THE FOUR-STROKE ENGINE - PART 2

CYLINDERS

Cylinders and Sleeves

In the 1950's and earlier, cylinders were bored out of a cast-iron block. The cast-iron blocks were typically lined with steel sleeves that were either cast into the block or pressed into the block. Cast-iron cylinders are extremely heavy in weight and do a poor job of transferring heat.

Cast-iron cylinders and motors were replaced in the 1960's with aluminum cylinders and aluminum engine cases. Aluminum is light and dissipates heat much better than iron. Air-cooled engines have fins on the outside of cylinders for transferring engine heat to the outside air. Water-cooled engines have channels called water jackets that circulate coolant around the cylinder walls.

Most aluminum cylinders use a steel sleeve that is either cast-in or pressed into the cylinder bore. Without the sleeve, the soft aluminum would wear down quickly. Cylinder wear results in blow-by and excess burning of oil. The piston rings no longer seal well against the cylinder wall, resulting in a lack of compression and power.

A steel sleeve that is "cast-in", is first placed into a cylinder mold and the molten aluminum is poured around the sleeve. The sleeve becomes a permanent part of the cylinder block. Due to wear over time, cast-in cylinder sleeves can be bored if necessary and fitted with oversize pistons. When the sleeve can no longer be bored due to its' becoming too thin, the cylinder must be replaced.

A manufacturing problem can occur with cast-in sleeves if an air pocket develops on the outside of the sleeve during the casting procedure. This creates a hot spot during engine operation and can cause the cylinder to fail.

Pressed-in sleeves are placed into an aluminum cylinder block after the block is cast. The cylinder bore is machined to be a few thousandths of an inch smaller than the sleeve. The cylinder is then heated to about 600 degrees, and when the bore diameter expands, the sleeve is pressed in. When the cylinder cools, the sleeve is locked in place. This “pressed fit” is also called an “interference fit”.

Pressed-in sleeves can be bored out (reconditioned) if they are worn down. After boring and honing approximately five thousandths of an inch, new oversize pistons can be installed to fit the bigger bore.

Pressed-in sleeves can also be replaced if they are too thin to stand up to further boring. The cylinder is heated again, the old sleeve is pulled out, and a new sleeve installed. The newly pressed-in sleeve has only a “semi-finished” bore size. The newly installed sleeve must then be “final bored and honed” to its finished size for correct piston clearance.

Installing a sleeve, and doing the final bore work, requires a boring bar, an oven, accurate micrometers, and a bore gauge for precision measuring. A cylinder hone is also needed to instill hatch marks (scratches) into the inside wall of the sleeve. The hatch marks trap a thin film of oil on the cylinder walls for lubrication and to also help seat the piston rings.

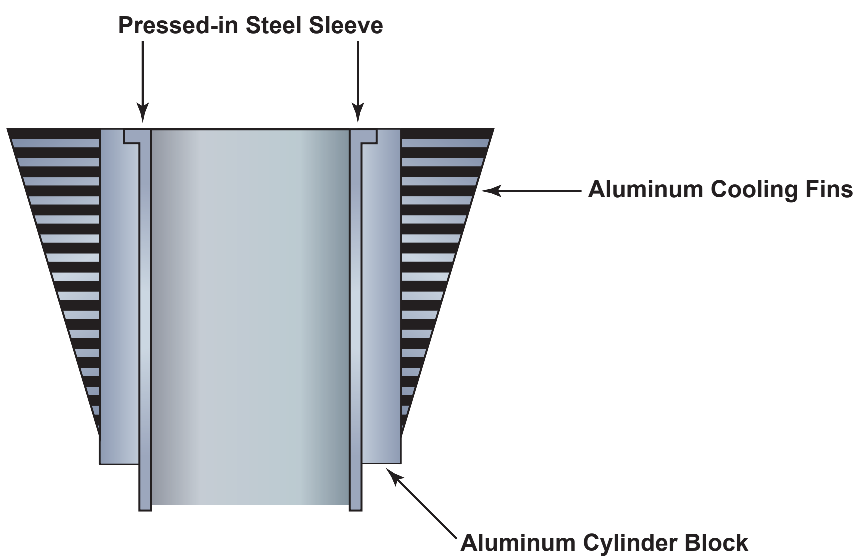
When a cylinder head is removed from a cylinder, pressure is taken off the cylinder and the cylinder “relaxes” a little when the head bolts are removed. The bore diameter may change slightly when the head bolts are removed. For this reason, torque plates may be required to bring the cylinder bore back to its normal “operating size” as if the head bolts were torqued down. Torque plates are required to be used with single Harley cylinders.

Torque plates must be clamped down on both sides of the cylinder in order to take accurate cylinder bore measurements, and to perform cylinder boring. The base gasket and head gasket are also installed between the torque plates. Torque plates keep the cylinder under the pressure of the torque specifications of the head bolts, so that the bore diameter will be accurate during drilling and during measuring.

Steel Sleeves

Steel sleeves are sometimes called "cast-iron" sleeves, although the cast-iron term is antiquated and not accurate. Steel differs from iron in that steel is made of iron mixed with metal alloys such as Moly 2000 chrome-moly. Chrome-moly contains carbon-chrome and molybdenum, which provide high tinsel strength and resistance to wear. Chrome-moly alloy cylinder sleeves have been made for motorcycles since the late 1940's.

Air-cooled Aluminum Cylinder



The wall thicknesses of cylinder sleeves are typically in the sizes of 1/16", 3/32" and 1/8". Wall sizes of 3/32" and 1/8" allow for oversize boring later and they are stout enough to preserve the strength of the cylinder block. If sleeves are too thin, the torqueing pressure of the head bolts may cause the sleeve to pinch the piston, which causes horsepower losses and high wear from friction.

Two-stroke engines require final port chamfering after installing a new sleeve, and special porting tools are needed.

Aluminum Composite Sleeves

Some companies are using cylinder sleeves made of aluminum ceramic composites as a replacement for steel sleeves. Aluminum composite sleeves provide higher thermal conductivity than steel sleeves, as well as higher wear resistance. They are also lighter than steel sleeves.

Aluminum composite sleeves are manufactured by blending aluminum powder, ceramic particles such as silicon carbide, and graphite. The materials are compacted with high pressure and heated – a bonding process called sintering.

Aluminum sleeves have not replaced steel liners. One manufacturing challenge is that if the carbide and graphite reinforcing particles are not distributed evenly throughout the sleeve surface, the piston ring can wear into the softer aluminum surface and cause premature wear and finally a lack of compression. The sintering process must be even and precise.

Plating Aluminum Sleeves and Cylinders

Aluminum sleeves and aluminum cylinders - (sleeveless aluminum cylinders) - need to receive electrodeposited plating in order to prevent wear and friction. Early plating materials consisted of hard-chrome, ceramic composites, or Boron. The invention of Nikasil proved to be a harder material and a worthy replacement of earlier plating materials.

Nikasil is the abbreviated name for nickel-silicon-carbide. Nikasil is an extremely hard ceramic – so hard that it permits larger bores with tighter tolerances. Nikasil is electroplated directly onto bare “soft” aluminum cylinder bores and then honed, (sleeveless aluminum cylinders). It can also be applied to aluminum sleeves or steel sleeves.

Nikasil facilitates the use of aluminum sleeveless cylinders that offer much better heat conductivity than cylinders with steel liners. These advantages are a primary requirement of cylinders used in racing engines. Nikasil is used in some production street motorcycles and racing dirt bikes. An aluminum sleeveless cylinder that is re-bored must also be re-plated with Nikasil.

Cylinder Numbering

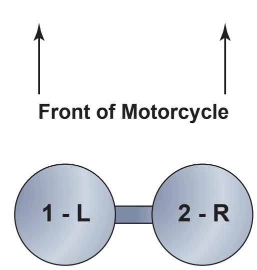
When doing compression tests, overhauling cylinders or doing valve adjustments, the cylinders must be identified so they do not get mixed up. In addition, pistons and cylinders should not get mixed up because of the rule in mechanics that “parts that wear together, stay together”.

Cylinders are identified and numbered in the service manual. If there is no service manual available, the following information represents what is customary in cylinder numbering. Note however that the cylinder numbering is not the same as the firing order of the cylinders.

Some engines have a crankshaft positioned in a “transverse” side-to-side location. These engines number the cylinders from left to right as each connecting rod is located on the crank. Left to right is from the perspective of the rider sitting on the bike and looking down. For example, inline four cylinder engines will be numbered 1,2,3,4 from left to right.

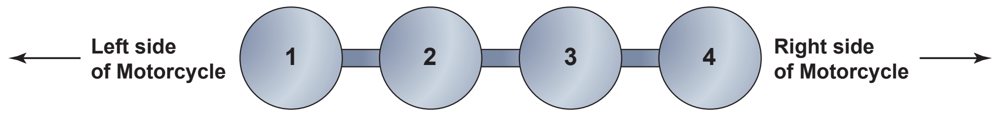
Other engines have a crankshaft positioned in a “longitudinal” front-to-back location. These engines will number the cylinders starting from the front cylinder and going to the back cylinder.

Parallel Twin Engine Configuration



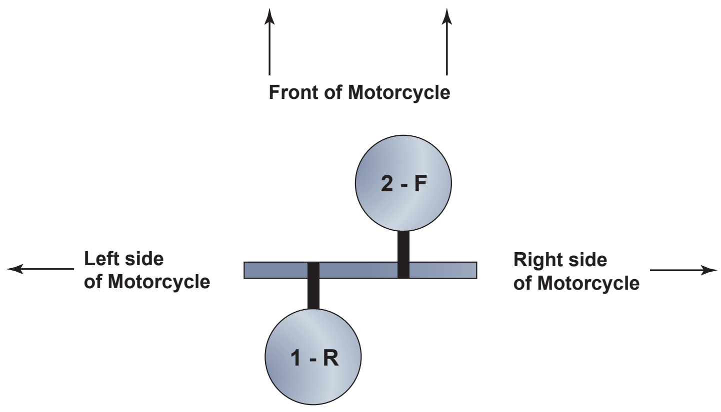
A parallel twin with transverse crankshaft has a number 1 or “left” cylinder identifier, as well as a number 2, or “right” cylinder identifier.

