JET FLOW FIELD DURING SCREECH

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Abstract

Measurements were made of the flow field structure and the near field parameters of a jet exhausting from a sonic nozzle with a 1.27 cm exit diameter. Compressed air was used for obtaining stagnation pressures up to ~5 atmospheres. The jet exhausted vertically from a settling chamber into an acoustically insulated room and through an insulated duct out through the roof. Measurements were made with several different reflecting surfaces at the nozzle exit as well as an insulating surface. Schlieren pictures at 500,000 frames/s were taken. Overall sound pressure level, impact pressure level downstream, and sound frequency analyzer measurements were made.

It was found that with a reflecting surface there was a radial oscillation of the jet which had the same frequency as the dominant sound (screech) frequency emitted by the jet. No axial motion of the inviscid part of the flow structure was detected. The insulated surface at the nozzle exit appeared to shift the dominant frequencies of the sound generated into the region above the audible (> 16 KHz). A reflecting surface yielded "pure tones" (screech) with one or two harmonics. The dominant (screech) frequency decreased as the stagnation pressure increased. The screech frequency was found to be approximately inversely proportional to the length of the first shock cell.

Nomenclature

- $C_0$: speed of sound in ambient gas
- $D$: diameter of nozzle exit
- $f$: frequency of pure tone (screech frequency)
- $L_1$: length of first cell, distance between nozzle exit plane and intersection of shock with shear layer
- $M$: Mach number based on isentropic expansion to ambient pressure
- $P_0$: stagnation chamber pressure
- $P_a$: ambient pressure
- $P_i$: impact pressure
- $R_{LB}$: distance from nozzle centerline to left boundary of jet
- $R_{RB}$: distance from nozzle centerline to right boundary of jet
- $t$: time
- $\tau$: period of screech, $1/f$
§ 1. Introduction

Profound changes in the jet mixing process have been shown to result under some conditions [1]. The production of excessive acoustic energy at a particular characteristic frequency is not primarily due to the preferential production of noise within the jet itself, but rather it is due to the preferential amplification of a particular frequency (or frequencies). It appears that a feedback loop is established wherein pressure pulses, which radiate from the downstream portion of the jet, travel through the ambient gas and create disturbances in the jet near the nozzle; these disturbances then interact with the shock structure of the jet as they propagate downstream within the jet. The overall amplification factor of this feedback loop is seemingly not greater than unity except under those particular jet conditions which must exist when "screech" occurs. The amplification of this feedback loop is strongly affected by the reflections of the sound waves near the base of the jet. Although certain elements of this feedback loop are well established, the entire loop has not been adequately defined. Quantitative predictions of frequency and intensity of the screech are generally not possible. In fact, the existence or absence of screech from a supersonic jet in many cases cannot now be predicted.

Most of the work done in attempting to rationalize and predict the entire jet noise phenomena has been somewhat random and grossly empirical in nature. This pertains primarily to measurements made, but also applies to much of the theory. The mathematical theory has not, unfortunately, provided a clearcut guide for quieting engines. The quieting techniques employed have been motivated by conflicting interpretations of the theory, and have met with only a fair degree of success. Furthermore, the explanation of successful muffler behavior is still a matter of speculation. Comparatively little theoretical work has even been attempted in connection with the special problem of the noise from choked nozzles.

While the generation of noise by subsonic jets is fairly well understood much information is still to be desired, especially for the higher Mach number subsonic jets. Although Lighthill [2, 3] established an analytical description of the generation of aerodynamic noise some time ago,