Bottom Line on Torque vs. Horsepower:
It's Just Math. Deal With It!

The battle lives on, despite everyone's best efforts to win it: Which is the deciding factor in airplane performance – the engine's torque or its horsepower?

Proponents of the "torque" argument point out that torque is what makes an engine able to screw a propeller through the air. They argue correctly that, given any set of conditions concerning a particular propeller, enough torque is required at any given propeller speed (revolutions per minute -- rpm), to get a good grip on the air and push it back behind the airplane. Fair enough; the argument is obvious.

Further, the "torque" apologists argue that more torque at lower rpm is a good thing. Propellers work more-efficiently at lower rpm, they argue, so slower is better. Propellers, though, are perverse devices. Their tips travel through the air at speeds much higher than their roots. There is, of course, a directly linear relationship between rpm and propeller diameter on one side, and tip speed on the other. When a propeller tip approaches and crosses the speed of sound, it loses efficiency rapidly, and it can subject itself to harmonics that can destroy the prop in seconds, causing more than just loss of thrust. In the meantime, the part of the blade near the hub needs to have a rather radical pitch, to "do its share" compared to the tip.

The "horsepower" gang says that it doesn't really matter how many rpm it takes the engine to make the required horsepower, because it's a relatively straightforward matter to put gears between the engine and the propeller drive hub, thus achieving any desired propeller rpm.

The results at the prop hub are the same… but both camps argue that they're somehow different.

OK, let's get to it:

The propeller doesn't know, or care, how it gets turned. It is responsible only for spinning in its designed speed range. If it has enough torque at any given rpm, it will get the job done. How that torque is achieved (whether through direct drive or through gear reduction) is of no concern to the propeller.

But it's not that simple, is it?

Yes, it is; and no, it isn't. Going back to basics, let's remember that torque (in pounds-feet) times rpm, divided by the constant 5252, equals horsepower. It's simple math. The prop doesn't care whether you have an engine producing 300 lbs-feet of torque at 2500 rpm to produce 142.8 horsepower (300*2500/5252=142.8) or whether there's a 5500 rpm engine, working through a 2.2:1 gearbox, producing 136 lbs-ft at the crankshaft to turn it that same 2500 rpm. (Note that the torque at the prop hub, 300 lbs-ft, is the same in either case. So is the horsepower and so are, at least theoretically, the cooling and fuel requirements.)

Differences arise, though, in propeller efficiency. In broad terms, a slower-turning prop can produce more thrust than a faster prop, even when both designs are optimized. That's great, if you have a tall taildragger that has the ground clearance for an 84" propeller and enough torque to turn it; but what if you're driving a hot tricycle Lancair? (Darryl Greenamyer, seven-time Unlimited champion and four-time Sport Class champion in the Reno Air Races, flies his tricked-out 700hp Lancair with the longest prop he can put on the engine. It's so long, in fact, that he once nicked the tips against the lids of the airport's underground gas tanks!)

When propeller tip speeds approach supersonic, further problems arise: the shock waves in the air make a lot of noise, and that noise is symptomatic of wasted power. (After all, the power is being used to create noise rather than thrust.) The problem becomes deeper, as the airplane goes faster: the forward speed of the airplane is added to the rotational tip speed of the prop. (On race planes such as Greenamyer's, the wasted power is figured into the "cost of doing business." He has so much power that, even though his prop's efficiency declines, he still gets some marginal benefit to the mostly-wasted power.)

> To illustrate how this argument perpetuates itself, let me cite an example: When I was with Mosler Motors, we fitted a Luscombe 8A with our "82hp" engine and a 60-inch prop. On its first flight, it took off like a rocket, but it couldn't break 70 mph, and returned to the field immediately, overheating. The prop choice was obviously wrong. The Mosler made its power at 3000 rpm, and the original C-65 peaked at just under 2700, though the tired original engine would no longer pull that speed. Even so, it provided thrust at lower rpm, allowing a more-efficient prop to produce the same thrust as the Mosler, but at lower rpm. With the C-65, the Luscombe would take longer to get airborne, but it had plenty left to convert into airspeed, once it leveled off.
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> We had another, more-suitable prop available to test, and were anxious to try it. That first flight spooked the airplane's owner, though, and we immediately replaced the Continental on the engine mount.

Real world scenarios:

OK, we don't race at Reno, and we don't have 700 horsepower. We want to go from here to there with minimum fuss. What implications are there, for horsepower nuts and torque fiends?

There are always tradeoffs. A smaller, lighter, high-rpm engine can produce a bunch of horsepower, but to deliver required torque to the prop, it needs to run through a gearbox. That adds some very real weight and complexity, and it wastes a few horsepower in mechanical action.

> The argument here should be apparent: it's not "torque vs hp" that is the battle; it's prop rpm that matters, and that is regulated by design, either by using a slow-turning crankshaft and direct-drive, or by running a fast crankshaft through a reduction drive.

The direct-drive torquemeisters, though, have their own drawbacks: in order to generate and handle the high torque, heavy components need to be used. Heavy crankshafts, heavy rods, beefy bearing saddles – these can sometimes outweigh good gearboxes. Longer propellers, too, need extra weight to be stiff along their long, cantilevered "wings."

Another factor that needs to be considered is vibration. Big engines (slow-turning, high-torque engines) make big (high-amplitude, low-frequency) vibrations, often requiring heavier engine mounts and pickup points. Additionally, propellers can be affected by the start/stop cycle that occurs with horizontally-opposed engines. A gearbox reduces those power pulses directly in proportion to the gear ratio. Further, a gearbox with an "odd" ratio (e.g., 2.13:1 vs, say, 2.0:1) can "un-synch" the vibrations, so they do not transfer firing vibrations in concert with the pistons' firing.

Optimize everything.

If you’re going to give your airplane the best propulsion, you’ll need to use the biggest prop that will work with your design, turned at the optimal rpm, by either a geared engine or a direct-drive engine. Either engine needs to develop the torque the prop requires.

> The prop can be slowed down “too much,” however. Remember that a long prop may not be good news, if there isn’t sufficient ground clearance!

Remember, torque=hp*rpm/5252. Always.

Whether the torque at the hub comes from a direct-drive hub or from a geared hub, the propeller cares not. If the prop doesn’t care, your personal preferences are all that matter, and taste is your own province.

Now, stop arguing and go enjoy some flying!