Inline-Four Engine Configuration



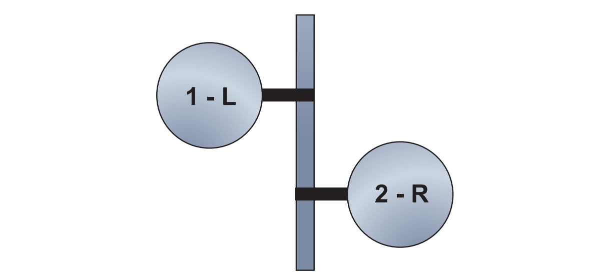
An inline four-cylinder engine has cylinders labeled 1 through 4 from left to right. For example, this is the cylinder numbering for a Suzuki GSXR-1000.

V-Twin Configuration Transverse Crankshaft



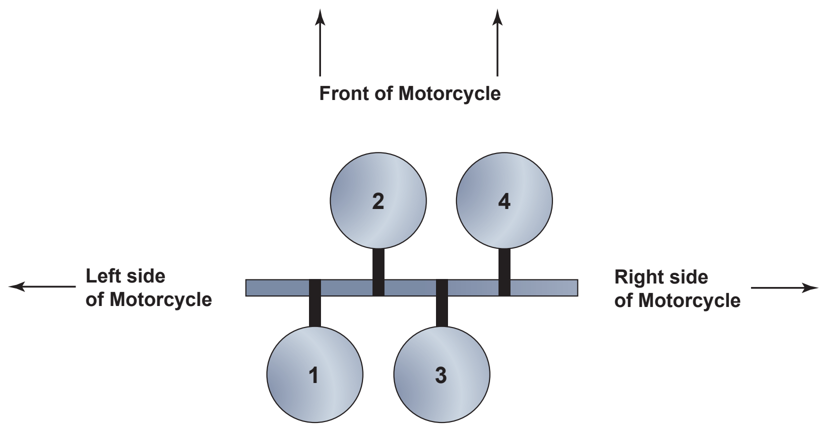
This V-twin with a transverse crankshaft has the rear cylinder labeled as the number 1 cylinder, and the front cylinder identified as the number two cylinder.

V-Twin Configuration Longitudinal Crankshaft



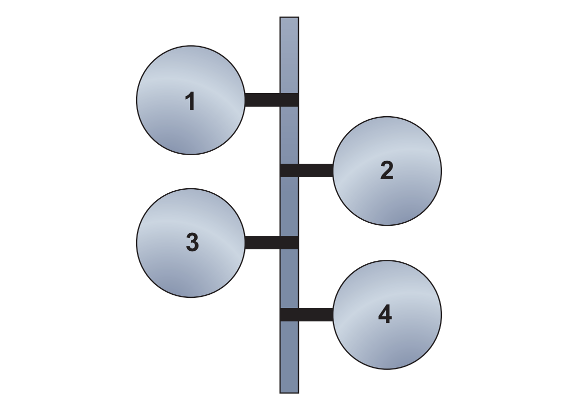
A V-twin engine with a longitudinal crankshaft has the cylinders labeled as number 1 (left side of crankshaft), and number 2 (right side of crankshaft).

V-4 Configuration Transverse Crankshaft



On a V-4 engine with a transverse crankshaft, cylinders may be numbered 1 through 4 from left to right. A V-4 may receive additional "front" or "rear" identifiers in a service manual, because there are front and rear cylinders.

V-4 Configuration Longitudinal Crankshaft



On a V-4 engine with a longitudinal crankshaft, cylinders may be numbered 1 through 4 from front to back. Note however that numbering can be in a different order depending on the make and model.

PISTONS

Piston Design

Cast aluminum pistons are made with a casting process where liquid aluminum is poured into casts. If pistons are to be used in high stress racing applications, the pistons will be made of forged aluminum alloy.

Flat top piston with cutaways to prevent contact between valves and piston. Arrow must point to the front of the engine to fit piston in correct position due to off-center crankpin. (HD Evolution engine piston).

Forged pistons are stronger and more durable than cast pistons. Forged pistons can withstand the abuse of racing. The forging process molds the metal with force and creates a condensed grain structure that is resistant to fatigue and shock. Forging maximizes the strength-to-weight ratio. Cast pistons do not have a strong grain structure and are more brittle.

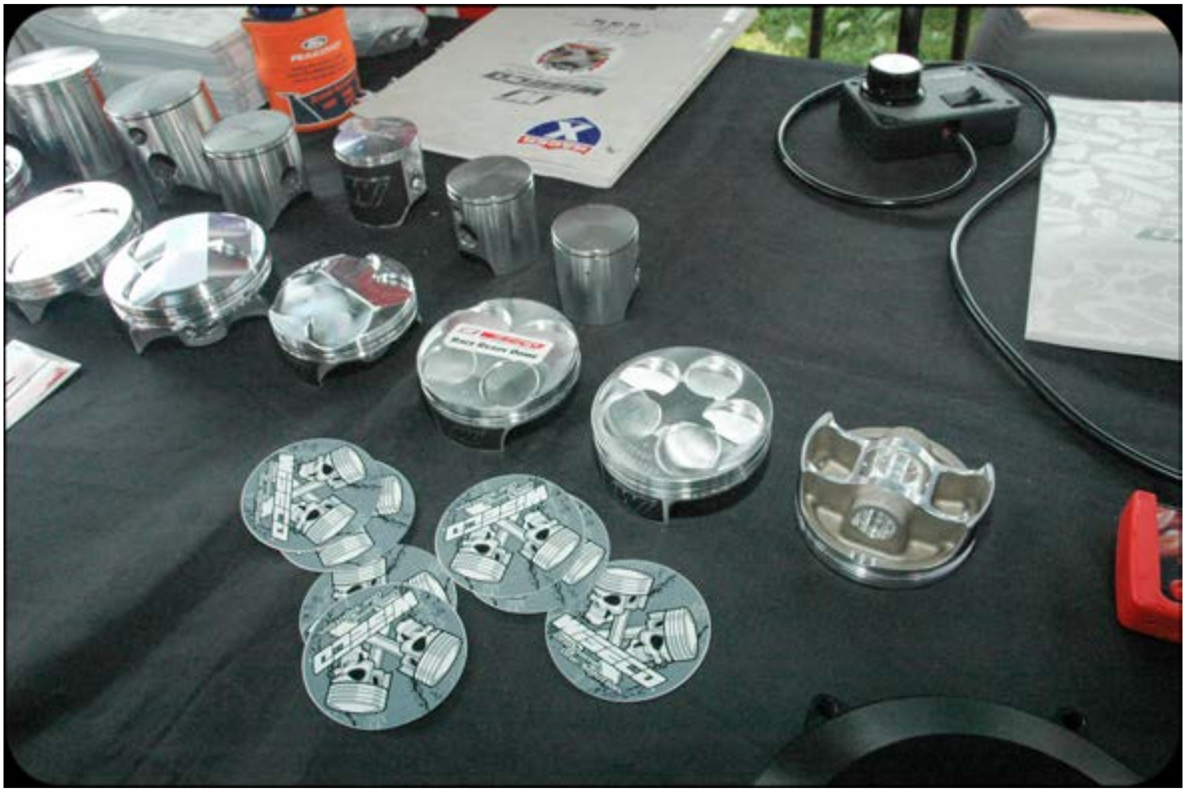
The basic parts of the piston are the crown, piston skirt, piston ring grooves, piston rings, piston pin bore, piston pin (also called the wrist pin), and piston pin retaining clips.

Piston crowns are either flat or dome shaped. The dome shape is used more in racing applications to create higher compression. The piston crowns of four-stroke engines will typically have cutouts for valve relief. There will be a cutout for the intake valve and also the exhaust valve. These cutouts illustrate how extremely close the valves come to hitting the pistons. A two-stroke engine piston has no valve cutouts in the piston crown, because there are no valves.

Bottom of piston shows where piston pin fits through the piston and the connecting rod.

Piston crowns receive the direct blast of heat and pressure from the exploding air-fuel mix in the combustion chamber. The thermal stress from the blast of exploding gasses in the combustion chamber reaches over 1,500 degrees Fahrenheit. Pistons must be able to disperse this heat or else the piston crown will over-heat and melt. Piston crowns are either flat, slightly domed, or they may have a “negative dome” and be slightly sunken down.

Pistons made with high domes are not commonly used due to the combustion problems they create. This is because the combustion flame front must climb over the piston dome and down the other side for complete combustion to occur. This is time consuming, inefficient, and creates breathing problems as rpm levels increase. For example, the old Shovelhead Harley engines with the high domed pistons had these breathing problems. These pistons were replaced with flat-top pistons in the Evolution engine in 1984, which replaced the Shovelhead engine.



Four-stroke dirt bike pistons on display with deep cutaways that prevent piston-to-valve contact. Note the short piston skirts.

The profile of a typical piston is designed with a narrowing taper toward the top. The top of the piston at the crown is narrower than the lower skirt area. This gives the crown room to expand as it heats up from the searing hot combustion chamber temperatures. Without this taper the crown would not have room to expand and the piston could seize in the cylinder.

Most engines disperse piston heat only through the piston rings and piston skirt as they contact the oil film on the cylinder wall. Some cooling is also afforded by the cool air-fuel mix that enters the cylinder. However, due to the higher engine speeds and higher compression in today's higher performance motorcycles, pistons receive additional cooling from oil jets that are aimed at the bottom of the piston crown. These jets shoot oil all over the bottom of the piston. Piston heat is then transferred into the engine oil. The application of special low-friction coatings such as tin or zinc on the piston skirt further reduces the friction of the piston against the cylinder wall and provides increased wear resistance.

