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Pistons and Rings

The Technical Price for Horsepower

The top compression ring is spiral wound to overlay in the piston ring groove.

For quite some time now, pistons and piston rings have been a hot topic of discussion among engine builders. At some point in our past, it seems as though there have been some piston shape and design changes along with some applied thermal and friction coatings – the same can also be said for piston rings. Piston rings seem to have become smaller with different shapes, finishes and coatings. So, where does this leave us when choosing a set of pistons and rings?

Today, it's not uncommon to have several choices for a specific application. It sometimes makes you wonder what manufacturers have found in rigorous testing that seems to be paving the way for the aftermarket. A very common question is "What gains can I expect from a piston and ring package when it comes to efficiency, power and longevity? The problem is, no one can answer the question!

We know that many different race teams have used different designs in their testing. But, we also know that these results have trickled down where they are placed into production. These changes not only affect gasoline engines but also diesel. So, where does this leave us in trying to decide what works? Hopefully, we can pull some data together to find what design works best for different applications and what gains have been found that implemented this design.

One of the most overlooked components of the internal combustion engine is the piston ring. It is, by scale, one of the hardest working components in the engine. And when you are building an engine, before choosing your piston rings you have to determine your application.

Let me repeat this so we're all on the same page: application, application and application! What environment is this engine going to see? The reason I stress this so strongly is that this small, delicate-looking part of the engine that is always overlooked has a big job to do. First of all, it must seal the combustion chamber. When you take a cylinder and compress gasoline or diesel fuel and air with a piston and the mixture ignites you have to seal that combustion. Think of it this way: you are trying to contain an explosion similar to dynamite with a piece of iron or steel wire – and EXPECT IT TO SEAL AGAINST THE CYLINDER WALL AND NOT LEAK!

Secondly, rings must transfer heat from the piston to the cylinder wall. This is one of the most overlooked functions by far.

This piston, connecting rod, and ring package are from a 1911 Benz (not Mercedes). Look at some of the intricate details of machining and craftsmanship that took place 105 years ago. It's truly amazing the detail and countless hours that went into these engine pieces with the tools that were available at the time.

Third, the rings must control oil from entering the combustion chamber.

When you're assembling an engine you never really think of the rings' efforts as being so grand. You install the piston rings that came with the engine kit and hope they seal. Once the engine is running with no problems, it never crosses your mind as to what the ring material was and what the long-term effects will be.

Have you ever stopped to think about where the piston ring came from? A man named John Ramsbottom developed the split piston ring back in the late 1800s. From my understanding, this invention immediately replaced hemp packing that was used to seal the pistons in a steam engine. The advantages of the split ring were overwhelming in terms of power, efficiency and maintenance.

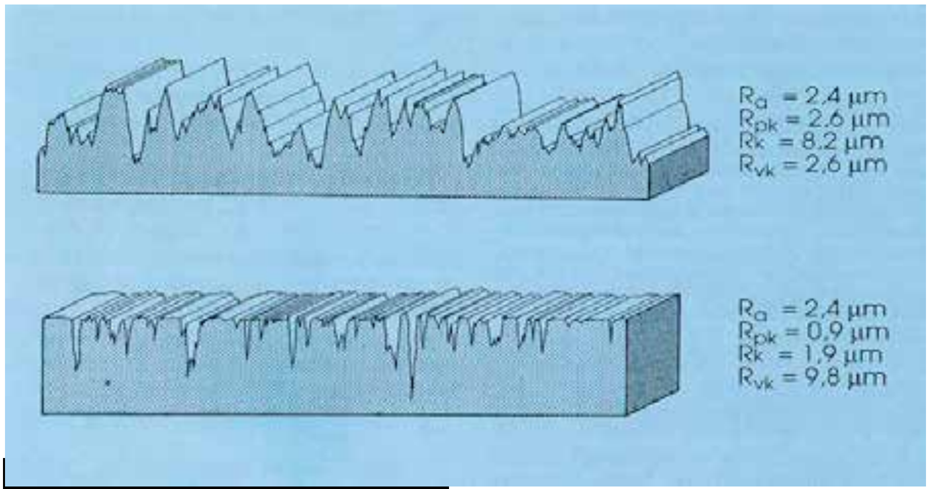
In order to understand where we are today in terms of material and size of the piston ring, we need to take a look at where we started and what we have learned to arrive at where we are now.

