What is the propeller efficiency, μ_p, of modern propellers for light sport aircraft?

Roskam's book on preliminary design gives a value of 0.7 for "homebuilt" aircraft and 0.8 for general aviation. What explains this difference in propeller efficiency? The content of Roskam's book is fantastic but some of the constants that he gives may be a bit dated as was the case for specific fuel consumption which was given as 0.7 for homebuilt aircraft when a modern engine like the Rotax 912UL has a sfc of 0.47.

On a search of Wikipedia, it is written that modern propellers can have an efficiency of 0.9.

aircraft-design propeller efficiency

edited Dec 8 '17 at 17:59
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asked Apr 22 '15 at 2:53
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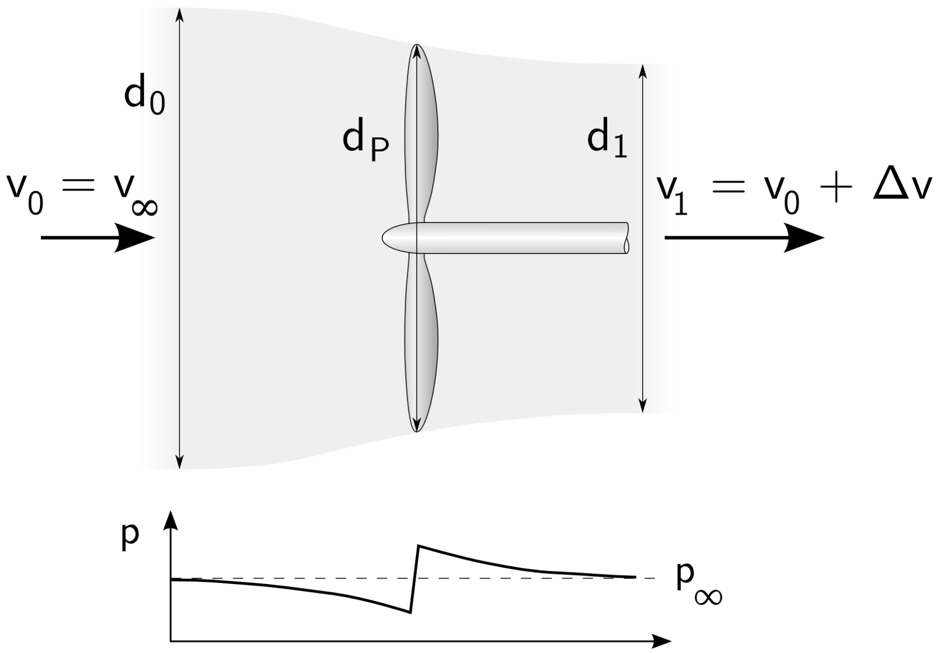
1 Propeller speed is the answer. Many homebuilds use converted car engines which run at higher speeds than the aviation-certified gasoline engines. – Peter Kämpf Jun 2 '15 at 19:42

Propeller charts assume some fuselage shape and somespinner shape, and these are important factors to consider. Especially if the configuration is a pusher-prop type. – Gürkan Çetin Jun 3 '15 at 19:15

3 Answers

Propeller efficiency is mentioned a lot here on Aviation SE, but lacks a good explanation. Here we go:

A propeller accelerates the air of density ρ which is flowing through the propeller disc of diameter d_P. This can be idealized as a stream tube going through the propeller disc:



The air speed ahead is $v_0 = v_\infty$ and the air speed aft of the propeller is $v_1 = v_0 + \Delta v$. The propeller effects a pressure change which sucks in the air ahead of it and pushes it out. Since the mass flow must be equal ahead and behind the propeller, the stream tube diameter is bigger ahead of the propeller and smaller downstream. In reality, there is no neat boundary between the air flowing through the propeller and that surrounding it, but for computing thrust this simplification works well if the airspeed is identical across the cross section of the propeller disc.