Note that in air-cooled engines, the piston is limited to transferring heat to the cylinder walls through the piston rings and the oil film on the cylinder wall. Some cooling is received by the piston crown when cooler air-fuel mix is drawn into the combustion chamber, however, this cooling is minimal.

Piston skirts do contact the cylinder walls in order to keep the piston stable and operating smoothly in the cylinder bore. Stability is necessary for proper sealing of the rings against the cylinder wall, low friction, and quiet operation at operating temperatures. Skirt shapes are designed to provide proper running clearance at the operating temperatures which the alloy will be experiencing. The skirts on aluminum alloy pistons are often coated with a solid Teflon-like lubricant that reduces friction between the piston and the cylinder wall.

Piston skirts on four-stroke engines are often very short in length. This reflects the efforts of engineers to reduce the friction between the skirt and the cylinder wall, as well as minimize reciprocating weight. In contrast, the pistons used in two-stroke engines have a full skirt and are also quite tall in comparison to their diameter.

Piston weight reduction of just a few grams can substantially reduce power losses in an engine that turns 14,000 rpm. An engine turning 14,000 rpm will jerk the pistons up and down 28,000 times in one minute. At the end of each stroke the piston comes to a dead stop at either BDC or TDC. The stress from the inertia of acceleration and deceleration is huge.

There are two basic movements and motions of the piston in a cylinder. First there is the up and down reciprocal movement. However, there is an additional movement from the pistons being shoved toward the front side of the cylinder and then shoved toward the backside of the cylinder. This “rocking” motion is due to the fact that the piston is responding to the rotating motion of the crankshaft where the bottom of the connecting rod is attached to the crankshaft.

Note that the piston ring gaps are never located in such a position that they fall on the front or the rear side of the cylinder walls. The front and rear side of the cylinder walls are “thrust surfaces” and are not to be scratched by the piston rings. These thrust surfaces receive the piston “rocking motion” pressures and friction.

In order to help ease the transition of the piston from the rotating motion to the reciprocating movement, (due to the crankshaft motion), many engine designs offset the cylinder from being directly in line with the axis of the crankshaft. The exact center of the cylinder is not in a direct vertical line with the exact center (axis) of the crankshaft.

Because of this offset, the piston must be attached to the connecting rod in the correct position. This position is inscribed on the top of the piston either with an arrow pointing to the front of the bike, or, the abbreviation of “IN” for intake side of the combustion chamber, or “EX” for exhaust side of the combustion chamber. The piston must be attached to the connecting rod in the correct position. If the piston is attached backwards, heavy wear and possible seizure of the piston will result.

Racing bikes may have their steel connecting rods replaced with lighter titanium connecting rods to further cut down on reciprocating weight.

Cam Grinding

Pistons are tapered and narrower at the crown than at the skirt. The crown needs room for heat expansion due to extreme temperatures in the combustion chamber.

Cam grinding allows for additional heat expansion. When cam ground, the measurement across the middle of the skirt is slightly greater than the measurement at the sides of the skirt. When a cam-ground piston is cold, it has an oval shape. When the piston is cold, the piston is big enough across the larger diameter to prevent rocking and piston slap. As the piston comes up to operating temperature, the piston will expand across the smaller diameter much more than the larger diameter. This will result in the piston being round when it arrives at operating temperature.

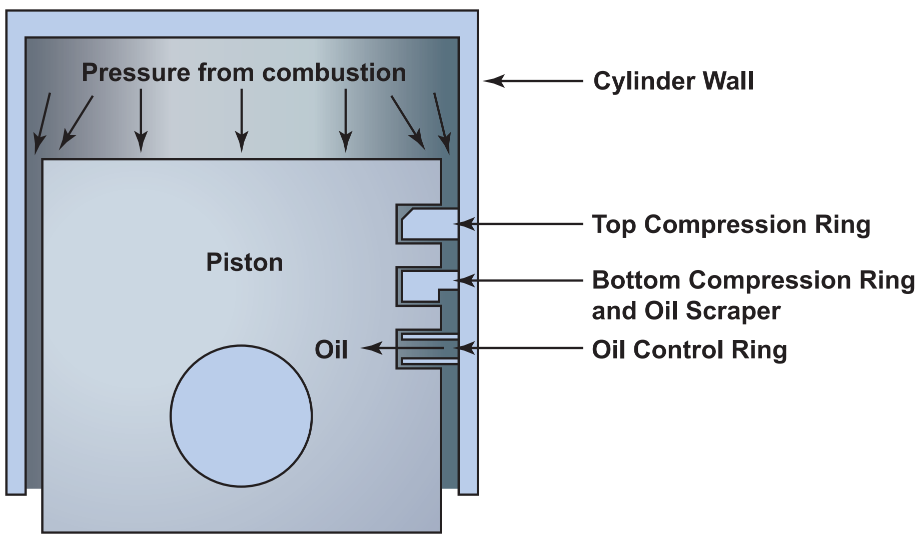
Piston skirts are exposed to forces under load that tend to flatten them. Cam grinding allows for load distortion of the piston skirt. Under high load, the skirt flattens to a nearly cylindrical shape.

Cam grinding allows the piston skirt to fit snug in the cylinder no matter whether the piston is hot or cold. This reduced piston- to-cylinder-wall clearance in the middle prevents the piston from slapping around in the cylinder when cold. As the piston heats up, the narrower parts of the skirt expand and this causes the piston to form an almost uniform “cylinder shape”. The piston skirt contacts the cylinder wall and bears the load of the piston as it is thrust against the cylinder wall during its up-and-down movement in the cylinder.

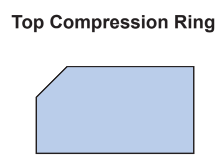
Piston Rings

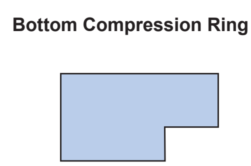
Piston rings provide a good seal between the piston and the cylinder wall. Piston rings sit in grooves in the upper part of the piston. Four-stroke engine pistons typically have three rings. The top two rings are compression rings and their main purpose is to seal the gap between the piston and the cylinder wall. The bottom ring is the oil control ring, which removes excess oil from the cylinder walls – thus keeping oil out of the combustion chamber.

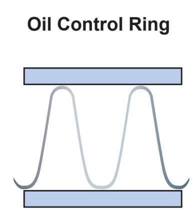
Piston Rings



Combustion pressure forces the compression rings against the cylinder wall to prevent pressure from leaking past the rings and into the crankcase. This would result in a power loss.







Top compression ring *Not all top compression rings have the indent on the top corner (shown)that helps to push the compression ring against the cylinder wall for a good seal.*

Bottom compression ring *The bottom compression ring also serves to scrape oil off the cylinder wall. This ring must not be installed upside down. A dot or other mark on this ring must typically face upward.*

Oil control ring *Oil that is scraped off the cylinder walls passes through the porous oil expander ring and then through holes in the piston wall that channel the oil back into the crankcase.*

The compression rings are sealed against the cylinder wall by cylinder pressure on the compression and power strokes. Cylinder pressure is channeled into the area behind the rings (inside the ring grooves) and this pressure pushes the rings against the cylinder walls to create a tight seal.

On the intake and exhaust strokes where there is little cylinder pressure, the rings create the seal against the cylinder wall by the static pressure of the rings alone. In other words, the rings, which are elastic, sit in the ring grooves in a compressed state – similar to a compressed spring – and they "expand out" and create pressure against the cylinder wall.

The second compression ring from the top of the piston may have a beveled edge that will help in scraping oil off the cylinder walls. This ring may be referred to as an "oil scraper" ring even though it is not the main oil control ring. This second ring will typically be marked with a dimple near the end of the ring. The dimple must face upward when the ring is inserted into the ring groove. This assures that the ring chamfer is facing the correct direction for oil scraping.

The bottom ring of a piston may be made up of three thin piston rings sandwiched together in the ring groove. This is the oil control ring. It is designed specifically for scraping oil off the cylinder wall.

Side view of piston and three rings. Note the bottom oil scraper that consists of an expander and two flat rings located on either side of the expander. (See prior page)

The oil control ring that comes in three pieces will consist of an expander ring that has a “wavy” sort of design. The expander is sandwiched between two very thin and flat steel rings called “side rails”.

The outer edges of piston rings are usually coated with chrome, chrome-ceramic or molybdenum.

It is very important to read the instructions that come with a new set of rings. For example, the instructions may tell you which side of the second ring – the oil scraper – will face upwards because of the stepped edge. It should not be inserted upside down.

Two-stroke engines do not have oil scraper rings because the oil is mixed with the fuel for lubrication. Two stroke pistons have only 2 compression rings. If the piston is used in racing, it may have only one compression ring. Two stroke piston rings are discussed in detail in the section on two-stroke engines.

Piston Ring End Gap

Compression rings must have an end gap while they are cold, so that when they expand from heat as the engine operates, the ends will not butt together and drive the ring into the cylinder wall, which could create damage.

Piston rings must be compressed so that the cylinder can slide over the piston and rings during assembly. This is another reason why there needs to be an end gap. The cylinder could not slide over the piston if the rings were sticking out of the ring grooves.

