Introduction to Aerospace Propulsion

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Lecture No - 31

Propeller blade shapes

and

Propeller Tutorials

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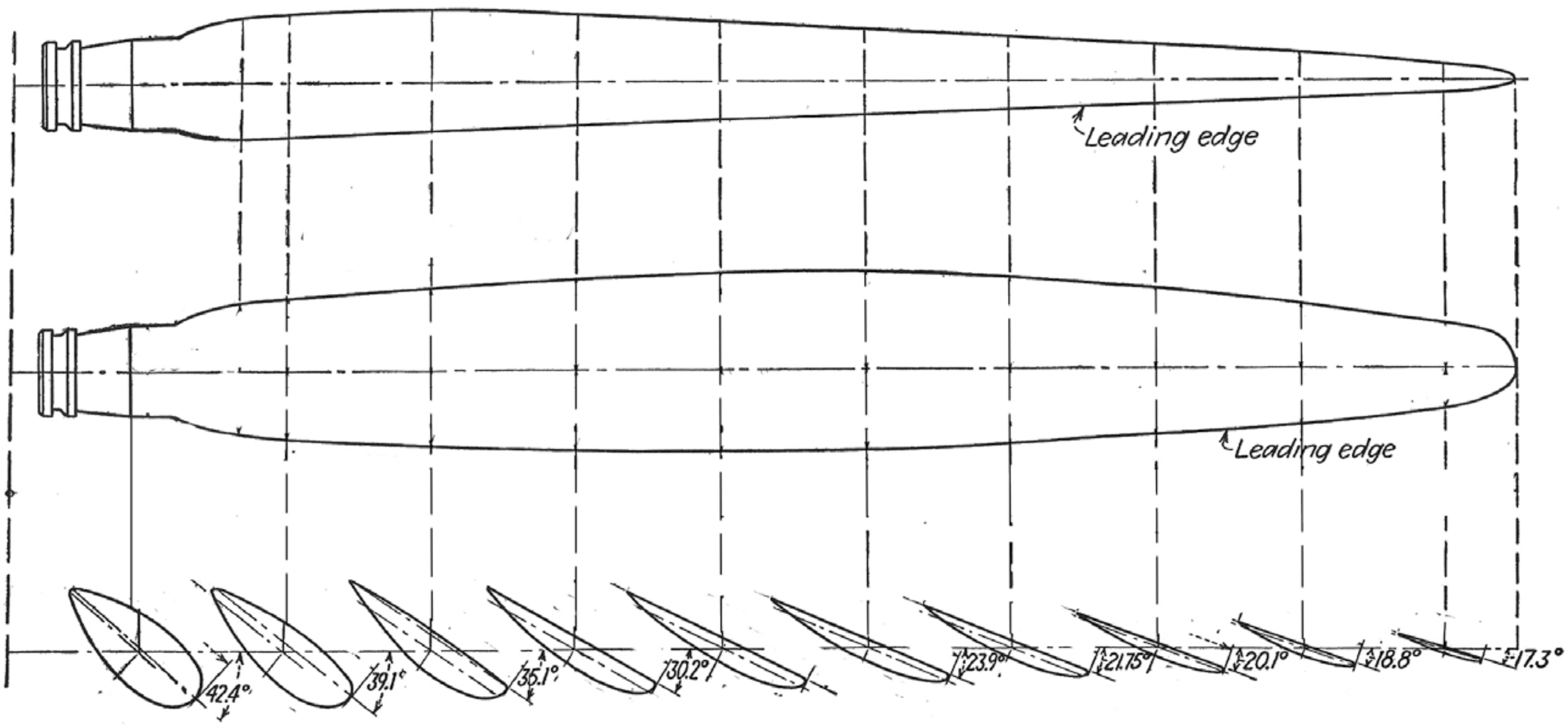
Typical Propeller Blade Shape