Let's start with cast iron, also known as grey cast iron. This material for piston rings has been used for years and is still used today because it has a great ability not to scuff or gall the bore. This provides adequate sealing for cast iron cylinder walls as long as it is sufficient in size. If you increase the operating loads of the engine and decrease the size of top ring when using cast iron, seal will become an issue.

When cast iron is used as a top ring, it is usually coated with moly or chrome to prevent bore wear. When used as a second ring, a ring is usually uncoated. Cast iron is very brittle and will break under heavy loads. Under a microscope, the cast iron ring has sharp rectangular grains that easily fracture.

From a manufacturing standpoint, cast iron rings have to endure quite a few production steps before being finished. This is an important point to remember because there are a couple of ways cast iron rings are made. One way is to mold cast iron into a form of a cylinder, then take the cylinder-shaped piece of nasty black cast iron and bore the center out to the desired inside diameter of the ring being processed. After boring the center out, manufacturers slice the rings one at a time from the molded piece like slicing a loaf of bread. Once the rings are cut they are then finished to exact tolerances for the application.

Another way of making cast iron rings is to form a mold much like the way a model car is made. When you open up a model car box, you find that all the pieces are formed on a plastic tree. You simply snap and break free the model car pieces from the plastic tree for assembly. Cast iron is poured into a piston ring mold in much the same way. After it is poured it is broken free from the tree and then machined



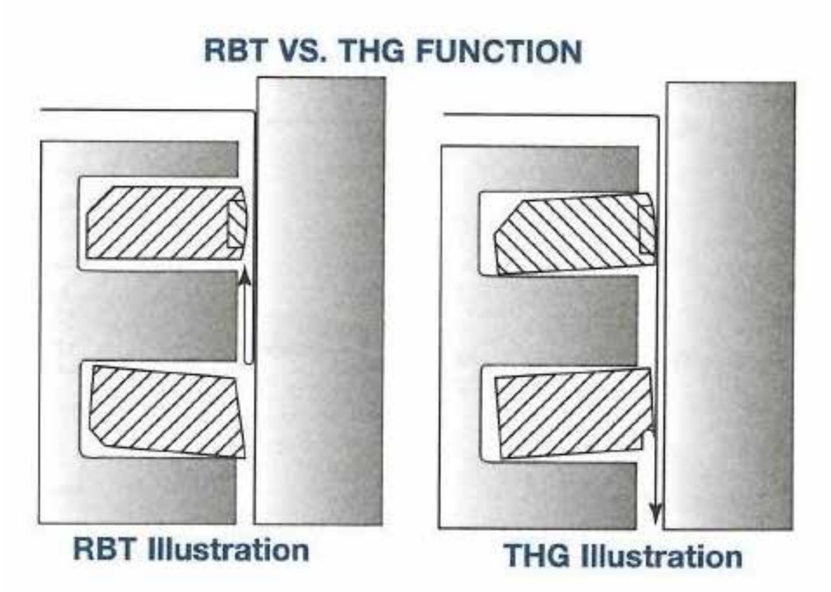
The one negative seen from a general movement towards "smoother" bore finishes is the tendency to apply them across the board too freely. While there can be measureable improvements, under the right (or wrong) conditions the smoother bore finish can hinder break-in.

and processed for use. Cast iron is a very affordable ring because of the material, but it still undergoes a lot of "hands on" in order to reach a finished product and there is also a lot of waste that must be recycled.

