MATERIALE DI SUPPORTO ELICHE E ROTORI AERONAUTICI

Power

$$P = \frac{1}{2}\dot{m}(V_4^2 - V^2) = \frac{1}{2}\dot{m}(V_4 + V)(V_4 - V) = TV_2 = T(V + v)$$

$$\eta_p = \frac{TV}{TV_2} = \frac{V}{V_2} = \frac{V}{V + v}$$

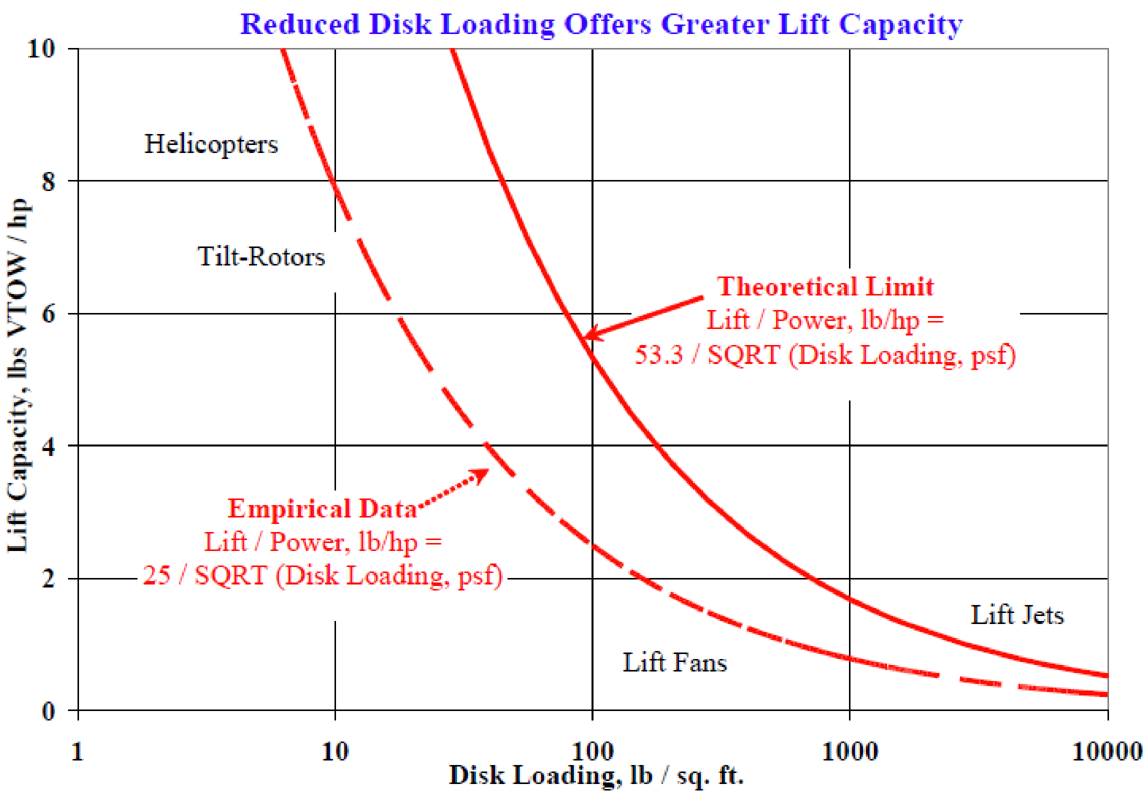
For V=0

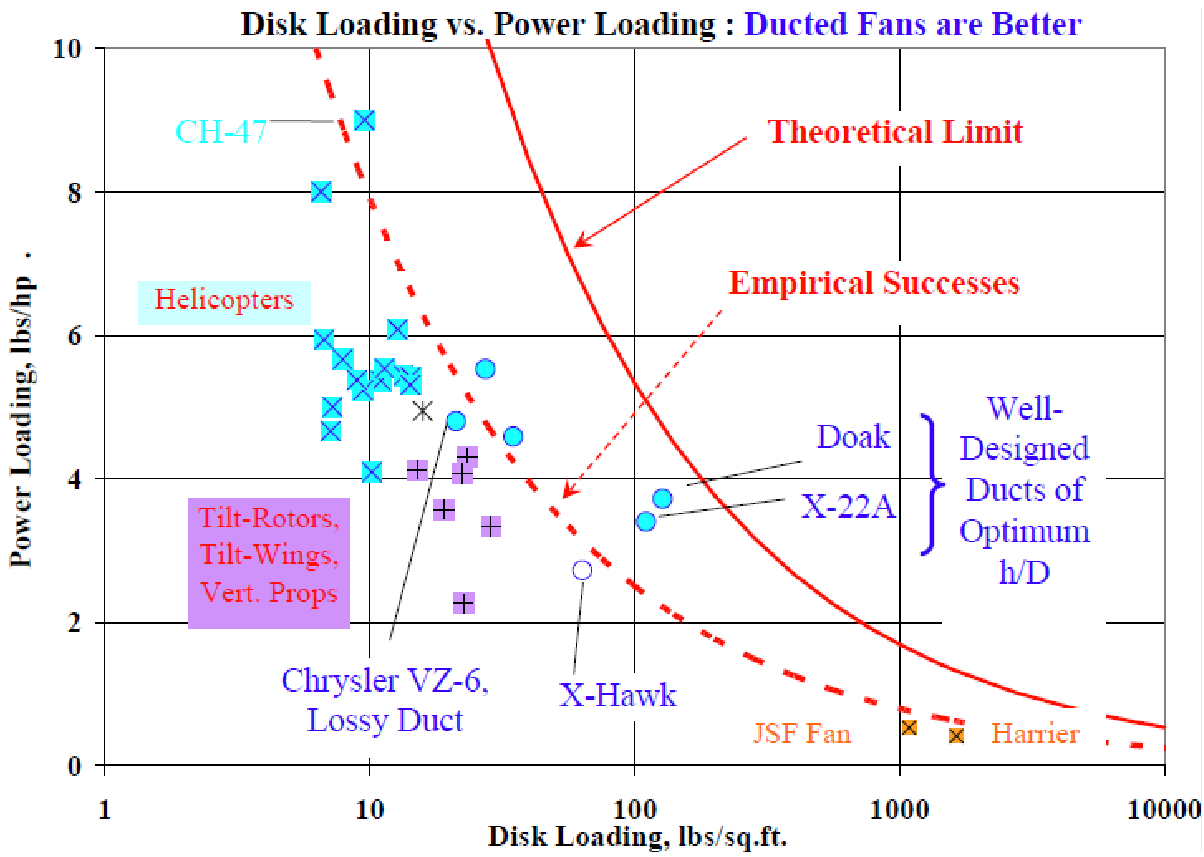
$$v = \left(\frac{T}{2\rho A}\right)^{1/2}$$