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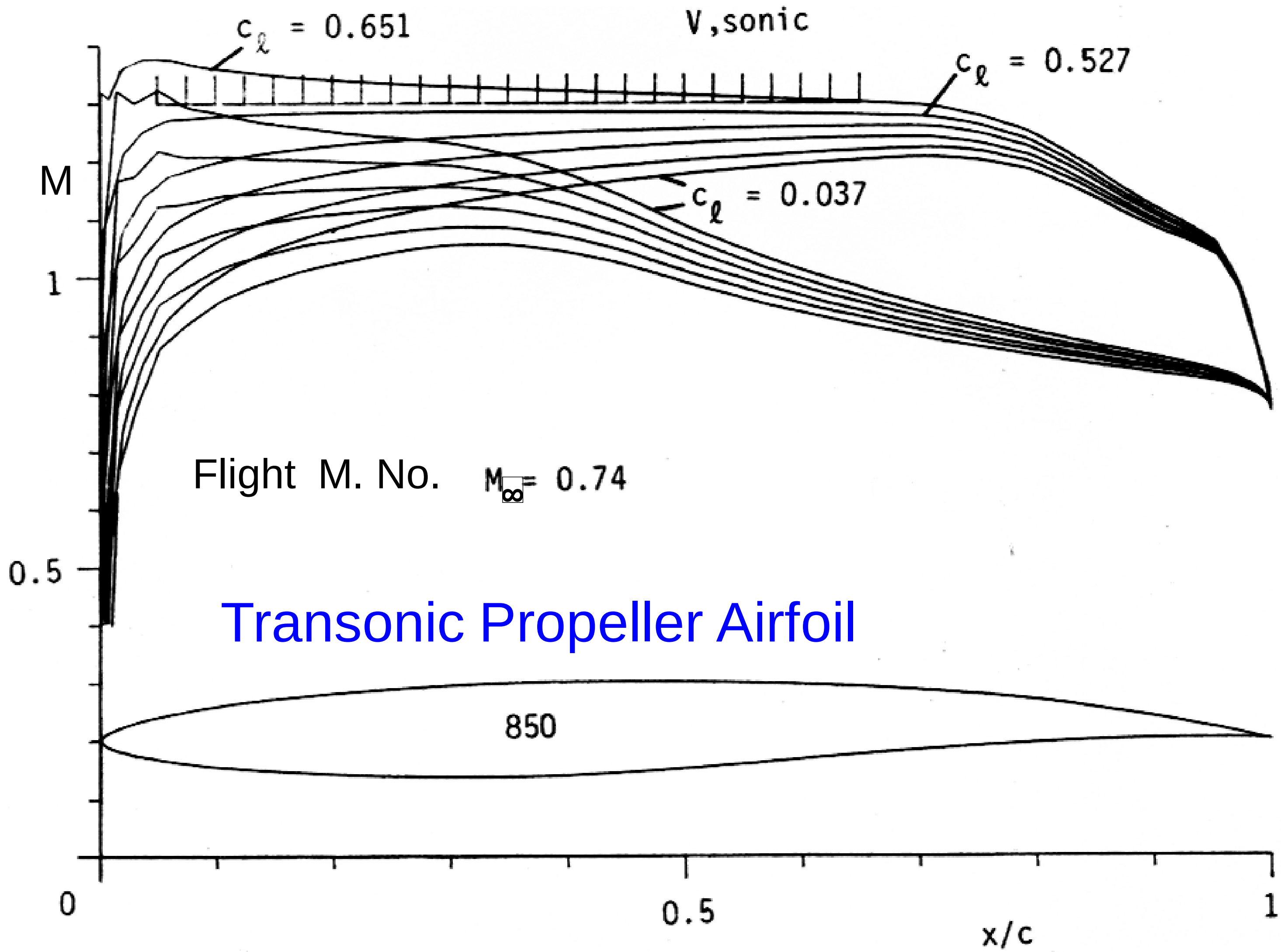
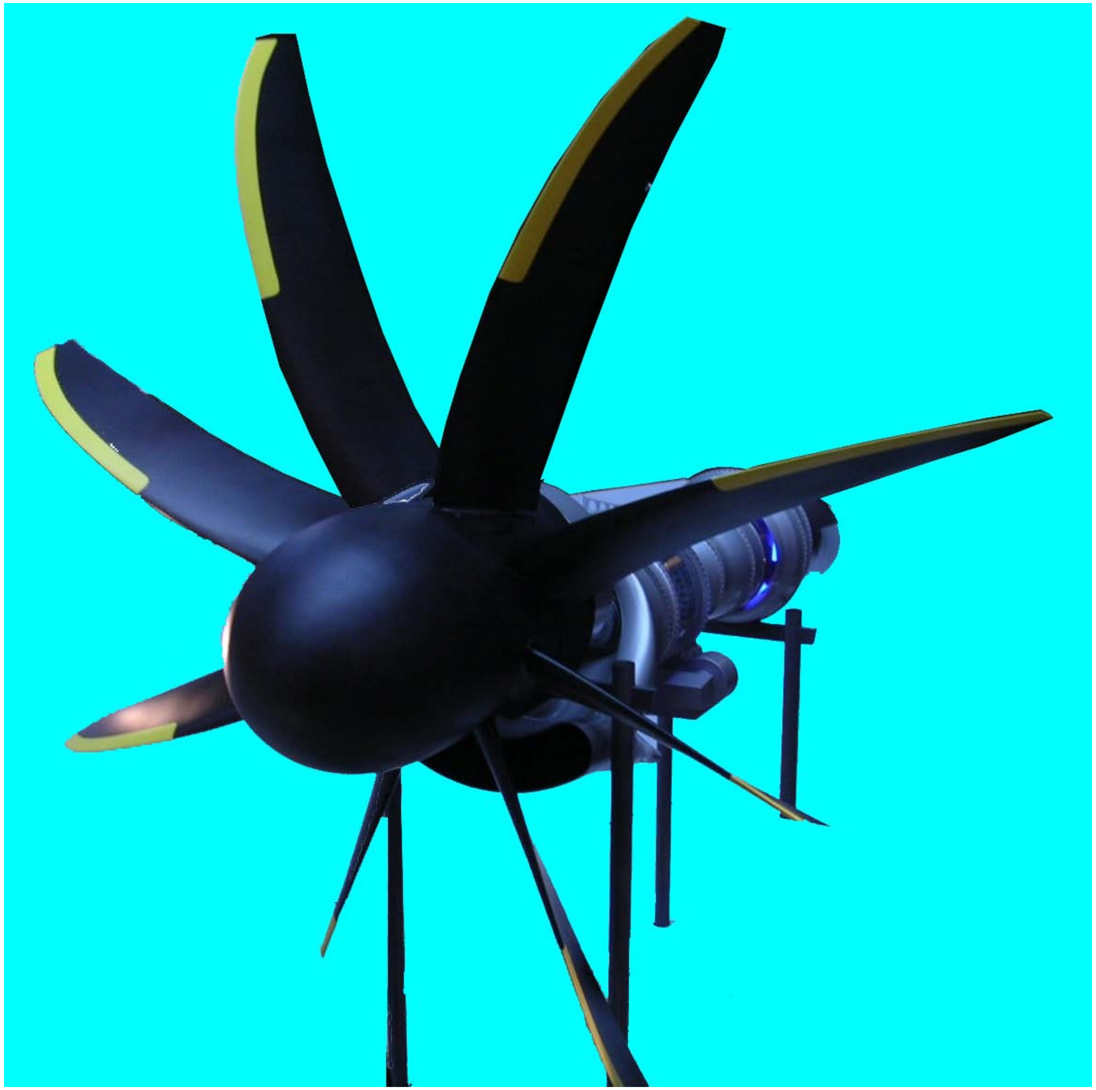


