CRANKSHAFTS & ENGINE BEARINGS

While some critics might disdainfully suggest that the basic techniques for line boring main and cam bearing bores in engine blocks hasn't changed much in 30 years others say that isn't necessarily a negative.

Sometimes (ever more rarely in the engine building business) you stick with what works. And while the techniques have definitely been improved, the basics of line boring and honing are still pretty familiar.

Because main bore alignment is so important, it should be the first thing that is machined on any engine. And it must be done accurately because most of the other critical dimensions center off the crankshaft.

A horizontal boring bar with cutters mounted on it is inserted into the block and centered in the main bearing or cam bearing bores with support bushings or necessary fixturing. The bar is then turned and advanced to shave metal off the inside of the bores so the inside diameter (ID) of the bores can be resized to the desired dimensions (back to standard size or to oversize).

An alternate method for machining the bores is to use a line hone. A hone uses abrasive stones rather than cutters to remove metal. Line honing typically removes less stock and leaves a smoother finish than line boring, making it well suited for applications where only minimal stock removal is necessary or where a smoother bore finish is desired or required (as in overhead cam cylinder heads where the cam journals have no bearing shells or inserts).

Why Bore?

There are three basic reasons for line boring the main bearing and cam bearing bores in engine blocks. One is to restore worn, out-of-round or damaged bores. If an engine overheats or loses oil pressure, one or more bearings on the crankshaft or camshaft may seize and spin. The resulting damage to the bearing bore must then be repaired by either machining the hole to accept a standard sized bearing or an oversized bearing.

With main bearings, a worn, out-of-round or damaged bore can be restored back to standard ID by grinding or milling the mounting surface of the main caps, bolting the caps back on the block, and then cutting the holes back to their original dimensions.

Reason number two for line boring a block is to restore proper bore alignment – a process often called "align" boring (or honing if a line hone is used instead of a boring bar). As rigid as an engine block might seem, there is actually quite a bit of residual stress in most castings. As a new "green" block ages and undergoes repeated thermal cycles, the residual stresses left over from the original casting process tend to distort and warp the engine. This affects the alignment of the crankshaft and camshaft bores as well as cylinders. Eventually things settle down and the block becomes more or less stable (a "seasoned" block). The bearings as well as the crankshaft and camshaft journals gradually develop wear patterns that compensate for the distortion that has taken place.

Additional warpage can occur if the engine is subjected to extreme stress (like racing) or overheats. If the original crankshaft or camshaft is then replaced without align boring the block, it may bind or cause rapid bearing wear. Likewise, if you're building a high performance engine with close tolerances, you don't want any misalignment in the main bores or cam bores.

The third reason for line boring or honing a block is to correct or change bore centers or bore alignment (as when "blueprinting" a high performance engine). The camshaft and crankshaft should be parallel in the block. If they are not, line boring can correct the misalignment to restore the proper geometry. With performance engines, there may also be a reason to change the centerline of the crankshaft or camshaft slightly to alter the piston or valvetrain geometry.

Line boring will also be required if the original main bearing caps are replaced with stronger aftermarket caps, or the block is being converted from two bolt main caps to four bolt main caps.

But why worry about the bore geometry anyway? Isn't the combination of the block, crank and engine bearings going to provide enough stiffness to keep things where they need to be inside the engine? As it turns out, a little misalignment may be acceptable…but "a little" means VERY little.

A light duty passenger car engine may not be as critical as a high revving performance engine or a hard-working diesel engine. As a rule, most passenger car and light truck engines call for .002˝ or less of misalignment between all the bores, and .001˝ or less misalignment between adjacent main bores. For performance engines, you can reduce these maximum tolerances by half or more.

During engine operation, the the crankshaft rides on a very thin oil wedge only about .00005˝ thick when the engine is running. With tolerances this tight, a properly polished crankshaft is a must. If there are any nodules or burrs poking through the surface of the journal it won't take much to wipe the oil film and cause a bearing failure.

All the force generated by combustion and the downward motion of the pistons is focused on the crank throws. The leverage effect of the force exerted on the crank journals twists the shaft and converts the up-and-down reciprocating motion of the pistons into rotational motion of the crankshaft. This creates torque that the crankshaft uses to turn the flywheel and rest of the drivetrain.

