

Extending Valve Life

Understanding why valves fail can prevent a lot of costly mistakes from happening more than once, especially when it comes to today's hotter running, tighter tolerance engines. Most manufacturers of valves operate technical telephone services, and all have received that caller who opens the conversation by saying, "Your valve ruined my engine; when are you going to pay to fix it?"

However, much as the rebuilder or vehicle owner might like to lay blame on the manufacturer for providing a bad product, it isn't always the reason for valve failure. Let's examine a typical case where "your valve ruined my engine" turns out to be a call from the owner of a truck which recently had its cylinder heads rebuilt. The truck ran 500 miles before a valve stem seized in a guide. The subsequent collision with the piston caused the rod to let go and exit the block on the passenger side.

Here's how the conversation might go: "Who rebuilt the heads and installed the valve?," asks the manufacturer's technical service representative. "Charlie did," the caller replies. "He's my buddy who owns the machine shop next door." The caller goes on to say that when Charlie took the cylinder head apart he ordered another new valve to replace the broken one. When this valve came in, he measured the valve stem and found it was "fat in the middle."

This was supposedly why the valve seized and the caller wanted the manufacturer to pay on the basis of Charlie's observations. However, the caller didn't know "how fat it was."

Well, the manufacturer's representative had seen every re-turned valve and couldn't remember a fat one. It was time to get back to basics. It was unlikely that the valve was fat when it was installed. However, it is possible that it could have become fat when subjected to excessive operating temperatures. It may have also been installed with insufficient clearance in the first place. Let's look at the importance of clearances and the effect of temperature on them.

Running clearances aren't all the same

Cold stem-to-guide clearances are set by the OE engine designer who pays close attention to the expansion of the valve material, the cylinder operating temperature and the rate of heat transfer out of the head to the water jacket. If a shop assumes that all valves run the same running clearances, they can get into a lot of problems, especially with late-model aluminum heads.

The 350 GM head specifications call for clearances of 0.0012" to 0.0027" on the intake valve and 0.0017" to 0.0032" on the exhaust. The 2.2L Chrysler needs 0.0009" to 0.0026" on the intake and 0.003" to 0.0047" on the exhaust. The reason for these rather large discrepancies is that they are the result of two separate manufacturing tolerances. These are the factory production tolerances on the valve stems and the guide hole sizes. The difference in the required minimum clearance between the GM intake and the GM exhaust valve (0.0005") is due to the change in operating temperatures between the two. This extra required clearance is built into the exhaust valve stem during manufacture and does not require any extra effort by the rebuilder. The guides should be reamed to the same size for both intake and exhaust and the extra required clearance will be designed in to the valve stem where the engine calls for it. On some engines this extra exhaust stem clearance can cause oil consumption problems and emission concerns. One current popular design fix for this concern is to taper the valve stem so that the stem diameter at the port end of the guide is 0.001" smaller than the diameter at the valve cover end.

Lets get theoretical for a moment and examine what happens to the valve at engine operating temperatures. We will use the following formula:

Thermal Expansion = Stem Diameter x Temperature x Coefficient of Thermal Expansion (CTE).

We need to use the following data:

- * Stem Diameter at the groove end = 0.3400";
- * Stem Diameter at the head end = 0.3390";
- * Temperature at groove end = 200°F;
- * Temperature at head end = 500°F; and
- * CTE for 21-2N Stainless = 10.22×10^{-6} .

Using our formula, the equation for the groove end expansion is: $0.340" \times 200 \times 0.00001022 = 0.0006936"$. The head end expansion equation is: $0.399" \times 500 \times 0.00001022 = 0.0017289"$. It can be seen that the head end expands almost exactly 0.001" more than the stem end, hence the built-in taper. Of course this is a theoretical example and assumes that heat transfer rates are the same throughout the length of the guide. The 350 GM exhaust was tapered in the late 1980s and all new valves supplied from quality manufacturers reflect this change today. The customer caller believed his valves should have been thin, not fat. So far we've only looked at one basic fact; let's look at another. If we assume that the clearance was correct, then obviously the valve got too hot and overexpanded.

Let's look at how the heat gets into and out of the valve during

operation.

The majority of the heat transferring out of the valve goes through the seat contact area. This is important when you realize that valve operating temperatures can reach 1500°F under heavy load. The seat width is very influential to heat transfer and great care should be taken when selecting seat cutters.

Let's look at some popular four-cylinder engines and some imports and compare seat width requirements. In general, it can be stated that seat width for domestic heads should be about 0.075" and about 0.055" for Toyota and Isuzu. Seat width requirements depend on the number of valves per combustion chamber, the rate of heat transfer into the water jacket and the material the valves are made of. Some import valve head thicknesses are so thin that it is almost impossible to locate a 0.070" seat on the valve face. These valves' heads are so thin, particularly late model multi-valve Honda heads, that it is impossible to reface them and they must be replaced when worn. These specs illustrate the need to follow OE specs when rebuilding each head. Perhaps the days of generic seat widths have passed. Diesels are especially sensitive to seat width requirements which are generally 0.030" wider than their gasoline counterparts. It is advisable to check seat widths regularly as tooling wears rapidly when used on today's hard seats. Too little seat width will inhibit heat transfer, causing valve overheat problems, face burning and stem galling.

