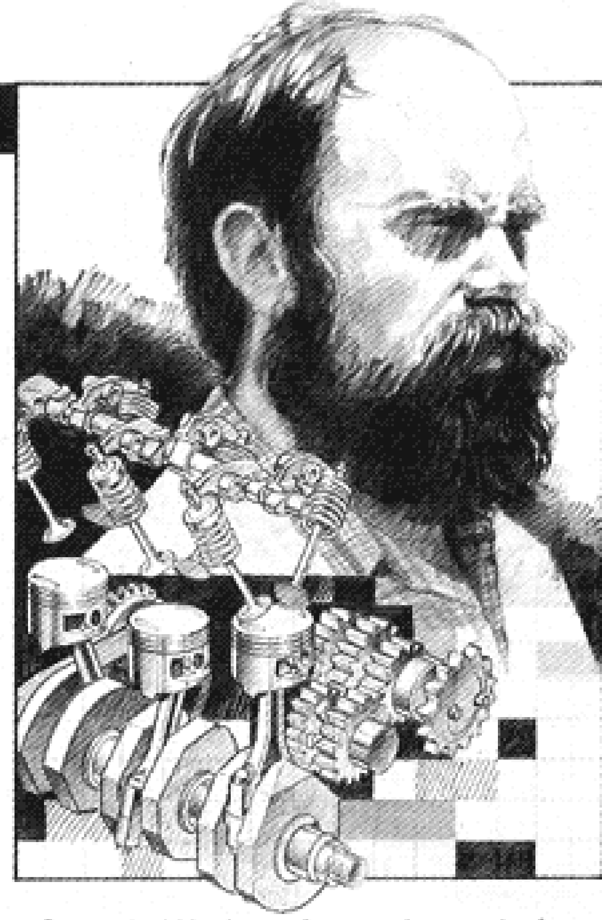
Kevin Cameron

Horsepower And Torque



☐ How do you judge a motorcycle? Looks? Hard to evaluate objectively. Handling? Better, but you need to be a skillful rider to push a bike to its limits here, and we still don't have an easily compared set of objective criteria. Price? Sure, that's objective, but who wants to ride some stone even if it *is* cheap? Quarter-mile times? Closer still, but how will that engine behave loaded down with an overweight pilot, passenger, and all their camping gear?

Horsepower and torque give us some of the most relevant, objective and easily compared information available for evaluating an engine's performance. Every motorcyclist is familiar with these terms, yet few understand them. We know that more is better, that touring riders like motorcycles with lots of torque while sport riders like bikes with gobs of horsepower, but how are the two related? And how do we get these figures in the first place? These overworked terms tend to lose their meanings, and understandable definitions need to incorporate familiar concepts. We'll begin with a little vocabulary, and then a bit of simple math.

First is force. Here is a valve spring holding its valve closed with 100 pounds of seat pressure. This 100-pound force isn't moving, but it is the same force of 100 pounds that propels a small air-to-air missile at 1000 feet per second. Moving or not, force is force.

Next definition: *work*. Work is the result of a force moving through a distance. If I push a heavy crate 15 feet across the floor, exerting a force of 150 pounds on it as I do so, that *work* is defined as force times distance, or 150 pounds x 15 feet = 2250 foot-pounds of work. Whether I push quickly or slowly doesn't matter; as long as the force and distance don't change, the amount of work is constant.

The third definition is *power*. Power is the rate of work done, (force multiplied by distance) divided by time. If it takes me ten seconds to push the crate across the floor, then I did that work at the rate of 150 pounds x 15 feet, divided by 10 seconds, or 225 foot-pounds per second.

Our more familiar unit of power is the horsepower, arbitrarily defined as 550 foot-pounds per second. To find my output in horsepower as I pushed that crate, we divide the number of foot-pounds per second by 550 (one horsepower in foot-pounds) and get 225/550, or 1/2 hp.

Thus, three steps take us from familiar concepts to horsepower.

Step 1: *Work* performed equals force times distance. 150 pounds x 15 feet = 2250 foot-pounds of work.

Step 2: *Power* exerted equals foot-pounds per second. 2250/10 seconds = 225 foot-pounds per second.

Step 3: To convert foot-pounds per second into *horsepower*, we must divide by 550. Therefore we have 225/550 = 1/2 hp.

The basis of horsepower is guised in three perfectly familiar concepts—force, distance and time.

All this is fine when we are talking about moving in a straight line, but what about rotating machines? In a rotating situation, we need equivalents for the familiar force, distance and time. The rotating equivalent of force is *torque*—a twisting force. Like force in a straight line, torque is separate from movement. At zero rpm or at 100,000 rpm, torque is torque. Remember our valve spring?

Unfortunately we often confuse the units of work (foot-pounds) with the familiar units used to measure torque (also called foot-pounds). To get around this, I'll define torque as pounds-feet so we can keep it separate from the foot-pound used as a unit of work.

The equivalent of straight-line distance in a rotating situation has to be the number of times the shaft turns—its revolutions. Straight-line work is force times distance, so rotating work is torque times revolutions.

Finally, time is still time, whether we work in a straight line or whirl around in circles. To find the rotating equivalent of straight-line horsepower (force times distance) divided by time, we must substitute torque times revolutions, divided by time. More simply, power is torque times revolutions per minute.

Simplified, the equation relating torque, revolutions per minute, and horsepower is this: rpm/5250 = hp/torque. If you have any two of these variables, you can figure out the third. If, for example, a well-known V-twin gives 55 pounds-feet of torque at 4000 rpm, we can get the horsepower as follows: 4000/5250 = hp/55 pounds-feet, and therefore hp = 42. Or, if a certain Morbidelli 125 happens to give 42 hp at 13,700 rpm, we can find its torque as follows: 13,700/5250 = 42/torque. Therefore the torque is some 16 pounds-feet.

So much for formal definitions. What do people mean when they say brake horsepower? This simply means horsepower measured on a brake, or dynamometer. Other ways of measuring horsepower give other results. Indicated horsepower is calculated from a graph of cylinder pressure versus piston travel, and is power before engine friction has taken its share. Rear-wheel horsepower simply means the power measured by a dynamometer connected to the final drive, while crankshaft horsepower implies the dyno is connected directly to the crank, eliminating the losses in primary drive, gearbox and final drive. These losses can easily amount to 15 percent of the total, so crank horsepower is always higher than rear-wheel horsepower.

Most confusing of all are power figures measured by strapping the rear wheel down against a roller-dyno. Here, much power is wasted in slippage and tire deformation, so the results are variable and inaccurate. Then there is horsepower "measured at the advertiser's pen," limited only by his imagination.

As riders though, we can still make seat-of-the-pants comments on both horsepower and torque, sometimes with surprising accuracy. When a rider says, "My bike has a lot of torque," he doesn't mean the same thing as an engineer who, fingering a point on a graph, says, "This engine has a lot of torque." The rider means that when he turns the throttle, he feels a powerful forward thrust over a wide range of rpm. He's talking about the *width* of his engine's torque spread, not about the actual number of pounds-feet of torque. A Kawasaki H2 and a Harley Sportster had identical *peak* torque figures back in 1972, but would anyone say they felt the same to ride? Certainly not. The Harley was a torquer because its high torque was spread all over the band, while the Kawasaki was a high horsepower machine because its torque was up at high rpm, centered over a narrow range. The Kawasaki may have been faster, but the Harley felt punchier. ■