# Transonic Resonance Demonstrated To Be a Source of Internal Noise From Mixer-Ejector Nozzles

Experimental studies have shown that convergent-divergent nozzles, when run at low pressure ratios, often undergo a flow resonance accompanied by the emission of acoustic tones. This "transonic resonance" phenomenon, not well recognized previously, was studied with single, round laboratory-scale nozzles, and the results were reported in reference 1. An unsteady shock occurring within the divergent section was thought to be responsible for the resonance. With increasing supply pressure, the frequency f_N of the resonance increased and "stage jumps" occurred. Within a stage, the frequency varied approximately linearly with the fully expanded jet Mach number M_j. The slope of the variation became steeper when the half-angle-of-divergence of the nozzle was decreased. Correlation equations based on the data were provided for predicting f_N. Another striking feature was that tripping the nozzle's internal boundary layer tended to suppress the resonance. A clean, smooth nozzle interior was a prerequisite for the resonance to take place prominently.

During noise field studies with mixer-ejector nozzles in NASA's High-Speed Research program, tones were often encountered. The tones would persist in the simulated "cutback" condition (shortly after takeoff). Unfortunately, we did not understand their origin and, thus, could not develop a logical approach for suppressing them. We naturally questioned whether or not some of those tones were due to the transonic resonance. This was studied with a 1/13th scale model of the High-Speed Civil Transport nozzle. The first objective was to determine if indeed tones could be detected in the radiated noise. The next objective was to diagnose if those tones were due to the transonic resonance. Agreement of the frequencies with the correlation equation (ref. 1) and the effect of boundary layer tripping were to be used in the diagnosis.
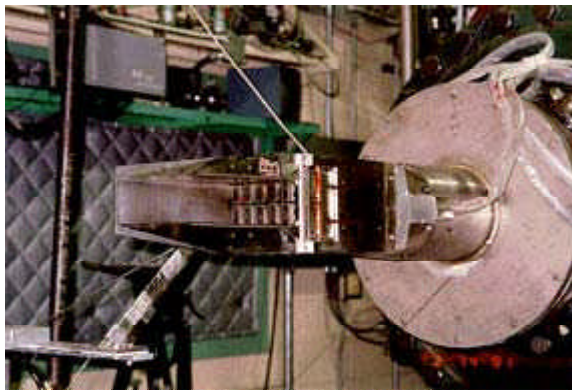

HSCT nozzle mounted in the open-jet facility.

The experiments were conducted in an open-jet facility at the NASA Glenn Research Center. The photograph shows the nozzle mounted on the facility. One wall of the ejector

was removed so that the chutes of the primary nozzle would be visible. The noise was measured using a microphone held at a fixed location. Sound pressure spectra are shown for several values of M_j in the graph on the left. It can be seen that the frequency of the spectral peaks generally increase with increasing M_j. Furthermore, a given spectrum is marked by a peak at a lower frequency (fundamental) and by another peak to the right that is approximately the third harmonic. These are characteristic of the transonic resonance. The frequencies are compared with a prediction from the correlation equation in the graph on the right. The dimensions of the chutes are used as input in the calculations. The procedure for determining the half-angle-of-divergence for the chutes and the correlation equations is given in reference 1.
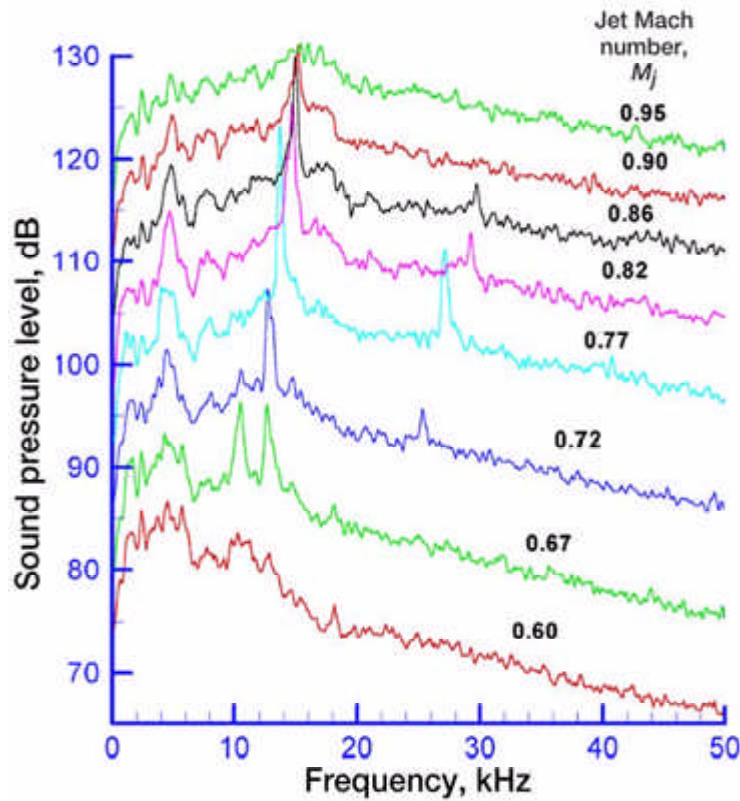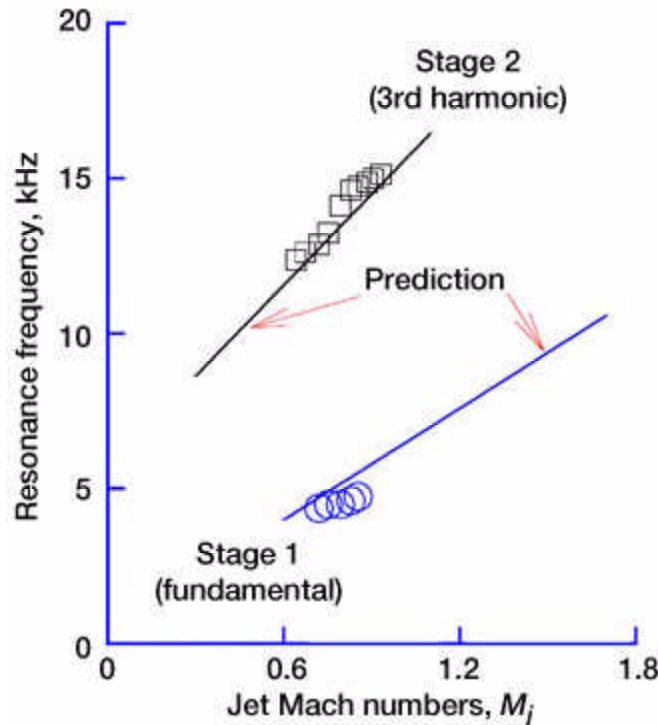
Left: Sound-pressure-level spectra measured at different fully expanded Mach numbers (Mⱼ). Right:Comparison of resonance frequency (spectral peaks of second figure) with prediction.

The solid lines represent predictions for the frequencies of the fundamental and the next stage. It is clear that the observed frequencies follow the prediction well. This provides strong support to the notion that the spectral peaks are indeed due to the transonic resonance phenomenon. The effect of boundary layer trip lends further support. Boundary layer tripping near the throat of the chutes reduced the amplitudes. Because of the complex geometry and difficulties in assembling and disassembling the nozzle, the tripping effect has not been completely studied yet. The results, nevertheless, suggest that noise may be reduced simply by appropriate boundary layer tripping.

Reference

1. Zaman, K.B.M.Q.; Dahl, M.D.; and Bencic, T.J.: Experimental Investigation of 'Transonic Resonance' With Convergent-Divergent Nozzles. AIAA Paper 2001-0078, 2001.

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