

Selecting Valve Seats for Gas and Diesel Engines

By Larry Carley

Hard working diesel engines, performance engines, and engines that run on dry fuels such as propane or natural gas produce a lot of heat in the combustion chamber and often require valve seats that are harder and more heat-resistant. Stellite, chromium, cobalt, tungsten and nickel alloy valve seats are commonly used for such high heat applications as are tool-steel valve seats. Beryllium-copper or copper-nickel alloy seats are often used in racing applications, typically with lightweight titanium valves.

Average combustion temperatures in a street performance engine can range from 1,400 to 1,700 degrees F. Nickel alloy cast seats can usually handle 1,400 degrees F with no problem, while cobalt is good for up to 1,650 to 1,700 degrees F. With nitrous oxide, temperatures can soar to 4,400 degrees F, which can make some seats become hard and brittle. This increases the risk of seat cracking and failure.

For ordinary passenger car and light truck engines, however, temperatures are lower so iron alloy valve seats are perfectly adequate. Iron alloys are less expensive and easier to machine than hard, high temperature alloys. But in recent years, powder metal seats have become the norm for most original equipment passenger car and light truck gasoline engine applications.

Powder metal valve seats are very different from cast alloy seats. Powder metal seats are made by mixing various metal powders and then pressing the powder under extremely high pressure (up to 100 tons!) into a mold. The seat is then baked at high temperature to sinter (partially melt) the ingredients so they stick together and form a homogeneous matrix. The end result is a valve seat that has very consistent and uniform properties, and requires minimal finish machining.

The neat thing about powder metal technology is that you can combine various ingredients that would not normally mix together if you were trying to create a cast alloy seat. Consequently, solid lubricants can be added to the mixture to improve machinability and wear resistance. What's more, the powder can be blended differently for different types of applications. Infusing the mix with copper, for example, can improve the seat's ability to conduct heat for high heat applications such as dry fuel engines, marine engines or motorcycle engines.

Powder metal seats often show little wear at high mileage. Consequently, if you are rebuilding a head with powder metal seats, the seats may only need a light touch-up. But because of the work hardening that occurs with powder metal seats, they can be difficult to machine.

The naturally smooth exterior surface finish of a powder metal seat also improves the metal-to-metal contact between the seat and its counterbore in the cylinder head for better thermal conduction. Adding a radius to the outside corner also makes installation easier. The powder metal matrix also has a certain amount of elasticity that helps retain the seat in the head with less interference fit. That's why many original equipment powder metal seats are installed in aluminum heads with only .002" to .003" of interference fit.

Powder Metal Seats in Diesels

In recent years, powder metal seats are starting to replace some of the hard alloy seats that have been commonly used in diesel engines, particularly in Europe. Most heavy-duty diesel seats, however, are still made of cobalt, iron or nickel based alloys.

Brian Bender of S. B. International in Nashville, Tennessee, says they are working with a vendor to develop a new iron-based alloy seat for diesel engines that are originally equipped with powder metal seats. "Stellite- and cobalt-based seats are very durable, but are also very expensive. We have patented iron-based alloys that work just as well in such applications, including Caterpillar, Cummins, Detroit Diesel, Mack, Navistar and John Deere diesel engines.

Bender says original equipment powder metal seats in gasoline engines can be replaced with the same, or with their Silichrome XB iron-based alloy seats.

The industry has seen a dramatic increase in the use of powder metal valve seats. Yet, many engine builders are asking for a more traditional iron alloy replacement seat because of the difficulty of machining high mileage powder metal seats. For most automotive gasoline engine applications, an iron-based alloy will work fine.

Some aftermarket suppliers are seeing more demand for unusually large outside diameter valve seats, such as four-inch seats for industrial engine applications. Such large seats require a special centrifugal casting process to assure there is no porosity in the metal.

A sobering fact of the matter in all of this is that premium-alloy valve seat prices throughout the industry have been skyrocketing due to the rising cost of nickel. It's a problem that is affecting all valve seat suppliers.

Powder Metal Seat Installation

If you are replacing powder metal valve seats with the same in a late model gasoline engine, several seat suppliers say you should not have to preheat the cylinder head or chill the seats prior to installation. Most powder metal seats have a radius on the outside corner and do not require as much interference fit as iron alloy cast seats. Most can also be driven in dry, so a lubricant isn't needed.

