Examining the relationship between compression ratios and octane

By Wes Fleming

Motorcycle manufacturers throw a lot of numbers at us, many of which are relatively meaningless in our day-to-day lives. We can memorize rake, trail, wheelbase and more; it's all important, but other than arguing about them on internet forums, they don't occupy much of our brain time in the saddle.

One of the numbers that has a lot of importance is the compression ratio of the engine. A ratio is an expression of two numbers as they compare to each other; if you have 200 pennies and 100 nickels, then your ratio of pennies to nickels is two to one, expressed as 2:1. Using one of BMW's popular models, the F800GS, I'll break down how a bunch of numbers work together to determine the compression ratio.

$$D = \frac{\Pi}{4} \times b^2 \times s \times c$$

Where
D = displacement
b = bore
s = stroke
c = # of cylinders

We start with the bore (diameter of the cylinder—82mm) and stroke (how far the piston travels—75.6mm). By using the following formula, one of the data points these numbers can give us is the total displacement of the engine.

Pi (3.14) divided by 4 is 0.785, and for the F800GS, bore squared is 6724, giving us:

798,085 = 0.785 x 6724 x 75.6 x 2

As this is expressed based on millimeters (from the bore and stroke), converting the result to cubic centimeters gives us 798cc, which indeed is the displacement of the F800GS.

The more important number, however, is the compression ratio, which isn't quite as easy to calculate. We already know the volume of each cylinder when the piston is at bottom dead center (BDC); we also need the volume of the cylinder with the piston at top dead center (TDC), which manufacturers usually just measure directly by placing the piston at the top and filling the cylinder with water.

The compression ratio is derived from the difference between these two volumes (cylinder with piston at BDC and at TDC); this

$$CR = \frac{(0.785 \times b^2 \times s) + V_c}{V_c}$$

difference is expressed as V_C

We already know from figuring the displacement that 0.785 x b^2 x s = 399cc. Because it's difficult to access a cylinder—and even if we could, no F800GS owner would likely want us pouring water into the cylinder—we can use BMW's stated compression ratio of 12:1 to solve for V_C and determine that the volume of the cylinder at TDC is about 33. In one F800GS cylinder, then, the fuel/air mixture takes up 399cc of space at BDC, but only 1/12th the space—or 33cc—at TDC.

By now, you're probably screaming "why should I care??" It's this complicated formula that determines what kind of gas you need to put in your bike and what kind of power it develops as a result.

The reason this matters is that the more highly compressed the fuel/air mixture is in the combustion chamber, the more potential energy is available when it finally does burn. In this regard then, a higher compression ratio is indicative of a more powerful engine, though the overall power of the bike is tied into far more than just the compression ratio.

This is where the octane rating of gas comes in. While there's a lot of voodoo, myth and misunderstanding surrounding octane, one important aspect of octane is the gasoline's ability to resist spontaneous combustion under compression. Compression of a gas—or in the case of internal combustion, a liquid/gas mixture—creates heat, which can preempt the ignition sequence. The higher the octane, the more resistant to spontaneous combustion the gas is; of course, combining gasoline vapor with air in a hot engine cylinder changes things a little, but the underlying concept is what's important.

A high compression ratio and high octane go hand-in-hand in modern high performance engines. Gasoline's ability to resist spontaneous combustion under compression is critical to preventing pre-ignition, which we refer to as knocking or pinging. As you can probably imagine, the mixture in the combustion chamber exploding before the piston has reached TDC is harmful to the engine, possibly damaging the piston, rings, valves and cylinder.

Most modern vehicles are equipped with knock sensors, which detect this harmful pre-ignition. When they do, they tell the fuel injection computer to delay the ignition cycle until the knocking is gone. It's this process that allows the use of lower-than-required octane gasoline for a period of time, though nearly every motorcycle manufacturer recommends against extended use of lower octane gas.