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Underexpanded Sonic Jets: A PIV Study

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ABSTRACT

The velocity field of underexpanded sonic air jets were investigated using digital particle image velocimetry (PIV). The jets were produced by a convergent nozzle connected to a settling chamber. Measurements were made for five different underexpanded jets with chamber-to-ambient pressure ratios of $P_o/P_a=1.89, 4.77, 14.26, 29.36$ and 38.41 (which correspond to fully-expanded jet Mach numbers $M_j=1, 1.68, 2.38, 2.85$ and 3.03 , respectively). For each jet, streamwise and transverse velocities were obtained in the range $x/D=0$ and 8 , D being the nozzle exit diameter. Mean velocities, turbulence intensities, turbulent shear stress and vorticity were obtained from 100 instantaneous PIV image pairs for each location. From these results the initial growth of the jets and the effect of underexpansion ratio on the flow structure was determined. Also, the effect of shock structure and shear layer growth on the mean velocity and turbulence fields were determined. It was found that the Mach disks that form in the near field of the highly-underexpanded jets significantly influence both the mean velocity the turbulence distributions. In general, the PIV method used provided good velocity data in the jet near field and allowed the identification of flow structures and their respective locations such as shock waves, expansion regions, slip lines and shear layers. However, the effect of particle inertia was evident just downstream of the Mach disk in the case of highly underexpanded jets.