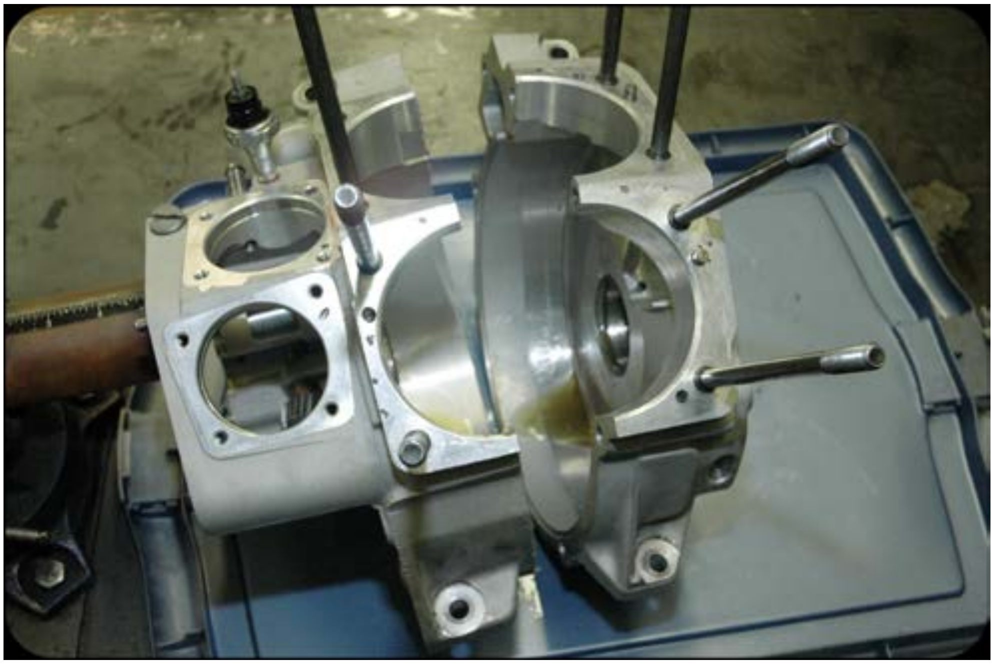
ENGINE CRANKCASES

Crankcases support the crankshaft and main bearings. The crankcase holds some engine oil and keeps out dirt and water. The cylinders sit on top of the crankcases and the cylinder heads are bolted to the top of the cylinders.

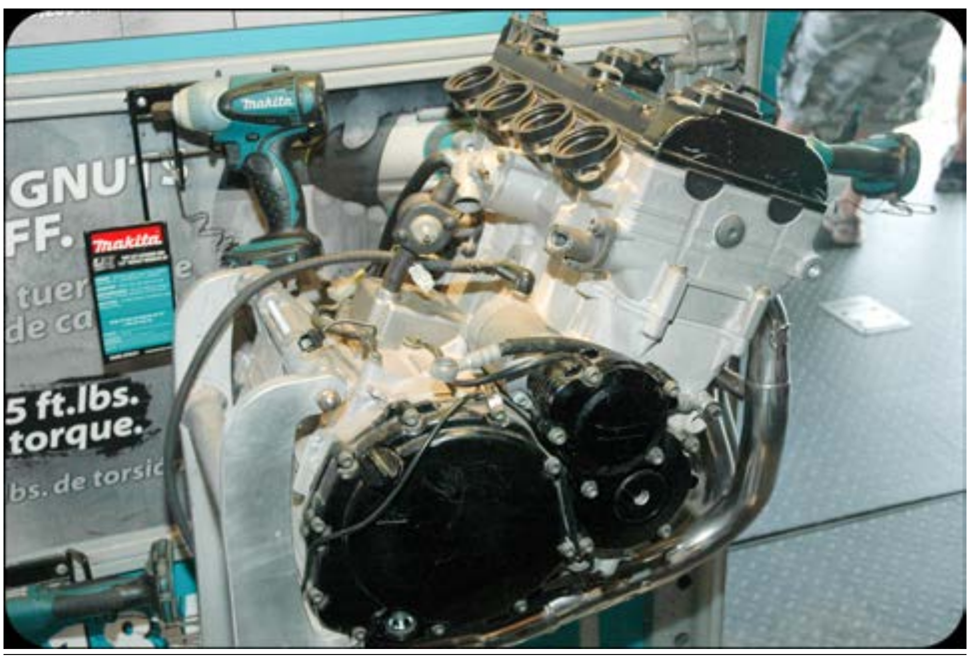
Crankcases are normally cast and are split either vertically or horizontally. Most bikes have a single case, which houses the engine, primary drive and transmission. A single oil is typically used which lubricates the engine, transmission and clutch.

Other bikes use a modular construction where the engine and transmission are housed in separate cases and can be detached from the motorcycle frame separately. A primary drive is then bolted on to connect the engine case to the transmission case with a chain or belt. The primary drive transfers engine power to the transmission.

The primary drive also includes a clutch. Bikes using a modular construction will typically use 3 different oils: engine oil, primary oil if the primary is enclosed and uses wet clutch plates, and transmission oil for the transmission.



V-twin crankcase that is vertically split in the middle.



The engine and transmission of this inline four-cylinder engine is contained in a single aluminum engine case.

Photo of an old air-cooled four-cylinder engine where the engine and transmission are housed in one single aluminum case.

ENGINE POWER FACTORS AND TUNING

Engine power factors must be considered when original equipment manufacturers build motorcycles. Power factors also must be understood and considered when bike owners want to improve the power of their personal motorcycle.

There are often misconceptions of what is really involved in increasing power. It is not unusual for someone to purchase a “hot cam” only to find out that the cam alone did not do much to improve power.

The following topics explore various principles of how engine power is created and measured.

Compression Ratio

For an engine to produce enough power, it must compress the air-fuel mix sufficiently. If compression is too low the engine will not produce enough power. If compression is excessively high, the engine will produce more power, but it can be harder to start and the life of the engine may be shorter.

The mechanical compression ratio, also called the static compression ratio, can be computed. For example, the compression ratio of a 1,000cc Suzuki GSXR-1000 sport bike is 12.5 to 1. The compression ratio of a Harley Davidson 81.7 cubic inch "Evolution" engine 8.57 to 1. The Harley compression ratio is substantially lower than the GSXR-1000.

The mechanical compression ratio formula is:
Compression Ratio = (Cylinder Displacement + Net Combustion Chamber Volume) / Net Combustion Chamber Volume

Cylinder displacement consists of the total displacement inside the cylinder that the piston displaces as it travels from BDC to TDC. Cylinder displacement is sometimes called "swept displacement".

The Net Combustion Chamber Volume equals the total volume of:

1) Combustion Chamber Volume
2) Plus, minus or no consideration for Piston Dome Volume (if the piston has a dome, or a depression machined into the piston crown)
3) Plus, minus, or no consideration for Deck Height Volume
4) Plus Head Gasket Volume
5) Plus Valve Relief Volume

Note that the number for the combustion chamber volume will always be the number 1 when represented in the final formula.

Compression Ratio Example:

Cylinder displacement for an 81.7 Cu Inch “Evolution” engine is 669.4cc. Net Combustion Chamber Volume for the 81.7 Cu Inch Evolution engine cylinder head is 88.45cc.

Compression Ratio = (669.4 + 88.45) / 88.45
Compression Ratio = 8.568118
Round to 8.57. Final compression ratio is expressed as 8.57 to 1.

The challenge in computing compression ratio is to compute the volume of the combustion chamber. The bore and stroke dimensions are written in the service manual, and so the “cylinder displacement” volume is not hard to compute.

Gross combustion chamber volume does not take into consideration the additional volumes of plus-or-minus piston dome volume; plus-or-minus deck height volume, head gasket volume, or valve relief volume.

The gross combustion chamber volume is computed by pouring water into the combustion chamber of a head that is turned upside down, and measuring the volume of water that is poured into it.

The spark plug is installed in the head and the combustion chamber is covered with a ¼” Plexiglas plate that has a small hole in the middle. Using a burette filled with water, the water is poured through the hole in the Plexiglas plate in order to fill the combustion chamber full of water.

The burette is used to measure the amount of water that is poured into the combustion chamber when the combustion chamber is finally full. The combustion chamber is full when the water reaches the underside of the Plexiglas plate. The burette measures the cc’s or “cubic centimeters” of the combustion chamber volume.

To arrive at “Net Combustion Chamber Volume”, adjustments must be made to gross combustion chamber volume.

Adjustments to arrive at net combustion chamber volume are: deck height (plus, minus, or no adjustment); head gasket volume; the valve relief depressions in the top of the piston; and consideration of the piston dome or machined-out depression in the piston crown (plus, minus, or no adjustment).

The deck height represents: A) the volume addition of the gap where the piston stops just short of being even with the top of the cylinder, or B) no additional volume if the piston stops dead even with the top of the cylinder, or, C) a subtraction of volume if the piston stops slightly above the top of the cylinder.

The head gasket bumps the head slightly higher and adds a small amount of volume. If an O-ring is used instead of a head gasket, the head gasket volume may be zero.

Modeling clay can be pressed into the piston valve relief depressions in order to measure the volume of the depressions. The modeling clay is then dropped into a burette, and the water displaced equals the total cubic centimeters of the valve relief depressions.

Corrected Compression Ratio

Corrected compression ratio is the more accurate method of computing compression ratio. This method takes into consideration the fact that the intake valve closes after the piston begins the compression stroke.

In other words, on the compression stroke, the entire cylinder displacement from BDC to TDC with the valves closed does not actually happen in reality. The intake valve closes after the piston begins the compression stroke, and therefore, cylinder displacement should begin to be calculated when the intake valve finally closes, and not at BDC.

The cylinder displacement value (stroke) will therefore be slightly less, and the corrected compression ratio will be slightly lower.

Engine Displacement

Engine displacement, or cylinder displacement, is the volume of space that is displaced in the cylinder as the piston moves from the bottom of its stroke at BDC, to the top of its stroke at TDC.

Cylinder displacement volume does not contain the volume of the combustion chamber and the head gasket and deck height – the volume which is needed to calculate the compression ratio.

Engine displacement is measured in cubic centimeters (cc's), or in cubic inches (ci), or as cubic inch displacement (cid). For example, in a four-cylinder 1000cc liter bike, each cylinder displaces 250 cubic centimeters.

In order to measure displacement, the cylinder bore diameter and the length of the piston stroke must be known. The total displacement of the engine is computed by calculating the volume of one cylinder, and then multiplying it by the number of cylinders the engine contains.

The formula for computing displacement =
Bore x Bore x Stroke x (0.7854 x Number of cylinders).
A shorter equation would be: B x B x S x (0.7854 x N)

Cylinder Displacement Example:

The two cylinder Harley Davidson V-Twin Evolution engine has a 3 ½" bore and a 4 ¼" stroke .

