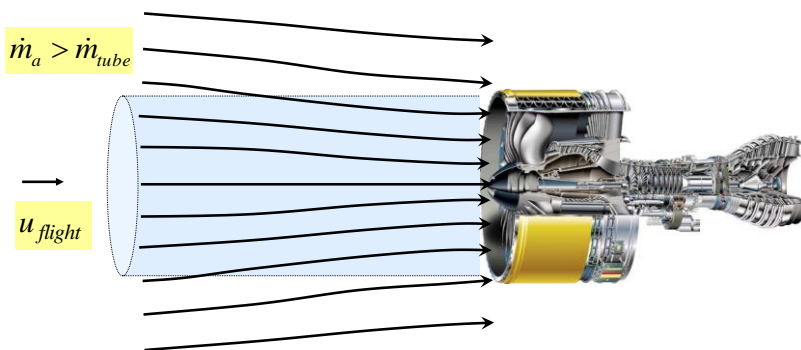


## Subsonic Inlets - Goals

- Produce desired diffuser exit Mach number
  - $M \sim 0.4-0.7$
- Create “uniform” flow at diffuser exit
  - inlet “distortions” can lead to operability problems (oscillations) and performance loss
- Minimize  $p_o$  losses
  - avoid boundary layer separation

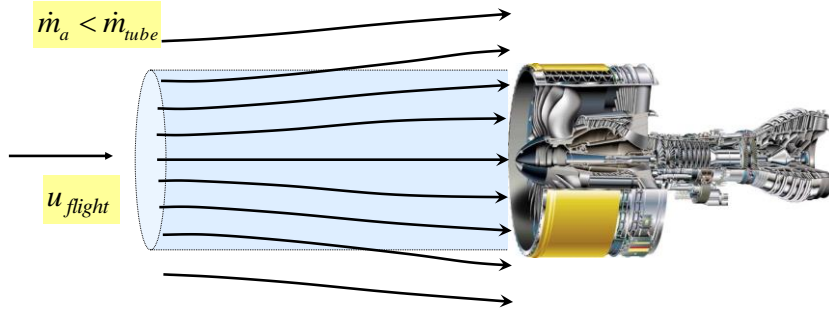
## Subsonic Inlet Flow Cases

- Accelerating inflow (high thrust, low  $u_{flight}$ )



## Subsonic Inlet Flow Cases

- Decelerating inflow (low thrust, high  $u_{flight}$ )



Subsonic Inlet-3  
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## Inlet Sizing: Throat Diameter

- Limit inlet throat Mach number,  $M < 0.8$   
– margin to prevent choked inlet

$$\dot{m} = \frac{P_o}{\sqrt{RT_o}} A \sqrt{\gamma} M \left( 1 + \frac{\gamma-1}{2} M^2 \right)^{\frac{\gamma+1}{2(1-\gamma)}}$$

$$\dot{m}_{required} = \frac{P_o}{\sqrt{T_o}} A_t MFP(\gamma, M_t) = \frac{P_o}{\sqrt{T_o}} A_t MFP(1.4, 0.8)$$

- For cylindrical inlet

$$d_t = \left[ \dot{m}_{required} \frac{4 \sqrt{T_o}}{\pi p_o} \frac{\sqrt{R}}{0.6595} \right]^{1/2}$$

$$d_t = 0.07413 \sqrt{\dot{m}_{c,max}} \text{ ms}^{1/2} / \text{kg}^{1/2}$$

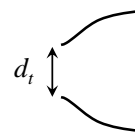
$$= 0.1636 \sqrt{\dot{m}_{c,max}} \text{ ft s}^{1/2} / \text{lb}_m^{1/2}$$

corrected mass flowrate

$$\dot{m}_c = \dot{m} \frac{\sqrt{T_o/T_{ref}}}{p_o/p_{ref}}$$

$$T_{ref} = 288.2 \text{K} (518.7 \text{R})$$

$$p_{ref} = 101.3 \text{kPa} (14.7 \text{psi})$$



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## Engine Mass Flow Requirements

- Use cycle performance calculations and engine thrust requirements to size inlet

