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Flow field and noise characteristics of a supersonic impinging jet

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This paper describes the results of a study examining the flow and acoustic characteristics of an axisymmetric supersonic jet issuing from a sonic and a Mach 1.5 converging–diverging (C–D) nozzle and impinging on a ground plane. Emphasis is placed on the Mach 1.5 nozzle with the sonic nozzle used mainly for comparison. A large-diameter circular plate was attached at the nozzle exit to measure the forces generated on the plate owing to jet impingement. The experimental results described in this paper include lift loss, particle image velocimetry (PIV) and acoustic measurements. Suckdown forces as high as 60% of the primary jet thrust were measured when the ground plane was very close to the jet exit. The PIV measurements were used to explain the increase in suckdown forces due to high entrainment velocities. The self-sustained oscillatory frequencies of the impinging jet were predicted using a feedback loop that uses the measured convection velocities of the large-scale coherent vortical structures in the jet shear layer. Nearfield acoustic measurements indicate that the presence of the ground plane increases the overall sound pressure levels (OASPL) by approximately 8 dB relative to a corresponding free jet. For moderately underexpanded jets, the influence of the shock cells on the important flow features was found to be negligible except for close proximity of the ground plane.

1. Introduction

While hovering in close proximity to the ground, short take-off and vertical landing (STOVL) aircraft experience a suckdown force, commonly known as 'lift loss'. This lift loss is due to the entrainment flow associated with the lifting jets which induce low surface pressures on the airframe resulting in a force opposite to lift. The lift loss in hover increases in magnitude as the aircraft approaches the ground. When the aircraft is in vertical landing mode and is near touch down, in addition to lift loss, the impingement of the high-speed lifting jets on the ground plane lead to significant ground erosion (Margason *et al.* 1997). Increased overall sound pressure levels (OASPL) associated with the supersonic jets are also of concern with respect to sonic fatigue of structural elements in the vicinity of the nozzle exhaust. These problems become more severe when the jets operate at supersonic speeds, which is the case in the future generation STOVL aircraft (e.g. the Joint Strike Fighter). Very limited data are currently available in the literature to characterize accurately the supersonic jet induced effects in hover. Using the simple configuration shown in figure 1, a series of experiments is conducted aimed at providing some understanding of the flow physics and identifying the main effects contributing to the hover lift loss.