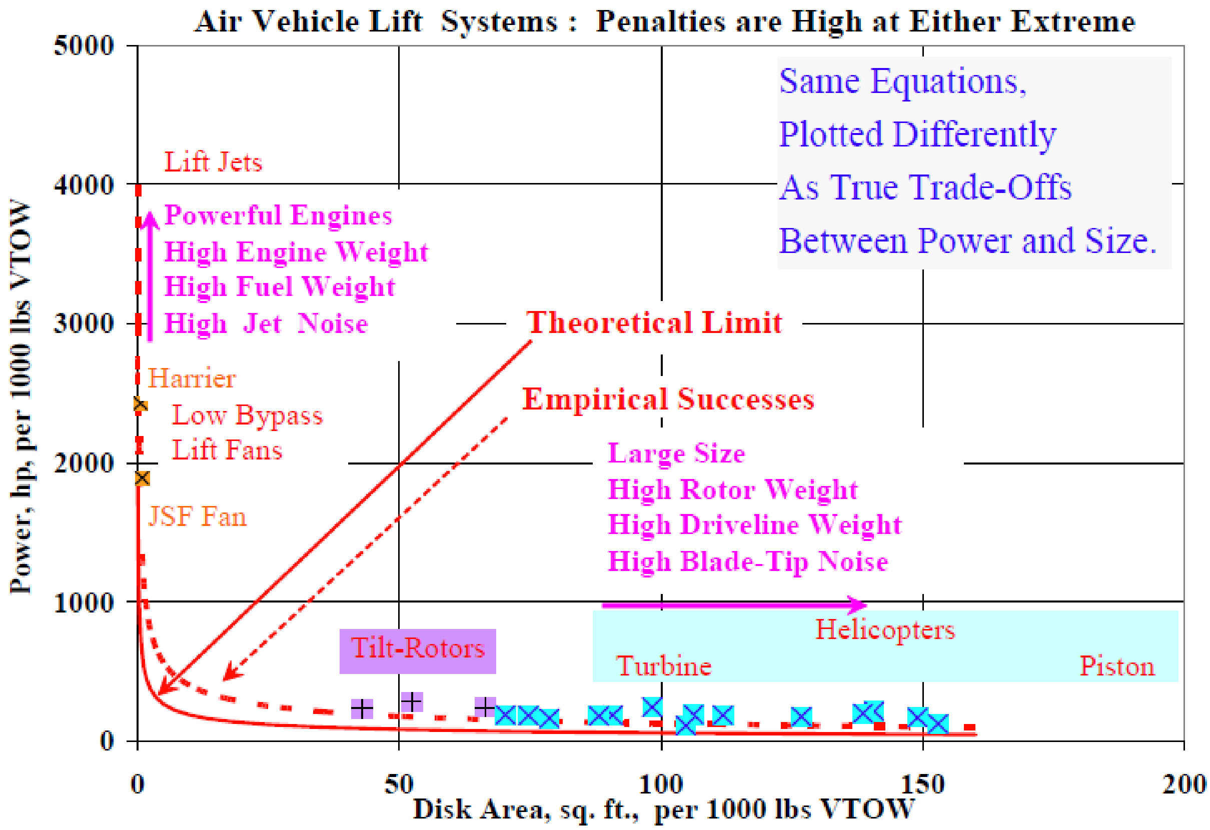
$$\frac{P}{A} = \frac{T}{A}V_2 = \frac{T}{A}v \propto \left(\frac{T}{A}\right)^{3/2}$$