The amount of interference fit that's required may be slightly more on a rebuilt engine than a new engine, however, due to wear and distortion in the seat counterbore. If the OEM seats were installed with .003" of interference, it may be necessary to go to .0045" to .005" of interference to assure a secure fit. Peening should not be necessary, and the use of any type of sealer is not recommended with powder metal seats because it may interfere with good heat transfer between the seat and head.

The valve guides should always be done first to assure the seat will be concentric with the centerline of the valve. The seat can then be finished after it has been pressed in using conventional valve refacing equipment. New powder metal seats typically have a hardness of

around Rockwell C 25, so they should cut normally with little or no chatter. Finish the seat angle and width to specifications.

Something else to keep in mind when replacing seats is that any head straightening, crack repairs or welding should be completed before you cut the counterbores and install new seats. The process of straightening a head can often push seats out of round and create misalignment between the seats and guides.

Alloy Valve Seat Installation

How much interference fit is necessary to keep an alloy seat in place? It depends on the application and who you ask. A seat installed in a brand new cylinder head with accurately cut, round smooth counterbores will require less interference than a seat installed in a high mileage head. Removing old seats from a head will often distort the hole requiring slightly more interference when a new seat is installed.

If the counterbore in the head is damaged and has to be machined to accept an oversize seat, the amount of interference fit may be dictated by the size of your counterbore cutter and the availability of a specific oversized seat from your valve seat supplier. For example, if you are machining a counterbore with a 1-5/8" (1.625") cutter, and the replacement seat comes with a 1.630" outside diameter, the interference fit when the seat is installed will be .005".

Make sure you understand how your valve seat supplier indicates their actual seat O.D. dimensions so you get the correct-sized seat and the correct amount of interference fit.

Recommendations for interference fit are often dictated by the type of casting (aluminum or cast iron) as well as the application. Engine builders should use .0045" to .005" of interference fit when installing alloy or powder metal valve seats in cast iron heads, and .007" of interference fit when installing seats in aluminum heads.

The use of anaerobic sealer on valve seats should not be necessary. The interference fit should be sufficient to keep the seats in place. Also, if the hole is round and smooth, there should be adequate metal-to-metal contact between the seat and head for good heat transfer.

Those who use some type of sealer on the seats say the sealer helps fill the gaps between the seat and head to improve heat transfer. Those who oppose the use of sealer say anything between the seat and head can form a barrier that may slow heat transfer from the seat to the head.

Some tips for ensuring good contact between the valve seat and head is to use seats that have a radius or bevel on the outside edge rather than a square edge. This will reduce the risk of galling the counterbore when the seat is driven in. Also, using a lubricant can make for a smoother installation. Preheating the head slightly (160 to 180 degrees F, but no higher) and chilling the seats in a freezer prior to installation can also make the installation go easier while reducing the risk of damaging the counterbore.

Seat Refinishing

Once the seats have been installed and the guides have been replaced, relined, or reamed to accept valves with oversized stems, seat concentricity should be checked with a dial indicator. Seats must be as concentric as possible to ensure a vacuum-tight seal with the valves, and to prevent valve flexing, which can cause metal fatigue and valve failure. A good number to aim for is less than .001" of runout per inch of seat diameter. Less is always best.

The best way to check concentricity is with a runout gauge. Pulling vacuum on the valve port with the valve in place is another method for checking the mating of the seat and valve. But the ability to hold vacuum is no guarantee of concentricity in itself. That's why both methods should be used to check the quality of your work.

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 turning at the optimum speed for the type of seat that is being cut. According to S.B. International, increasing the spindle speed up to 50 percent when cutting powder metal seats will give the best results. They recommend a cutting speed of 350 to 400 rpm to achieve the best surface finish.

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 mirror-like finish, but the finish is only as good as the tools that are used to cut them. If your valve guide pilot has too much play for accurate valve work, you won't get a good finish on the valve seats. For performance engine work, the pilot-to-guide clearance should be .0002" or less. If it is up around .0004", there will be too much play for accurate machining. One way to reduce play is to use a high pressure lubricant on your pilot.

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