

MEM 255 Introduction to Control Systems: *Jet Engine Compressor*

Harry G. Kwatny

Department of Mechanical Engineering &
Mechanics

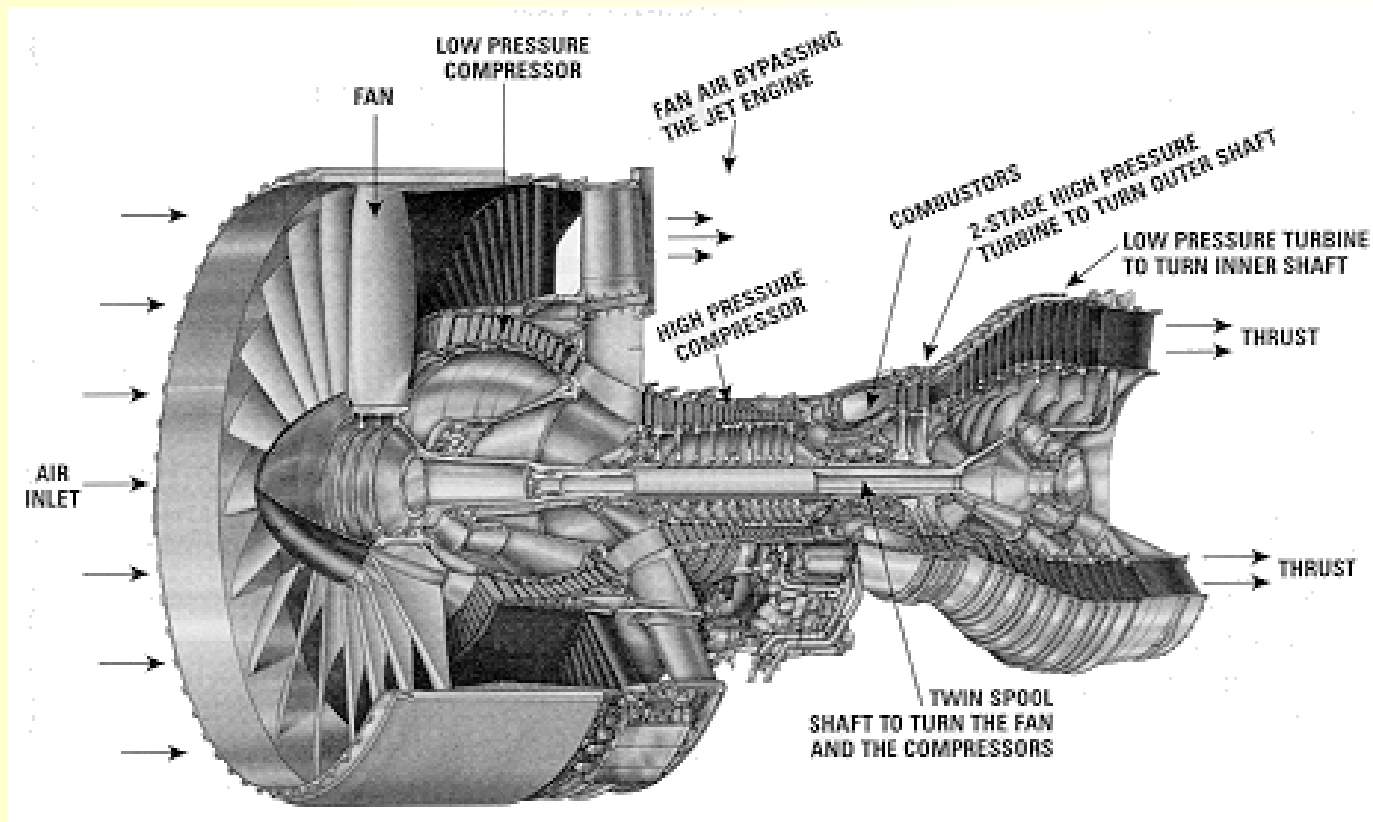
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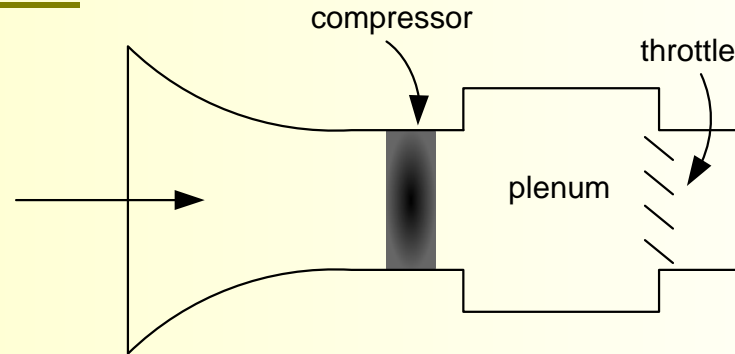
Outline

- **Jet engine compressor**
- **Axisymmetric dynamics**
- **Equilibria**
- **Linearized dynamics**
 - **State equations**
 - **Transfer function**

Jet Engine (Commercial Airline)