$$\frac{P}{T} \propto \left(\frac{T}{A}\right)^{1/2}$$

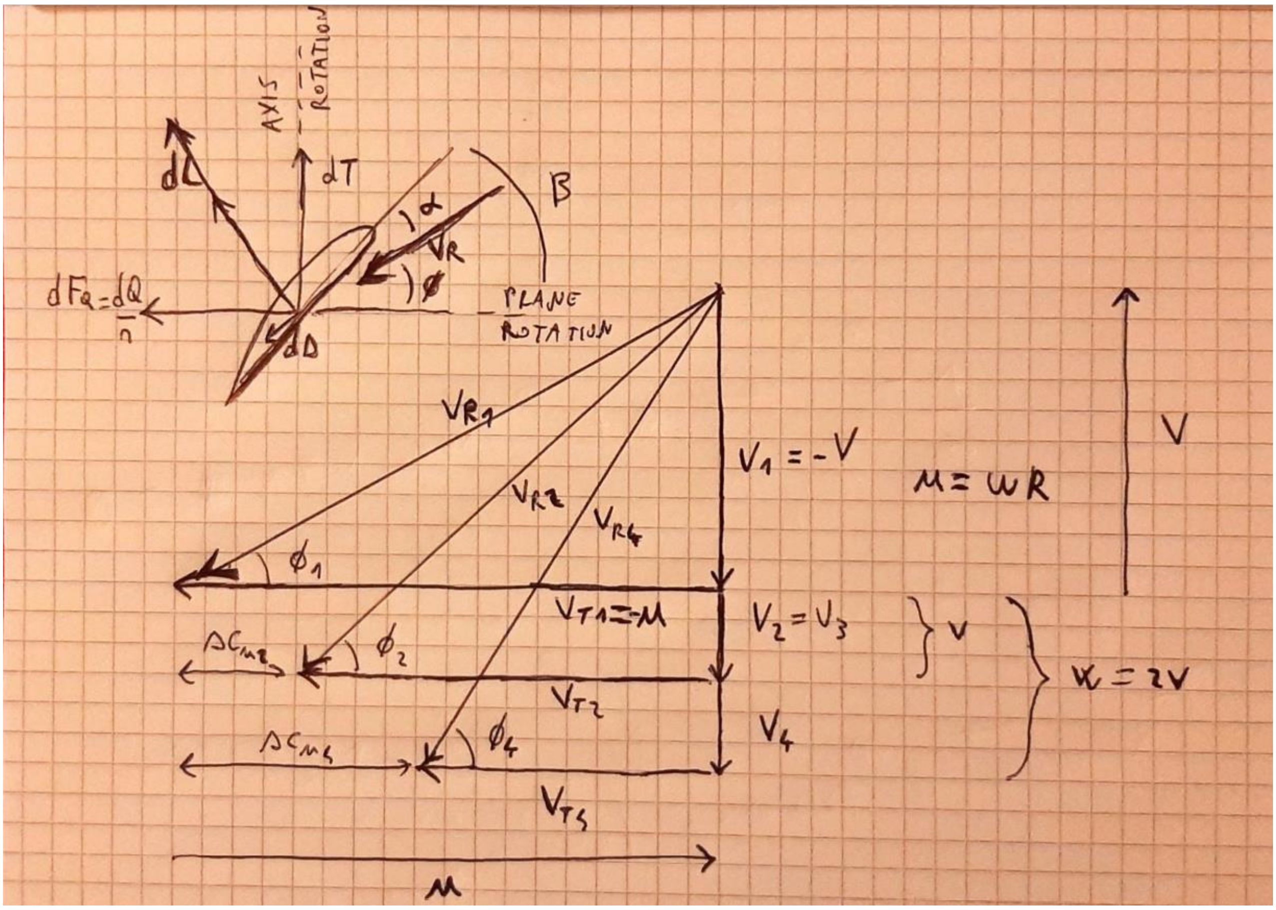
$$C_p \propto C_T^{3/2}$$




Disk Loading vs. Power Loading : Ducted Fans are Better
Power Loading, lbs/hp
Disk Loading, lbs/sq.ft.
10
8
6
4
2
0
1
10
100
1000
10000
CH-47
Helicopters
Tilt-Rotors, Tilt-Wings, Vert. Props
Chrysler VZ-6, Lossy Duct
X-Hawk
Theoretical Limit
Empirical Successes
Doak
X-22A
Well-Designed Ducts of Optimum h/D
JSF Fan
Harrier


Air Vehicle Lift Systems : Penalties are High at Either Extreme
Power, hp, per 1000 lbs VTOW
Disk Area, sq. ft., per 1000 lbs VTOW
5000
4000
3000
2000
1000
0
0
50
100
150
200
Same Equations, Plotted Differently As True Trade-Offs Between Power and Size.
Lift Jets
Powerful Engines
High Engine Weight
High Fuel Weight
High Jet Noise
Theoretical Limit
Empirical Successes
Harrier
Low Bypass Lift Fans
JSF Fan
Large Size
High Rotor Weight
High Driveline Weight
High Blade-Tip Noise
Tilt-Rotors
Helicopters
Turbine
Piston

Triangoli di velocità

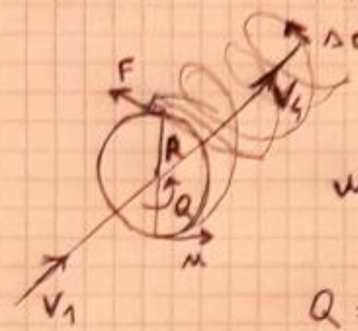


Perdite per moti elicoidali

$$J' = \frac{V}{u} \propto J = \frac{V}{nD}$$

$$C_{\Delta p} = \frac{\Delta p}{\rho u^2} \propto \frac{T/D^2}{\rho n^2 D^2} \propto C_T = \frac{T}{\rho n^2 D^4}$$

$$\eta_{conv} = \frac{P_J}{P_{el}} = \frac{\frac{1}{2}\dot{m}\left(V_4^2 - V_1^2\right)}{\dot{m}\, u\, \Delta C_u} = \frac{\frac{\Delta p}{\rho}}{u\, \Delta C_u}$$



