VALVES & VALVE SEATS

Valve seats and valves are an integral combination in today's engines and should always be thought of as a team. The seats draw heat away from the valves and conduct it into the cylinder head. This provides most of the cooling that the valves receive and is absolutely critical with exhaust valves.

Anything that interferes with the seat's ability to cool the valves (such as a loose fit or deposits between the seat and its counterbore) can lead to premature valve failure and expensive comebacks.

Replacing valve seats is one of those basic jobs that is often necessary when rebuilding aluminum or cast iron heads with cracked, damaged or badly worn seats. But there's a lot more to replacing a valve seat than simply prying out the old one and driving in a new one. Replacing a seat involves a number of decisions and steps, all of which affect the outcome of the repair job.

Is the head cast iron with integral seats? It will need to be machined to replace the seat. If the head is aluminum, the seat counterbore may have to be machined to accept an oversize seat if the bore is loose, deformed or damaged. Either way, you'll need to figure the amount of interference that is required for the new seat before cutting the head on a seat-and-guide machine.

A seat may also have to be replaced if it's loose or if the cylinder head is cracked and requires welding in the combustion chamber area (the seats should be removed prior to welding).

There are a variety of opinions about the right way and wrong way to replace valve seats, especially regarding the amount of interference fit that is required to keep seats in aluminum heads. A common fear expressed by many engine rebuilders is the possibility of seats falling out, particularly in aluminum heads where the difference in coefficients of thermal expansion between the head and seats can cause seats to loosen if the head overheats.

The seat alloy and hardness must also be matched to the application and compatible with the type of valves that are installed in the engine. Again, there are often differences of opinion regarding the selection and use of various seat materials.

Nonintegral valve seats can fail for a number of reasons. Most of the seats that end up being replaced are either cracked or too worn to be reground or remachined. Seats can crack from thermal stress (engine overheating usually), thermal shock (a sudden and rapid change in operating temperature) or mechanical stress (detonation, excessive valve lash that results in severe pounding, etc.).

A small amount of valve recession results from normal high mileage wear, but it can also occur when unleaded gasoline or a "dry" fuel such as propane or natural gas is used in an engine that isn't equipped with hard seats. Recession takes place when the seats get hot and microscopic welds form between the valve face and seat.

Every time the valve opens, tiny chunks of metal are torn away and blown out the exhaust. Over time, the seat is gradually eaten away and the valve slowly sinks deeper and deeper into the head. Eventually the lash in the valvetrain closes up and prevents the valve from seating. This causes the valve to overheat and burn. Compression is lost and the engine is diagnosed as having a "bad valve." The seat also has to be replaced, but in many instances it may not be recognized as the underlying cause of the failure.

As a rule, a seat should be replaced if the specified installed valve height cannot be achieved without excessive grinding of the valve stem tip (less than .030˝), or if the specified installed spring height can't be achieved using a .060˝ spring shim. This applies to integral valve seats as well as nonintegral seats. The only other alternative to replacing the seat is to install an aftermarket valve that has an oversized head (.030˝). This type of valve rides higher on the seat to compensate for excessive seat wear or machining, and can eliminate the need to replace the seat.

Seat Check

As a rule, most experts recommend replacing OEM valve seats with ones that are of a similar material – except in cases where extra durability is required because of a change in fuels (converting to propane or natural gas, for example), or an engine is being built for racing.

There are a number of different valve seat materials from which engine builders can choose. Many of these materials will work in a wide variety of performance applications while others are designed primarily for special applications such as industrial engines that run dry fuels like propane or natural gas. The only consensus is that different valve seat materials can be used successfully in most performance engines.

What kind of materials are we talking about? Everything from nodular/ductile iron alloys and powder metal steel seats to hard aluminum-copper and bronze alloys, and beryllium copper alloys. Many valve seat suppliers have their own proprietary alloys while others use industry standard alloys. But you don't have to be a metallurgist to appreciate the differences between some of these materials.

A valve seat must do several things. It must support and seal the valve when the valve closes, it must cool the valve, and it must resist wear and recession. Consequently, a performance valve seat material should provide a certain amount of dampening to help cushion the valve when it closes at high rpm. Very hard materials, especially on the intake side, are not the best choice here because intake valves tend to be larger, heavier and close at faster rates than exhaust valves. The wilder the cam profile, the more pounding the valve and seat undergo at high rpm.

