MICROPHONE-PROBE AND FARFIELD MEASUREMENTS IN TORCH JETS AND FLAMES

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Introduction

A modified version of a Lenze [1] type of cooled microphone probe was developed, calibrated and used in the gas-mixture jets and flames of welding and heating torches. It was hoped that the data obtained from the probe would explain the high-frequency acoustic "peak" and large-angle noise directionality measured externally from these flames. [Optical studies have failed to identify the acoustic sources.]

Experimental Details

Four different flame settings were used. For the oxy welding-torch, the volumetric mixture ratio was varied over a range of 2.7/1.0 to 4.1/1.0. The oxy torch tip was a single hole with an internal exit diameter of 2.6 mm. Air could not be put through the welding torch without blowing the flame off the burner. A heating torch, used for radiator repair work, was purchased in August 1983. The burner had a central hole surrounded by two annuli. The effective diameter was ~ 10 mm. Oxygen cannot be used in the heating torch.

Given that one was forced to use differently-sized (and shaped) burners and different oxidants, the author decided to use the same oxygen/LPG mixture ratios for the four test cases. Since air consists of 21% oxygen by volume, five times the O_2 flowrate was required (using air as the oxidant) by the heating torch to produce the same "combustible" mixtures as used in the welding-torch test cases.

Due to the oxy/LPG flame having an adiabatic flame temperature of 3000 K, the minimum distance between the probe tip and the burner exit plane was 65 mm. Close distances would boil the probe cooling water, precluding calibration. All data reported in this paper are measured at an axial distance of 65 mm above the burner face. The probe was laterally traversed from the flame/jet centreline (R = 0 mm) to the edge of the flame/jet (R = 10 mm).

Data Acquisition/Analysis

All data were recorded on magnetic tape. The overall, or dB [LIN], value of the sound-pressure level (SPL) was recorded while taping the data. The taped probe data were first played through a Statistical Distribution Analyzer. [The probe measures total-pressure fluctuations.] The welding-torch flames and jets produced probe data with an average variance of 3 - 4 dB from the mean measured values. The heating-torch flames/jets produced probe data which had negligible variance from the mean values. One-third octave analysis has been performed on all data. Narrower bandwidth (60 Hz) analysis has been performed on the welding-torch data, but will not be reported in this paper.

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Microphone-Probe Results

Although the burner exit velocity of the heating torch decreased by 1/4 to 1/3 of the equivalent welding-torch values, the measured SPL always increased with the air/LPG flames or jets.

(i) Combustible-Mixture Jets

All four test cases, using either oxygen or air plus LPG, gave similar results. The overall SPL values were usually within 6 dB of the equivalent flame value. The maximum SPL values were all obtained at 250 Hz and along the jet centreline [R = 0 mm]. The 1/3 octave spectra from each torch were similarly shaped. Those from the heating torch had a single peak at 250 Hz. The spectra from the welding torch all had a second peak at 1.25 or 4.0 kHz which was 7 to 11 dB less than the peak at 125 Hz.

(ii) Air/LPG flames

The maximum values of overall SPL and 1/3 octave filtered data were always obtained at the flame axis [R = 0 mm]. The spectra all had double peaks. The first peak always occurred at 250 Hz; the second peak occurred at either 3.15 or 4.0 kHz. The second peak was larger than the first peak for two test cases, the same as the first peak for one test case, and slightly less than the first peak for the fourth test case.

(iii) Oxygen/LPG flames

The maximum values of overall SPL and 1/3 octave filtered data always occurred at 5 mm from the flame axis. This is halfway across the flame radius of 10 mm. The 1/3 octave spectra also had double peaks. The first peak occurred at 50, 250 or 400 Hz in order of increasing burner exit velocity. The second peak also occurred at either 3.15 or 4.0 kHz. The second peaks were 2.5 - 11 dB less than the SPL values at the first peak in the spectra.

Farfield Acoustic Results

An articulated microphone boom was used to measure farfield noise at radii of 0.26, 0.50 and 1.0 metre. The vertical flow axis was treated as 0 degrees azimuth. Data were tape-recorded at 30, 45, 60, 75, 90 and 120 degrees azimuth angle at each radial distance.

(i) Overall Sound-Pressure-Levels

With respect to a particular torch, each test setting gave similar results. The overall *flame* SPLs were of the order of 100 dB at a radial distance of 260 mm, for either torch, at the various azimuth angles. For each test setting, the *flames* produced linear SPLs within a 3 dB range using either torch. The isothermal (unignited) gas-mixture *jets* had very different acoustic behaviour, depending upon the oxidant used. The air/LPG jets produced overall readings very similar to, but generally larger than, the linear values for their equivalent flames (~ 100 dB at 260 mm). The oxygen/LPG jets gave overall SPLs exactly the same as the background noise in the laboratory (~ 70 dB). The cold-flow Reynolds numbers of each test setting were all in the turbulent region (4 k - 17 k). The values for the air/LPG mixtures were ~ 1,000 less than those for the same test settings using oxygen.

(ii) Directivity

Both types of unignited gas mixtures always produced classical jet noise (quadrapole) directionality. The maximum SPL was 30-45 degrees from the flow axis. Both types of burning mixtures shifted their directivity to 75-90 degrees from the flow axis.

(iii) One-third octave analysis

One-third octave analysis has been performed on the farfield acoustic data obtained at each radius and at each azimuth angle. The oxygen/LPG flames produced essentially broadbanded spectra with maximum values typically in the 3.15 k to 6.3 kHz range. The air/LPG spectra always had a significant "dip" in the 4 k to 8 kHz bands. The attenuation was 2 dB less for the flames than for the 8-10 dB dip produced by the jets. The flames also had a narrower frequency range over which the dip occurred (one or two centre-frequency bands). The author attributes this dip in the spectra to the equipment used; it is probably valve noise. The spectra have their maximum values at ~ 20 kHz. The flame spectra are broadband, if one ignores the "dip". The jet spectra have a steep, almost linear rise to 20 kHz and have only $\leqslant$ 3 dB attenuation (from that maximum value) at 40 kHz. The maximum values of the jet spectra are 0-10 dB larger than the maximum values for their equivalent flame spectra.

Summary

With the oxy welding-torch probe data, the SPL of the cold mixture jets was 3-15 dB higher than the values measured from the equivalent flames. The heating-torch probe data was generally 3-6 dB higher for the flames than for the cold mixture jets. Many factors would influence this reversal in trend. Two major factors would be the much larger flowrate required by the heating torch and the fact that the adiabatic flame temperature of the welding torch is 3000 K, while that of the heating torch is 1500 K.

The farfield results of both flame types are similar in level (~ 90 - 100 dB) and directivity angle (75-90 degrees from the flow axis). The air/LPG jets produced overall SPLs similar to, but generally larger than, their equivalent flames. The oxygen/LPG jets gave overall SPLs exactly identical to the background noise in the laboratory (~ 70 dB). The directivity angle of both types of combustible mixtures was 30-45 degrees from the flow axis. Cold-flow Reynolds numbers are approximately the same for each test settings using either oxidant (4 k - 17 k range for all four settings used).

Conclusion

Probe results indicate that the hot oxy/LPG flames have a shielding effect upon their equivalent mixture jets. The cooler air/LPG flames are slightly noisier than their jet mixtures. Farfield results are unusual for the oxy/LPG jets, which are 20-30 dB below the air/LPG jets and both flame types.

References

1. R. Günther, 'Measurements of Flame Turbulence: Aims, Methods and Results', J. Inst. of Fuel, June (1970).