COMMENTS ON "CHOKED FLOW: A GENERALIZATION OF THE CONCEPT AND SOME EXPERIMENTAL DATA"

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In the article by Hoge and Segars[1] the argument is against the ejector model which assumes that the supersonic primary stream and the walls of the mixing tube form a converging channel in which the secondary stream expands to sonic velocity. Recent air ejector studies made at the Air Force Institute of Technology by Nelson[2] confirm that the area variation of the primary stream is insufficient to choke the secondary stream for the test conditions presented in Ref 1 where the ratio of the mixer area to the primary nozzle exit area A_m/A_p was 3, and the ratio of the mixer length to its hydraulic diameter L/D was 10.6. We would argue, however, that this result might be altered for higher ratios of primary stream total pressure to secondary stream total pressure P_{op}/P_{os}.

The situation, for example, at an A_m/A_p of 2 is quite different. As can be seen from Figures 1 and 2, a primary stream entering the mixer through a diverging nozzle at a Mach number of 2 rapidly expands entrained ambient air to supersonic speeds before an oblique-normal shock system forms. the interferogram (Figure 2) shows that the mixer wall and the alternate expansion and contraction of the nonideally expanded primary jet form a convergent-divergent nozzle. It may be noted also that relatively little mixing occurs until the primary stream is decelerated substantially. It is, therefore, clear that shear and area variation are the dominant factors in the acceleration of the secondary stream.

Other important conclusions from Reference 2, which are of interest to investigators of ejector performance and turbulent mixing, are as follows.
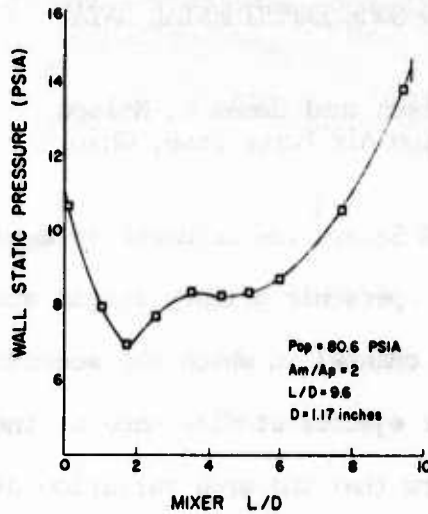
Fig. 1 Mixer wall static pressure profile.

1) Mixer wall static pressure profiles are not an adequate indication of the rate of mixing or completeness of mixing in supersonic ejector systems for cases where the secondary flow is supersonic or where strong shocks are present.

2) Interferograms indicate that the mixing region in a supersonic ejector system does not appear to be changed appreciably in width when passing across shocks that are present in the primary or secondary flow. The mixing region is displaced laterally as it crosses an oblique wave, and the direction of displacement is dependent upon whether its primary stream has been compressed or expanded.

3) It was found that the boundary-layer assumption of $\partial P/\partial y = 0$ across the mixing region was a quite close approximation, but the centerline static pressures were not equal to the wall static pressures. In each region of the primary stream between oblique waves, there is a static pressure variation. However, for the flows to remain separated with a mixing region for a boundary, the pressure gradient indeed must vanish at the boundary.