The rotating mass of the crankshaft combined with that of the flywheel and harmonic balancer also creates inertia and momentum that keeps everything spinning. This gives the crankshaft enough energy to push the pistons up on the compression and exhaust strokes, and to pull air and fuel into the cylinders on the intake stroke. It's basic physics in motion and the torque that's produced is what propels every gasoline and diesel-powered vehicle on the road today.

But don't forget the other part of the equation, the engine bearings. Almost delicate pieces, the engine bearings must handle the loads from the crank and rotating assembly. They don't move, they don't create horsepower, but without them, the engines you build wouldn't go very far.

That's why understanding their role in the overall operation of the engine, their design features and how to install them properly is so important. Engine bearings are a relatively inexpensive component compared to the cost of labor and many of the other parts that go into rebuilding an engine, but if one fails or causes a problem that results in a warranty claim, it can prove to be very costly.

Bearings actually have a variety of roles inside an engine, including:

• Supporting the crankshaft and camshaft;

• Limiting the fore and aft movement of the crankshaft (this job belongs to the thrust bearing);

• Reducing friction;

• Lubricating the rotating shafts and connecting rods;

• Providing splash lubrication for the pistons, rings and cylinder walls (which also helps cool the pistons);

• Conducting heat away from the rotating parts; and

• Affecting how much oil pressure the engine develops at idle and higher rpms.

Crank Wear Woes

As vehicles chalk up the miles, their crankshafts take constant pounding. Engine builders have to pay close attention to the condition of the crankshaft because it bears the brunt of the power produced by the engine.

Crankshaft wear is a concern as the miles add up. Journals must be carefully inspected and measured for wear, out-of-roundness, taper, hourglass or barrel distortion. If worn beyond specifications (typically more than .001˝ of specified diameter), the journals must be reground to undersize and polished to restore the bearing surface.

The amount of grinding that can be done on the crankshaft journals is limited by the depth of the case hardening as well as the availability of undersize bearings for the application. Bearings for ten, twenty or even thirty thousandths undersize journals are usually available, but on some passenger car engines ten thousandths may be the limit due to the thin case hardening or the small size of the journals.

When journals are too badly damaged to be reground or are worn beyond a certain limit, the journals can be built back up by hard chroming, metal spraying or welding – if the cost is justified. Welding large diesel and industrial engine cranks often makes sense because of the high cost of replacement cranks, but on most passenger cars and light trucks it's usually much less expensive to replace a worn or damaged crank than to weld and repair the original crank. Welding a crank also requires straightening and redoing the heat treatment, which adds cost. It all boils down to how much a customer is willing to spend on the repairs.

Every piston fires at a different instant in time, which creates vibrations in the crankshaft that grow in magnitude with the number of cylinders, the length of the crankshaft and engine speed. The constant pounding and stress may cause small hairline cracks to develop in and around journals, and particularly around oil holes. That's why crankshafts should always be examined with a magnetic particle inspection machine to check for cracks before they are reused.

Used crankshafts also have to be checked for straightness. The constant loading and pounding combined with wear in the main bearings may result in a bent shaft. Straightness can be checked by placing the ends of the crank in V-blocks and using a dial indicator to measure deflection in the center main bearing as the crank is rotated. If the crank is bent more than about .0015? (specifications will vary depending on bearing clearances), it must be straightened in a hydraulic press or replaced. Forged steel cranks will typically accept more correction than a cast crank. But if the crank is bent beyond the point where it cannot be straightened without weakening or cracking it, it must be replaced.

A trick that continues to grow in popularity, especially among the racing community, is cryogenic treatments for crankshafts. Freezing the crank to minus 300 degrees F helps relieve residual stresses and produces changes in the microstructure of the steel that improve strength and fatigue resistance. It's a popular trick with racers (many of whom believe they're the only ones using the process!) but can also increase durability in any hard-working engine.

Surface finish

Crankshaft grinding is considered by many to be an art form if you are polishing with a manual belt machine. But with today's OEM finishes being extremely smooth and flat, achieving this level is more and more important. There are some good machines available for polishing and micropolishing, no doubt, but they must be used properly.

Customarily with an aftermarket crankshaft, rebuilders mic the journals and go through a two- or three-step polishing process. If the crank proves salvageable and it doesn't have to be ground, some engine builders start with a #400 grit belt, moving to a finer cork belt or other fine grit micropolishing belt for final finish. Other experts say to start with a #320 belt, then go to the #400 before moving on to the finer belt for a few revolutions.

