MEASUREMENTS OF THERMAL EFFECTS ON ACOUSTIC SCREECH IN A CHOKED CIRCULAR JET EMANATING FROM A SHARP-EDGED ORIFICE

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Summary Experiments are performed in a 24.4 mm diameter choked circular hot and cold jets issuing from a sharp-edged orifice at a fully expanded jet Mach number of 1.85. The stagnation temperature of the hot and the cold jets are 319 K and 299 K respectively. The results suggest that temperature effects on the screech amplitude and frequency are manifested for the fundamental, with a reduced amplitude and increased frequency for hot jet relative to the cold jet. Temperature effects on the second harmonic are also observed.

INTRODUCTION

Supersonic jet screech represents an important consideration as the intensity (as high as 170 to 180 dB) in the nearfield with a significant upstream directivity can induce fatigue and cause structural damage to aircraft and launch vehicles [1]. Physically screech noise is shown to be manifested by the interaction of shock-cell structures with acoustics waves [1] and other instability waves. The existing data on the screech noise, which are primarily limited to convergent-divergent and choked nozzles, suggest that uncertainties persist concerning the nature of the temperature effects on the fundamental and higher harmonics [2]. To the author's knowledge, screech data from choked nozzles issuing from a sharp-edged orifice are presently unavailable. Such applications arise in purge systems.

The objective of the present work is to report measurements of screech amplitude and frequency for a cold and a hot jet issuing from a sharp-edge orifice at the same fully expanded jet Mach number. Temperature effects on the screech amplitude and frequency on both the fundamental and higher harmonics are reported.

EXPERIMENTAL SETUP AND ANALYSIS

Test Setup

Nitrogen flows from a chamber through a sharp-edged orifice of 2.44 cm diameter. The total pressure is 0.65 MPa. The total temperature for the hot jet and the cold jet are 319.4 K and 299 K respectively. The jet static pressure ratio is 3.18, and the ambient temperature is 299 K. The fully expanded jet Mach number is 1.85. The jet exit Mach number is 1.05. The jet Reynolds number (based on jet diameter) is about 2.5×10^6. Static pressure and total pressure are measured by pitot tubes, and the acoustic pressure is measured by B&K microphones with a frequency range of 10 kHz. Both axial and radial traversing in the jet is carried out.

CFD Analysis

An axisymmetric CFD (Computational Fluid Dynamics) analysis is conducted with the aid of NASA OVERFLOW Navier-Stokes code [3]. Similar CFD analysis for supersonic jets was conducted with this code in [4]. A simple one-equation Spalart-Allmaras turbulence model is considered.

RESULTS

Fig. 1 shows the jet Mach number contours as obtained by the CFD analysis, showing several shock-cell structures characteristic of an under-expanded jet. Based on a 10% decay of the jet center-line velocity, CFD results suggest a jet angle of about 8 deg, whereas both the pressure data and infrared photographs suggest a spread of about 7 deg.

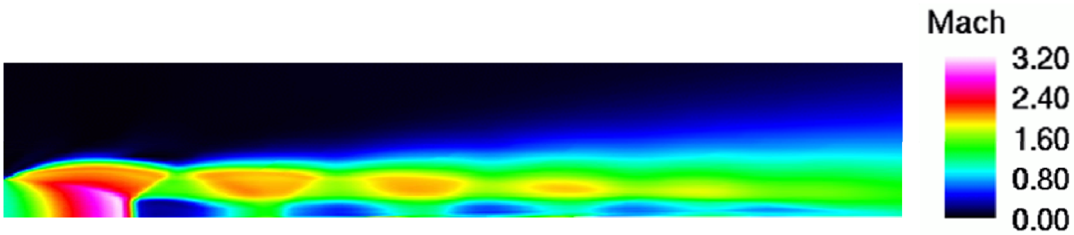

Fig. 1. Mach number contours in the heated axisymmetric jet.

Fig. 2 presents a comparison of the jet centre-line Mach number for the hot jet. Reasonable agreement is noticed between the data and the prediction except near the jet exit. The CFD solution seems to indicate a more dissipative character.