Transonic Propeller Airfoil



Modern 8-bladed propeller with transonic airfoils near the tip and swept blade shapes

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Solved Example

An aircraft cruises at 644 km/hr speed at seal level, is powered by a 3-bladed propeller (connected to the engine, which rotates at 2600 rpm, through a 1:2 gear box) and is supplied 1491.5 kW of power. The propeller is designed with blades of NACA blade sections. Compute the propeller diameter and the efficiency of the propeller at this operating condition. If the propeller is a variable pitch propeller what would be its efficiency at 161 km/hr.

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Density of the air at this sea level operating condition,

$$\rho_{air} = 1.22\ kg/m^3.$$

where the flight speed as given is,

$V_\infty = 644\ km/hr = 178.88\ m/s$, and

It is using power,

$P = 1491.5\ kW = 1491500\ J/s$,

while the propeller rotates at ½ the engine rpm i.e. at 1300 rpm i.e. 21.666 rps.

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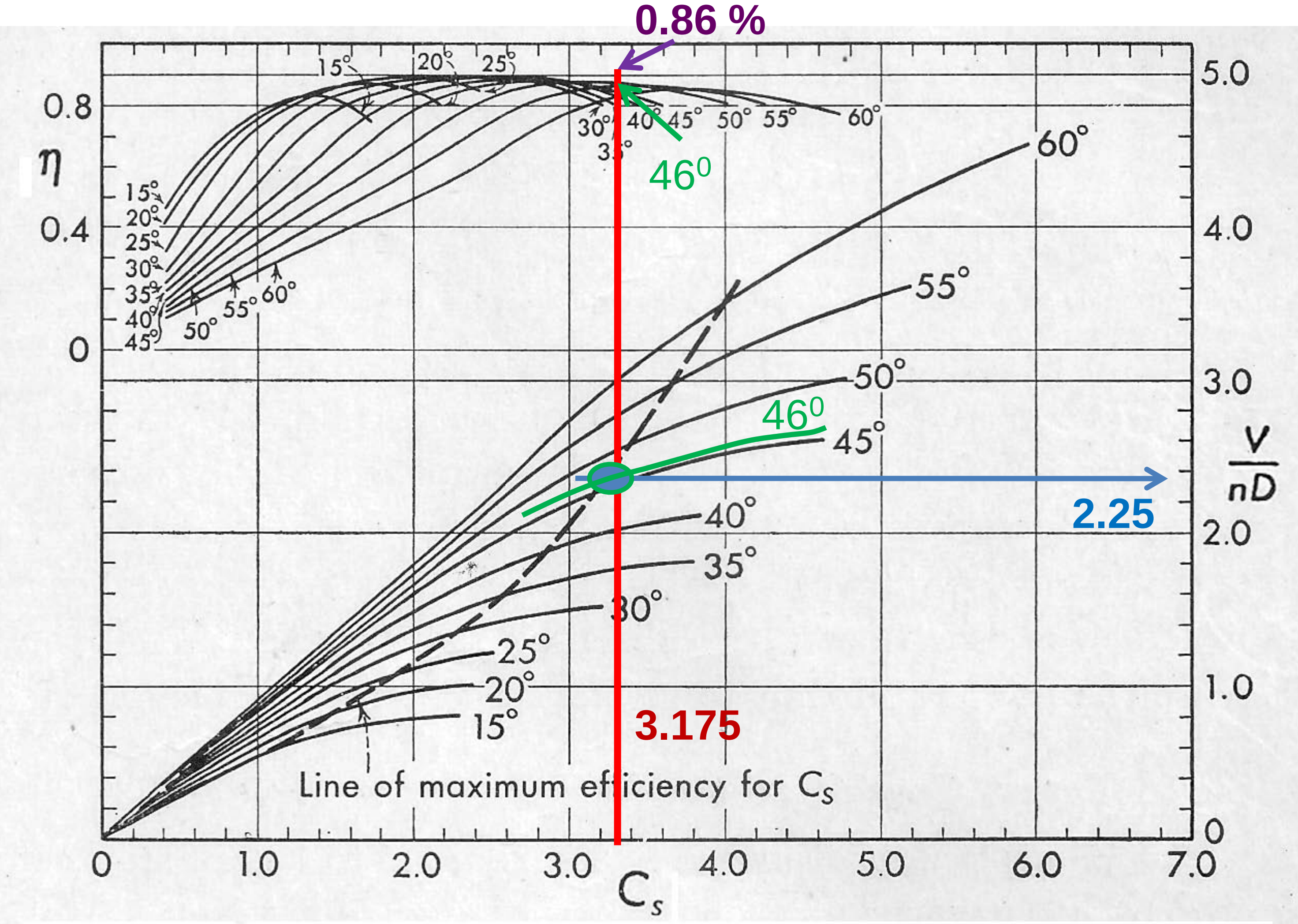
The speed-power coefficient may be calculated from its definition,

