Propeller Efficiency
Full Throttle Constant Altitude Cruise

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Introduction

From previous articles recall that propeller efficiency can be characterized by two nondimensional parameters, the advance ratio, J, and the power coefficient, C_p, given by

$$J = \frac{V}{ND} \quad \text{and} \quad C_p = \frac{\text{BHP}}{\rho\, N^3\, D^5}$$

where V is the true airspeed, N is the propeller RPM, D is the diameter of the propeller, ρ is the local density and BHP is, of course the brake horsepower. From these nondimensional parameters we see that propeller efficiency depends on the physical parameters — true airspeed, V, how fast the propeller is rotating, RPM, propeller diameter, D, the air density, ρ, and the engine horsepower, BHP.

From the discussion of cruise propeller efficiency[†] we developed A Simplified Rule of Thumb (ASROT)[‡] that generated an initial estimation of ASROT = 15.2 for choosing an appropriate RPM for a given cruise true airspeed (KTAS) that resulted in maximum or near maximum propeller efficiency. Using the *knee curve* from the pilot operating handbook, as shown in Figure 1, we calibrated our initial estimate to yield an ASROT of

$$\frac{RPM}{KTAS} = 14.5$$

In a second article[*] we illustrated that propeller efficiency during takeoff is significantly lower than during typical cruise flight.

[†] *Cruise Propeller Efficiency on this website*
[‡] Pronounced AS ROT
[*] *Takeoff Propeller Efficiency on this website*

A third article** illustrated that, for a normally aspirated aircraft, climbing at a somewhat higher airspeed than recommended in the pilot operating handbook increased propeller efficiency.

Full throttle constant altitude cruise

Once the desired cruise altitude is reached, the power, propeller and mixture settings are reconfigured to conform to mission requirements. If time is of the essence, then a rich of peak (ROP) mixture at full throttle and high RPMs is selected. If reduced time with fuel economy is desired a lean of peak (LOP) mixture setting with, typically, full throttle at Carson speed is selected. If maximum range is required to complete the mission, then a LOP mixture, the speed for $L/D_{\max}$ and appropriate propeller and throttle selection is used.

At a constant altitude at full throttle, horsepower available is generally controlled by adjusting propeller RPM. The question then becomes: What is the effect of RPM on propeller efficiency? As a specific example consider level flight at 8000 ft and full throttle in a Continental IO-520BB. In order to find the propeller efficiency, both the power coefficent and the advance ratio are required. Hence, brake horsepower and true airspeed are required. At 8000 ft the manifold pressure is approximately 21.5 inches of mercury. At constant manifold pressure and altitude brake horsepower available is obtained from the manufacture's operation manual.†

True airspeed is available from the performance knee curve, as shown in Figure 1 by the dashed line at 8000 ft. These values are shown in Table 1 in the columns labelled Data and in Figure 2. The results from curve fits for this data are also shown in Table 1 in the columns labelled Calc and as curves in Figure 2. Calculated values for the advanced ratio, J, brake horsepower, BHP, and the power coefficient, C_p, are also shown in Table 1.

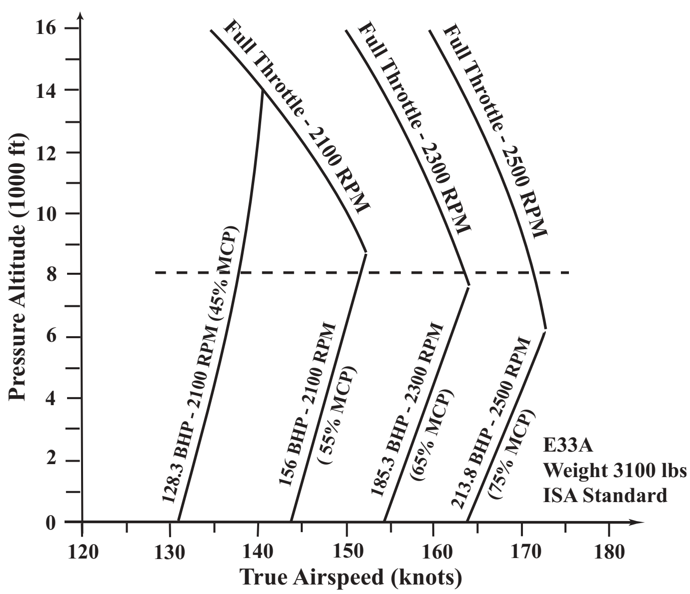

Figure 1. Knee curve.