The efficiency η of thrust creation is the work done on the mass flow through the propeller $W = m \cdot \Delta v \cdot v_0$ relative to the impulse change of the air $\Delta I = m \cdot \frac{v_1^2 - v_2^2}{2}$:

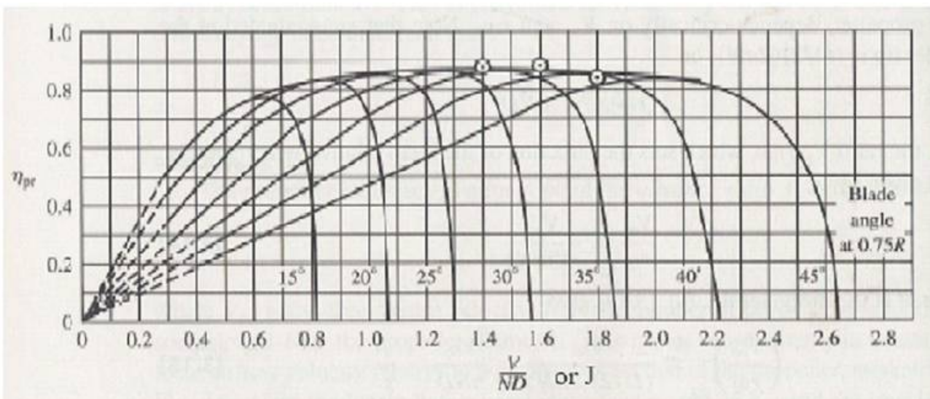
This equation assumes that air is uniformly accelerated straight backwards. To be more precise, you need to add the swirl losses, since the air receives a rotational component ω from the propeller, spinning with the angular velocity Ω, as well:

$$\eta_{Prop}^{opt} = \frac{1 - \frac{\Delta v \cdot \left(v_\infty + \frac{\Delta v}{2}\right)}{d_P^2 \cdot \Omega^2}}{1 + \frac{\Delta v}{2 \cdot v_\infty}}$$

Still, we have not included friction losses yet and our prop spinner and engine nacelle are also not included. Now we must enter into a definition what propeller thrust is: Is it just the lift acting on the propeller blades in forward direction, or is it the remaining forward force after the additional drag of the airplane components in the slipstream of the propeller has been subtracted?

To avoid lengthy computations, charts can be used where the efficiency is plotted over a range of parameters.

To cut the discussion short: Generally it is safe to assume a top propeller efficiency of 0.85 (85%) with big, slowly spinning propellers (1000 to 1700 RPM). If the twist distribution along the blade does not match the local angle of attack distribution (say, if the propeller is optimized for high speed, but operated at slow airspeed, like during take-off), efficiency can easily drop to 0.7 (70%). Things become worse if the pitch of the blades is fixed. See below for a typical example of a variable pitch propeller. Each of the curves is for a different pitch setting, the x axis shows the advance ratio (the ratio between airspeed and circumferential speed; here off by a factor of $1/\pi$), while the y axis shows the efficiency.



Each curve is for a different pitch angle, β

What can be seen from the equations above is that it is more efficient to accelerate lots of air a little than to accelerate a little air by a lot. This means that small propellers on ungeared engines, spinning at high RPM, are at a distinct disadvantage; this is why Roskam assumes only 70% for them and only 80% for GA propellers.

The 90% you name has to my knowledge only been scratched at by some very efficient (slow, large, contra-rotating) propellers operating under ideal conditions. To play it safe, I would choose a slightly smaller number for them.

edited Jun 3 '15 at 17:39

answered Jun 3 '15 at 15:04

Peter Kämpf
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It's quite low... After a series of gliding experiments made with a Luscombe 8E, and published by the AIAA, the conclusion was that the prop efficiency was around 62%...

https://engineering.purdue.edu/~andrisan/Courses/AAE490A_S2010/Buffer/AIAA-46372-872.pdf

edited Mar 17 '17 at 17:46

answered Mar 17 '17 at 17:35

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Upvoted just for the link to the paper. By the way, the prop efficiency is 81% while the overall efficiency drops to 62% due to slipstream losses. The drag in powered flight is **30% higher** from prop-airframe interaction! – Peter Kämpf Jul 24 at 21:31

For example constant speed props typically achieve 10% better efficiency than fixed pitch. Also wood props are about 5% less efficient than the equivalent metal prop because the metal prop can be made with a longer and thinner airfoil.

The most efficient prop I have ever seen was rated at 92% for a Mooney. Aviation technical books typically rate wood fixed pitch at about **65-70%** and metal at **70-75%**, followed by constant speed at **80-85%**.

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The Science of Flight, W N Hubin - 1992
Design for Flying, David Thurston - 1978
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edited Dec 9 '17 at 9:29

answered Dec 9 '17 at 9:09

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