The Role of Large Scale Coherent Structures on Screech Amplitude

Anjaneyulu Krothapalli*, Mehmet B. Alkislar†, and Luiz M. Lourenco‡

Department of Mechanical Engineering
Florida A&M University and Florida State University
Tallahassee, FL 32310

The flow field of a screeching rectangular jet of aspect ratio 4 is studied using stereoscopic Particle Image Velocimetry. Phase locked velocity field measurements at the maximum screeching condition show that the jet is dominated by large-scale coherent structures. The magnitude and extent of these structures, characterized by their circulation, is found to correlate with the screech tone intensity. At operating conditions of the jet away from the maximum screech, the strength of the large-scale vortical structures measured by the magnitude of the coherent vorticity weakens. Therefore, it is concluded that the presence of well-organized coherent structures is closely associated with the intensity of the screech tone.

1. INTRODUCTION

Since the pioneering work of Powell[1], many theoretical and experimental investigations have been carried out to elucidate the features of discrete sound, commonly referred to as screech tones. These tones are commonly generated by imperfectly expanded supersonic jets (the reader is referred to numerous experimental studies cited in a recent review article by Raman[2]). Using a feedback mechanism Powell described the screech phenomenon as being generated by disturbances in the shear layer that are convected downstream and come in contact with a shock cell boundary. This interaction, particularly at the end of the shock cell, produces intense sound. This sound propagates upstream in the ambient medium, interacts with the incipient shear layer at the nozzle exit and produces a new downstream traveling disturbance that continues the feedback cycle. It is assumed that the sound waves moving in the upstream direction adjacent to the jet are of sufficient strength to affect the stability of the shear layer surrounding the shock cells. Upon reaching the nozzle exit, the acoustic wave is assumed to give rise to a localized pressure force, which excites the shear layer. This initial small disturbance usually forms regular undulations, which take on a slightly wavy form. The rapid growth of these undulations results into eddies[3], which are clearly depicted in figure 1.

It is also commonly believed that eddies seen in the flow visualization pictures are a manifestation of the shear layer instability process, and correspond to the nonlinear stages of free shear layer instability in which the infinitesimal wave grows and distorts to form a vortex[4]. The rapidly growing instability waves, related to the flapping mode in a rectangular jet, evolve into the intense coherent eddies as seen in figure 1. An accurate prediction of the screech frequency can be made given the knowledge of the shock cell structure mean flow characteristics coupled with the tools of stability analysis[4]. However, the screech tone amplitude prediction remains elusive and it is the purpose of this paper to address this issue.

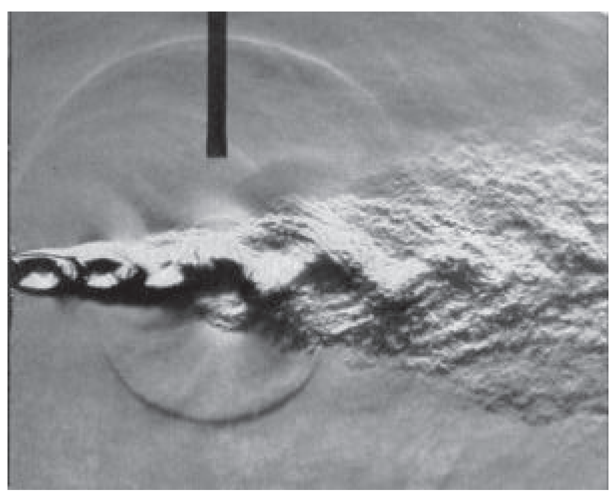

FIGURE 1: PHASE LOCKED SCHLIEREN PICTURE OF SCREECHING RECTANGULAR JET. ASPECT RATIO OF THE CHOCKED NOZZLE *AR* = 10, NOZZLE PRESSURE RATIO *NPR*= 3.5 (FROM REF. 5).

* Professor and Chairman
† Graduate Student
‡ Professor