Another ring material that has been used in gas and diesel applications is ductile iron. Ductile iron is also known as nodular iron because, under a microscope, it has rounded nodular-shaped grains that form from the induction of graphite during the smelting process. The ductile iron ring is twice as strong as cast iron, has more tensile strength and is used in high output applications such as turbocharged engines. The ductile iron ring can be twisted like a pretzel and will not break.

Ductile iron top rings in diesel applications were often referred to as "keystone" rings because the keystone shape resembles a sideways triangle and the ring groove of the piston is triangular in shape. Keystone rings are still used today and the benefit is these are a self-actuating ring. The up-and-down motion helps in ring loading and in groove cleaning.

Back in "the day," the keystone ring was effective because diesel fuel was not as clean. This helps keep the rings and pistons clean of carbon deposits.



Today, with diesel emissions devices placed on engines, carbon deposits are inevitable with EGR valves and often lead to carbon packing of the keystone ring. This type of ring can often be found in two stroke applications.

If you do not know what material is in the rings in your engine, here is a simple way to find out: drop the piston ring on a table in your shop. If the piston makes a ringing sound it is ductile iron. If the piston ring makes a thud sound, then most likely it is cast iron.

The newest trend is a smaller, thinner ring, because manufacturers are increasingly seeing the benefits of steel rings. There are many advantages with steel rings: these are stronger and harder than ductile iron and also resist breakage. The most important advantage, however, is steel rings are easier to manufacture. In simple terms, the ring is made from steel wire that is formed in the diameter of choice. While it may not technically be cheaper (but is becoming more cost effective), there is no waste and there are fewer steps in the manufacturing process.

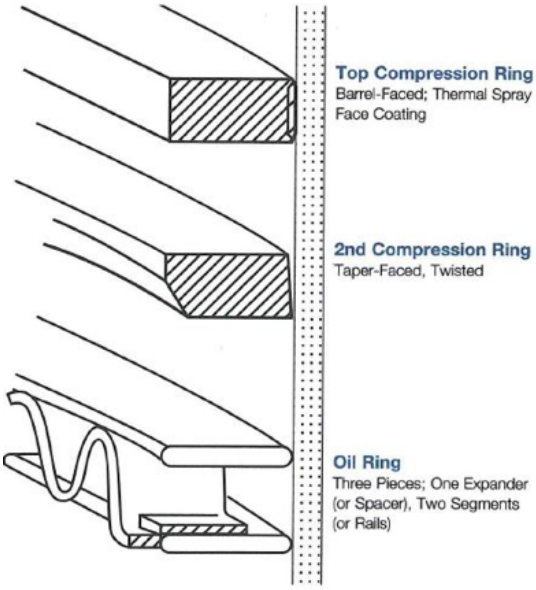
Apart from manufacturing, the best thing about steel is that it has thermal stability. The ring can handle more heat stress from harsh environments and still maintain its composure. This is a good opportunity to mention the term “free gap.” Free gap is seen when you take the piston ring out of the box and lay it on a table; the free gap between the ring lands should be, let’s say for example, .600˝. You install the ring in the bore and the gap is .020˝ for your application. After you run the engine for a year and tear it back down, you find that the free gap is now .500˝. This is considered normal and shows that the steel ring has held its thermal stability. If, however, you were to find that the free gap had closed up to, say, .100˝, then something would definitely be wrong. The steel ring would not have distorted this badly unless something was really wrong with your combination, which led to major detonation.