ΔC_u = variazione velocità tangenziale flusso d'aria

$\omega R = u$ velocità tangenziale elica

$Q = \dot{m} R \Delta C_u$ teorema variazione momento della q.d.m.

$$P_{el} = \omega Q = \dot{m}\, u\, \Delta C_u$$

$$\eta_{conv} = \frac{u \Delta C_u - \frac{\Delta C_u^2}{2}}{u \Delta C_u}$$

$\frac{\Delta C_u^2}{2}$ → energia dissipata per moto elicoidale

$$\frac{1}{2}\left(\frac{\Delta C_u}{u}\right)^2 - \frac{\Delta C_u}{u} + \frac{\Delta p}{\rho u^2} = 0 \Longleftarrow \frac{\Delta p}{\rho} = u \Delta C_u - \frac{\Delta C_u^2}{2}$$

$$\eta_{conv} = \frac{1 + \sqrt{1 - 2C_{\Delta p}}}{2} \qquad \eta_p = \frac{2}{1 + \sqrt{1 + 2\frac{C_{\Delta p}}{J'^2}}}$$

$$\eta_{conv} = 1 - \frac{\Delta C_u}{2u} \qquad \eta_{el,id} = \eta_p \eta_{conv} = \frac{1 + \sqrt{1 - 2C_{\Delta p}}}{1 + \sqrt{1 + 2\frac{C_{\Delta p}}{J'^2}}}$$

Elica intubata vs Elica libera

$$P = \frac{1}{2}\dot{m}\left(V_4^2 - V_1^2\right) \qquad T = \Delta p A = \dot{m}\left(V_4 - V_1\right)$$

FOR $V = 0$

$$P = \frac{1}{2}\dot{m} V_4^2 \qquad T = \dot{m} V_4 \qquad \dot{m} = \rho A V_2$$

ELICA INTUBATA $V_4 = V_2$

$$T = \dot{m} V_2 \rightarrow V_2 = \sqrt{\frac{T}{\rho A}}$$

41% LARGER

$$P = \frac{1}{2}\dot{m} V_2^2 = \frac{1}{2}\frac{T^{3/2}}{\sqrt{\rho A}}$$

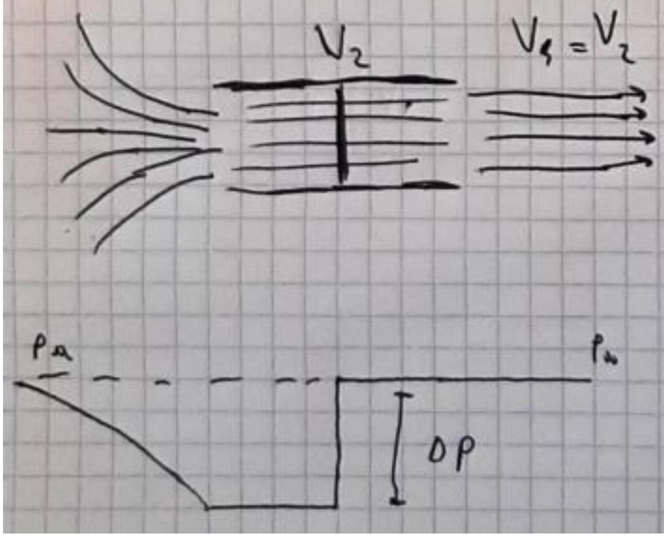
29% SMALLER!

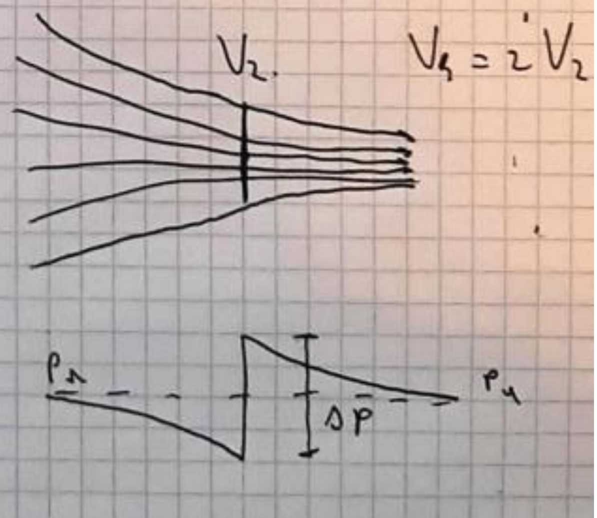
ELICA LIBERA $V_4 = 2V_2$

$$T = \dot{m}\, 2V_2 \rightarrow V_2 = \sqrt{\frac{T}{2\rho A}}$$

$$P = \frac{1}{2}\dot{m}\left(2V_2\right)^2$$

$$P = \frac{1}{\sqrt{2}}\frac{T^{3/2}}{\sqrt{\rho A}}$$





Zubr class hovercraft (Project 1232.2, NATO reporting name "Pomornik")

