

## Getting A Good Seat

The growth in the valve seat insert market can be traced back to the early 1970s when the switch to unleaded fuel took place. Most of the engines in use or that were in core or inventory storage had to have replacement seats inserted in the exhaust side to prevent valve seat recession that occurred when the engines were run on unleaded gas.

Many people think that lead was a lubricant and somehow prevented wear. In fact, the lead caused a chemical reaction with the cast iron of the cylinder head and the stainless steel valve, forming oxides and halides that locally hardened the wear surfaces. This local hardening is what actually helped to prevent seat recession.

During the changeover period, it was not uncommon for a vehicle that had been initially run on leaded fuel to be switched to unleaded. The initial use of leaded fuel had created the local hardening required and the switch to unleaded created no problems. However, if these same heads were then reconditioned, the machine shop would machine away the protective layers and seat recession would occur very rapidly, sometimes in as little as 3,000 miles.

The OEMs used an induction hardening technique to locally harden the valve seat areas. This process was supposed to produce a hardness depth of around .070", but in many cases it was found to not be deep enough to allow for re-machining during head rebuilding. These early unleaded fuel heads also needed to have exhaust seat inserts fitted to them when they were rebuilt. The growth continues today in demand for rebuilt cylinder heads, especially with the extensive use of aluminum. With the exception of diesels and truck engines, almost all cylinder heads are now produced in aluminum. These heads have inserts already fitted at the factory; this has contributed to the growth in the seat insert market at the OEM level.

When the time arrives for these aluminum heads to be rebuilt, they are often cracked around the valve pocket areas; the factory inserts must be removed to weld up the cracks. New inserts are usually then required to complete the repair process. All of these changes have contributed to a replacement valve seat market that is estimated to be about 7 million units in North America alone.

### Valve seat materials

The growth in the OEM seat market has led to the widespread use of powder metallurgy to produce inserts in large volumes. Powder met itself allows a greater variety of material "cocktails" to be produced.

Some of these are engine specific and can almost exactly replicate the heat transfer characteristics of the parent metal of the cylinder head. In most cases a replacement seat insert is not offered through the OEM service organizations as the replacement of seats is not considered an approved service procedure. The use of powder met demands very large production runs to justify the tooling costs, but it does produce a part that is very close to finished size. Very often there is little extra machining required after installation to complete the job.

This lack of machining has led to the use of some very hard alloys that are extremely difficult to re-machine during the head rebuilding process. In fact some of these latest alloys work-harden after one or two turns of the cutter blade, blunting the cutter almost immediately. In most passenger car type heads running on gasoline, these seats are overkill and can be replaced with a material with much more machinability.

The volume requirement of powder met has so far precluded the use of that technology for most of the replacement seat market. All of the companies supplying the aftermarket offer individually cast replacement seat inserts in varying grades of materials and sizes to suit individual applications. The lower grade materials are normally iron-based alloys that are perfectly capable of withstanding the heat and corrosion in today's passenger car engines.

These alloys are commonly at or around the composition of cast XB. This material offers a good compromise of machinability with good strength and corrosion resistance at a reasonable cost. Lesser materials are available and can give good service provided they are used in the correct application. The cast XB type materials can be used in passenger car, light truck and even some diesel engines, and will give excellent service. Typically, these alloys contain about 20% chromium and 1.5% to 2% nickel and are referred to as "hard seats" in the industry. Their hardness is about 40 HRC at room temperature; most will work-harden in use to about 45 HRC or higher after a few thousand miles.

High output diesels and gaseous fuel engines require upgraded materials to provide good service life. These upgraded materials are often nickel- or cobalt-based and come with a corresponding increase in cost. The composition of these nickel-based alloys is about SAE610b, numbers 11, 12 or 13 compositions. These seats are capable of withstanding higher operating temperatures and higher levels of corrosion found in LPG type engines. Gasoline leaves behind an ash content that acts as a lubricant between the valve face and seat insert. LPG type fuels burn very cleanly and this ash content is missing. Severe wear will take place if the correct grade of material is not used

in LPG engines. Very often the valve material must also be changed to provide good service life in these applications. The last series of materials are the cobalt- or stellite-based alloys which are normally application specific. A good example of this is the Cummins K Series engines. The intake valve in the Premium #1 engine is made from Tribaloy and must be run with a Tribaloy seat insert to give the best service.

These alloys have hardness values around 50 to 55 HRC and maintain higher hardness at elevated operating temperatures. They are also very abrasion resistant and cost more money to produce. They contain about 30% chromium and typically would be around the composition of SAE610b, number 14, which is also known as Stellite #3. These seats are normally the hardest to machine of all the seat alloys used in the replacement market. It is no longer recommended to use plain cast iron for any valve seat application in today's engines. Most machine shops fit seats by size. It is not uncommon to see old cast iron seats that come back for warranty because they were still on the customer's shelf and were installed by mistake. Non-applicable, old cast iron seat inventories should be thrown out to avoid such problems.

