HEAD & BLOCK DECKS & GASKETS

The good news for engine builders is that as long as passenger cars and light trucks require engine oil and coolant, drivers will neglect them, engines will run dry and damage will occur.

To be fair, it isn't ALWAYS the customers' fault – sometimes it's the fault of the OEM. Certain vehicles have been particularly prone to failure: the Dodge Neon 2.2L, Ford 3.8L V6 and Toyota 3.0L and 3.4L V6 engines, as well as the 1.3L and 1.5L Hondas. Going further back, we all remember the problems GM had with the 2.3L Quad-4 head gaskets. All of these engines have experienced a high rate of premature failure because the OEM head gasket couldn't keep a seal.

The reasons for these failures have been many and varied. Often, it was simply a case of the cast iron engine block expanding at a different rate than the aluminum cylinder head.

Aluminum heads save weight but expand 1.7 times faster than cast iron when they get hot. This difference in expansion rates creates a lot of motion and scrubbing between the head and block. If the head gasket can't handle this motion and isn't strong enough to withstand the shearing forces that occur every time the engine is started, run and allowed to cool back down, it will eventually leak.

Other failures are caused by poor engine designs. High operating temperatures, small radiators, localized hot spots and even insufficient or poorly located fasteners can cause overheating and eventual gasket failures.

To combat these challenges, gasket manufacturers are constantly looking to improve the seal in engines. With bi-metal engines, the aluminum is softer than cast iron and can brinell, which is the displacement of material in certain areas and can create a groove in the aluminum itself. This could be a concern if you have excess levels of thermal expansion or clamp load. Because aluminum is much more flexible, OEMs have reduced the amount of bolt torque required in today's engines. Traditional head bolts can result in inconsistent torque values if there is dirt on the threads or they haven't been cleaned or lubed with the right lubricant. With torque to yield (TTY) head bolts it is far easier to install the bolt correctly, because

you know you're getting the right amount of torque – which has eliminated most of the ways to incorrectly torque the head, say industry experts.

One of the first real successful examples of a product that could seal bi-metallic engines was the graphite head gasket. When you put a graphite gasket between an aluminum head and iron block, however, it encounters vastly different rates of expansion. Graphite is very compatible with aluminum because it is a dry lubricant which allows the cylinder head to slide back and forth without biting into or tearing the gasket. If it didn't allow that sliding action the head would dig into the gasket, say experts.

Bi-metallic engines have created new challenges for gasket makers, and MLS is an exceptionally good material for bi-metal engines, say industry experts. It allows the head to slide around but also has the added benefit of high tensile strength.

When manufacturers design a gasket for the aftermarket they don't look too much at how the OE did it, they are looking more at what is needed in the aftermarket. So some gasket makers use heavier, much more dense material than OE and they also open up the fire rings to accommodate the oversize bores.

Because of the steel inner layers, it's very difficult to tear an MLS gasket apart. The MLS also helps maintain a more cylindrical bore. When you torque the head down onto the block the bolts pull up from the inside of the engine where the threads are and may warp the engine block. Warping can result around the bores and that, in turn, warps the surface. MLS gaskets provide a consistent amount of pressure around the top of the cylinder, and it helps prevent bore distortion when the head is torqued down.

Blaming the customer or the OEM for doing something to cause a gasket failure is easy – but when a machine shop has to take the blame it's another story. Unfortunately, when it comes to failures with MLS gaskets in the aftermarket, it's often machine shops that have to bear the brunt of the criticism.

When cast iron V8s and straight six cylinder engines were the most commonly rebuilt engines, surface finish requirements weren't as critical and conventional abrasives were adequate for the task at hand. Heads could be ground, milled or even belt sanded and be smooth enough and flat enough to seal most head gaskets.

Though there are many upsides to MLS, one of the difficulties engine builders have faced in the past has been their ability to achieve the proper surface finish for a good seal. More than other types of gaskets, MLS gaskets require very smooth, flat surfaces in order to seal properly. Although OEMs can achieve consistently smooth levels of surface finish with Ra (roughness average)numbers in the 8-10 range, engine rebuilders often vary in their ability to achieve this level of smoothness. The reason for this is relatively simple – it can be expensive to upgrade to equipment capable of producing the recommended Ra numbers.