Compressor Axisymmetric Dynamics



Compressor
characteristic

Throttle
characteristic

$$\dot{\phi} = -\psi + \Psi_c(\phi)$$

$$\dot{\psi} = (\phi - \Phi_T(\psi)) / \beta^2$$

$$\phi = \frac{\dot{V}}{\omega D^3}, \text{ flow coefficient} \quad \psi = \frac{\Delta P}{\omega^2 D^2}, \text{ pressure coefficient}$$

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Equilibria

Instability corresponds to surge

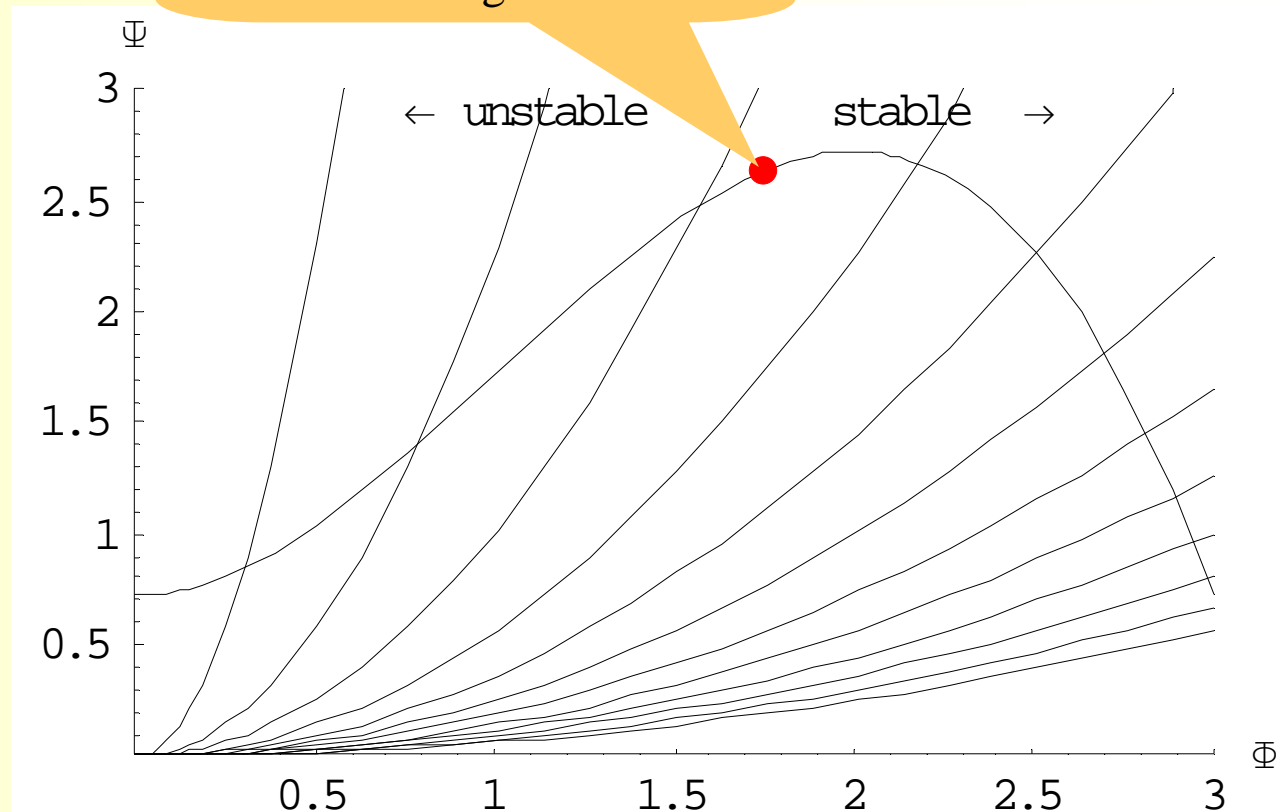
$$\dot{\phi} = -\psi + \Psi_c(\phi)$$

$$\dot{\psi} = (\phi - \Phi_T(\psi)) / \beta^2$$

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$$\psi = \Psi_c(\phi)$$

$$\phi = \Phi_T(\psi)$$



$$\Psi_c(\phi) = \Psi_{c0} + H \left(1 + \frac{3}{2} \left(\frac{\phi}{W} - 1 \right) - \frac{1}{2} \left(\frac{\phi}{W} - 1 \right)^3 \right)$$

$$\Phi_T(\psi) = \gamma \sqrt{\psi}$$

Compressor Flow Control

Equilibrium point: $\gamma = 2.5, \phi = 2.2825, \psi = 0.889038$

$$\frac{d}{dt} \begin{bmatrix} \delta\phi \\ \delta\psi \end{bmatrix} = \begin{bmatrix} -1.875 & -1 \\ 1.40845 & -0.414407 \end{bmatrix} \begin{bmatrix} \delta\phi \\ \delta\psi \end{bmatrix} + \begin{bmatrix} 0 \\ -2.12788 \end{bmatrix} \delta\gamma$$

$$y = \delta\phi$$

$$G_p(s) = \frac{2.12788}{s^2 + 2.28941s + 2.18546}$$
$$= \frac{2.12788}{(s + 1.1447 + j0.935477)(s + 1.1447 - j0.935477)}$$

Summary

- Axisymmetric dynamics of compressor
- Analysis of equilibria
- State space & transfer function