

theory, when appropriate allowances are made for the noisy freestream and the nonlinear disturbances not identified by the linear theories. It remains to be determined if the incompatibility of planar boundary-layer instability phenomena with classical linear stability theory is a unique feature of the planar boundary layer or if it is a noisy wind-tunnel characteristic that affects planar boundary layers but not conical boundary layers. Quiet tunnel stability experiments would be very helpful in resolving this planar configuration problem and evaluating other conventional wind-tunnel transition issues.

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Downstream Influence Scaling of Turbulent Flow past Expansion Corners

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Introduction

A CLASS of high-speed viscous-inviscid interaction that has not been well studied is that between a turbulent

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boundary layer and an expansion at a convex corner (Fig. 1). Some previous studies at Mach 1.76-7.4 are found in Refs. 1-6. These studies reveal that the surface pressure decreases toward the downstream inviscid value obtained by a Prandtl-Meyer expansion. This Note identifies a downstream influence of the corner based on the mean surface pressure distribution and proposes a scaling law for this distance.

Hypersonic Similarity

For hypersonic flows, the inviscid Prandtl-Meyer expansion is characterized by the hypersonic similarity parameter

$$K = M_\infty \alpha \quad (1)$$

where α is the corner angle in radians. In the limit of $M_\infty \rightarrow \infty$, the inviscid pressure ratio⁷

$$\frac{p_2}{p_1} = \left(1 - \frac{\gamma - 1}{2} K\right)^{2\gamma/(\gamma - 1)} \quad (2)$$

Equation (2) is an exact expression and is not limited to small expansion corners. Figure 2 compares the Prandtl-Meyer pressure ratio as a function of K for a wide range of Mach numbers from 1.5 through 15 with Eq. (2), this limiting case being shown as a thick line. Some previous experimental conditions^{1,3-5} and conditions for a Mach 8 flow past 2.5- and 4.25-deg⁸ expansion corners are also plotted in this figure. It can be noted that the present choice of expansion corner angles gives values of K comparable to previous supersonic conditions. The excellent collapse of the pressure ratio through a wide range of K , even at quite low Mach numbers, may be attributed to the isentropic nature of the inviscid expansive flow.

Care must be exercised in interpreting Fig. 2. For a given Mach number, there is a maximum value of K corresponding to expansion to vacuum, this maximum value being smaller at lower Mach number. Further, the plots in Fig. 2 are of inviscid flows that can be turned through large corner angles. (The lower Mach number curves in Fig. 2 have been chopped below the maximum inviscid solution to reduce clutter.) In reality, the boundary layer would separate at some critical corner angle, this angle being dependent on the Mach number, amongst other parameters. Thus, as previously alluded to, extremely strong hypersonic expansions, which are beyond the scope of the present investigation, will not have supersonic



Fig. 1 Schematic of hypersonic flow past an expansion corner.

- Bloy (1975), $M_\infty = 7.4$
- ▽ Chew (1979), $M_\infty = 1.8$ & 2.5
- △ Goldfeld (1984), $M_\infty = 3$ & 4
- ◇ Dussauge & Gaviglio (1987), $M_\infty = 1.8$
- present study, $M_\infty = 8$

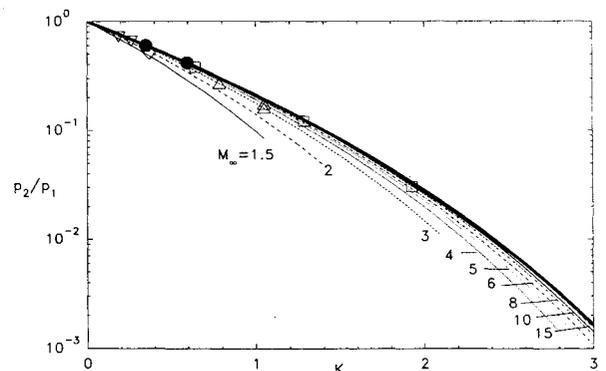


Fig. 2 Inviscid pressure ratio across an expansion corner as a function of the corner hypersonic similarity parameter.