The formula for computing its' displacement = 3.498 x 3.498 x 4.250 x (0.7854 x 2). This formula yields a displacement of 81.6863 cu inches. The final cylinder displacement is rounded to read 81.7 cubic inches. In common Harley references, it may be rounded further to just 80 cubic inches.

Bore-To-Stroke Ratios

Bore and stroke relationships determine the shape of the engine power curve. The bore-to-stroke ratio simply compares how large the cylinder bore is in comparison to the piston stroke. The bore-to-stroke ratio equals the ratio of the bore diameter divided by the stroke length. (Bore / Stroke).

A ratio of 1 to 1 means that the bore is equal to the stroke and this geometry is referred to as a “square” engine.

Over Square Bore-To-Stroke Ratios

If the ratio is larger, such as 1.3 to 1 – this is referred to as an “over square” engine because the bore diameter is larger than the piston stroke. High performance sport bikes have over square engine geometry. The bores are big and the piston stroke is shorter than the bore diameter. Sport bike bore-to-stroke ratios range from about (1.2:1) to (1.6:1).

For example, the bore of a Suzuki GSXR-1000 sport bike is 2.9 inches, and the stroke is 2.323 inches. The bore-to-stroke ratio computation is: (2.9 / 2.323) = 1.2483. Therefore, this bore to stroke ratio is 1.25 to 1 (rounded) . This is an over square bore-to-stroke engine design.

Very short piston strokes allow sport bike engines to safely and easily turn very high rpm for high speed racing on the track. A shorter stroke means the piston does not have to travel so far up and down the cylinder in order to complete the four-stroke cycle.

For example, the redline for a Suzuki GSXR 1000cc sport bike is about 12,000 rpm. The redline for a Yamaha R6 - 600 cc sport bike - is a stunning 16,000 rpm. Redline is the maximum rpm the factory has programmed the electronic control module to allow the engine to be run.

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Larger bore-to-stroke ratios will usually permit an engine to have more valves and larger valves for better breathing in order to sustain the higher rpm. Maximum horsepower will then happen at high rpm.

Most sport bikes have 2 intake valves and 2 exhaust valves in each cylinder head. This allows for much better and faster breathing as the air-fuel mix can be drawn into the cylinder much quicker with 2 intake valves than with 1 intake valve. Likewise, the exhaust waste can be pushed out of the cylinder quicker with 2 exhaust valves than with only 1 exhaust valve.

However, there are diminishing returns when the bore-to-stroke ratio becomes too large. This is because the combustion chamber becomes very wide and the combustion flame must travel much further to complete combustion. Also, the combustion chamber is much shorter top-to-bottom, and this results in very inefficient combustion. One solution is to install 2 spark plugs in each cylinder head to reduce flame travel distance.

Under Square Bore-To-Stroke Ratios

If the bore diameter of an engine is less than the piston stroke, this engine is referred to as an “under square” engine. A good example of this is a Harley Evolution engine. The bore of an Evolution v-twin engine is 3.50 inches and the stroke is 4.25 inches. The bore-to-stroke ratio is: 3.50/4.25 = .82. The ratio is thus .82:1. The cylinder bore diameter is less than the length of the piston stroke.

An under square type of engine produces the torque, or “pulling power” that is most practical for longer distance touring bikes that have little use for extreme highway speeds and high rpm. Thus, the Harley V-twin has been very popular through the years for long distance touring riders. Under square bore-to-stroke geometry produces maximum torque and horsepower at lower rpm.

However, an engine with longer stroke may produce more torque at lower rpm, but it will be limited as to how many rpm it can produce. Lower rpm will limit how much horsepower the engine can produce, and also limits its’ high-speed capabilities.

Effects of Increasing Engine Displacement

Building a bigger engine is the easiest way to build more horsepower and torque. Installing cylinders with bigger bore diameters and bigger pistons increases cylinder displacement.

Another way to increase power is to increase the stroke of the pistons – the distance the pistons travel up and down the cylinder. This also increases displacement.

Unfortunately, greater displacement does not always return greater horsepower. Look again at the rpm factor in the horsepower formula. Horsepower = (Torque x rpm) / 5252. The rpm factor is a critical factor in the formula. Longer piston strokes and big heavier pistons may increase torque initially, which helps the horsepower equation. However, the longer strokes and heavier pistons will limit how fast the engine can produce rpm and “spin up”, thus diminishing some of the horsepower potential. If the torque factor increases, but the rpm factor decreases, the increase in horsepower may be marginal.

Cylinders of greater displacement will require more air-fuel mix and will require heads with bigger intake and exhaust ports, as well as bigger valves, and/or more valves, for faster and more efficient cylinder filling. A taller cam lift may also be needed to open the valves further and keep the valves open longer. Thus, a change in one part of the engine, such as displacement, will require other parts to be changed as well.

Typical “hop up kits” for Harleys for example may include bigger cylinders, bigger pistons, new heads (bigger valves and bigger ports), new cam, adjustable pushrods, a bigger carburetor (for more air-fuel mix), a more free-flowing air filter, and maybe even a new flywheel assembly. Thus, an increase in cylinder size plus the additional parts required, results in almost a complete new engine assembly!

This illustrates the fact that just increasing the cylinder bore may not improve torque and horsepower significantly, if the breathing required to fill the bigger cylinders is not also improved and increased. Therefore, bigger valves, bigger ports, and a bigger carburetor are required to improve breathing.

Increasing Cylinder Pressure: Displacement / Compression Increases

The combustion of the air-fuel mix creates cylinder pressure. It is cylinder pressure that rams the pistons down the cylinder on the power stroke. An increase in cylinder bore and/or stroke increases the amount of air-fuel mix that can be drawn into the cylinder and combusted. Therefore, cylinder pressure is increased, and in turn torque and horsepower are increased.

Another way to increase cylinder pressure is to increase the compression of the air-fuel mix during the compression stroke. Thus, increasing the compression ratio also yields power gains.

Optimizing Cylinder Pressure With Correct Air-Fuel Mixture (Tuning)

Another method of increasing cylinder pressure is tuning the engine correctly through creating the proper air-fuel mix. For example, if the air-fuel mix is not balanced correctly, less power and performance will result.

For example, if an engine is running lean – the air-fuel mix contains too much air (or not enough fuel) – the engine will make less power as it is not burning enough fuel.

An example of an air-fuel mixture that is extremely lean would be roughly 16.2 to 1 which is too much air to fuel.

A balanced “stoichiometric mixture” of air and fuel would contain 14.7 parts air for one part fuel – a 14.7 to1 mixture ratio. This is expressed as weight, not volume. In the stoichiometric mixture, there is no unburned fuel or oxygen. However, the stoichiometric air-fuel ratio is too lean for most engine requirements.

An example of an air-fuel mixture that is slightly rich would be roughly 13.4 to 1. An air-fuel ratio in the range of 12.7:1 to 13.4:1 will produce the most power.

A common modification on some cruiser bikes is to install a “drag pipe” exhaust pipe that has no baffles or back pressure and of course produces a louder exhaust note that riders like.

This type of pipe will create a more free flow of air and fuel through the cylinders, and will likely create a lean condition in the engine. The engine will then run hotter and produce less power. The solution is to install a bigger pilot jet and main jet into the carburetor in order to increase the fuel portion and balance out the leaner air-fuel mix.

If an engine is running excessively “rich”, and the air-fuel mix contains too much fuel, the engine will not be able to burn all the fuel and less power will result. In an excessively rich condition, there is not enough oxygen to facilitate complete combustion of all the fuel.

Increasing Cylinder Pressure With More Explosive Fuels

Racing fuels contain hydrocarbon and carbon atoms that create enormous heat energy upon combustion. High performance motorcycle drag bikes may burn methanol or nitro methane in order to rocket down the drag strip as quick as possible. Although more explosive fuels are not a practical option for the typical motorcycle, it is an option for racing motorcycles.

Better Tuning By Minimizing Exhaust Reversion

Exhaust reversion happens when exhaust gasses blast past the exhaust valve and into the exhaust port. In the exhaust port, the air may not be moving properly. If high-speed exhaust gasses smack into “still air” in an exhaust port, the collision creates a “bounce back” sonic wave effect from the impact.

This wave of energy bounces back through the exhaust valve, across the cylinder, and into the intake tract during valve overlap. This can cause “fuel standoff” and inhibits the air-fuel mix from entering the combustion chamber. This of course is very undesirable. This “bounce back” of exhaust gasses is called a “reversionary wave”.

One cause of exhaust reversion could be an exhaust port or exhaust header that is too big for the amount of displacement in the cylinders. An exhaust port or header that is too large will not keep the gasses flowing at a rate that would prevent the creation of reversionary waves.

A smaller exhaust port and exhaust header, as well as an anti-reversion tube in the exhaust pipe can minimize exhaust reversion.

Exhaust Pipe Backpressure

An exhaust system that is properly designed will create an optimum pressure balance between the intake and exhaust system. This pressure balance is created when an exhaust system creates the correct amount of backpressure.

Too little backpressure can result from using exhaust pipes that have no baffles. Pipe designs with this feature are called “drag pipes” or “shorty pipes”. This can result in over-scavenging of the cylinder during valve overlap which reduces both power and fuel economy. Introducing some backpressure slows the flow of exhaust gasses in the exhaust system so that scavenging is not overdone.

On the other hand, too much backpressure can slow down scavenging to the point of reducing power.

The best factors in creating the optimum pressure balance in the intake and exhaust flow through the combustion chamber, is the use of correct exhaust header diameters, the correct length of exhaust pipe out the back of the bike, and the use of internal exhaust pipe baffles.

As mentioned earlier, a common exhaust pipe that is sometimes used on cruisers is a “shorty drag pipe”. This type of pipe is too short, has no baffles, and creates too fast of exhaust gas flow which typically results in a reduction of power and a lean running condition in the cylinders.

An example of a better aftermarket pipe would be a “Supertrapp” 2-into-1 pipe commonly used on Harleys. This pipe can also be tuned by removing or adding discs at the end of the pipe.