$$C_s = \sqrt[5]{\frac{\rho . V^5}{P . n^2}} = 3.175$$

Use the speed power coefficient as the figure of merit. Then use graph of Cs to arrive at the blade setting angle from the maximum efficiency consideration. The problem may be solved at the propeller design reference radius 0.75 R.



Design chart for the NACA 5868–9 three-bladed propeller with spinner. Blade angle at $0.75R$.

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From the graph using a tangential extrapolation of the maximum efficiency locus, which takes the best match point slightly outside the graphical curves. Hence an extrapolated blade angle line of 46^0 is also drawn

Best blade angle = 46^0, and
Best efficiency , η_{prop} = 86%. and
Matched advance ratio, J = V/nD = 2.25

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From these one can compute the diameter ,

$D = V/(2.25.n) = 3.667$ m.

Thus at prescribed flying speed of

$V_\infty = 161$ km/hr $= 27.777$ m/s.

We get

$J = 0.562$ (using the propeller dia.)

At which $C_s = 0.793$.

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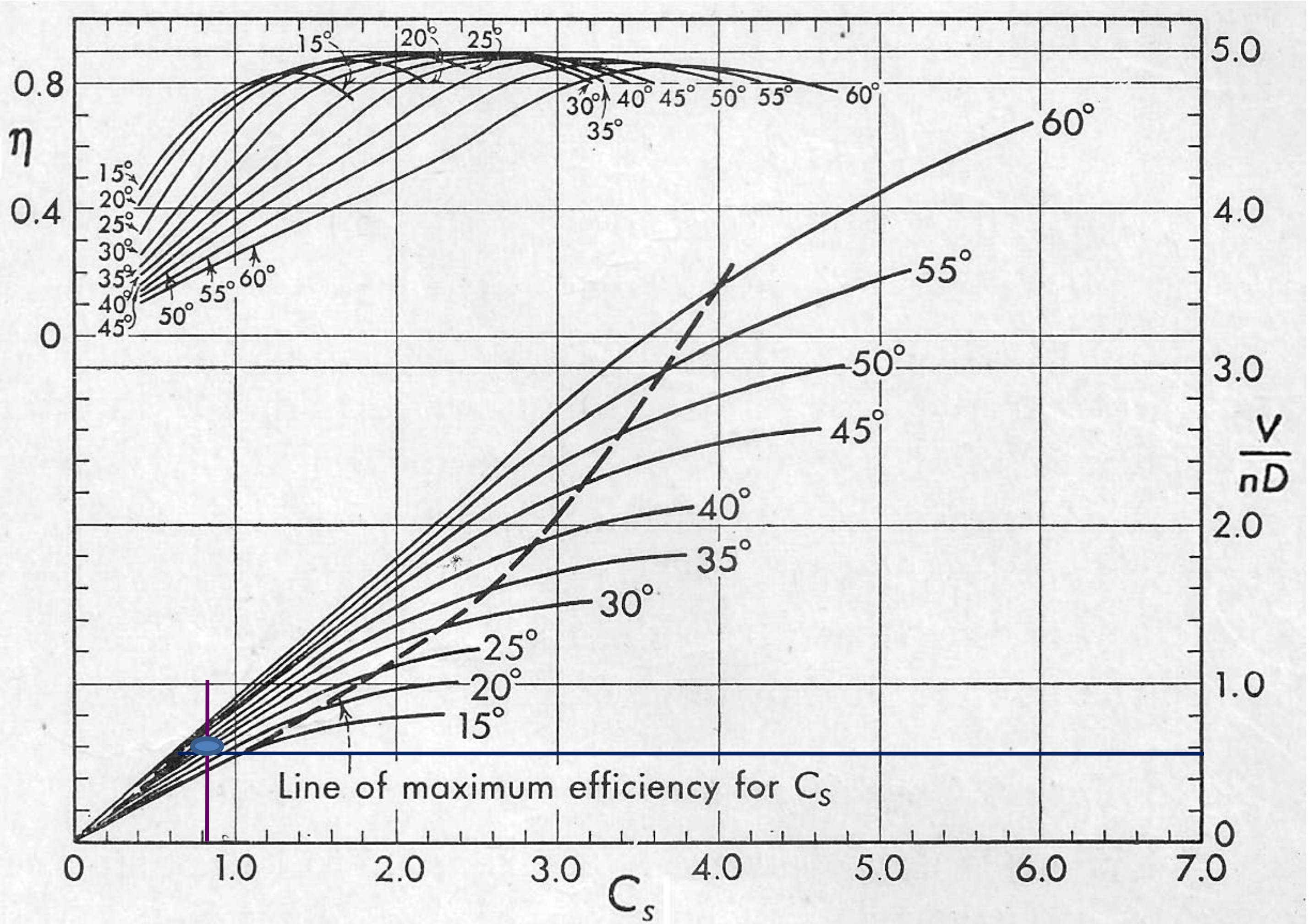