** *Climb Propeller Efficiency on this website*

† Teledyne Continental Motors, Aircraft Products Division, "IO-520 Series, Operator's Manual", Form No. X30041, September, 1980

Table 1 Full Throttle Cruise Data

RPM Data	BHP Data	KTAS Data	KTAS Calc	J Calc	BHP Calc	C_p Calc
2700	199		182.2	1.026	197.42	0.048
2600	188		177.2	1.037	190.50	0.052
2500	184	171.5	172.2	1.048	182.63	0.056
2400	172		167.2	1.060	173.84	0.061
2300	164	163.5	162.2	1.073	164.10	0.065
2200	156		157.2	1.087	153.44	0.070
2100	142	153.5	152.2	1.102	141.84	0.074
2000	128	146.0	147.2	1.119	129.30	0.078
1900	116		142.2	1.138	115.83	0.081

Altitude = 8000 ft, MP = 21.5 ”Hg, Propeller Diameter 80 in
IO-520BB (285 BHP), Weight = 3100 lbs, standard day

Using the calculated values from Table 1 the effect of reducing RPM from 2700 to 1900 is shown as the dashed line on the bare propeller map depicted in Figure 3 on the next page. As the RPM decreases, propeller efficiency increases from approximately 88% to 91%. Notice that the cruise conditions, represented by the colored dots, from the knee curve at altitudes near 8000 ft cluster around the RPM propeller efficiency curve. Also, notice that even for RPMs as low as 1900 the propeller is not at the maximum pitch stop.

Conclusions

Reducing propeller RPM in constant altitude full throttle cruise increases propeller efficiency by approximately 3%. However, other considerations may preclude operating at low RPMs.

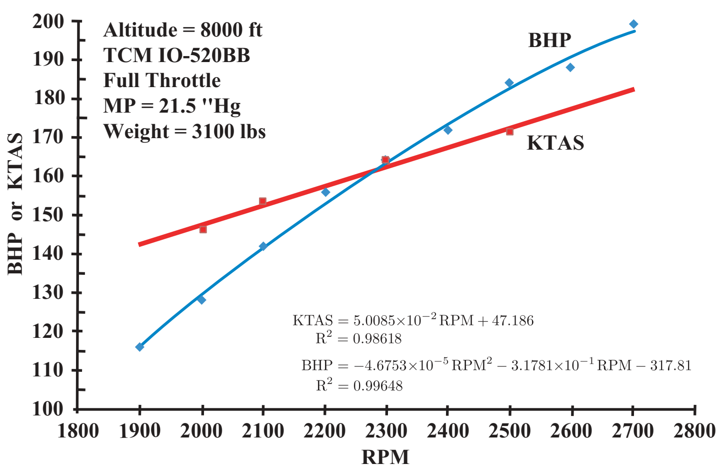

Figure 2. BHP and KTAS at full throttle and 8000 ft

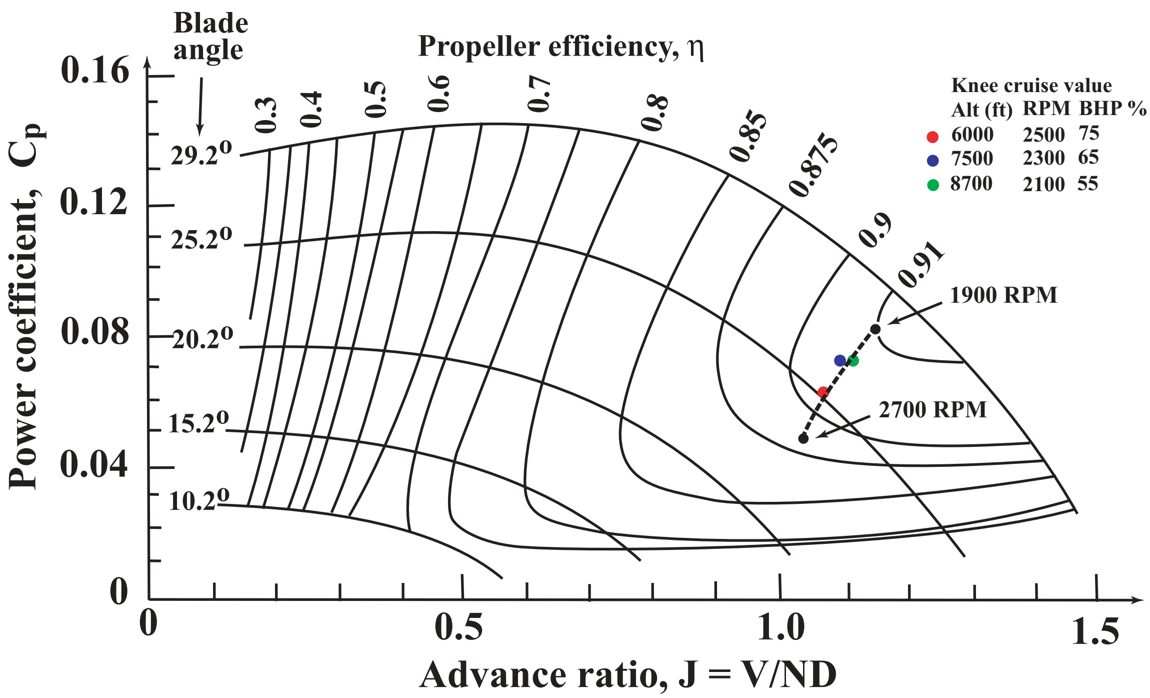

Figure 3. Propeller map.