HEAD & BLOCK 

DECKS & GASKETS Guide

The modern engine is made up of a wide variety of metal components, some common and some exotic. Despite the advancements in metallurgy, it's a fact that cylinder heads and blocks may need to be resurfaced to restore flatness or to improve the surface finish, or milled to change the deck height for a variety of reasons.

Though cast iron is cheap compared to most other metals, it's strong and durable and can be easily cast and machined to make engine blocks, cylinder heads, crankshafts, connecting rods and other engine parts. However, it also has characteristics that make it less than appropriate in certain applications.

As automotive technology has continued to advance, more exotic metals are finding their way into what was once the exclusive domain of cast iron.

Actually, cast iron is not a single metal but a whole family of iron-based metal alloys that contain iron and carbon. There are hundreds of different cast iron alloys, but the kind that's typically used for standard engine blocks and heads is gray cast iron, which is about 92 percent iron, 3.4 percent carbon, 2.5 percent silicon and 1.8 percent manganese. Gray cast iron has a tensile strength of around 25,000 psi and a hardness of around 180 on the Brinnell scale.

Gray cast iron is relatively easy to machine with carbide abrasives or cubic boron nitride (CBN), and cracks can often be repaired by pinning. But cast iron is very difficult to weld and requires high temperature furnace welding, nickel brazing or spray welding. Except for diesel cylinder heads, antique engine parts or high dollar value parts, badly cracked or broken cast parts are usually cheaper to replace than to repair.

Such "new" metals as high silicon alloy aluminum for engine blocks, aluminum metal matrix composite (MMC), discontinuously reinforced aluminum (DRA), and nickel plated aluminum blocks and cylinders, compacted graphite iron (CGI) engine blocks with or without nickel plated cylinder bores and even bimetal engine blocks made of cast magnesium around aluminum cylinders are finding their way into your shop more often.

Ceramics, carbon fiber materials or even high temperature plastics may be in tomorrow's engines. Concept engines have been constructed from all of these materials as engineers continue to push the envelope for lighter, stronger and better materials.

The deck surface on the head or block may need to be resurfaced if the surface isn't smooth or flat. A head may need to be resurfaced after welds or other repairs have been made, or milled to increase the compression ratio. The manifold surfaces on a head may need to be cleaned up due to corrosion or erosion, or the angle changed slightly to better align with an aftermarket intake manifold. The deck surface on the block may need to be resurfaced. Whatever the reason is for resurfacing these parts, you want to do it quickly, efficiently and correctly. Mistakes here can be very expensive, because once metal has been removed there is no putting it back.

Gasket technology advancements have played a significant part in the longevity and durability of today's engines. A robust gasket design is one that will hold up for the life of the engine under less than ideal operating conditions. Your customers expect and demand nothing less. Clamp loads may vary, fatigue and gasket creep may set in, a flange may warp or distort, but the gasket must continue to do the job despite such circumstances. To counteract these issues, gasket makers have employed a healthy dose of ingenuity and high-tech materials to help you keep your engines in service and free of leaks.

The gap between the cylinder head and block joint is the most difficult to seal on an engine, and therefore gets a lot of attention from gasket makers in research and design. Gasket development in the aftermarket is generally the result of new OEM designs – and in fact, it's usually the aftermarket that finally gets it right. As new engines become lighter and more fuel efficient, sealing them can become a greater challenge. For the most part, aftermarket gasket makers follow along the same lines as the OEM design, but there are instances, especially where the original design may have been flawed to begin with, where aftermarket gasket manufacturers decide to take a different approach.

Head gaskets have several functions. The primary function of a head gasket is, of course, to seal compression. If it doesn't seal compression the engine doesn't run very well. The second thing it has to do is seal fluids. It needs to keep the coolant in the water jackets and oil in the galleries (in many cases it has to seal high pressure oil for OHC engines) and compression in the compression chamber, etc.