Engine Power and Piston Speed

Building a powerful engine will involve three general factors: engine cylinder displacement, rpm, and compression. At higher rpm, piston speed will be much faster, and the “g loads” of the piston will be much higher as well. Go to any drag strip and you can see an occasional engine self-destruct when the wear and strain on pistons, rods, crankshaft and cylinders becomes more than the engine can handle.

At any given number of rpm, the pistons will travel up and down at a certain speed to achieve those rpm. If the stroke length is increased, the pistons must travel faster to produce the same rpm. Motors that have a long stroke will require higher piston speeds in order to produce the same rpm as motors using a shorter stroke.

“Stroked motors” may be fun to ride because of the initial acceleration from high-torque, but longevity may become an issue depending on how hard the engine is run. Higher piston speeds also result in the connecting rod bearings taking quite a beating as the pistons are “jerked” up and down faster and harder.

Piston speed is measured in average feet per minute. For street riding, a safe piston speed will be a maximum of about 4,000 to 4,500 feet per minute.

An engine will be stronger if the crankshaft, rods and pistons are made heavier and thus stronger. However, this means the engine will produce more g forces which is harder on all of the parts at high rpm.   A compromise must be found to make these parts lighter as well as stronger.

Sport bike engines used for racing will have lighter titanium connecting rods, pistons and piston pins. This will reduce the g forces and allow these reciprocating parts to operate at a higher and safer rpm range. The stock Yamaha R-6 600cc sport bike redlines at around 16,000 rpm which illustrates the amazing potential of a short stroke and light reciprocating weight.

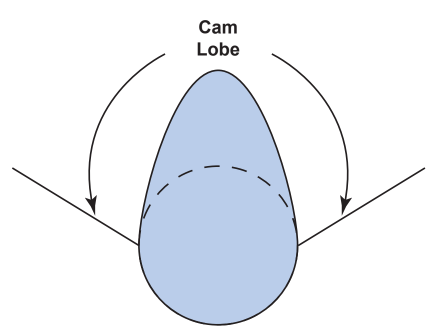
The ability of the engine to operate at high rpm is also a factor of how much air-fuel mix the cylinder heads can flow. This means the intake ports, the valves, the combustion chamber and exhaust ports must be optimized in design to be able to flow the most air-fuel mix possible.

The cylinder heads of racing engines are put on flow bench machines that test and measure the volume of flow the heads are capable of sustaining through the ports and valves.

CAMSHAFT GEOMETRY

Camshafts control the timing of when the intake and exhaust valves open and close. For example, the intake valve might open at 15 degrees before top dead center (TDC) – toward the end of the exhaust stroke and just before the intake stroke begins at TDC.

Cam Lobe

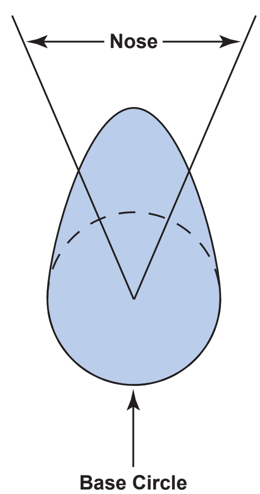


The cam lobe starts to rise off the base circle on the left side.
The cam lobe ends at the base circle on the right side.

Cam lobe profile determines how long the valve stays open – this is referred to as “duration”. The duration is measured in degrees of the crankshaft. For example, an intake valve may be open for 234 degrees of the crankshaft. It may be easier to think of the crankshaft as rotating 360 degrees, and therefore the intake valve will be open for 234 degrees out of the 360 total degrees, as the piston goes down on the intake stroke.

The exhaust valve will also have a duration measurement. For example, the exhaust valve may also be open for 234 degrees – the same amount of time as the intake valve. However some camshaft lobe profiles may make the exhaust valve duration last longer than the intake valve duration. For example, intake duration is 246 degrees and exhaust duration is 254 degrees for the Edelbrock Performer RPM Camshaft for a particular model of Harley Davidson engine.

Cam Base Circle and Cam Nose



The base circle is the round “cylinder” part of the cam construction.
The nose of the cam rises from the base circle. The nose of the cam lobe opens and closes the valve at the end of the valve train. The “valve train” consists of the camshaft, lifter, pushrod, rocker arm, valve spring and valve in a valve train using pushrods.

Camshaft lobes also control how high the valve opens into the combustion chamber – this is called the “lift” of the cam lobe.

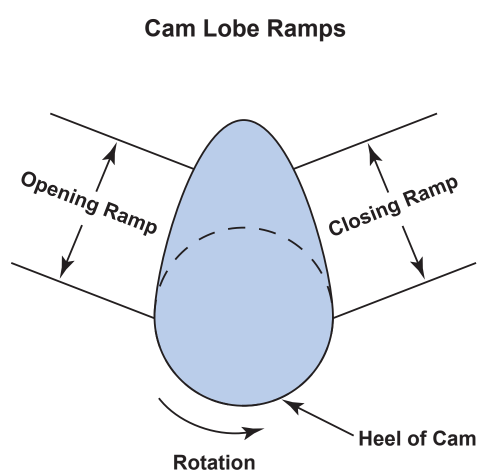
The higher the intake cam lobes rise, the higher the valve will lift to let more air-fuel mix enter the cylinder. The profile of a cam that lifts the valves high is commonly referred to as a “high-lift cam”.

If the “high lift” cam lobe rises gradually, and is not so “steep” in profile, this means the valve will stay open longer - as well as lift high - to let in more fuel. A more gradual lift will result in longer duration. A steep and quick lift will result in shorter duration – i.e. the valve will stay open for a shorter period of time.

The lift of the cam is measured from the base circle to the top of the cam lobe. The top of the cam lobe is called the nose.

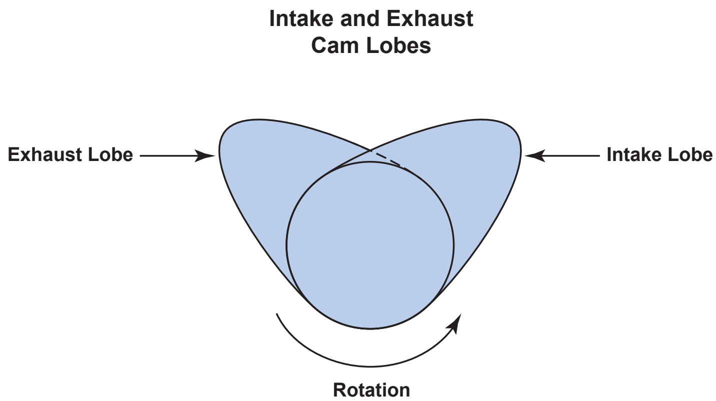
The short length of the cam nose - where the valve stays completely open for a very short period of time (or only a few degrees of the crankshaft) – this short length on the cam nose is called the lift dwell.

The opposite side of cam – located 180 degrees opposite the nose of the cam lobe – is called the heel of the cam.

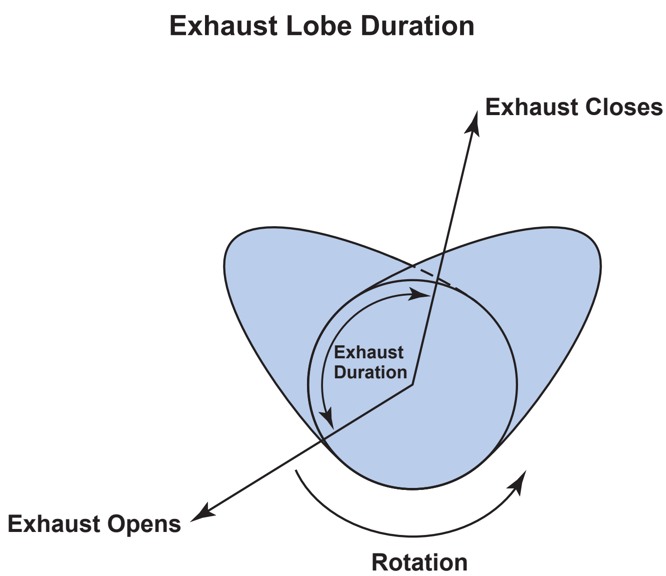


With the cam lobe rotating counterclockwise, the left side of the cam lobe – the opening ramp – opens the valve. The closing ramp then closes the valve with the help of the valve spring.

Most all camshafts are designed to provide valve overlap. Overlap is when both the intake and exhaust valves are open at the same time at the top of the exhaust stroke. Overlap occurs near the end of the exhaust stroke, near TDC, when the intake valve opens before the exhaust valve closes. Valve overlap is measured in degrees.

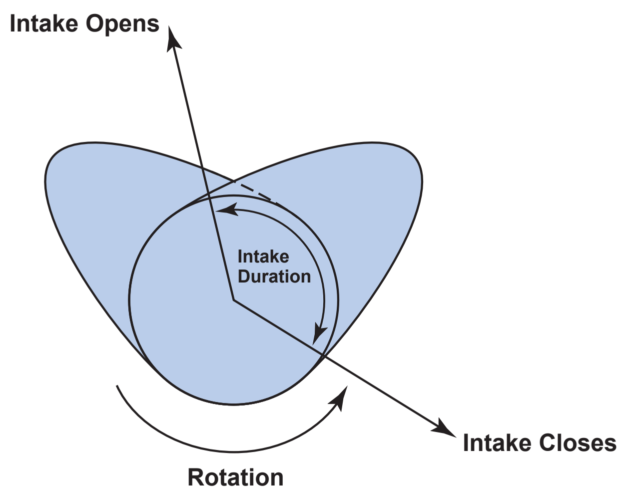


This illustration displays the intake and exhaust cam lobe and their relationship to each other. In a counterclockwise camshaft rotation, the exhaust valve opens and closes ***first*** *during the exhaust cycle of the engine. After the exhaust valve closes, the intake valve then opens to supply air-fuel mix. Note that the cam lobes are not opposite of each other. The intake lobe performs its job immediately after the exhaust lobe performs its function.*



The profile of the cam lobe determines how long the valve will stay open – referred to as the duration of the cam. This drawing illustrates the exhaust lobe duration.