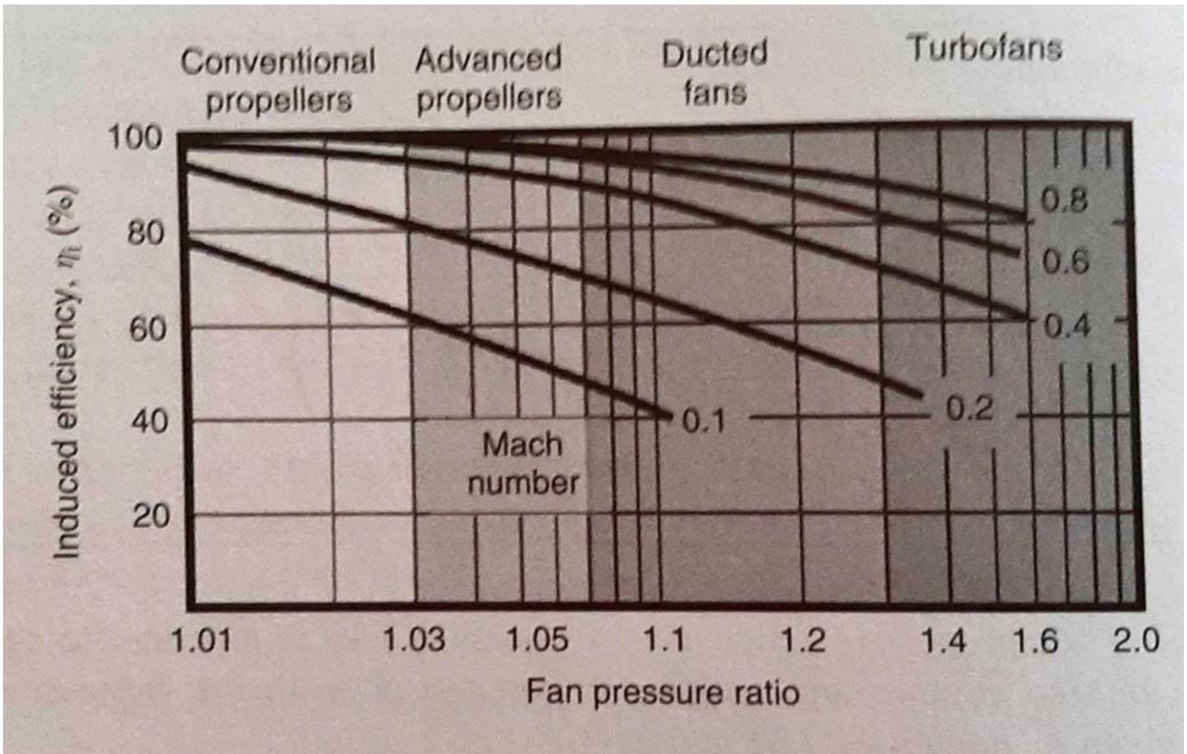
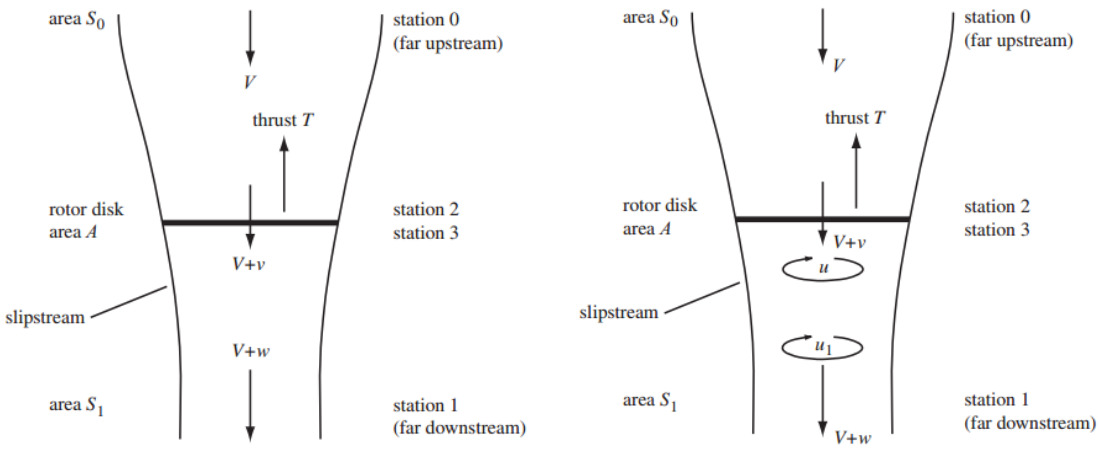