If the engine was static and never ran it wouldn't be difficult to seal the joint. But in reality, what happens every time a cylinder fires, pressure in that cylinder (1,200 - 1,800 psi of cylinder pressure) lifts the head up slightly off the engine. In turn, that relaxes the load on the gasket. As soon as that cylinder is fired and the load is gone it clamps back down on the engine.

The head gasket actually acts more like a spring than a flat object because it's essentially giving and relaxing and compressing, thousands of times as the cylinders fire. Despite the movement, everything is fine, usually - unless there's more pressure than there is spring available in the gasket.

When engines start making more power, as is common in performance applications, there is more liftoff on the head and loss of load on the gasket. Therefore, gasket makers have to account for a number of variables: how much load can the gasket handle? How thick does the center need to be? Should extra beading be used around the combustion chamber to increase the load? Modern engines rarely cause concern about gasket-destroying detonation and pre-ignition issues because of the electronic engine controls and the knock sensor used in every electronic engine to retard the timing if it detects anything. However, performance or stock application where engines don't use a knock sensor, though, could conceivably start getting into these issues again, according to experts.

Part of the OEM attraction to multi-layer steel is that it doesn't simply compress and stay compressed like a composite gasket. An MLS gasket acts more like a spring that seals two moving parts. Manufacturers say that MLS gaskets have continued to gain dominance in the market in large part because the OEMs now use them in the majority of their engine applications. In fact, as the transition occurs from composite gaskets, almost all head gaskets today are MLS design, say experts.

While the main reason for the switch to MLS was to accommodate a greater amount of movement, some experts point out that there are cases where graphite gaskets work fine, and OEMs may not have made any other major engine design changes besides switching to MLS just for the sake of technology.

In some cases, OEs have continued using composite gaskets. For example, when Chrysler replaced the 2.2L and 2.5L platform with the Neon 2.0L and 2.4L platform, they switched to a MLS gasket with the new engine design, while the Jeep 4.0L has been around for decades with the same composite gaskets.

So for all of the moves to MLS there are still plenty of old engines still in production. The 3.0L Taurus engine is another example; it still uses a composite gasket that Ford has never upgraded.

The biggest development in MLS gasket technology at the OEM level, say experts, has been the reduction of the number of layers in an MLS gasket, while still maintaining optimum sealing performance. The OEs have accomplished a more efficient design in some cases as a result of the advances in technology. So experts say the trend will be more two and three layer gaskets instead of fours and fives, but not necessarily across the board.

Materials and Designs

With regard to materials and designs, aftermarket gasket manufacturers have continued to make steady improvements in bead designs, stopper designs and coatings where possible. Experts say even though there haven't been major design changes, fine-tuning has allowed the aftermarket manufacturers to continually improve products available to rebuilders.

The point that needs to be continually stressed, however, is that surface finish is critical. To seal properly, a head gasket requires a surface finish that is within a recommended range. The specifications vary depending on the type of head gasket. If the surface is too rough (or in some cases too smooth), the gasket may not seal properly and leak or fail. One common mistake to avoid here is not looking up the recommended specifications for a particular engine and/or a particular type of head gasket.

As a rule, the recommended surface finish for a traditional composition style soft-face head gasket in an engine with cast iron heads and block is 60 to 120 microinches Ra (roughness average). But the recommended surface finish for the same type of head gasket in an engine with an aluminum head on a cast iron block is smoother, typically 20 to 50 microinches Ra. On late model engines with multi-layer steel (MLS) head gaskets, the OEM surface finish recommendations tend to be even smoother, say 20 to 30 microinches Ra or even 7 to 15 Ra. But the aftermarket also sells MLS gaskets with special coatings for many of these same applications that can handle surface finishes in the 50 to 60 microinch Ra range. So you have to know your gaskets and the surface finish recommendations for them by the gasket manufacturer, or the OEM if you are using a factory-style replacement head gasket.

