the instability in the combustor rig, which has many of the complexities of an actual aircraft engine combustor (NASA TM-2003-212535, "High Frequency Adaptive Instability Suppression Controls in a Liquid-Fueled Combustor" report. For information about the report, contact cto@grc.nasa.gov.)

This work was done by George Kopasakis of **Glenn Research Center.** *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland Ohio 44135. Refer to LEW-17460.

This **Block Diagram** represents a mathematical model of combustion instability and a control system that would suppress the instability by the method described in the main text.