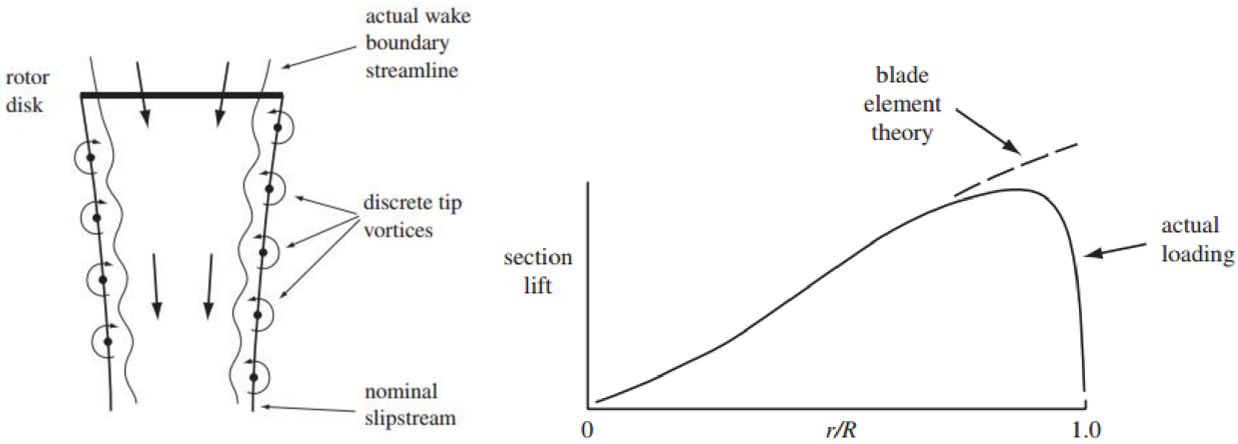
Figure 3.33 Induced efficiency measurements (Courtesy NASA [6].)

Power component	At peak efficiency	Off peak
Ideal induced power	74% to 78%	65%
Profile power	10% to 19%	25%
Nonuniform inflow	5% to 7%	6%
Swirl in the wake	less than 1%	less than 1%
Tip losses	2% to 4%	3%

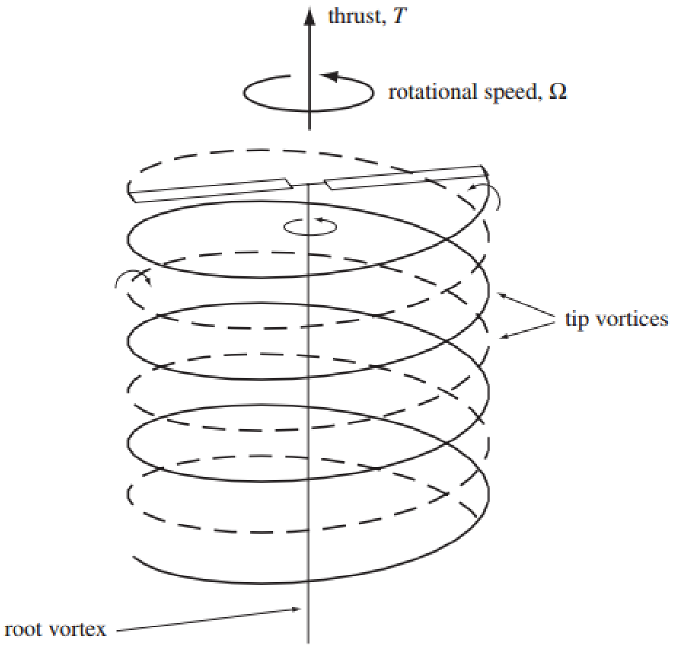
Rotor power components



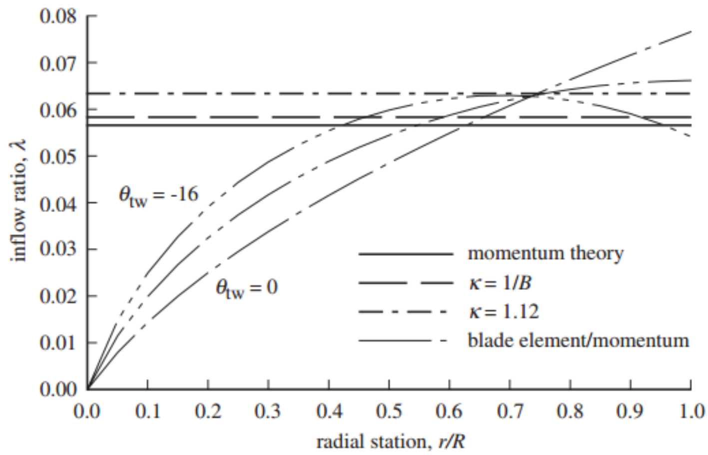
Ideal induced power (left), swirl in the wake (right)