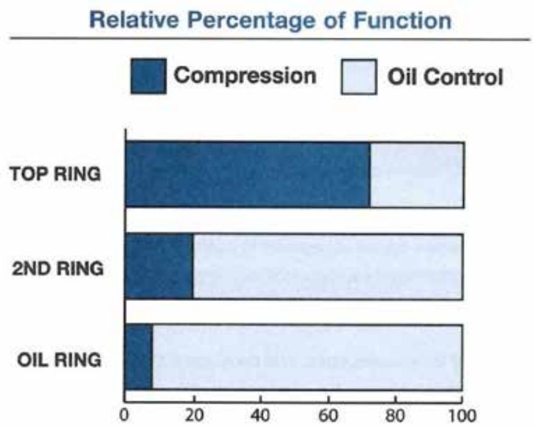
Steel rings also offer better ring seal if used in narrow low tension applications because if the rings are too thick they will not conform to the bore. The steel top ring usually has a bevel on the inside top surface which will help induce twist. So when the cylinder fires, the thin top ring is pushed down against the bottom of the top piston groove and then gas pressure pushes the ring against the bore. As the piston goes down in the bore, the barrel face design of the steel ring means that the center of the piston ring is in contact with the cylinder bore. Keep in mind that steel rings are usually not compatible with cast iron bores unless they are coated with moly, chrome, PVD or gas nitriding.

Knowing this means you need to know a little something about coatings.

Moly - Also known as molybdenum, moly has a very high resistance to scuff. When applied to the face of the ring it becomes porous, which offers great oil retention. Moly has a very high melting point that has the capability to live under harsh conditions.

Chrome – This very hard coating is used mostly in harsh environments such as dirt racing. Because moly is porous, it can serve as a trap for foreign





The "hook" configuration of the bottom outside edge on the napier (second) ring creates a more effective scraping action of the oil from the cylinder walls while also providing a reservoir on each downstroke. The running face of the napier is still tapered, similar to the conventional style ring, which rides smoothly on a film of oil on the upstroke.

material; whereas chrome resists the impregnation of dirt and can send debris out of the exhaust port.

PVD (Physical Vapor Deposition) – This process is done under a high vacuum where high quality titanium or chromium is either evaporated by heat or the induction of ions with a reactive gas, usually nitrogen. This deposits a thin adherent uniform coating on the ring that is very hard, smooth and temperature resistant.

Gas Nitriding – This is a heat process that impregnates the surface with nitrogen to case harden the rings. This usually hardens the surface of the ring to a depth of .001˝. This level of hardness will usually wear the cylinder bore before the piston ring shows any type of wear.

Black Phosphate – This black coating is usually found on all rings, but is a rust preventive coating for shipping and storage only.

There are a few things that need to be mentioned that are trending present day. For second compression rings, ring manufacturers are transitioning from cast iron and ductile iron to steel as well. Second rings do most of the oil scraping in the cylinder bores and in the past were usually coated with moly. Manufacturers now offer the second ring with no coating because they have found that there are no advantages of coating. Second rings are beveled on the underside to induce torsional twist because the second ring usually has a taper face used to scrap the oil from the cylinder walls. With the use of steel top rings that now use less tension, which produces less friction, the use of napier or hook face rings is also popular. The hook face pockets the oil that is being scraped from the cylinder walls.

Aluminum blocks are making a big comeback in production, of course. A good example of a "challenging" block from the past was the Aluseal engine blocks in the Chevy Vega that had terrible bore wear. Steel-coated top rings were used along with steel second rings. Cast iron second rings wear really badly. Also the use of some exotic cylinder bore coatings such as moly-titanium-dioxide which is very porous offering great oil retention so tighter tolerances and smaller ring packages can be used. The only down side is for right now it is very expensive.

The use of diamond finished rings are becoming very popular. Keep in mind that because of their exact tolerance the piston may be fitted to the ring not the piston ring to the piston. Clearance issues could result causing the ring to seize and stick the cylinder in the bore.

Remember, the cylinder bore is much like a bearing. The recommended finish of the cylinder bore is specified for proper oil retention for the lubrication of the rings. People often think that the smoother the better, and while this may look pretty and you may believe that it offers less friction, too smooth could actually lead to accelerated ring wear and cylinder failure.

Another mistake is commonly made when filing piston rings. Always make sure that, when filing the piston ring, you chamfer and debur as little as possible and keep the ends square. The more chamfer the end of the piston ring has is equivalent to more end gap, which causes more leakage. ■

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