Efficiency

WEBSTER'S DEFINES EFFICIENT as "performing in the best possible and least wasteful manner." Efficiency is therefore a perfect test for the quality of any concept…or machine. So it's not surprising that when we refer to engines, we have several popular categories of efficiency. Alas, the internal combustion, gasoline-fueled engines in our motorcycles don't score very highly on the most important measures.

Thermal Efficiency refers to an idealized ratio between the ultimate heat energy in the fuel and the energy needed to accomplish the work that's been done—often given as a percentage between zero and 100%

Gasoline releases 19,000–20,000 BTUs (British Thermal Units) per pound when burned (exceptionally high energy density that's ideal for vehicle storage). A single BTU is the heat energy required to raise the temperature of one pound of water by 1°F and is equivalent to 777.6 lb.-ft. Because one horsepower equals 33,000 lb.-ft. per minute, each hp would require 42.4 BTU's of thermal energy per minute. If an engine could achieve this performance, it would have 100% thermal efficiency.

But something like this is more likely: With the bike loaded on an accurate dyno, some form of brake is used to prevent the bike from achieving greater speed on the rollers. The maximum arresting force is easily measured and divided by the leverage arm to learn the torque applied, which can then be plugged into the hp formula using 33,000 lb.-ft. per minute. If the engine is consuming enough fuel for 100 hp, we can count ourselves lucky if the dyno finds closer to 30 peak hp at the rear wheel. Where'd the rest go?

A simple way to think of it is to imagine the loss as all the heat that escaped before it could press down on the pistons. Metallurgy puts the ultimate limits on how much heat our engines can accept, and gasoline is a very hot fuel. Overheated pistons melt, overheated valves burn, overheated cylinder blocks and heads warp. Overheating, I used to warn my students, will turn engines to junk faster than any other breakdown—shut it down fast!

So, we need our cooling systems (air, oil and/or coolant liquid) to function so we can pull nearly a third of the fuel's energy out of the engine and release it as heat into the atmosphere before it does any harm. Another third of the fuel energy is lost out the exhaust pipe. The greater the heat that escapes, the less that has been turned into work before exiting the combustion chambers. The remainder of the heat is what's left to do the work, and a good number for thermal efficiency is approximately 30%—not impressive.

But we're not home free yet. Mechanical Efficiency also gets a share of that power. Mechanical systems are never frictionless. In fact, it's the law—and the Second Law of Thermodynamics must be obeyed—thus the patent office will never sanction a perpetual motion device.

Our engines, despite the best efforts of lubrication systems, still make a lot of friction. The starting and stopping of the pistons and rings—testing the strength of the oil film on the cylinders—is the biggest source, camshafts driving against the pressures of valve springs is the next highest, but there are many others: bearing and pumps (which typically increase drag exponentially with rpm) and dozens of smaller sources.

To account for these losses, the SAE allows hp ratings to be increased by a standard figure of 15% in order to be certified for gross horsepower.

Don't forget that the definition of efficient includes doing work in the "least wasteful" manner. Everywhere we reduce waste, we increase efficiency—of every kind. The highest temperature that can be safely applied to the pistons is a measure of its efficiency. Outside the combustion chambers, everywhere differences in temperature exist between the motor and the ambient environment, energy is wasted.

Looked at this way, improvements can take obvious directions. Inside the combustion chambers, higher compression ratios will increase heat and pressure, tighter combustion chambers will allow less area for heat loss, high-tech coatings can insulate pistons so they tolerate higher temps before softening. High-temp ceramics might replace metals altogether.

Outside the combustion chambers, a turbocharger could capture otherwise wasted exhaust energy to pressurize intake air for a net gain in power. Pumps can be turned by electric motors at consistent high-efficiency speeds.

Or cooler ambient air can be delivered to the engine with proper ducting and insulation, for greater temperature differentials with combustion. The rule of thumb is that for every 7° F drop in intake temperature, hp rises by 1%.

Novel means to recapture otherwise wasted energy are bound to expand exponentially in the future. Formula One cars are now allowed to use Kinetic Energy Recovery Systems or KERS to charge a high energy electric battery that can supply an additional 80 hp for up to six seconds per lap. Unlike the regenerative braking systems now being used on hybrid automobiles, they take energy off the end of the crankshaft, using the engine's off-throttle inertia as a power source. And *Discovery* magazine reports this month that MIT engineers have just devised energy recovery shock absorbers. These convert the energy that would otherwise heat the shock's hydraulic fluid and be released as radiant heat into the atmosphere into electrical power instead. The first application is for heavy trucks on rough roads (maximum power potential) but smaller units will surely follow.

The prism of first principles will show us where we can both conserve energy and also where we might find new energy sources. Everywhere you find large differences in temperature you have the potential to either reduce them or take advantage of them.

My favorite visionary, Nikola Tesla, was horrified that mankind had become dependent on polluting non-renewable fuels. He proposed that we drill deep enough to tap temperatures created by the Earth's molten core to generate power. If we can put a man on the moon, why can't we do that?

Put on your thinking caps. The breakthroughs often come from individuals who can think outside the box. Cheers!

Dave Searle

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Editor