Micropolishing is considered the most advanced way to achieve OEM-level surface finishes on cranks today, but rebuilders who believe that using a very fine belt won't remove material are mistaken. With micropolishing it is possible to consistently remove the peaks and get down closer to the valleys in the surface creating a finer finish with higher load-carrying ability.

Micropolishing machines are the high tech way to achieve OEM-like surface finishes, but costs may put these machines out of reach of smaller shops.

Even though the end goal of line boring has remained constant, some innovations in the recent past have made line boring any-thing but a boring subject.

One of the disadvantages of using a traditional horizontal boring bar is that it tends to sag. This has to be countered by using adequate support so all the bore holes are cut straight and true with no misalignment between holes and no variations in bore size.

One way to eliminate the effects of gravity on the boring bar is to use a vertical boring machine. Rotating the block and bar 90° so the block and bar are straight up and down provides a truer, straighter cut says one manufacturer of this type of equipment. It also saves floor space because the machine has a smaller footprint.

Another way to circumvent the issue of bar sag is to use a 90° right angle cutter attachment on a milling machine. Instead of using a long steel bar to pass single or multiple cutters through the main bores, the 90° cutter is lowered into the space between each main bore, then moved sideways to machine the bore ID. It's sort of like working around a corner. With CNC technology, each hole can be precisely machined to exact dimensions and the centerline of each hole perfectly located and aligned with all the rest. This technique works especially well on large, heavy blocks that may be too long for most boring bars.

Bearing Sizes

Main bearings and rod bearings are typically available in standard size and .010,″ .020″ and .030″ undersizes for passenger car and light truck engines. Undersize means the inside diameter (I.D.) of the bearing is smaller to accommodate a crankshaft that has been reconditioned by grinding the journals to a slightly smaller size.

For bearings to last, crankshaft journals must be smooth (no grooves or roughness), round (no flat spots or eccentricity) and flat (no barrel or taper wear). By the time most engines need a new set of bearings, the crankshaft journals are also worn. This requires removing the crankshaft and regrinding the journals to undersize, or replacing the original crankshaft with a crankshaft kit that includes a reground crankshaft and bearings. Sometimes the original crankshaft can't be reconditioned because the journals have too much wear, a bearing has seized and damaged a journal or because the crankshaft is cracked or broken.

When a crankshaft is reconditioned, it is always checked for cracks (using magnetic particle detection) and wear. If the journals can be reconditioned without removing too much metal, the crank will be ground and the machinist will stamp numbers on one or more counterweight to indicate how much the journals have been ground (10-, 20- or 30-thousandths of an inch undersize).

The main and rod bearings must have the same undersize to fit the crankshaft properly. If standard size bearings are accidentally installed on an undersize crankshaft, the bearings will have way too much clearance, causing a severe drop in oil pressure, excessive bearing noise and rapid bearing failure. Likewise, if undersize bearings are accidentally installed on a crankshaft with standard-size journals, there won't be enough bearing clearance and the bearings will bind causing an immediate failure when an attempt is made to crank or start the engine.

To reduce confusion regarding bearing sizes, most bearings have a number on the back of the shell to indicate the bearing size (standard or undersize). Some bearing manufacturers also add color codes for easier identification. One bearing manufacturer marks its standard sized bearings with a brown color code, .010″ undersize bearings with a black color code, .020″ undersize bearings with a pink color code and .030″ inch undersize bearing with a yellow color code.

The other method requires special measuring equipment. Calipers are used to measure the outside diameter of the crankshaft journal. The inside diameter of the bearings are measured with a dial bore gauge. Rod bearings are measured with the bearings installed in a connecting rod, and main bearings are measured with the bearings installed in a main bore. The inside bore diameter is measured vertically at the center of the bearing shell, not at the bearing parting line (because bearings are slightly eccentric to compensate for crush and loading). The outside diameter of the crankshaft journal is then subtracted from the inside diameter of the bearings to determine the clearance for each set of bearings.

Experienced engine builders know that checking each and every bearing clearance can prevent assembly problems. Crankshaft journals may not always be ground to the exact same undersize, so checking bearing clearances is insurance against these kinds of mistakes.