However, that's not the end of the seat width story.

For many years the machinist would cut the seat angle one degree less than the valve face angle to create what was called an "interference angle." The valve face and seat face would then "pound-in" to create a tight seal across its complete width.

Times have changed and this is no longer recommended shop procedure. The use of induction hardening on seats found in cast iron heads, and hard seat inserts in aluminum heads and as replacements in older iron heads, will not allow this pound in to occur. Today the interference angle concept results in seat widths of 0.020" or less with the valve overheat results previously described.

Valves with stellite facings or with heads made from nickel-based super alloys are particularly sensitive to seat angle problems. The special head or facing material is very hard and when combined with a hard seat material is extremely resistant to pound-in. Many times valve overheat occurs well before any appreciable seat face width has been established. So checking seat angles in the head is important, too. But, there are still other factors that can cause galling and valve overheat.

Guide-to-seat runout

Valve guide-to-seat runout is one of those other substantial factors. The ideal runout is, of course, zero. Most engines will function well with 0.001" - 0.002" TIR. Any more than this will affect guide-to-stem clearance as the valve will be operating cocked in the guide. This misalignment reduces clearance at the top of the guide on one side and the bottom of the guide on the opposite side. This will cause stem galling in these areas which may not be enough to hold the valve open, but will cause catastrophic guide failure very quickly.

The use of a port vacuum tester gives no guarantee of guide-to-seat alignment. The guide-to-seat runout can measure as high as 0.006" and the head will still pull vacuum through the ports. The only way to check runout accurately is to use a gauge specifically designed for that purpose. Check with your equipment manufacturer or shop supply house to secure a runout gauge which mounts on a pilot located in the guide bore.

The same factors that affect the machining of the seat also affect the accuracy of the gauge readings. Worn pilots will cause alignment problems and measurement errors. Even carbide pilots wear eventually and should be checked on a regular basis. Tapered pilots will not give an accurate gauge reading and can cause measurement errors exceeding the total runout specifications. The guide hole must be cleaned of all machining debris preferably by using a small brush. Dirt here will offset the pilot causing excessive runout.

In most cases the pilot can be used as a "go/no go" gauge in a production environment. The practice of replacing the pilot with one several tenths smaller, if the correct one will not go in, is to be frowned upon. The pilot is telling you that there is a size problem or that dirt is present, either of which should be corrected, not bypassed.

Cylinder head warpage can also affect valve-to-seat alignment and face contact area.

With the drive to lighten head castings in modern engines, warpage of the valve seat area has become more common. Some of these warpage problems can be created by the installer of the head or the engine. If a head gasket from the wrong model year is installed, coolant holes could be missing. Even wrong heads with the same problem can be fitted. These problems will cause the engine to overheat the cylinders affected by the blockage without necessarily showing up on the temperature gauge. There are also engines that must have the cooling system bled when installed in certain vehicles or the head will overheat. The 2.2L Chrysler is one of these and requires

the removal of a bleed plug from the thermostat housing during radiator filling. Some engines need a special thermostat to be installed or the thermostat to be in a certain position before the cooling system can be filled properly.

Most aluminum head repair involves some degree of crack welding. These cracks normally extend into the water jacket behind the valve seats. If extensive grinding and welding is necessary, care must be taken not to completely weld up the water passages. This can create hot spots behind the seats and prevent proper valve cooling.

The use of torque plates for boring lightweight cylinder blocks is well known. This technique will soon be required for heads too as late model Nissan V-6 heads are produced this way at the factory. Torque plates simulate the stresses and distortion induced in the head when bolted to the cylinder block. It is very likely that torque plate machined heads will not pull vacuum when tested in the untorqued condition. The installation of the wrong valve can also be a reason that the valve shows signs of overheat. In many engines, specific installations require the use of upgraded materials to ensure acceptable service life. The assumption that "one valve fits all" can easily get the rebuilder in trouble.

The 460 Ford truck engine is a good example of this. The introduction of fuel injection in the 1988 model year required the use of a valve with an Inconel head. Inconel is a nickel-based super alloy with good wear properties and higher tensile strength. The early and late valves are virtually identical dimensionally, but if the early valve is installed in a fuel injected engine severe valve face wear will result. This wear will break up the valve face and the valve will exhibit signs of overheat and stem galling.

We can't finish this without looking at the effects of fuel mixtures.

An overheat condition in only one engine cylinder can be caused by a blocked fuel injector, a crack in the intake manifold or an intake manifold gasket leak. A lean condition in all cylinders usually indicates a fuel delivery or mixture adjustment problem. A lean condition in a gas engine overheats the valves causing stem galling. It's not commonly understood that the reverse is true in a LPG/propane-fueled engine; with these fuels a rich condition causes the problems. So, there are many things to check before blaming the valve. Hopefully our analysis of the "fat valve" mystery will help to clarify the factors that can contribute to having valve failure. With this information in hand, the machine shop can help ensure the longevity and the performance of every rebuilt cylinder head.

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