Unlike horseshoes and hand grenades, close enough is not good enough. Eye-balling the surface finish will tell you if the surface is really smooth (a mirror-like finish), really rough (like sandpaper) or somewhere in between, but that's subjective – it won't tell you if you are in the recommended range. Dragging your fingernail across the surface isn't much better, either, because a 30 Ra finish feels almost identical to a 50 Ra finish. And the smoother the finish gets, the more difficult it is to see or feel much difference.

The only way to accurately determine if the surface finish is within the correct range is to check it with a profilometer. This is an expensive electronic instrument that drags a diamond-tipped stylus across the surface to calculate its profile characteristics. The profilometer can then display various values for the surface including roughness average (Ra), average peak height (Rpk), average valley depth (Rvk), and even waviness. These numbers may not be needed for an economy Chevy 350 rebuild, but they can be critical when building high performance engines or durability engines. The mistake to avoid here is assuming the surface finish is correct when you haven't actually measured it.

Here are some other common mistakes engine builders may make when surfacing block or head decks.

Wrong Feed Rate/Speed

The quality and smoothness of the surface finish requires using the correct feed rate and speed for the type of tool bit. This, in turn, will vary depending on the diameter of the cutter head.

To achieve the best possible finish, you should use a higher spindle speed and lower table feed rate with a very shallow cut on the final pass (less than .001˝).

If you are using a carbide insert to refinish a cast iron head, the spindle rpm required will typically be about 140 rpm for an 11˝ cutter, 120 rpm for a 13˝ cutter or 110 rpm for a 14˝ cutter.

With CBN (cubic boron nitride) or PCD (polycrystalline diamond) inserts, the recommended spindle speeds are much higher: 1040 rpm for a 11˝ cutter, 880 rpm for 13˝ cutter, or 720 rpm for a 14˝ cutter. If the head or block being resurfaced is harder, high silicon content alloy, the speeds need to be slowed down a bit: 690 rpm for a 11˝ cutter, 580 rpm for a 13˝ cutter or 540 rpm for a 14˝ cutter.

With a single CBN or PCD insert cutter spinning at 1,000 to 1,500 rpm, the feed rate should probably be less than two inches per minute on the final cut to achieve a surface finish in the low teens.

Not Checking Flatness

Never assume a head is flat. You can't tell if a head or block is flat or not unless you measure it with a straight edge and feeler gauge. You should always check for flatness, especially in critical areas like those between the cylinders.

Flatness specifications vary depending on the application, but on most pushrod engines with cast iron heads, up to .003˝ (0.076 mm) out-of-flat lengthwise in V6 heads, .004˝ (0.102 mm) in four cylinder or V8 heads, and .006˝ (0.152 mm) in straight six cylinder heads is considered acceptable. Aluminum heads, on the other hand, should have no more than .002˝ (.05 mm) out-of-flat in any direction. On a performance engine, the flatter the better.

If the face of an aluminum head is warped, don't assume the only way to straighten it is to grind metal off the face until it is flat again. The whole head is warped. If the head has one or two overhead camshafts, the cam bores will also be misaligned in most cases. The best fix here is to straighten the head BEFORE it is resurfaced. This can greatly reduce or possibly even eliminate the need to remove more than a couple thousandths of metal.

Aluminum heads can be straightened by counter shimming the head on a heavy steel plate (place shims under either end of the head to offset the amount of distortion), clamping it down, then heating it in an oven to about 425° F for several hours, then letting it slow cool. The goal is to get the cam bores straight. Once they are in alignment, chances are the face of the head will be reasonably flat, too, and require minimal machining to refinish the surface.

Another method for straightening aluminum heads is to use a torch to head the top of the head, starting in the center and working towards the ends. The trick here is to keep the head temperature under 500° F to prevent softening the head too much.

Taking Too Much Metal

A head or block with a depression in the surface, or a surface that is out-of-flat can be made flat again by simply increasing the depth of cut when the part is resurfaced. The rule here is to always remove the LEAST amount of metal that's necessary to restore flatness. Remove too much metal and you could end up with problems.

