SECOND EDITION

MECHANICS AND THERMODYNAMICS OF PROPULSION

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area to inlet area. The internal pressure rise depends on the reduction of velocity between entry to the inlet diffuser and entry to the compressor (or burner, for a ramjet). Nacelle size required for low drag can be quite strongly dependent on the degree of external deceleration. In realistic analyses one must consider compressibility effects.

Inlet Performance Criterion

As Chapter 5 showed, one may characterize the differences between actual and ideal performance of aircraft engine inlets by a "diffuser efficiency" or by a stagnation pressure ratio. We define these as follows:

a. Isentropic efficiency. Referring to Fig. 6.5, we can define the isentropic efficiency of a diffuser in this form:

$$\eta_d = \frac{h_{02s} - h_a}{h_{0a} - h_a} \approx \frac{T_{02s} - T_a}{T_{0a} - T_a}.$$

State ⓪②ⓢ is defined as the state that would be reached by isentropic compression to the *actual* outlet stagnation pressure. Since

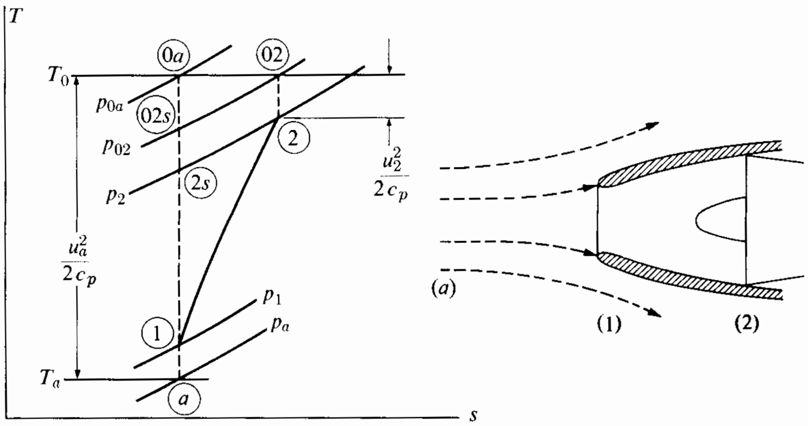
$$\frac{T_{02s}}{T_a} = \left(\frac{p_{02}}{p_a}\right)^{(\gamma-1)/\gamma} \quad \text{and} \quad \frac{T_{02}}{T_a} = 1 + \frac{\gamma - 1}{2}\text{M}^2,$$

the diffuser efficiency η_d is also given by

$$\eta_d = \frac{(p_{02}/p_a)^{(\gamma-1)/\gamma} - 1}{[(\gamma - 1)/2]\text{M}^2}. \tag{6.4}$$

b. Stagnation pressure ratio, r_d. The stagnation pressure ratio,

$$r_d = p_{02}/p_{0a}, \tag{6.5}$$



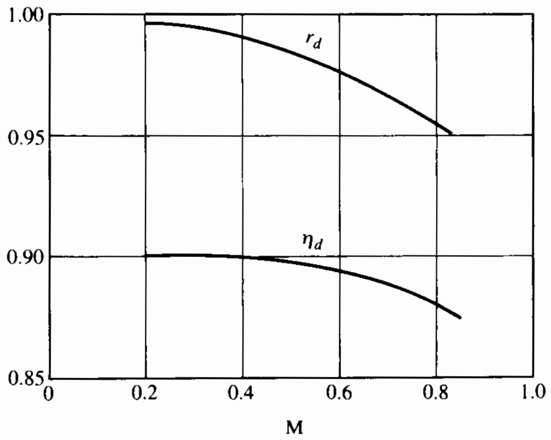


FIGURE 6.6 Typical subsonic diffuser performance; $\gamma = 1.4$.

is widely used as a measure of diffuser performance. Diffuser efficiency and stagnation pressure ratio are, of course, related. In general,

$$\frac{p_{02}}{p_a} = \frac{p_{02}}{p_{0a}} \cdot \frac{p_{0a}}{p_a} = \frac{p_{02}}{p_{0a}}\left(1 + \frac{\gamma - 1}{2}\mathrm{M}_2\right)^{\gamma/(\gamma-1)},$$

and, with Eqs. (6.4) and (6.5),

$$\eta_d = \frac{\left(1 + \frac{\gamma - 1}{2}\mathrm{M}^2\right)(r_d)^{(\gamma-1)/\gamma} - 1}{[(\gamma - 1)/2]\mathrm{M}^2}. \tag{6.6}$$

Because η_d will be primarily affected by the internal deceleration ("diffusion"), it is unfortunate that these criteria are based on overall deceleration rather than on internal deceleration. The relationship between internal and external deceleration depends on engine mass flow rate as well as flight Mach number M. But for illustrative purposes Fig. 6.6 gives typical values of stagnation pressure ratio r_d. The diffuser efficiency η_d was calculated from r_d, with the use of Eq. (6.6).

6.3 SUPERSONIC INLETS

Even for supersonic flight it remains necessary, at least for present designs, that the flow leaving the inlet system be subsonic. Compressors capable of ingesting a supersonic airstream could provide very high mass flow per unit area and, theoretically at least, very high pressure ratio per stage. However, the difficulty of passing a fully supersonic stream through the compressor without excessive shock losses (especially at off-design conditions) has so far made the development of fully supersonic compressors a possibility that is somewhat remote. As we will see in Chapter 8, the Mach number of the axial flow approaching a subsonic