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We believe that this last observation makes a one-dimensional analysis such as that of Reference 1 invalid for an ejector with a supersonic primary stream. The average pressures of the primary and secondary stream legitimately cannot be assumed to be equal. The streams must be allowed to interact to provide equal pressures at the edge of the mixing region. The best analytical effort of this sort that we have seen is that of Chow and Addy.[3]
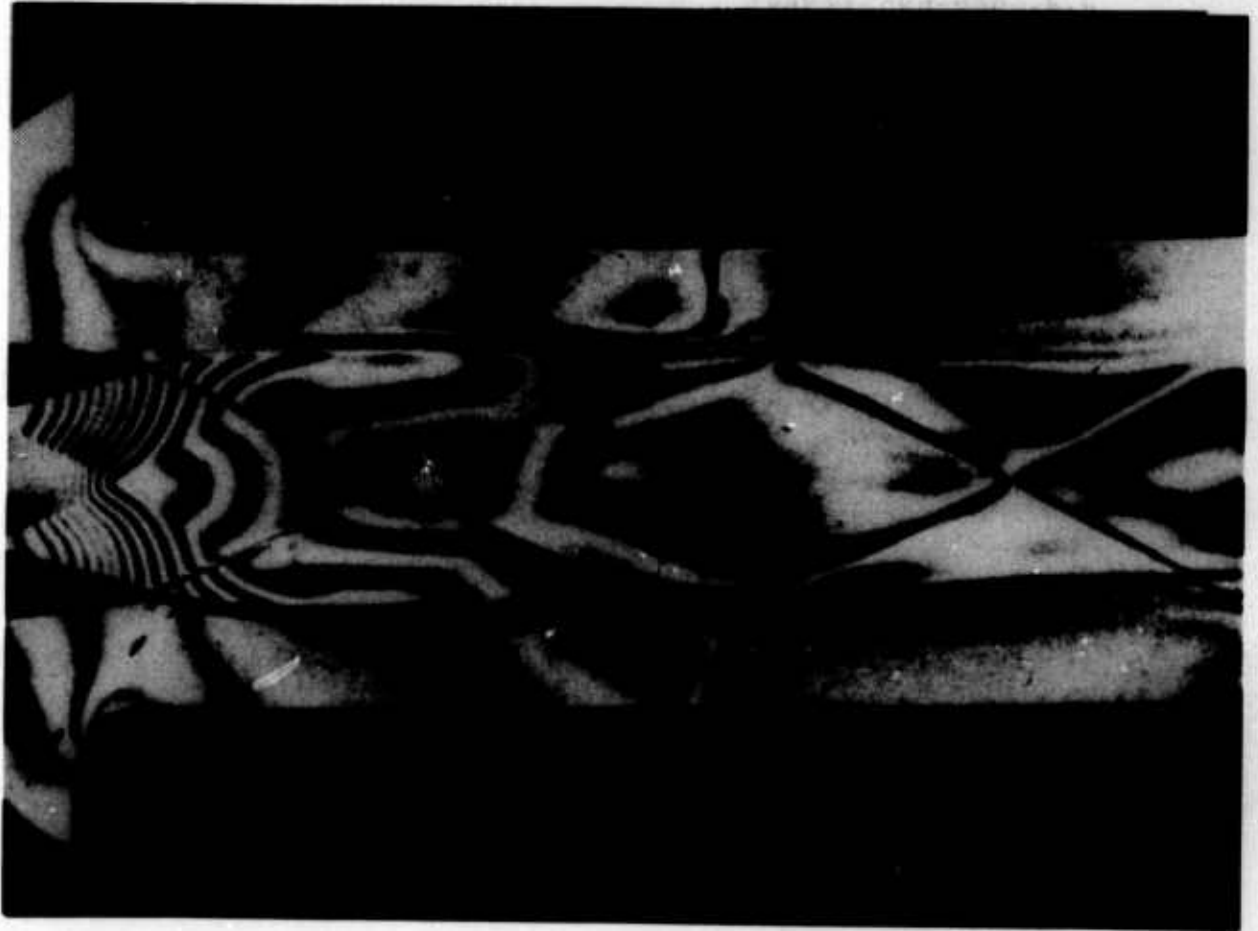

Fig. 2   Interoferogram of Mixer Flowfield (Am/Ap = 2, Mp = 2)

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References

1. H. J. Hoge and R. A. Segars, "Choked Flow: a Generalization of the Concept and Some Experimental Data," AIAA J.3, 2177-2183 (1965).

2. J. R. Nelson, "Investigaticn of the Mixing Region Between the Primary and Secondary Stream of a Two-Dimensional Supersonic Air-Air Ejector System," M.Sc. Thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base OH (June 1965).

3. W. F. Chow and A. L. Addy, "Interaction Between Primary and Secondary Streams of Supersonic Ejector System and Their Performance Characteristics," AIAA J.2, 686-695 (1964).