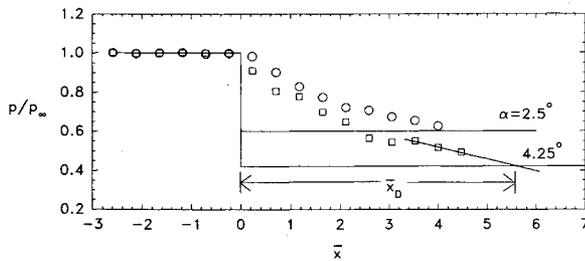


Fig. 3 Surface pressure distribution of turbulent flow past 2.5- and 4.25-deg expansion corners at Mach 8.

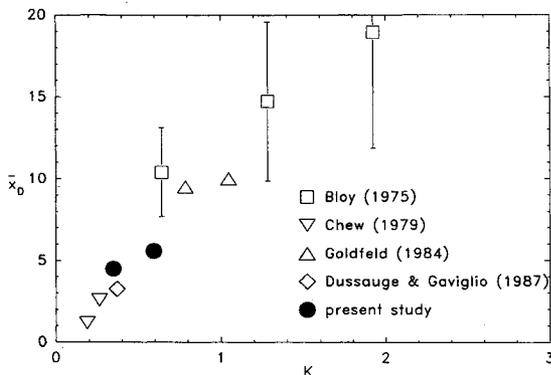


Fig. 4 Downstream influence in turbulent flow past expansion corners.

counterparts. These facts have to be borne in mind when comparing data obtained at low and high Mach numbers.

Downstream Influence Scaling

The mean surface pressure distribution for the two test cases, normalized by a static pressure measured $2.6\delta_0$ upstream of the corner, are plotted in Fig. 3 against $\bar{x} = x/\delta_0$, where x is the streamwise surface coordinate centered at the corner and δ_0 is the undisturbed boundary-layer thickness at the corner location. Also shown in this figure are the inviscid pressure distributions for an incoming Mach 8 flow. No upstream influence of the corner is detected, an observation consistent with previous turbulent studies.³⁻⁵ This is unlike laminar flows where the corner exerts an upstream influence.^{9,10} The measured pressures approach the downstream inviscid values some distance $\bar{x}_D = x_D/\delta_0$ from the corners, although adequate downstream data could not be obtained due to model limitations. (The pressure decay should strictly be asymptotic to the downstream inviscid value.) The "downstream influence" of the corner x_D was estimated as that from the corner to the intersection of the tangent through the downstream pressure data with the inviscid downstream pressure as depicted in Fig. 3. The present data show that the larger the corner angle, the stronger the expansion, and thus the longer the downstream influence.

It was thought that the downstream influence depends primarily on an inviscid parameter characterizing the expansion process, namely K .¹¹ Therefore, the downstream influence data are plotted together with data extracted from previous investigations in Fig. 4. Bloy's data¹ showed excessive scatter and are included simply to reveal the trend of \bar{x}_D with higher values of K . The collapse of data from Mach 1.76-8 supports the validity of K as a scaling parameter, at least for x_D up to $K \approx 1$ where reliable data exist. This validity is particularly striking between the fairly good collapse of Dussauge and Gaviglio's⁵ downstream influence with one of the present test cases for approximately the same value of K . It can also be seen from Fig. 4 that the surface pressure of weak expansions reaches the downstream inviscid value quickly. These weak conditions can be achieved at low supersonic Mach numbers

even for considerably large corner angles as in the case of Dussauge and Gaviglio.⁵ In the past, this has led to the conclusion that the surface pressure reaches the downstream inviscid value in a distance of about one incoming boundary-layer thickness.²

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Flow of Rarefied Gas past a Liquid Sphere

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Introduction

THE slow flow past a liquid drop has been studied by many authors because of its fundamental importance in engineering applications. In particular, the rarefied gas flow past a liquid drop will be encountered in various processes such as extraction and atomization of small liquid particles whose characteristic lengths are relatively small compared with the molecular mean free path of the surrounding gas. For very small values of the Weber number, $W_e = \rho_\infty u_\infty^2 / \sigma$, where ρ_∞ and u_∞ are the uniform flow density and velocity, and d

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