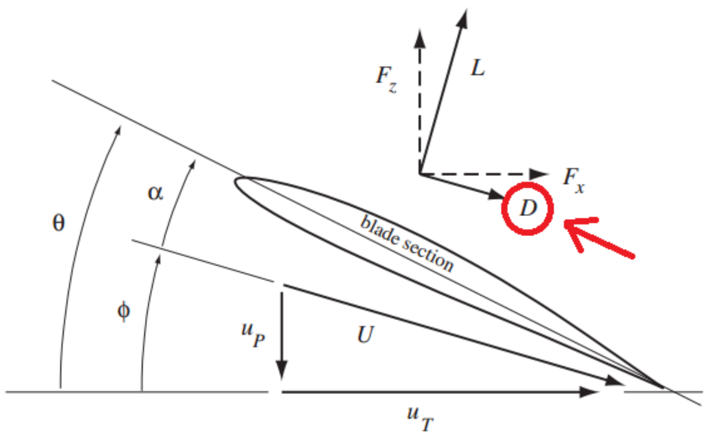
Tip losses



Rotor wake



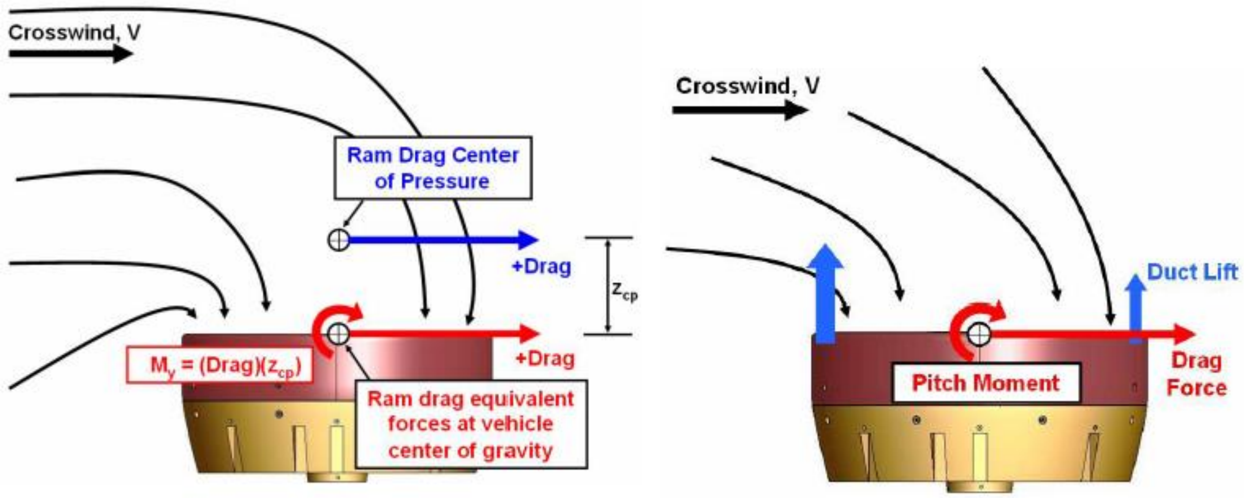
Non-uniform inflow



Profile losses

Kamov Ka-50 Black Shark

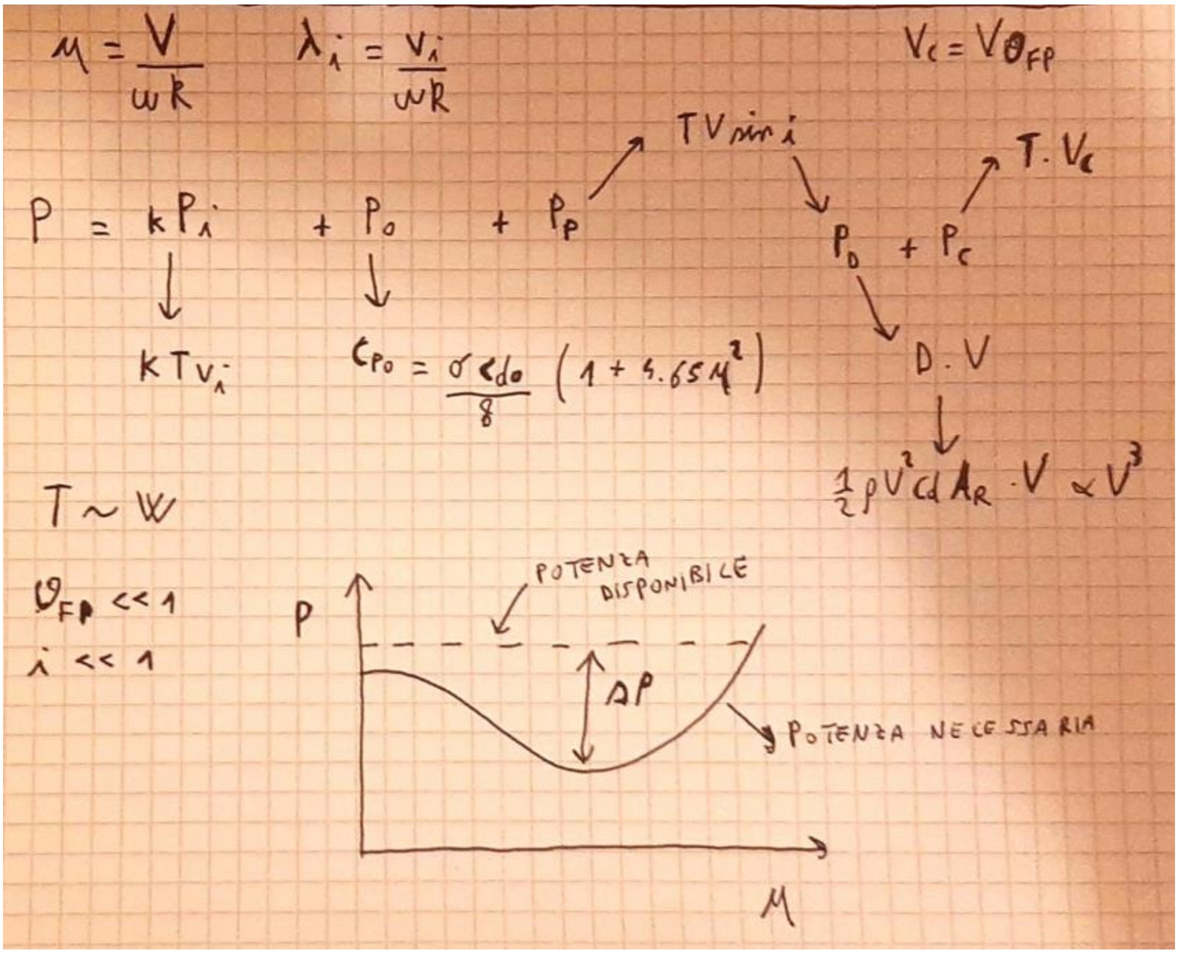
Boeing CH-47 Chinook

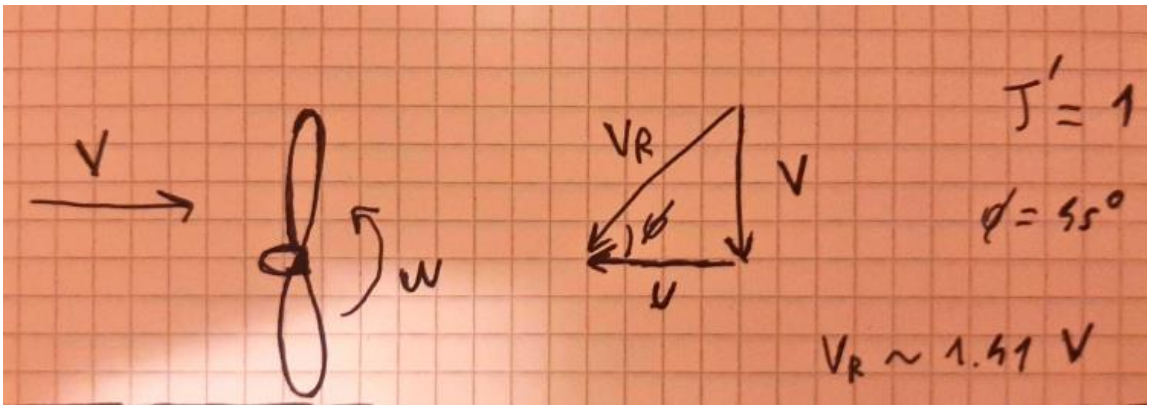


Ram Drag and Pitching Moment of a Ducted Fan in tangential forward flight

