ACTIVE CONTROL OF COMBUSTION INSTABILITIES

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Self-excited oscillations frequently occur when combustion takes place within a resonator. Any small unsteadiness in the rate of combustion generates sound, producing pressure and velocity fluctuations. But these in turn disturb the flame and lead to further perturbations in the combustion. If the phase relationship between the pressure and the unsteady heat release is suitable [1], small disturbances grow rapidly and the flame is unstable.

The afterburner of a gas turbine is one practical example where combustion takes place within a resonator. The afterburner can lead to a considerable thrust augmentation but its performance is limited by the onset of a low frequency combustion instability called reheat buzz. This involves the interaction of longitudinal acoustic waves with the reheat flame. Perturbations can become so intense that they do structural damage.

A similar combustion instability occurs when a premixed flame burns in a duct. The geometry of a laboratory rig designed to investigate this instability is shown in Figure 1. Air is supplied at constant temperature and

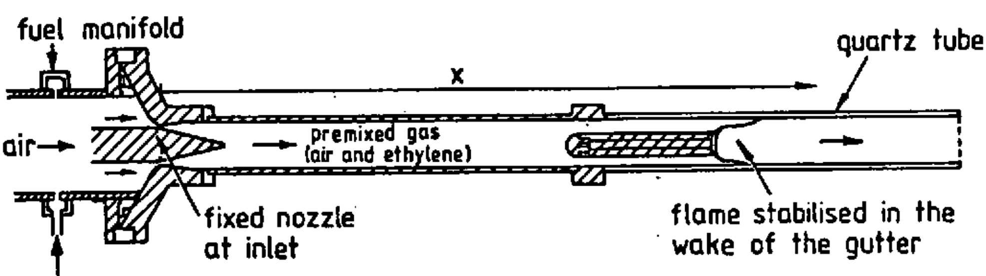

Figure 1 The geometry of the Cambridge Reheat Buzz Rig

pressure upstream of a choked constriction to ensure that the mass flow rate remains constant irrespective of disturbances downstream. The fuel (ethylene) is supplied through a manifold with ten choked holes. It mixes well with the air in the nozzle so that the fluid enters the working section as a premixed gas. It then burns as a turbulent flame in the wake of a bluff body or 'gutter'. At a typical running condition the air flow rate is 0.135 kg/s and ¼ MW of heat is released within the duct. Intense unsteady pressure oscillations are produced, with sound pressure levels in excess of 160 dB.

Active control has been applied to combustion instabilities involving laminar flames [2-4] and to turbulent diffusion flames with low mean flow rates [4,5]. We apply control to our rig by actively changing the upstream boundary condition. The fixed choked nozzle at inlet to the working section is replaced by a choked plate and a movable centre-body which can be oscillated axially, as illustrated in Figure 2. The choked plate ensures that the mean flow supplied to the rig

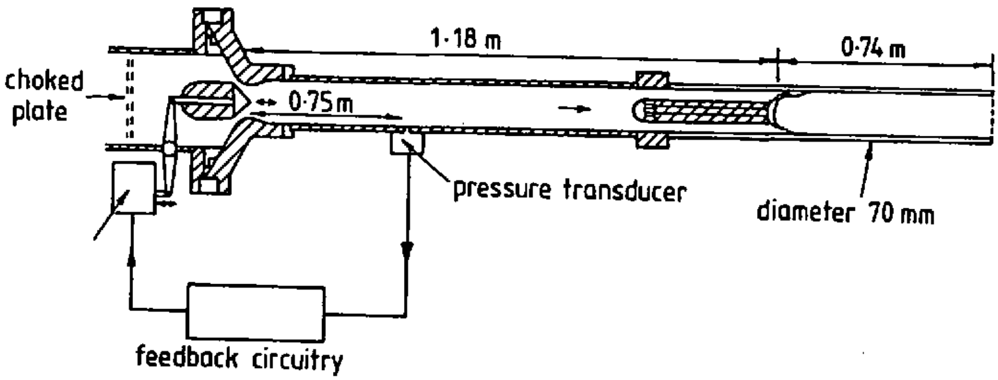

Figure 2 The Reheat Buzz Rig with active control

is unchanged when the controller is switched on. A pressure signal from the rig is filtered and phase-shifted using analogue components and then fed into a 300 W commercial vibrator. This in turn oscillates the centre-body via a mechanical linkage. Axial motion of the shaped centre-body alters the blockage to the flow, thereby producing a fluctuating mass flow into the working section and modifying the upstream acoustic boundary condition. Figure 3 shows the effect of control. Results for the controlled case are compared with those for a centre-body clamped at the same mean position and, of course, for the same air and fuel flow rates. The controller reduces the peak in the pressure spectrum by some 20 dB and eliminates the second harmonic. The sound power in a 0-800 Hz bandwidth is reduced to 1/10 of its value without control.

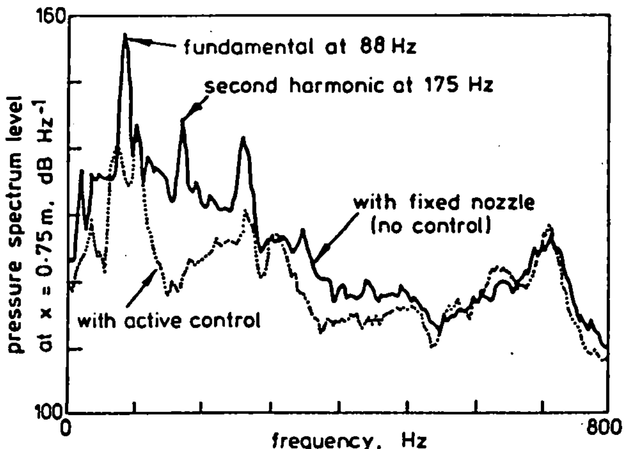

Figure 3 The effect of active control on the pressure spectrum

We have developed a theory to describe combustion oscillations in the basic configuration of the rig [6-7]. The theory is basically a linear stability analysis of a flame in a duct, and can be extended to explain the active control results by simply changing the upstream boundary condition. This theory is able to explain the change in frequency, stability and mode shape produced by the controller [8].

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