The key to achieving high quality ultra-smooth surface finishes is using the right equipment, the right abrasives and the right resurfacing techniques. Most of the surfacing equipment that's being sold to shops today has been redesigned for high speed milling with CBN and PCD. The machines have been beefed up with more powerful motors, heavier castings, electrically driven ball screw tables, and tighter assembly tolerances. Some can hold machining tolerances to one tenth of a thousandth of an inch (.0001″)! You might not need that kind of accuracy for an economy smallblock Chevy V8 rebuild, but you might want that kind of accuracy for a megabuck high performance engine or even a late model high output overhead cam engine. There's no such thing as too much accuracy.

Yet equipment suppliers remain frustrated because some shops are still trying to "make do" with outdated surfacing equipment such as broaches and grinders. But many of these shops are learning the hard way that yesterday's equipment can't deliver the kind of finishes that are required for today's engines.

We're talking surface finishes with microinch roughness averages in the single digits on some late model engines as well as performance engines that are running MLS head gaskets. Even when a super-smooth finish isn't required, having the flexibility to reproduce any kind of surface finish on any kind of cylinder head or block is a definite plus.

Engine builders have different capabilities than the OEs when it comes to gaskets and surface finish. Some shops still use older equipment to machine heads and blocks. In the past, having a surface finish of 60-120 Ra was acceptable for sealing a composite gasket.

Many late model engines are equipped with MLS head gaskets which help reduce cylinder bore distortion and typically have much lower clamping loads than traditional head gaskets. But they also require an extremely smooth, flat surface finish on both the block and head to seal properly, typically 20 to 30 microinches Ra or less. Consequently, if your resurfacing equipment can't achieve these kinds of numbers, you're going to have problems rebuilding some of these late model engines.

It's not surprising, therefore, that one of the most often replaced machines in shops today is surfacing equipment. According to the 2006 Machine Shop Market Profile, while 86 percent of surveyed shops say they currently have surfacing equipment, six percent say they will be replacing it this year. No other type of equipment has a higher estimated rate of replacement. In 2005, 3 percent of our survey respondents replaced their resurfacing equipment – likely old broaches and grinding machines – with purpose-built high-speed surfacers that use long-life superabrasive inserts. Some of these machines are also multi-purpose machining centers with manual or CNC controls that can also be used for boring blocks.

Abrasive Personality

No more than a decade ago, superabrasives such as polycrystalline diamond (PCD) and cubic boron nitride (CBN) were considered too exotic and too expensive for the average engine builder to use. Today, PCD and CBN are mainstream and you can hardly afford not to use them.

The need for faster production speeds and higher quality surface finishes has made superabrasives almost mandatory for most resurfacing, honing and grinding operations.

What makes these materials so indispensable for engine building today? Their superior hardness is a major factor because it provides outstanding tool life that far exceeds conventional abrasives. A set of metal bond PCD diamond honing stones can typically do 50 to 100 times as many cylinder bores as conventional vitrified stones before they're worn out and have to be replaced.

A CBN grinding stone for resurfacing flywheels will typically last ten times as long as a conventional stone. CBN pucks in a milling machine will cut 20 to 50 times as many heads as ordinary carbide pucks. Because of this, superabrasives can provide better overall consistency and reduce down time for tooling changes, and even though they cost more initially, typically provide lower operating costs over the long run.

Another improvement that often comes with an equipment upgrade is increased productivity. With the right fixturing, you can reduce the time it takes to mount the parts on the machine and set up your cut. If a new surfacer is easier to use and reduces setup and cycle times 5, 10 or even 20 minutes per job, the savings can really add up. Less time spent setting up and operating the equipment means more time for other work and/or a higher volume of jobs completed every day.

In a custom shop where you may be working on several different engines at the same time, a surface that can be reset quickly from one job to the next can keep work flowing smoothly instead of creating a bottleneck. Some surfacers can be set up and mill a head in five minutes or less, which is pretty quick in a fast paced shop. And if you're doing several identical heads in a row, the actual milling time may only be a couple of minutes. It all depends on the speed of the cutter head, the number of tool bits, the feed rate and how smooth the finish on the parts needs to be.