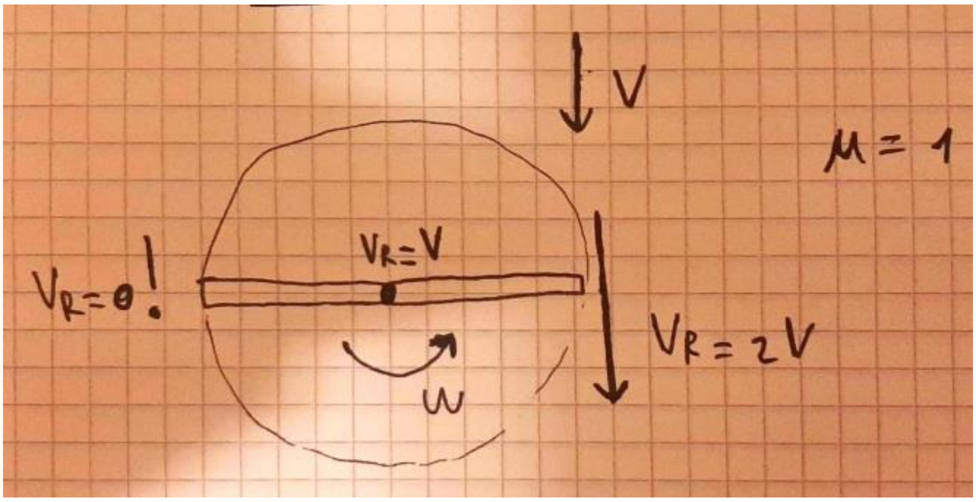
Bell X-22

Potenza elicottero

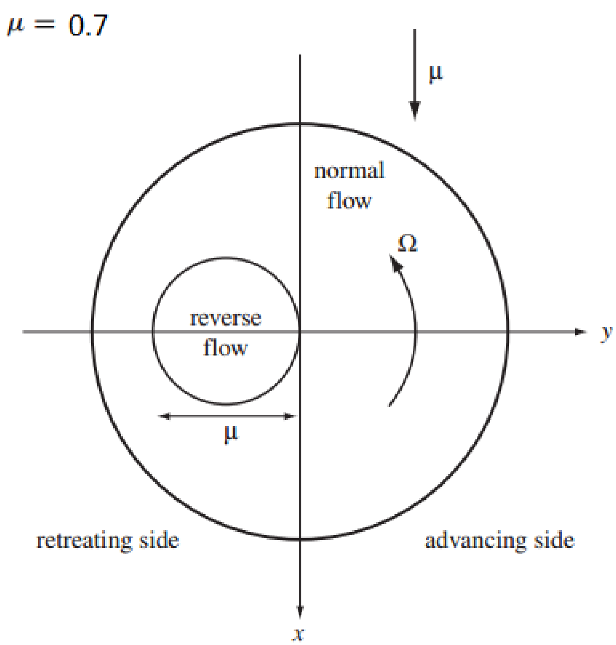




Propeller



Helicopter rotor



Reverse flow region in a helicopter rotor

How does a Helicopter fly?

https://www.youtube.com/watch?v=2tdnqZgKa0E

Swashplate (piatto oscillante) animation

https://www.youtube.com/watch?v=-kWhNi-MZAM