Related Head Gasket and Liner Concerns for Heavy-duty Diesel Engines

BY STEVE SCOTT

A blown head gasket, and occasionally a cracked liner in the heavy-duty diesel engine are not unheard of, but what can these two failures have in common?

Head gaskets are commonly made by bonding layers of metal core and composite materials. The number of layers of each varies by application and manufacturer. As shown in this example, the fire ring is surrounded by a fire wrap. The wire material is formed into a circle and then welded into a ring. The diameter of the wire and the weld are critical. The weld must be able to crush consistently with the ring, and the fire wrap must be flexible enough to crush without fracturing when the cylinder head is installed. Tensile strength, creep relaxation, and crush resistance are all important properties in developing a quality gasket that meets the demands of these heavy-duty applications. There are also MLS, or multi-layer steel gaskets, which are very strong, but are less forgiving of surface imperfections and variances. There are a number of resources available on the internet where you can find more detailed information about gaskets, gasket materials, and designs.

Head gaskets are designed to withstand the demand placed on them for particular applications, but other components and conditions can increase the stress past the breaking point of the gasket. Incorrect liner protrusion, bad spacer plate, too high or too low torque value, torque sequence, timing, poor cooling systems, condition of head bolts, and the so-called “performance enhancement” methods and adjustments are just a few of the many reasons for a head gasket to fail.

So, what can both a failed head gasket and a broken liner flange have in common?

To dimensionally measure a cylinder liner is one thing, but most shops are not equipped to check the cross hatch or hardness of a liner. And, destructive testing is needed to determine the chemistry of the material, case depth of the hardness, and tensile strength. The integrity of the casting, the machining and heat treating processes are all vital to producing a quality liner. Get any of these wrong, and the liner can fail. Induction hardened liners are also susceptible to cracking if they are not handled properly. Dropping them hard enough can start a fracture that may not be evident until after the engine is put back into service.

Many of the Cat engine models are “spacer plated” engines, meaning that on top of the cylinder block is a spacer plate gasket, followed by a spacer plate, then the head gasket, and finally the cylinder head. The liner flange sits directly on the surface of the cylinder block. On non-spacer plated engines, the liner sits down in a counter bore of the block eliminating the need of the spacer plate gasket and spacer plate. “Parent bore” engines do not have replaceable liners, and may be repaired using machined sleeves.

(continued)
Whether the engine is spacer plated or non-spacer plated, one area that doesn’t get enough attention is the surface of the block that supports the liner flange. Journeymen technicians and machinists understand how critical this area is for properly supporting the cylinder liner, and for maintaining the positive seal of the head gasket. As an example, an OE specification for flatness on a Cat 3406 or C15 engine over the entire cylinder block surface must be within 0.10mm (0.004”) and cannot vary more than 0.05mm (0.002”) over any 150mm (6”) to 177mm (7”) section of the block’s surface, depending on the specific application. However, the specification for damage to the liner seat area is not more than .025mm (0.001”) deep in localized areas, and cannot be more the ½ the width of the seat (001” is not very much). In fact, it’s less than the thickness of the spray paint we sprayed on this piece of aluminum.

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The photos below show the top of a worn cylinder block. There’s a noticeable ring around each of the bores. Enlarging the photo shows that this block is in pretty poor shape. (continued)
At a slightly different angle the damage is obvious (see photo at right). It’s well over the .025mm (.001”) in depth and covers more than 50% of the width of the seat for the liner.

Erosion generally destroys the milling marks on the block surface; however, technicians have advised that they have measured blocks that drop off or taper, and the milling marks were still visible. It is always best to measure the block, and not just depend on visual inspection or on the liner protrusion. To help illustrate the point, we took a new cylinder liner and some lapping compound, and worked-rotated the liner on this worn surface just to see how a new liner would contact the block, as shown below.

We were not trying to seat the liner, we just wanted to do enough to see a pattern. After removing the liner, the green arrows shown in the photo (above middle) indicate the width of the worn area from the old-worn out liner flange. The red arrows indicate where the new liner is now making contact. There were also areas where the new liner did not contact the block surface at all.

Unfortunately until the engine is disassembled and the liners are removed from the cylinder block, there’s no way to know the condition of the block surfaces. At this point, the engine owner or repair shop may not be prepared for the added expense and down time to repair the block properly, and may decide to assemble the engine back as it is, which would result in the liner actually sitting on a narrow ridge instead of the liner sitting firmly on a flat surface. If assembled in this condition, the ridge can be enough to support the liner so that the liner protrusion is within the spec range. However, if placed into service in this condition, with the liner not seated firmly, the liner will begin the move, causing wear, then actually drop down reducing the liner protrusion and the clamping force on the fire ring of the head gasket (above right).

Diagrams above left shows the liner is actually sitting on a narrow ridge instead of the liner sitting firmly on a flat surface. If assembled in this condition, the ridge can be enough to support the liner so that the liner protrusion is within the spec range. However, if placed into service in this condition, with the liner not seated firmly, the liner will begin to move (or flex) under the operating forces of the engine. As that movement wears the components together, the liner can actually drop down reducing the liner protrusion and the clamping force on the fire ring of the head gasket. At some point the head gasket may no longer be able to maintain a positive seal and combustion gases would no longer be contained (i.e., through no fault of its own, the head gasket will fail.

In some instances, although the head gasket had failed, the liners and block may have worn together by then. If the liner protrusions is still within specification, and a new head gasket is installed, then the second head gasket may survive…but, if it does, then this it
is NOT an indication that the first head gasket was defective, nor that the second head gasket was of better quality.

Another possible mode of failure is that localized operating forces are greater than the strength of the liner, which causes the liner flange to fracture (see diagram above). In both examples, the part (gasket or liner) failed, but not because these parts are defective.

Something as simple as debris under the liner flange can also result in a failed liner. The photos, top right, show indentations in the bottom of this broken liner flange. The force of the cylinder head torque applied to the liner (that had debris trapped between the cylinder block and liner flange) fractured a section out of the flange.

For a block to be repaired correctly, it may need to be resurfaced and/or machined. If inserts are to be installed, the damaged area of the block is cut out, and the insert is installed rebuilding the liner seat. Often, this can be done with the cylinder block still in the chassis. The quality and fitment of the insert is critical. This is not a time or place to use cheap/low quality parts, nor a job for a machinist that doesn’t know what they are doing. The insert must stand up to the same forces as the original cylinder block, and the fitment must support the insert. If the insert moves or crushes, you're right back in the same situation as before, but with more expenses and less block material to work with for the next repair.

The photos and examples in this article are primarily from Caterpillar 3406 and C15 engines, but these same discussions do apply to many other engine designs. What’s the cause? Whose fault is it? It’s easy to blame the parts, and sometimes it can be a defective part. As we are all aware, engines and parts wear over time, but more often than not a suspected failed part is the result of conditions it was subjected to, and not the root cause. Not taking the time to rebuild an engine properly, or not accurately diagnosing a failure, can be an expensive lesson. And, the added expense and downtime to repair the engine the second time is far more costly. Until an engine is disassembled, there really is no way to know exactly what the conditions are on the inside. Accordingly, time schedules and cost estimates may need revised in order to do the job correctly.

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