Effect of Conical Flameholders on Combustion-Generated Noise

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Nomenclature

D = diameter of burner tube
F = fuel mass fraction
P = acoustic power
S_L = laminar flame speed
U = flow velocity of reactants
ϕ = equivalence ratio

Theme

IT is a common observation that turbulent combustion systems become noisier once combustion is initiated as opposed to the noise in cold flow. Hence, in practical hardware such as turbopropulsion systems and industrial furnaces, combustion noise can contribute a significant amount to the overall noise output. Most recently, extensive data have been reported on sound radiation from premixed flames anchored at the ends of burner tubes and radiating to a free field.[1,2] A question arose at this point as to whether or not the results of Ref. 1 are unique as far as open free flames are concerned. Stated otherwise, it was necessary to know the extent to which the method of flame retention would influence the noise characteristics of open free flames quoted in Ref. 1. Furthermore, it is a theoretical result[3] that for a fixed fuel flow and airflow the noise output should be independent of the stabilization method, unless strong spectral content changes are in evidence. With a view to clarifying the preceding concerns, a different method of flame stabilization is used in the present program. The present experimental study investigates the noise characteristics of premixed flames stabilized through external conical flameholders and compares the results with those pertaining to premixed flames anchored at the ends of burner tubes.

Contents

The noise experiments of the present program were conducted in an anechoic chamber. A simple burner configuration was chosen for rational interpretation of the experimental results. The burners used are of 0.42, 0.652, and 0.96 in. i.d. Conical flameholders of two sizes, with 0.625- and 1-in.-diameter bases, were used to stabilize the flames. Gaseous propane, ethylene, and acetylene fuels have been used, with air as the oxidizer. Since the flames tend to blow off the flameholders at high velocities, the use of a hydrogen pilot flame became essential. An enlarged view of the burner-flameholder assembly is shown in Fig. 1. The flow velocity was varied from 50 to 300 fps. Sound pressure levels were measured by five 0.5-in. condenser microphones placed at a constant radius with respect to the base of the flameholder and at angular locations between 15° and 120° to the flow direction. The output of the microphones is read out directly as sound pressure level on a microphone amplifier, one at a time. These signals, after amplification, were recorded on five channels of a magnetic tape recorder at a speed of 30 ips. The spectral analysis of the nose signals was carried out through the use of a digital Fourier analyzer and associated instruments. The reader is referred to Ref. 3 for further details on experimental setup and data-reduction techniques.

Over the entire range of experimental variables, combustion noise was found to dominate over jet and flameholder interaction noise. The directionality of the combustion noise, determined by the variations in sound pressure levels with azimuthal angle, was observed to be a weak one. Since the same facts are reported in Ref. 1 also, one can conclude that the limited flameholder geometries tested did not affect the directionality patterns of the noise radiated from open turbulent flames, and combustion noise seems to be a monopole noise source regardless of the retention techniques within the range of experimental variables. Frequency spectra display the usual combustion noise spectral characteristics, having a broadband noise with a single peak in the frequency range of 250-1500 Hz. The frequency dependence of the directionality is brought out in Fig. 2. It can be seen that the spectra at various azimuthal locations are almost parallel to each other, thereby establishing the fact that the directionality is almost independent of the frequency. The effect of fuel type on spectral shape also is illustrated in Fig. 2. It clearly is evident that peak frequency values (i.e., frequency corresponding to the maximum power per unit frequency interval in the spectrum) of the acetylene-air combination are higher than those of propane-air. This effect appears because acetylene has a higher S_L value than propane.