Intake Lobe Duration



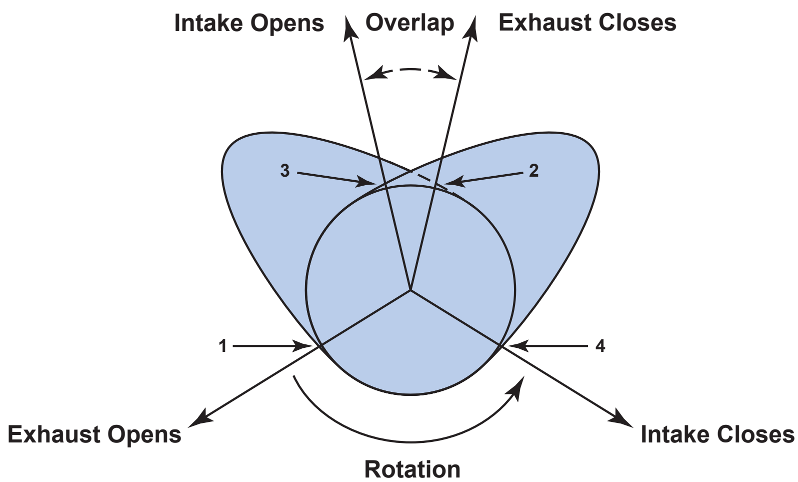
This drawing illustrates the intake cam lobe duration.

The exhaust port and exhaust headers can be tuned to make the most efficient use of scavenging during the overlap time period. If the intake port and exhaust port velocity is high, less overlap is needed for effective scavenging.

Remember that scavenging is using the “low air pressure” created behind exiting exhaust gasses to help the “higher pressure” incoming air-fuel mix rush past the intake valve, and into the combustion chamber during the very beginning of the intake stroke.

Domed pistons are convex in shape on the top of the piston. If a domed piston is used, more overlap will be needed for the exhaust gasses to escape and the air-fuel mix to enter the cylinder. Both the air-fuel mix and the exhaust gasses must climb over the dome as they move in and out of the combustion chamber. The dome is somewhat of an obstruction. However, the dome is used to create higher compression in the combustion chamber than is possible with a flat top piston.

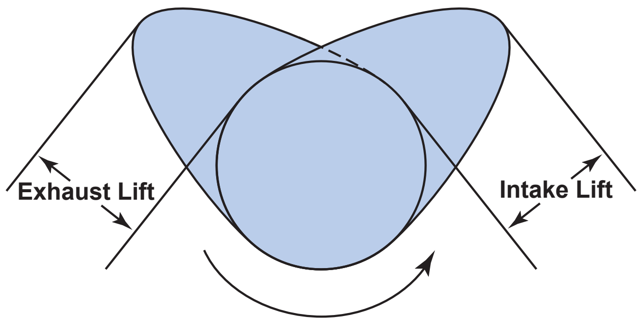
Camshaft Overlap



This somewhat advanced camshaft illustration can be confusing. This common layout has been simplified with numbers that represent certain points. Overlap happens when the exhaust valve is still open for just a short moment while the intake valve is just opening.

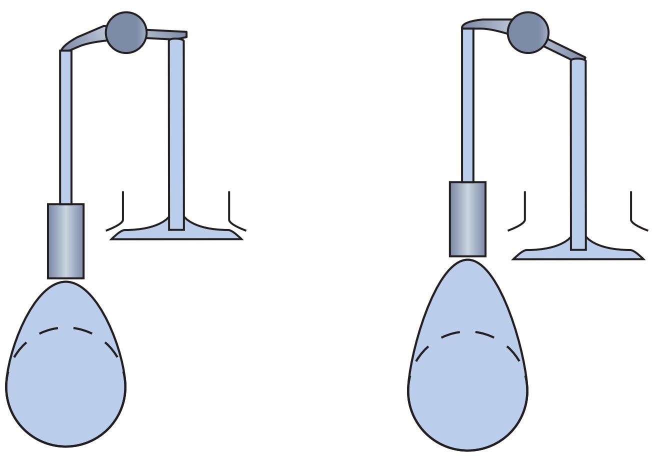
1 = Exhaust valve opens
2 = Exhaust valve closes
3 = Intake valve opens
4 = Intake valve closes
Overlap occurs between 3 and 2
Both valves are completely closed between 1 and 4

Camshaft Lift



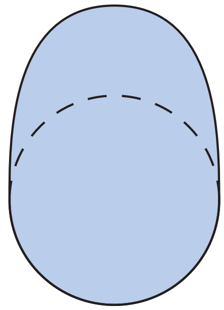
This illustration displays cam lift. The cam lift and duration changes how and where the engine makes torque and horsepower in the engine power band.

Low Lift Cams and High Lift Cams



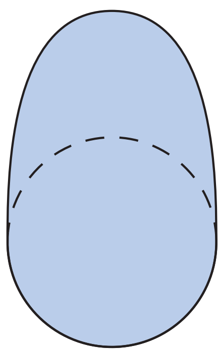
The high lift cam lobe on the right raises the valve much higher off the valve seat than the lower lift cam lobe on the left.

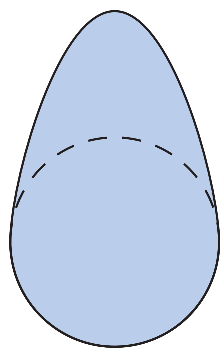
Medium Lift and Long Duration Cam



This drawing illustrates a common cam lobe that is designed for typical motorcycle operating requirements. It features a medium lift and a long duration.

High Lift Cam Profiles

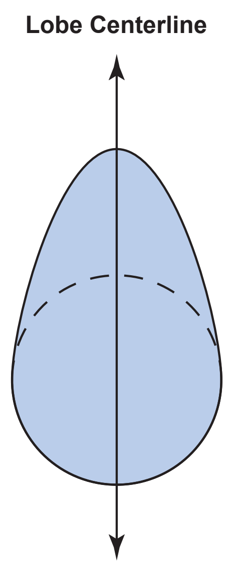




The cam lobe on the left features a high lift and a long duration. The cam lobe on the right features a high lift and a shorter duration.

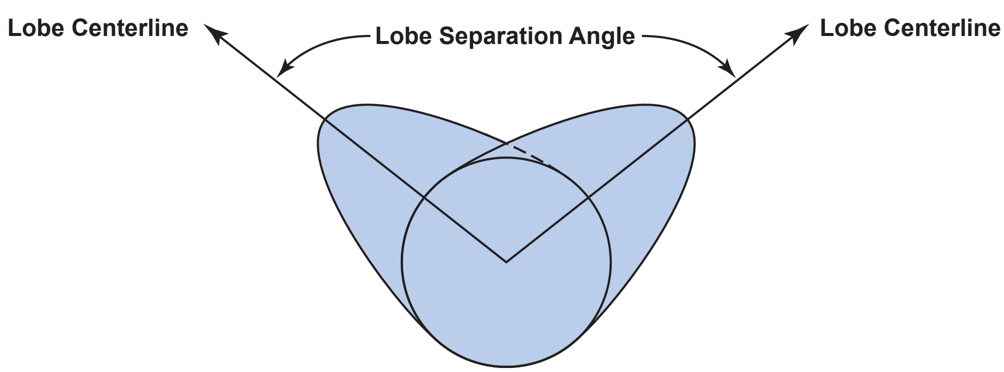
A higher lift allows more air-fuel mix to enter the cylinder quickly. These cam profiles are used in higher performance engines with larger displacements – engines typically run at high rpm when there is much less time available to get the air-fuel mix into the cylinder before the compression stroke begins.

Cam Lobe Centerline



The cam lobe centerline goes through the middle of the cam lobe.

Cam Lobe Separation Angle



Cam lobe separation angle is the distance measured in degrees between the centerline of the intake lobe and the centerline of the exhaust lobe. The lobe separation angle determines valve timing and the period of valve overlap. It directly effects how the cam will make power during engine operation.

If the intake manifold and intake port is large in design in order to flow more air-fuel mix, the air-fuel mix will have less velocity as it travels into the combustion chamber, and a longer duration cam profile will be required.

A longer duration cam profile will cause the intake valve to open earlier before the end of the exhaust stroke (during overlap), and, the intake valve will close later after the piston starts up on the compression stroke.

If valve overlap is long in duration, the engine will idle a bit rough. Long overlap will also result in less fuel economy.

Cam lobe lift and duration affect how an engine develops power. Some cams will make more power at lower rpm for more torque, but will not be able to build more power at higher rpm. Top speed will be lower.

Other cams will be designed to make less power at lower rpm, but will make more power and continue to accelerate the bike to faster speeds at higher rpm. Balanced cams will make power more linearly over the entire rpm range.

The cam lobes on this “stock cam” have long duration and a medium lift that is not radical. (Stock Harley evolution camshaft).

In a simple two-cylinder engine with 4 valves, the camshaft will have four cam lobes. Two lobes will open the two intake valves, and the other two lobes will open the two exhaust valves.

Adding a camshaft with higher lift and greater duration will not increase performance if the valve sizes, intake port, and exhaust port cannot provide the increase in flow of air-fuel mix that is needed to keep up with the high-performance cam.

The only certain way to test camshaft performance is through dyno testing or using engine simulation programs.

In general, if an engine is built to run at higher rpm, the camshaft must open the valves earlier and the valves must close later as there is less time to get the air-fuel mix in and out of the cylinder at high rpm. Longer duration is required.

Also, if an engine cylinder is built with greater displacement, the camshaft must open the valves earlier and close later as there is more air-fuel mix that must fill the cylinder.

Overhead camshafts are mandatory for high performance cylinder heads that contain two intake valves and two exhaust valves for each piston and cylinder.

