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Turbulence and noise suppression of a high-speed jet by water injection

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An experimental investigation has been carried out on a supersonic jet of air issuing from an $M = 1.44$ converging–diverging rectangular nozzle of aspect ratio 4. Particle image velocimetry measurements of the flow field along with near-field acoustic measurements were made. The effect of injection of a small amount of water ($\sim$5% of the mass flow rate of the jet) into the shear layer of the jet, on the unsteady flow structure and sound generation were examined. The presence of water droplets in the jet modified the turbulence structure significantly, resulting in axial and normal r.m.s. velocity reductions of about 10% and 30%, respectively, as compared to that of a normal jet. An even larger effect is found on the peak values of the turbulent shear stress with a reduction of up to 40%. The near-field noise levels (OASPL) were found to reduce by about 2–6 dB depending on the location of the injection and the water mass flow rate. Far-field acoustic measurements carried out on a heated $M = 0.9$ (jet exit velocity $= 525\,\mathrm{m\,s^{-1}}$) jet show significant (6 dB) reductions in the OASPL with moderate amounts of water injection (17% of the mass flow rate of the jet) suggesting that the technique is viable at realistic engine operating conditions.

1. Introduction

In need of a rational approach to supersonic jet noise suppression, fundamental studies are being conducted in our laboratory using modern experimental techniques. Recognizing that an essential prerequisite is that the nature and location of the important noise sources be clearly understood, our work is focused on describing the unsteady flow of a supersonic jet in some detail using particle image velocimetry (PIV). In this paper, we describe the flow characteristics of an $M = 1.44$ ideally expanded rectangular cold jet. It is then followed by a PIV study of the role of water injection on the turbulence characteristics. Concomitantly, near-field acoustic measurements are made to demonstrate the efficacy of this technique for noise suppression. Encouraged by the near-field noise measurements, an additional experiment is conducted to obtain the far-field noise measurements in a recently built high-temperature anechoic jet facility using a heated $M = 0.9$ axisymmetric jet, with and without water injection. The exit velocity of the axisymmetric jet is comparable with that of the rectangular jet.

The far-field mixing noise of a supersonic jet appears to be comprised of three major noise components (Crighton 1977). The first is a field coherent in phase, but of high frequency and short wavelength. The flow-visualization pictures show that the waves, commonly referred to as Mach waves, have plane phase fronts and are