Propeller and Rotor Ideal Power by Momentum (Actuator Disc) Theory

Induced velocity, slipstream velocity, ideal power and ideal propulsive efficiency of a propeller, fan or rotor from its thrust, disc diameter and flight speed.

Method: Rankine–Froude momentum (actuator disc) theory

Input parameters

Unit system: SI

Parameter	Value	Unit
Thrust	2,500.0	N
Disc (propeller) diameter	1.9000	m
Flight or advance speed (0 for static or hover)	50.000	m/s
Air (or water) density	1.1120	kg/m³
Real-to-ideal efficiency (figure of merit, typically 0.75–0.85)	80.000	%

Calculated results

Parameter	Value	Unit
Induced velocity at the disc	6.9604	m/s
Far-slipstream velocity	63.921	m/s
Ideal power T(V₀ + v_i)	142.40	kW
Estimated shaft power	178.00	kW
Ideal propulsive (Froude) efficiency	87.780	%
Disc loading	881.74	Pa

Notes for this case

- Rankine–Froude actuator disc: half the final velocity increase occurs at the disc. Real propellers need more power for profile drag, swirl and tip losses, taken here by the real-to-ideal factor.

Formula and method

$$T = 2\rho A v_i (V_0 + v_i), \quad v_i = \frac{1}{2}\left(-V_0 + \sqrt{V_0^2 + \frac{2T}{\rho A}}\right)$$

$$P_{ideal} = T(V_0 + v_i), \quad \eta_{ideal} = \frac{V_0}{V_0 + v_i}$$

Variables

T	Thrust	N
D	Disc (propeller) diameter	m
V_0	Flight or advance speed (0 for static or hover)	m/s
ρ	Air (or water) density	kg/m³
η_{rel}	Real-to-ideal efficiency (figure of merit, typically 0.75–0.85)	-
v_i	Induced velocity at the disc	m/s
V_s	Far-slipstream velocity	m/s
P_{ideal}	Ideal power T(V₀ + v_i)	W
P_{shaft}	Estimated shaft power	W

η_{ideal}	Ideal propulsive (Froude) efficiency	-
T/A	Disc loading	Pa

Method and standards

Momentum theory of an ideal actuator disc.

Assumptions and limits

- Uniform inviscid flow through the disc, no swirl.

References

Rankine–Froude momentum (actuator disc) theory

Report details

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