### **Press fits and surface finishes**

The powder met OEM seats that we discussed earlier are often made of a material that closely matches the expansion rate of the parent material it is going to be installed in. For this reason they often have press fits of about .003", but can be as low as .002". The replacement cast seats, however, need varying press fits to prevent them from falling out during heat soaks.

Most aftermarket seats need about .005" press when installed in iron heads and about .007" press when installed in aluminum heads. Seat suppliers usually build the required press fit into the O.D. of the seat. A 1.500" O.D. seat will measure 1.505" for cast iron applications and 1.507" for aluminum heads. This is why it is best to consult your seat suppliers catalog and use the correct part number listed for that specific application.

Always use the press fit recommended by your seat supplier not the value listed in OEM manuals. Selecting a seat by size only could create a problem in obtaining the correct interference fit. The light press on some OEM seats can create problems when the heads are cleaned in ovens. If the temperature is not closely controlled the OEM seats can fall out during the heating process or loosen to create problems later.

Many rebuilders find that aluminum heads can be oven cleaned with the head upside down to prevent these type of problems from

occurring. Most seats are finished on the O.D. to about a 15 Ra surface finish. The finish in the counterbore should be equally smooth and round to within .001" T.I.R. This will ensure good contact area and excellent heat transfer properties for the valve to operate against.

### **Seat cutting techniques**

More and more shops are changing to seat cutting equipment to replace their older grinding systems. To ensure good tool life with these systems it is necessary to keep close control over feed and speed rates wherever possible. The spindle speed should be adjusted from intake to exhaust valves especially where large diameter differences are involved. The cutting speed increases with the increase in the diameter from the exhaust to the intake side.

Generally speaking, uncoated carbide inserts work best for seat inserts. A sharp cutting edge (no hone) on the uncoated carbide will provide lower cutting forces overall. Although C2 grade carbide can provide satisfactory results, our research suggests that C4 carbide will provide the best overall tool life and process flexibility. Check with your tool supplier for availability of both these grades.

Carbides used for steel (grades C5 to C8) do not work well with valve seat insert materials. If ceramics can be obtained they will offer increased productivity, but they are more fragile and need more careful handling. Cermet cutters also will provide excellent results on iron-based materials. Chart 1 contains recommended feed and speed rates for the different seat materials and different carbide grades.

Cutting speeds are in feet per minute. Feed speeds are in inches per revolution.

To use the above information you first need to know your carbide grade. Then the formula for calculating cutter rpm is:

Surface Speed x 12 / 3.142 / Seat Diameter (inches) = RPM.

To use the above formula assume a seat with a 1.500" I.D. and a C2 grade cutter. The material is iron-based. The calculation would look like this:

$200 \text{ (feet/min)} \times 12 / 3.142 / 1.5 = 509 \text{ RPM.}$

This means that the C2 cutter should run at about 500 rpm on iron-based materials with a 1.5" cutting diameter. From this it can be seen that larger diameter seats require a slower spindle speed to maintain the correct cutting rate. It should also be noted that the harder the

material the slower the surface speed required. If your machine requires you to provide inches per minute of feed rate, the formula to calculate it looks like this:

Feed Rate (inches per rev) x Spindle RPM = Inches per Minute.

Using the same example as above, this works out to: .003 (inches per rev) x 500 RPM = 1.5 Inches per Minute.

The speeds and feeds listed above should be used as a guide because of differences in carbides. Your machine may require some fine tuning, but normally you will end up pretty close to the above values.

### **Accuracy requirements**

There are three main requirements to be aware of, i.e., seat width, seat angle and seat runout.

**The seat width** is important because about 70% of heat transferred from a valve goes out through the seat contact area. The old rule of thumb used to be to try to maintain a seat width of about .070". Today's engines, however, have valves that are so thin it is impossible to locate a seat that wide on the valve face. The little Subaru Justy engine's intake valve seat width requirement is only .020" to .040". It is important to remember that valve seat width problems show up on the valve and rarely burn up the seat.

**If a seat is installed but never cut afterwards.** The end result of this error was a burnt valve that was returned for a warranty claim. A list of valve seat contact width requirements is available from S.B. International, Nashville, TN, free of charge.

**The seat angle is also very important.** By far, more mistakes are made on seat angles on the 6.9/7.3L Navistar than any other engine. The mistake made is to cut the exhaust seat at 30° instead of 37.5°. The result is a fine line contact point that is guaranteed to burn the valve out quickly. Rebuilders should also keep in mind that tool holders wear more than is recognized, and then allow the cutter to tip during operation. The runout requirement is generally between .001" and .002". The larger the valve head the more runout allowed.

Excessive runout will eventually break the valve head off at the overhead radius due to the flexing that occurs every time the valve opens and closes against the seat. The most common causes of excessive runout are a loose fitting pilot and the condition of the machine spindle bearings.

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