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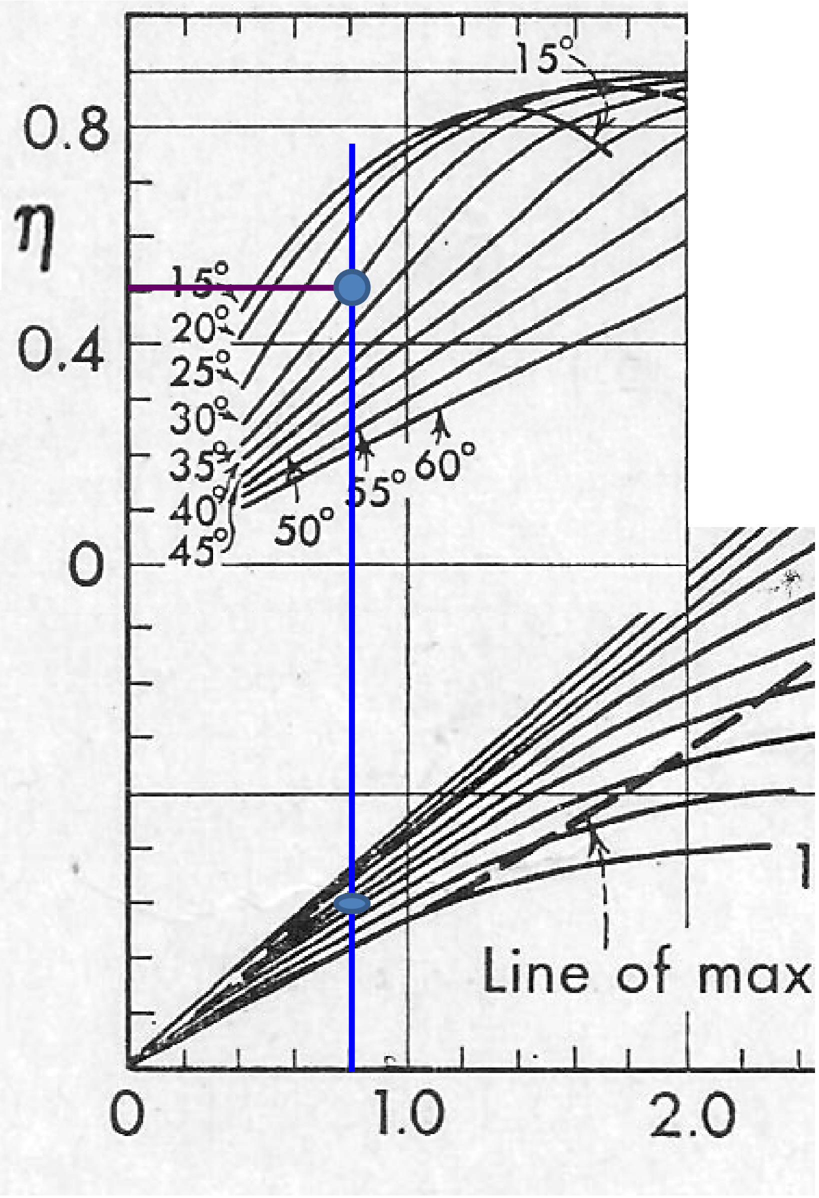