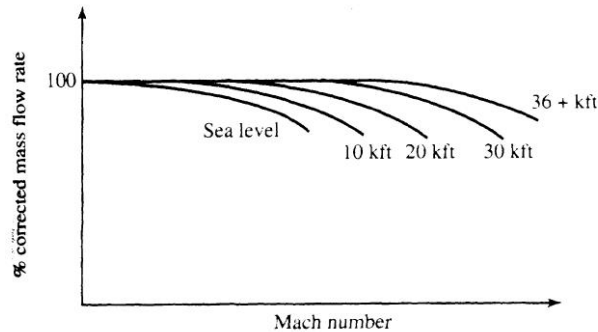


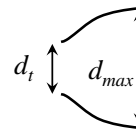
Figure 10-4 from Mattingly, *Elements of Gas Turbine Propulsion*

Subsonic Inlets-5  
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## Exit Sizing: Maximum Diameter

- Area ratio of inlet determines exit Mach number
  - $M_{\text{exit}} = f(A_{\text{exit}}/A^*)$
- Fan or compressor has maximum allowable inlet Mach number
  - modern turbofans allow for relatively high inlet Mach numbers
  - little diffusion required (except at high  $M_\infty$ )
  - inlet still required to minimize distortions (described below)

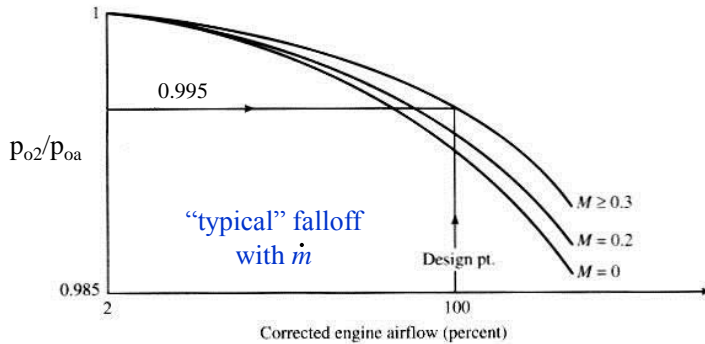


Subsonic Inlets-6  
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## Pressure Loss

- Internal pressure loss in diffuser depends on mass flow rate
  - standard  $r_d$ , or  $\eta_d$  approach does not capture this



After Figure 10-3 from Mattingly, *Elements of Gas Turbine Propulsion*

Subsonic Inlets-7  
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## Internal Flow Separation

Diagrams illustrating internal flow separation in a diffuser. The length of the diffuser is  $L$  and the maximum diameter is  $d_{max}$ .

- "good" flow:** Shows smooth flow lines following the diffuser walls.
- transitory stall:** Shows flow lines starting to separate from the walls.
- steady stall:** Shows significant flow separation and recirculation.
- "jet" flow:** Shows a narrow jet of flow in the center of the diffuser, with large recirculation zones.

- Too high a rate of diffuser area increase leads to stall
  - $d_{max}/L < \text{critical value}$
- Boundary layer separates if adverse pressure gradient too large and not enough turbulent mixing with freestream to "energize" boundary layer
- High angle incidence can also lead to separation

**high incidence angle**  $\theta$

**Inlet Distortion**  $= \frac{P_{o,max} - P_{o,min}}{P_{o,avg}}$  over  $(r, \theta)$   
constrained by fan/compressor

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## External Nacelle Flow

- Typically external flow decelerates approaching inlet
- Flow then accelerates around nacelle forebody
- High velocity leads to friction drag
- Separation can also occur near lip where velocity reduced

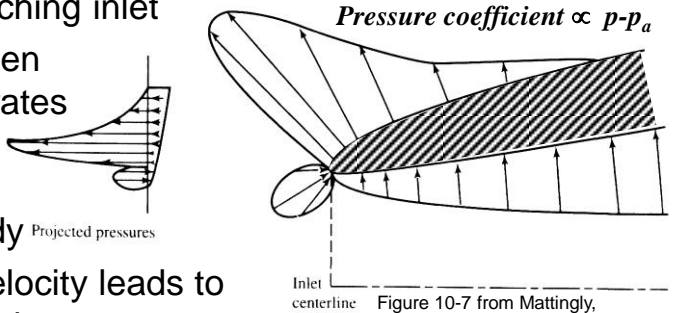


Figure 10-7 from Mattingly, Elements of Gas Turbine Propulsion

## Inlet Sizing Summary

- **Inlet area tradeoff**
  - $d_i$  sized to pass maximum required flowrate
  - larger inlet requires external decel. and nacelle drag at cruise conditions
- **$d_{max}/L$  tradeoff**
  - small value reduces internal flow separation
  - large value reduces boundary layer losses