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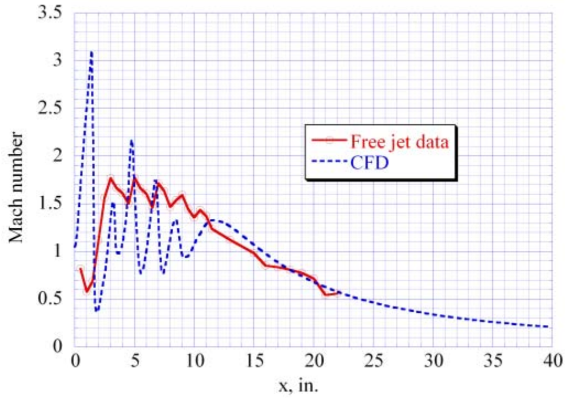

Fig. 2. Distribution of jet centre-line Mach number for the hot jet.

Fig. 3a illustrates the narrow band spectral sound pressure level for the hot and the cold jet at an axial station of 48.3 cm from the jet exit, and at two radial locations (17.8 cm and 45.7 cm). Fig. 3b indicates the narrow band spectral sound pressure level for the hot and the cold jet at an axial station of 78.7 cm from the jet exit, and at a radial location of 40.6 cm. These data for the free jets reveal the presence of screech. The overall sound pressure level (OASPL) are also indicated. The character of screech amplitude and screech tones for the hot and cold jets from sharp-edged orifices is in general agreement with the nozzle data of Ahuja et al. [2].

Calculations based on existing correlations for the screech frequency for nozzles [5] yield a frequency of 1700 Hz, which is close to the measured value of about 1800 Hz. Data for the hot jet suggest that the fundamental screech amplitude is slightly decreased while the fundamental frequency is slightly increased relative to the cold jet. For the second harmonic, the screech amplitude remain unaltered by temperature.

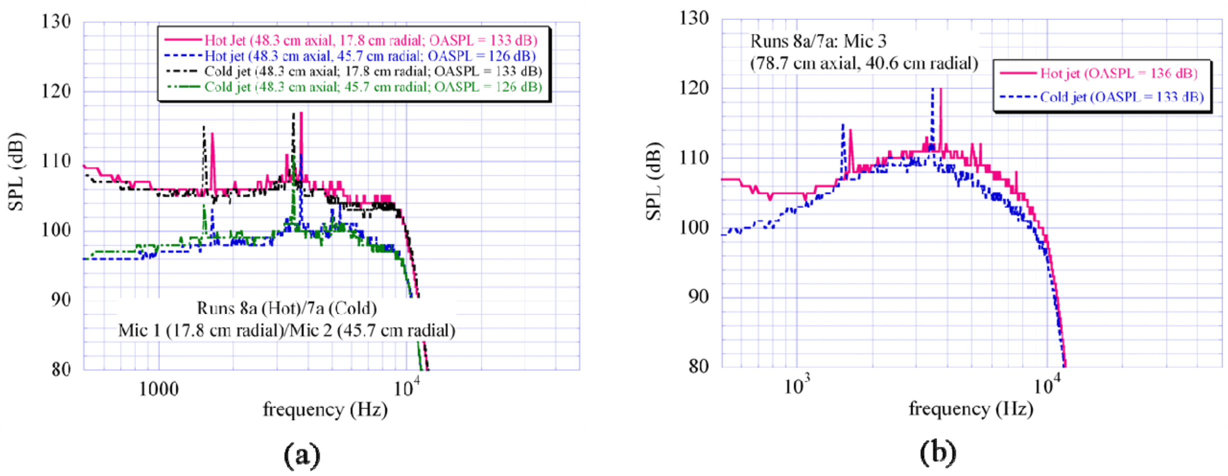

Fig. 3 Narrowband acoustic spectrum for cold and heated jets.

CONCLUSIONS

The present experiments on choked circular jets suggest that for the hot jet the fundamental screech amplitude is slightly decreased while the fundamental frequency is slightly increased relative to the cold jet. With regard to second harmonic, the screech amplitude remain unaltered by temperature, while the frequency of the second harmonic is larger for the hot jet. Data with larger temperature differences will be helpful in future investigations.

References

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