Many late model domestic and import engines have seats that are made of powder metal. These types of seats are very hard and durable, so they typically show little wear at high mileages. Consequently, the seats may need little work when the cylinder head is rebuilt.

One difference between cast alloy seats and powder metal seats is the way the seats are manufactured. Cast alloy seats are made by melting and mixing different metals together so they combine chemically. The molten soup is then poured into a mold and cast to shape. The rate of cooling and subsequent heat treatment of the metal determines its microstructure, hardness, strength and other physical properties.

Powder metal seats, by comparison, are made by mixing together various dry metal powders such as iron, tungsten carbide, molybdenum, chromium, vanadium, nickel, manganese, silicon, copper, etc.), pressing the mixed powders into a die, then subjecting the die to high heat and pressure (a process called "sintering"). This causes the powders to bond together and form a solid composite matrix with very uniform and consistent properties.

One of the advantages of powder metal sintering is that materials that are difficult or impossible to mix together in a molten state can be blended together and bonded to create totally unique materials. For example, in powder metal bushings and ball joints, graphite is combined with steel to make the material "self-lubricating."

Another advantage of the powder metal process is that parts can be manufactured very close to final tolerances, reducing the amount of machining that's needed to finish the part to size. This lowers production costs and boosts manufacturing productivity.

The main reason why vehicle manufacturers have switched from cast alloy seats to powder metal seat inserts is to extend durability. Most late model engines have to be emissions-certified to 150,000 miles or higher depending on the application and model year. If the valve seats can't go the distance during durability testing, the vehicle manufacturer can't certify the engine.

Powder metal seats are very good at handling thermal stress as well as impact stress, and typically show minimal wear after tens of thousands of miles of use. The homogeneous consistency of a powder metal seat also improves heat transfer, which is good for the valves, too. Powder metal seats also tend to experience less micro-welding between the seat and valve even at high combustion temperatures, which helps extend the life of both components.

Cool It

As stated earlier, exhaust valves run much hotter than intake valves so cooling is more critical on the exhaust side. Heat transfer from the valve to the seat provides cooling during the time when the valve is closed, and by conduction up through the valve stem and into the valve guide and head.

It's more noticeable in performance engines. Titanium valves do not shed heat as quickly as stainless steel valves, so the tradeoff for switching from steel to titanium to save weight is often hotter running valves. The higher the temperature of the exhaust valve, the greater the risk of the valve causing a preignition or detonation problem. There is also increased risk of the valve burning. That's why many suppliers of titanium valves recommend seat materials such as beryllium copper.

For racing applications using either stainless steel or titanium exhaust valves, some suppliers recommend a sintered valve seat insert, which includes a blend of finely dispersed tungsten carbide in a matrix of tempered M22 tool steel and special alloy iron particles. These powder metal seats have a very uniform microstructure, and are highly machinable. Because powder metal seats work harden as they age, they don't have to be as hard initially to provide good long term durability, and the self-lubricating qualities of the material allows it to handle a wide variety of fuels, including unleaded and leaded gasoline, straight alcohol, nitrous oxide and nitro methane. A shot of nitrous will cause combustion temperatures to soar, but the dose usually doesn't last long enough to have any detrimental effect on the seats.

The next step up is a high alloy seat material, for applications where high heat resistance is required, such as a propane or natural gas fired stationary engine but also for high performance engines, heavy-duty and extreme duty engines where longevity is a must. Seats are made out of a high speed tungsten carbide tool steel, which gives it ceramic-like characteristics for extreme temperature resistance.

Conversely, because they tend to run much cooler than exhaust valves, low alloy seats work well with intake valves in performance applications, even in such extreme cases as offshore racing boats that run for hours on end.

Powder metal seats tend to be very hard (up to Rockwell 40 to 50) and can be difficult to machine.

Refinishing powder metal seats requires a slightly different touch than cast alloy seats as a rule. If grinding, you typically need harder stones (ruby, nickel-chrome or stellite). If cutting, you need a good sharp carbide cutter and to slow it down a bit.

The one thing you want to avoid when cutting powder metal is any chatter on the seat surface. Powder metal seats can accept a high quality finish, but the finish is only as good as the tools that are used to cut them.

Just as there are a variety of valve seats to choose from, there are a variety of machines for installing, repairing and customizing those seats. From the relatively basic "no-frills" models to CNC-operated units which can cut valve seat profiles that were previously impossible to imagine, to "do it right" in today's competitive market, you need up-to-date equipment that can handle all the complexities of today's engines.