Again, from the Cs graph,

Blade angle required is 29^0 and

Efficiency, η = 50%.

It can be seen that at this value of J = 0.562 if a blade angle 15^0 could be set then an efficiency of 80% could be achieved. This would have give a speed –power coefficient of 1.1. At that value the propeller would go on a over speeding to absorb the power supplied. Thus, even if variable pitch mechanism is used, constant speed operation results in low efficiencies at low speed. The solution would be to reduce the power setting to operate the blade with 15^0 setting and $C_s = 1.1$ to achieve an efficiency of 80%.

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Tutorial Problems

1) A propeller of diameter d that develops thrust T when operating with advance ratio J and rpm N ---- is to be replaced by a pair of equal propellers of the same shape, operating at the same velocity V and advance ratio J and producing together the same thrust T.

Find out the diameter d" and the rotational speed N" of the two new propellers. Prove that the total power required by the two propellers equals the original propeller power.

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2) An aircraft flying at 592 km/hr is powered by a propeller rotating at 1800 rpm. The propeller is of 3.05 m diameter and uses NACA 0015 airfoil section. At the reference blade section at 0.9144 m from the root, where the blade angle is 47.7^0 compute the local flow angle at the station.

Ans: [43.7^0]

3) An aircraft is propelled by a 4.572 m diameter propeller, which produces 35.6 kN of thrust. The aircraft is flying at an altitude where the atmospheric conditions are such that the density of air is 1.03 kg/^{3}. Using momentum theory compute : (i) the induced velocity through the disk, (ii) the final velocity of the flow in the far wake.

[Ans: (i) 5.516 m/s; (ii)189.9 m/s)]

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4) Compute the diameter of the flow field in the far wake of a propeller of diameter 3.05 m, which produces a propulsive thrust of 8.9 kN of thrust while flying at a speed of 322 km/hr.

[Ans : 2.95m]

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5) A 907.2 kg helicopter is powered by a 9.144 m diameter rotor. When the helicopter is landing it descends at an uniform rate under sea level conditions, and the induced velocity is ⅓ the rate of descent of the helicopter. Compute the velocity at which the helicopter is descending.

[Hint : Rotor upward thrust = Helicopter weight = $2.A.\rho(V - v).v$]

[Ans : 15.82 m/s]

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6) An aircraft while cruising at 724 km/hr is expected to encounter 5927 N of drag. The propeller flying this aircraft is of diameter 3.657 m and is designed with NACA 5868-9 3-bladed propeller blades. The engine delivers 1491.4 kW while the propeller runs at 1300 rpm. Check if the aircraft propeller matching for cruise flight is achieved. Compute any extra power or power shortfall that may be found.

[Cruise flight is possible; 82 kW extra power available.]

Next

Jet Engine Ideal Cycle Analysis

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