Test Questions
Four-Stroke Engine – Part 2

1) Todays cylinders are made of

A) Cast iron
B) Aluminum
C) Both A and B

2) Aluminum cylinders receive a steel sleeve that is

A) Pressed in
B) Cast in
C) Most cylinders do not need a steel sleeve
D) A or B

3) Cylinder wear results in

A) Blow by
B) Excess burning of oil
C) Lack of compression
D) Loss of power
E) All of the above

4) Cast-in cylinder sleeves cannot be bored. T/F

5) Pressed-in cylinder sleeves cannot be bored. T/F

6) Final cylinder boring may require the use of

A) A shop clamp
B) Torque plates

7) Torque plates

A) Mimic the clamping pressure of head bolts
B) Bring the cylinder to the actual bore size used when in use on the road
C) Are not necessary for measuring bore diameter
D) A and B
E) B only

8) Hatch marks are

A) The result of honing
B) Trap oil in the cylinder wall surface
C) Are not always necessary
D) A, B and C
E) A and B

9) Base gaskets and head gaskets are used with torque plates. T/F

10) Steel sleeves are made of

A) Iron
B) Metal alloys
C) Often use “Moly 2000” chrome-moly
D) All of the above

11) Chrome-moly contains and has

A) Molybdenum
B) Carbon-chrome
C) Low tinsel strength
D) High resistance to wear
E) A, B and D

12) Cylinder sleeve thicknesses run thicknesses of

A) 3/32”
B) 1/8”
C) 1/16”
D) ½”
E) All of the above
F) A, B and C

13) Cylinders can be “sleeveless” and use no sleeves. T/F

14) Electrodeposited plating is most typically used on

A) Aluminum cylinders with no sleeves
B) Aluminum sleeves
C) Iron sleeves
D) A and B

15) Electrodeposited plating consists of hard materials such as

A) Boron
B) Krypton
C) Ceramic composites
D) Hard-chrome
E) A, C and D

16) Nikasil and sleeveless cylinders offers better heat conductivity than hard alloy steel liners. T/F

17) After Nikasil is electroplated into aluminum cylinders, the cylinders must then be honed. T/F

18) Nikasil can be electroplated onto

A) Aluminum “sleeve-less” cylinders
B) Steel sleeves
C) Aluminum sleeves
D) A, B and C
E) A and B only

19) Cylinders and pistons must be identified and kept together during a tear down and re-build because

A) Parts that wear together stay together
B) It does not really matter if they are mixed and matched as they are all the same anyway.

20) Transverse positioned crankshafts

A) Are located “side-to-side” under the rider
B) Are located “front-to-back” of the bike

21) Longitudinal positioned crankshafts

A) Are located “side-to-side” under the rider
B) Are located “front-to-back” of the bike

22) Cast pistons

A) Are poured into molds
B) Are poured into molds under pressure
C) Have a weaker molecular grain structure than forged pistons
D) A and C

23) Forged pistons are molded under high pressure and

A) Maximize strength to weight ratio
B) Are more brittle than cast pistons
C) Are more resistant to fatigue and shock
D) A, B and C
E) A and C

24) A two-stroke piston has more shallow valve cutouts than a four-stroke piston. T/F

25) Most engines disperse the heat of the piston only through the piston rings, piston skirt and the cylinder oil film. T/F

26) Piston skirts are not meant to contact the cylinder wall. T/F

27) Four-stroke engines have full piston skirts. T/F

28) An engine turning 13,000 rpm will cause the piston to be jerked up and down 26,000 times per minute. T/F

29) Pistons with an arrow etched into the crown on a transverse engine must have the piston facing

A) The front of the bike
B) The back of the engine

30) With cam grinding, pistons are typically wider at the crown than at the middle of the piston skirt. T/F

31) Cam grinding prevents piston slap when the piston has warmed up. T/F

32) With four-stroke pistons having three rings, the top two rings serve as compression rings. T/F

33) Compression rings seal against the cylinder wall because of cylinder pressure on the

A) Intake and compression strokes
B) Compression and exhaust strokes
C) Compression and power strokes
D) Compression stroke

34) Piston rings seal against the cylinder wall by static pressure on the

A) Compression and exhaust strokes
B) Compression stroke
C) Intake and exhaust stroke
D) Intake stroke

35) Two-stroke engines sometimes have an oil scraper piston ring. T/F

36) Two-stroke engines may have either two compression rings or only one compression ring. T/F

37) End gap is important because of

A) Heat expansion
B) Getting the cylinder to slide over the rings
C) Contraction during cooling
D) A and B
E) A, B and C

38) Engine cases support the

A) Pistons
B) Crankshaft
C) Piston rings
D) A and C

39) Engines using a modular construction with a separate transmission and a wet clutch primary that is separate from the engine case will use:

A) Engine oil, transmission oil, primary oil
B) Engine oil and transmission oil
C) One oil that lubricates everything

40) A sport bike engine with the transmission located inside the engine case will likely use:

A) Engine oil and separate primary oil
B) Engine oil and transmission oil
C) One oil type that lubricates everything

41) The following add to, subtract from, or have no effect on gross combustion chamber volume:

A) Valve relief depressions
B) Piston dome or crown indentation
C) Head gasket
D) Deck height
E) All of the above

42) Cylinder displacement does not contain the volume of the combustion chamber. T/F

43) Uncorrected cylinder displacement is the volume of space that is displaced in the cylinder when the piston moves from BDC to TDC. T/F

44) Corrected cylinder displacement adjusts for

A) A late closing intake valve
B) An early opening exhaust valve
C) Both A and B

45) To compute cylinder displacement, one must know:

A) Bore diameter
B) Combustion chamber volume
C) Stroke
D) Number of cylinders
E) A, B, and C
F) A, C, and D

46) The formula for computing displacement is
A) B x B x S x (0.5478 x N)
B) B x B x S x (0.7854 x N)
C) B x B x S x (0.3241 x N)

47) The formula for computing displacement for a two-cylinder engine with 3.50” bore and 4.25” stroke is:

A) 3.50 x 3.50 x 2 x (0.7854 / 2)
B) 3.50 x 3.50 x 4.25 x (0.7854 x 4)
C) 3.50 x 3.50 x. 4.25 x (0.7854 x 2)

48) Bore-to-stroke ratio

A) Equals bore divided by stroke
B) Equals stroke divided by bore
C) Determines the shape of the engine power curve
D) Compares how large the bore is in comparison to the piston stroke
E) A, C and D
F) B, C and D

49) If an engine is considered to have “square” engine geometry, then the bore-to-stroke ratio is

A) 1.5 to 1
B) 1 to 1
C) 1 to 1.5

50) If an engine is considered “over square”, an example of the bore to stroke ratio may be

A) 1 to 1.3
B) 1.3 to 1

51) If an engine is considered “under square”, an example of bore-to-stroke ratio may be

A) 1.5 to 1
B) 1 to 1.5

52) In an over square engine

A) The bore diameter is longer than the length of the piston stroke
B) The bore diameter is equal to the piston stroke
C) The bore diameter is shorter than the piston stroke

53) In an under square engine

A) The bore diameter is longer than the stroke
B) The stroke is equal to the bore
C) The bore diameter is shorter than the stroke

54) An under square engine will emphasize the production of

A) Torque and “pulling power”
B) High rpm engine speed
C) A and B

55) An over square engine will emphasize the production of

A) High torque
B) High rpm and top speed

56) An under square engine will likely be found in

A) A Harley Davidson engine
B) A Japanese sport bike engine

57) An over square engine will likely be found in

A) A Harley Davidson engine
B) A Japanese sport bike engine

58) The formula to compute horsepower is

A) HP= (Bore x Stroke) / 5252
B) HP = (Bore x rpm) / 5252
C) HP = (Torque x rpm) / 5252

59) Increasing displacement can be done by

A) Increasing bore diameter
B) Increasing torque
C) Increasing stroke
D) A and C

60) A stoichiometric mixture of 14.7:1 is the ideal perfect air-fuel mixture for creating engine power. T/F

61) Exhaust reversion can cause

A) Problems during valve overlap
B) Fuel standoff
C) A and B

62) Exhaust reversion is caused by

A) A bounce-back of exhaust gasses
B) A reversionary wave
C) Exhaust smacking still air in the exhaust port
D) All of the above

63) Exhaust reversion can be minimized by

A) Having an exhaust port and header that is bigger
B) An exhaust pipe that has an anti-reversion tube
C) Having an exhaust port and header that is smaller
D) A and B
E) B and C

64) Too much back-pressure causes over-scavenging in the combustion chamber during valve overlap. T/F

65) Three general factors that affect engine power are

A) Compression
B) Displacement
C) RPM
D) Using nitro-methane fuel
E) A, B and C
F) A, B and D

66) Camshafts control

A) When the valves open and close
B) How long the valves stay open
C) Valve overlap
D) The operation of pushrods
E) A, B and C only
F) All of the above

67) Camshafts control

A) Lifters
B) Pushrods
C) Rocker arms
D) All of the above
E) A and C only

68) Camshaft duration is measured in

A) Degrees of the cam heel
B) Degrees of the crankshaft
C) A and B

69) If an engine is built for high rpm

A) Camshaft duration must be longer
B) Camshaft duration must be shorter because there is less time at high rpm

70) If the intake and exhaust port velocity is high

A) More overlap is needed for effective scavenging
B) Less overlap is needed for effective scavenging

Test Question Answers
Four-Stroke Engine – Part 2

1) B

2) D

3) E

4) F

5) F

6) B

7) D

8) E

9) T

10) D

11) E

12) F

13) T

14) D

15) E

16) T

17) T

18) D

19) A

20) A

21) B

22) D

23) E

24) F

25) T

26) F

27) F

28) T

29) A

30) F

31) F

32) T

33) C

34) C

35) F

36) T

37) D

38) B

39) A

40) C

41) E

42) T

43) T

44) A

45) F

46) B

47) C

48) E

49) B

50) B

51) B

52) A

53) C

54) A

55) B

56) A

57) B

58) C

59) D

60) F

61)C

62) D

63) E

64) F

65) E

66) F

67) D

68) B

69) A

70) B