Diamond valve guide hones have become popular as a means of refinishing valve guides, and work well on harder guide materials such as silicon bronze and powder metal. Solid carbide valve guide reamers are another option.

For refacing valve seats, 3-angle cutters made of tungsten carbide are still the industry standard and deliver excellent results. Apparently no one is making 3-angle cutters out of polycrystalline diamond (PCD) or cubic boron nitride (CBN) for the aftermarket yet, but you can buy triangular PCD and CBN bits for cutting seat pockets and finishing valve seats one angle at a time.

PCD inserts with flat or sharpened 10-degree sides, and negative or positive rake are available for use on nonferrous metals such as aluminum heads and beryllium copper valve seats (for use in performance heads equipped with titanium valves). The PCD bits provide extended life compared to carbide and ceramic bits, and can be used for both roughing and finishing operations. For PCD 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. Triangular valve seat bits are also available in CBN for cutting seats in cast iron heads, and refacing integral valve seats, hardened steel seats and powder metal seats. The recommended cutting speed for CBN is slower, and ranges from 400-1,300 ft/min depending on the application.

The best advice for choosing the right superabrasive for a given machining operation is to ask your tool supplier what is recommended with regard to lubricant or coolant and what cutting speed or grinding speed will produce the best results.

There are a number of different valve seat materials from which to choose. Many of these materials will work in a wide variety of performance applications while others are designed primarily for special applications such as industrial engines that run dry fuels like propane or natural gas.

Welcome To The Machine

There are basically three types of seat and guide machines on the market today. The first type of machine is what is sometimes referred to as a "drill press" machine. This type of seat and guide machine has a solid column for the tooling and the table floats to move from guide to guide.

These are very basic seat and guide machines and, while they may not have the bells and whistles of some of the more advanced machines, their limitations are acceptable to many, especially smaller, machine shops. A small shop that may not be able to justify the more expensive machines and also wouldn't have the volume to be concerned about doing hand grinding and lapping may be ideally suited for such a machine.

Floating table machines offer more vertical travel and often may be more universal, therefore more appealing, to some smaller operations, according to some manufacturers. In some cases, seat and guide machines that also do surfacing are available, so shops can actually get more than one machine for the price of one.

The second type of seat and guide machines is the floating powerhead machine, which is virtually the standard in many engine builders' shops today according to our research. Ranging in price from $25,000-$30,000, these machines keep the cylinder head stationary below a floating powerhead. The powerhead floats above on flat ways, which adjust front-to-back and side-to-side.

The powerhead weighs much less than the cylinder head being machined, so when it is centered (and they all center similarly), the powerhead is floated and centered with the pilot. When the operator lets off the foot pedal to lock it in place, it becomes a very rigid platform.

Many of today's cylinder heads have canted valves in them also, and on an old-style machine the fixture must be relocated and tilted in order to accommodate each one. With new-style seat and guide machines the powerhead itself tilts and can be adjusted for whatever angle you need. Once the powerhead angle is set it is a relatively simple matter to go up and down the line with the same degree of tilt for each valve seat, whether it's 7°, 9° or more. Most new-style machines can accommodate 15° or more.

The third type of seat and guide machine is the live pilot design. There are two types of pilots: live pilots and dead pilots. A dead pilot remains stationary in the guide as the tooling rotates, whereas a live pilot spins with the tooling in the guide. Precision is a must when fitting live pilots into guides or else there could be too much play and result in a seat that isn't concentric.

Today most seat and guide machines use three-blade carbide cutters with three-angles or more built into the cutter itself. These cutters are called form tools and give a very consistent profile and seat width for every seat since it's all built into the tooling. Some manufacturers offer slightly different tooling but the basic principle is the same: a form tool containing built-in angles.

A new style of machine uses a single point cutter spindle to machine valve seats, much like a CNC lathe, which allows an operator to create profiles that would be very difficult to produce with traditional machining methods. According to the manufacturer, the profile is generated by interpolating two axes. The machine calculates the feed and spindle travel for the profile being created and then cuts it using a single point, triangular carbide cutter using just the tip of the point. No pressure is exerted and no plunging is required. This technique allows more complex and longer profiles to be created with a fixed point system, says the manufacturer.

Seat materials today are, say experts, much harder, and so to machine them, spindle speed must often be reduced to as low as 45 rpm in order to cut them properly. Machining technology has improved over the years to the point that today's machines are much more accurate than the older versions, with the ability to hold incredibly close tolerances and offer nearly infinite spindle speed variations. EMPG