Following Ref. 2 and considering U, D, S_L, and F as the important parameters influencing acoustic power computations, a least-squares fit was carried out for the experimental results. Using 35 different tests, the following expression was obtained for the acoustic power radiated from open turbulent flames anchored on the external flameholders:

$$P=0.67\times 10^{-6}U^{2.83}D^{2.77}S_L^{\ 1.89}F^{-0.89}\text{Watts} \qquad (1)$$

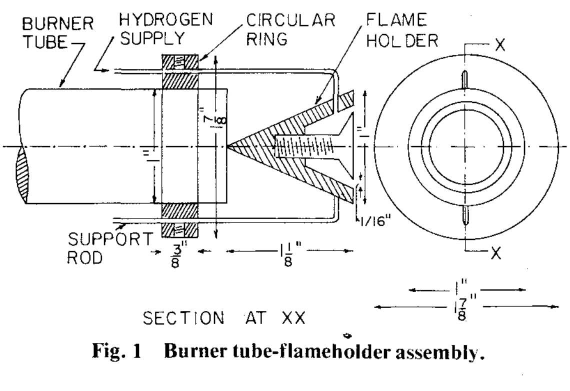

Fig. 1 Burner tube-flameholder assembly.

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Index category: Aircraft Noise, Powerplant.

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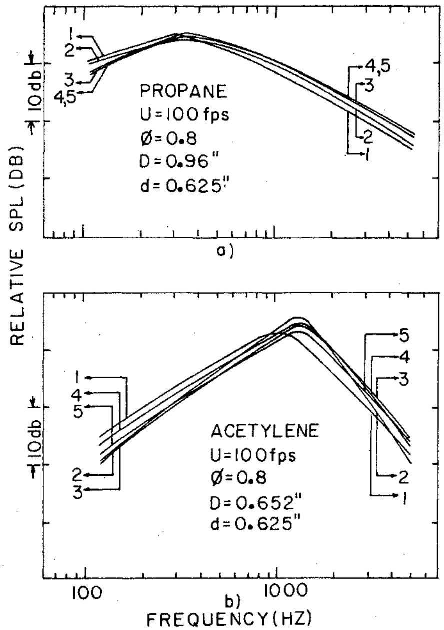

Fig. 2 Frequency dependence of directionality. The numbers 1-5 indicate microphone locations between 15° and 120°.

where

$$50 \leq U(\text{fps}) \leq 300,\ 0.0335 \leq D\,(\text{ft}) \leq 0.08,\ 0.6 \leq \phi \leq 1.0$$

and U and S_L are in feet per second and D is in feet. The mean error in the regression analysis was 9.87%, and the standard deviation amounted to 47.6%; Ref. 2 also quotes an almost identical expression for flames stabilized at the burner tube ends. Moreover, for identical conditions, the acoustic power output of the present investigations differs from that of flames stabilized on burner tubes by a maximum factor of 2 only. This leads to the conclusion that, within the range of flame stabilization techniques used, the variations in acoustic power output are not significant, thereby lending credence to the theory. It also was observed that a change in the flameholder size seems to have little influence on the acoustic power radiated. A scaling law for peak frequency (f_c) was obtained by regression analysis of the peak frequencies measured from frequency spectra. The peak frequency is given by

$$f_c = 0.42 \times 10^{-2} U^{0.58} D^{-1.37} S_L^{\ 0.7} F^{-1.7} \text{Hz} \qquad (2)$$

where the limitations on U, D, and ϕ are the same as those of Eq. (1). The number of tests used for Eq. (2) was 31. The mean error was 3.63%, and the standard deviation was 27.6%.

References

[1]Shivasankara, B.N., Strahle, W.C., and Handley, J.C., "Combustion Noise Radiation by Open Turbulent Flames," *AIAA Progress in Astronautics and Aeronautics: Aeroacoustics: Jet and Combustion Noise; Duct Acoustics*, Vol. 37, edited by H. Nagamatsu, AIAA, New York, 1975, pp. 225-248.

[2]Strahle, W.C. and Shivasankara, B.N., "A Rational Correlation of Combustion Noise Results from Open Premixed Turbulent Flames," *Fifteenth Symposium (International) on Combustion*, The Combustion Institute, Pittsburgh, Pa., 1975, pp. 1379-1385.

[3]Muthukrishnan, M., Strahle, W.C., and Handley, J.C., "The Effect of Flameholders on Combustion Generated Noise," AIAA Paper 76-39, 1976.