Excessive milling reduces the volume of the combustion chambers and increases compression, possibly to the point where detonation may become an issue even with higher-octane fuel. On overhead cam engines, milling too much metal off the face of the head changes the installed height of the head and retards cam timing. On

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a pushrod head, it will alter the valve train geometry and may require corrections in the length of the pushrods. The only way to restore lost head height and combustion chamber volume is to use a copper or steel head shim with the head gasket, or replace the head.

Don't 'Make Do' With Outdated Equipment

Extremely smooth finishes require high quality resurfacing equipment to achieve really low Ra numbers. It doesn't matter if you use carbide, CBN or PCD tool bits to resurface a head as long as you use the correct feed rate and speed – and the equipment is rigid enough to hold the cutter steady so the tool bit doesn't lift or chatter when it makes in interrupted cut.

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.

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 .0001˝!

The Wrong Tools

Though the experts recommend using PCD on aluminum and CBN on cast iron, many shops find CBN works fine on both types of metals and eliminates the need to change tooling when resurfacing different types of heads.

CBN may not be the best choice for milling aluminum because aluminum tends to stick to CBN and leave a smeared finish. Even so, there is a way to prevent this from happening: just spray a lubricant on the surface or the cutter. According to one source, the absolute best lubricant to use for this purpose is olive oil. Only a little is needed, and it's non-toxic, doesn't stink and is relatively inexpensive.

PCD works better on aluminum than CBN (and costs about the same), but PCD is not recommended for resurfacing cast iron heads or blocks because diamond gets too hot at high cutting speeds, reacts chemically with iron and breaks down. CBN can handle higher temperatures than PCD, and dissipates heat about four times faster than silicon carbide or aluminum oxide, making it a good choice for high speed resurfacing.

Something else that must be considered when using CBN to resurface heads and blocks is the 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).

Trying To Get Too Much From A Bit

CBN and PCD last a lot longer than carbide, but they don't last forever. One common mistake that's made is trying to cut too many heads or blocks with the same edge. If you are using a CBN button for resurfacing, you should rotate the button about 5 degrees after 20 to 30 heads to maintain an optimum cutting surface.

Rotating the button just a little bit when it starts to get noisy will expose a fresh edge and reduce the risk of chipping the button or wearing it too far. Buttons with a beveled edge can be relapped to restore the edge if they are not too badly worn. But if the button has lost too much of its edge, the only option is to replace it with a new one.

Trying To Resurface Rusty Heads

Iron oxide on a cast iron head will kill the life of a tool insert. The same goes for hard calcium deposits in water jacket openings. The cutter tool bit can also pick up this debris and drag it across the surface, leaving a groove. The mistake to avoid here is trying to resurface a dirty head that has not been properly cleaned. Remove all of the rust and calcium BEFORE the head is resurfaced. This can be done with chemical cleaners, a shot blast cleaner or a tumbler.

Lack Of Maintenance

You can't expect to get high quality surface finishes if you've neglected your equipment. Dry milling doesn't require any coolant so there's no coolant to maintain. But the resurfacer itself needs to be set up correctly and checked periodically to make sure it is still in proper alignment.

Resurfacers need to be leveled with an accurate level. Place the level on the ways of the machine or on the table-mounting surface. Adjust the machine front to back as well as left to right until it is perfectly level in all directions.

Next, check the table to make sure it is running true. Attach a magnetic dial indicator in the cutter head and traverse the left and right to see if the table is true to the wheel head. You should see no more than .002˝ of variation across the entire traverse of the table. If the table is not running true, contact the equipment supplier for the correction procedure.

Also check the parallels, using a dial indicator and granite plate to make sure they are straight. If the parallels have runout, the resurfacer won't cut straight. The cylinder head and block rollover clamps also need to be checked to make sure everything is straight.

If the cutter head has more than one tool bit, all must be set to equal height (no more than .0005˝ variation) to get consistent results. **MEPG**