Compression Ratio

The secret to power and economy

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Compression ratio is one of a few measurements that determine engine performance. It determines an engine's power, its fuel economy, and its tendency to knock or detonate.

The Basics

The compression ratio measures how much the air-fuel charge is compressed in the engine's cylinders. As the crankshaft rotates on the intake stroke, the piston travels from top dead center (TDC) to bottom dead center (DBC) [the engine stroke] the cylinder is filled with the air-fuel mixture. See Figure 1. Then, as the crankshaft continues to turn, the piston moves up and compresses the air-fuel mixture. The extent of this compression determines the engines power. The more the air-fuel mixture is compressed the greater the pressure in the cylinder before the air-fuel mixture is ignited. This leads to more combustion pressure at ignition and increased push on the piston. The burning gases also expand to a greater volume. These effects combine to produce more power on the power stroke. All other things being equal, an increase in compression ratio from 8:1 to 10:1 will produce a 5 to10 percent increase in torque/power across the operating range and 5 to 10 percent better fuel economy.

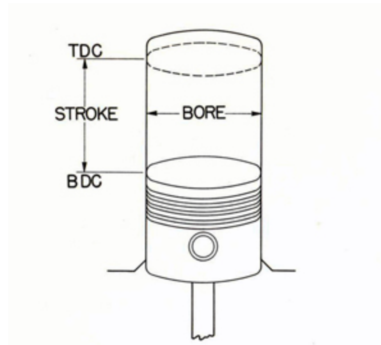

Figure 1 - Cylinder volume is the difference between TDC and BDC.

Early attempts to increase the compression ratio were limited by available fuels which would detonate at about a compression ratio of 4:1. Once Tom Midgley of General Motors Research Corporation discovered the anti-knock properties of tetraethyl lead in 1922, engine compression ratios steadily increased to as high as 11:1 in performance engines at the peak of the muscle-car era, with many cars in the 1960s having a compression ratio around 10:1. Along with the lead additive, better understanding/control of the combustion process and improvements to gasoline refining also contributed to the increase. After the first fuel crisis of the 1970s and before the advent of computer control, most engines were designed with compression ratios ranging from 8:1 to 8.5:1.

Octane number is a guide to a fuel's detonation resistance. Today, the octane shown on the pump is the Pump Octane Number or PON, which is an average of the Motor Octane Number and the Research Octane Number (RON). Years ago, RON was the displayed octane number. Because of averaging, the RON of premium fuel before (97-99) is equivalent of the 93-94 PON of today. The consequence of this tidbit is if a high compression muscle car engine did not knock on then current fuels, it probably will not knock on today's premium, provided it is in like-new condition.

Calculating the Compression Ratio

Determining the compression ratio can be helpful in diagnosing engine problems and rebuilding of engines. Several factors can combine to affect an engine's specified compression ratio, e.g., carbon buildup in the cylinder head and on the piston top, differences in the manufacture of replacement components versus originals, thickness of head gaskets, etc. The compression ratio is calculated by measuring the volume of the cylinder volume at BDC and then dividing this volume by the cylinder volume measured at TDC, see Figure 2.

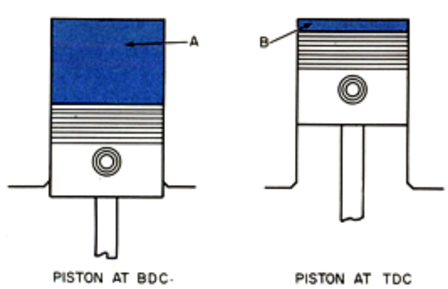

Figure 2 - Compression ratio is the volume of a cylinder with the piston at BDC divided by its volume with the piston at TDC or A divided by B.

Although the compression ratio calculation is simple math, it requires several measurements which must be precisely made – even minor changes in these measurements can have a significant effect on the compression ratio. The volume at TDC is comprised of several measurements and related calculations:

- ***Deck clearance*** – the distance from the top of the piston *flat* surface to the block deck, ignore any valve relief notches or domes. This distance multiplied by the area of the cylinder provides the volume.
- ***Head gasket*** – the compressed thickness of the gasket and the diameter of the cylinder opening in the gasket. The area of gasket opening multiplied by the thickness results in the head gasket volume.
- ***Head volume*** – the volume of the combustion chamber in the head with the valves installed. Head chamber volume is measured with a burette and flat plate sealing the head surface.
- ***Piston variations*** – since not all pistons have perfectly flat surfaces, these variations need to be determined. Valve relief notches or depressions add to TDC volume and domes decrease it. Sometimes, piston manufacturers can provide the necessary volume information for these variations; in other instances it must be measured.

Detailed guidance for how to make these measurements is provided in many engine building books. The sum of these four calculations, making sure that piston variations are properly included, provides the total volume at TDC.

The volume at BDC is calculated by first determining the cylinder volume at BDC and then adding the volume at TDC to it. The cylinder volume at BDC is obtained by multiplying the cylinder area by the distance from the block deck to the top of the flat piston surface less the deck clearance as determined before (this is the engine stroke).

Basic math is all that is required. However, these calculations are simplified using a web-based calculator that accepts the measured values or specifications without the need for unit conversions. (Visit the following site - www.csgnetwork.com/compcalc.html.)
This tool enables one to easily run the calculation with "what-if" variations to determine the impact of changes such as head volume or head gasket thickness on the compression ratio.

The foregoing measurements must be done for each cylinder. The spread between the compression ratios for all cylinders should be less than 0.1. Variations can be expected in deck clearance and cylinder head volume. With appropriate machining, the desired range of the compression ratio can be obtained. Ideally, the higher the compression ratio the better, as long as it can run on available pump gasoline without the need for retarding the distributor.