Most of today's high speed surfacers are designed to use CBN or PCD inserts in their cutter heads. Which is best depends on the type of metal that's being resurfaced. As a rule, cutting bits made of PCD diamond work best when resurfacing nonferrous metals such as aluminum, while CBN is recommended for cast iron and steel. CBN is not the best choice for milling aluminum because aluminum tends to stick to CBN and leave a smeary finish. Even so, a common trick for using CBN to resurface aluminum is to spray the surface with a lubricant or wax.

But why would you use CBN on aluminum if PCD diamond works better? This compromise can help save the time and cost of changing tooling when you're switching from one type of cylinder head to another. CBN also works well to resurface hard-to-cut heads such as cast iron diesel heads that have hard precombustion chambers. Some specially designed 1/2″-diameter cutter bits are available for these applications that will leave a nice finish without the chatter or waviness that often results from trying to cut these heads with conventional abrasives.

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The reason diamond isn't recommended for surfacing cast iron and steel has nothing to do with hardness, however. It's because CBN can handle heat better than diamond. At high cutting speeds, diamond gets too hot and starts to react chemically with iron. This causes diamond to dull and lose its cutting edge. This isn't a problem if the cutting speed is kept low enough (as when honing with diamond stones). But in a high-speed milling machine with only one or two cutting bits, diamond bits get too hot. Diamond starts to revert back to graphite (a very soft form of carbon) at temperatures above 1,500 degrees F while CBN can withstand temperatures up to 2,500 degrees F. CBN also has high thermal conductivity, and dissipates heat about four times faster than silicon carbide or aluminum oxide.

Diamond works well on aluminum because aluminum is a much softer metal than cast iron or steel. The hard particles of silicon that are usually alloyed with aluminum dull conventional abrasives. When a carbide cutting edge hits a silicon crystal in aluminum, it tends to push rather than cut. This dulls the tool and leaves a rough finish on the surface of the metal. Diamond, on the other hand, is much harder than silicon carbide, aluminum oxide or tungsten carbide, and cuts right through the silicon crystal without dulling the tool or tearing the metal. The result is a smoother finish with little wear on the tool bit.

Something else that must be considered when using CBN to resurface heads and blocks is the minimum depth of cut. CBN inserts typically have a honed edge, so the minimum depth of cut is usually limited to about .004˝ or .005˝ on cast iron. If too shallow a cut is attempted, the result can be edge deterioration, poor tool life or chipping of the insert (CBN is sometimes coated with titanium to improve tool life).

Too slow a cutting speed with CBN can also increase tool wear. To cut efficiently and cleanly, CBN needs a fast enough speed so it doesn't "rub" across the surface. A surface speed of 1,800 to 4,000 feet per minute (ft/min) is usually recommended for rough milling soft cast iron (at a depth of cut of .025˝), and a surface speed of 2,000 to 5,000 ft/min for finishing cast iron.

When resurfacing aluminum heads or blocks with PCD diamond that have less than 12 percent silicon content, a surface speed of 800 to 6,000 ft/min is recommended for rough cuts, and 1,000 to 10,000 ft/min for finish cuts.

Because CBN and PCD are designed for high speed milling, replacing the carbide inserts in an older surfacer won't necessarily achieve all the benefits that these superabrasives are capable of delivering – especially if an existing surfacer lacks the horsepower, rigidity or adjustability to operate at higher spindle speeds. Rigidity becomes a factor as operating speeds increase. A machine that lacks the required rigidity can't deliver ultra smooth finishes at high speed because there's too much movement between the workpiece, table and cutter head.

Superabrasives can also handle higher machining and grinding speeds – in fact, they require it! The ability to cut faster means shorter cycle times, improved productivity and profitability. High cutting speeds, though, also require equipment that is designed to operate at higher speeds.

Simply switching your tooling from carbide to PCD or CBN may not cut it if your equipment lacks the horsepower or the adjustability to operate at higher spindle speeds.

Rigidity also becomes more important as operating speeds increase. For example, a converted grinder may be able to mill heads and blocks. But the spindles and table drives in many of these older machines cannot hold close enough tolerances to achieve a really smooth, flat finish.

One equipment manufacturer said grinding and milling machines that are more than five years old are probably incapable of producing consistent results and should be replaced. **EMPG**