Recommended oil clearances vary, so the installer should follow the engine manufacturer's recommendations. Some engines today run very tight clearances of .0015″ or less. High-performance applications may require different bearing clearances than unmodified engines. Many engine builders target a clearance range between .0022″ and .0027.″ Clearances greater than .003″ are not normally recommended. Large bearing clearances will lower oil pressure, and may require a high volume oil pump.

What's The Clearance?

The best way to make sure the bearings fit properly is to measure the installed clearances by one of two methods. The easiest method is to use "Plastigage." This is a soft plastic material that is placed between the bearing and journal when the bearing is assembled. A strip of the plastic is positioned lengthwise across the journal below the center of the bearing. The main cap or rod cap is then installed and the fasteners are torqued to specifications to crush the plastic between the bearing and journal. The joint is then disassembled to remove the plastic strip. The crushed width of the plastic strip is then compared to a chart to determine bearing clearance.

An engine should maintain a minimum oil pressure of 10 lbs. per 1,000 rpm.

Some bearings are also available with an oversized outside diameter for reconditioned connecting rods. Many late-model engines have powder metal connecting rods where the parting line between the rod and cap is formed by literally cracking the rod apart rather than cutting and machining the rod and cap.

The advantage with this approach is that it creates a better fit between the cap and rod for better cap alignment. The disadvantage is that a cracked connecting rod cannot be reconditioned by recutting the cap and honing the bore back to standard size. If the bore is distorted, it must be honed to oversize to accept a bearing with a larger outside diameter. Or, the connecting rod must be replaced with a new one.

Bearing Materials

Bearing materials have changed a lot in recent years, and are improving all the time. Most late-model domestic and Asian engines are factory equipped with aluminum alloy bearings. The type of alloy will vary depending on the supplier that manufactures the bearings and the application.

Without getting into a Brand A versus Brand B debate, suffice it to say that all bearing suppliers use a variety of alloys and some aluminum alloys are tougher than others depending on how much silicon, tin, copper and other elements are in the mix. Aluminum bearings are very corrosion resistant and long lasting, and are even used in some diesel engines. Some also have an overplate layer to enhance embedability and conformability.

Tri-metal copper/lead bearings were the industry standard for many years, and are still used as original equipment in many European engines. Tri-metal continues to be popular with many aftermarket engine builders and performance engine builders because of its high embedability, conformability and load-carrying properties. Like aluminum bearings, there are various alloys from which to choose. A typical tri-metal bearing will have a top layer of lead/tin/copper over a layer of copper/lead on a steel backing plate. The bearing may also have a bright tin flash plating on the outside to enhance its cosmetic appearance.

High-performance tri-metal bearings for racing applications typically use a stronger copper/lead alloy in the base layer, a stronger steel shell and may not have a tin flash surface plating because the tin plating can migrate across a bearing's steel backing under race conditions, causing high spots on the inside diameter. These high spots may distort the bearing and have an adverse effect on the oil clearance. It can also concentrate loads and increase the risk of fatigue failure. For supercharged drag racing, many racers use babbit or other special alloy bearings.

Some high-performance bearings also incorporate additional design features such as extended oil grooves to improve lubrication, side chamfers for additional clearance on crankshafts with larger radius fillets on the journals, and special thrust-bearing surfaces that improve lubrication and durability.

Some customers have very strong brand preferences or prefer a certain type of bearing material. Some say the best approach is to replace same with same (aluminum with aluminum, and tri-metal with tri-metal) – unless the engine is being built for a performance application, in which case the bearings may have to be upgraded to a stronger high-performance material. The best advice is to follow the bearing supplier's recommendations.

Coated Bearings

Coated bearings have been available for many years in the aftermarket from some niche-oriented companies, but they've been introduced within the past couple of years by some of the larger bearing manufacturers as well.

Various types of coatings, including molybdenum disulfide, moly/graphite and tungsten disulfide, have been used to reduce friction, improve wear resistance and heat management. But the primary purpose of today's bearing coatings is to protect those sensitive bearing surfaces against dry starts and damage if oil pressure is lost.

The coatings are typically .00025˝ to .0003˝ thick, so they don't require you to compensate for any extra thickness. And, according to coating manufacturers, the coatings can extend the life of a bearing anywhere from two to ten-times over that of an uncoated bearing in racing applications. Some even recount the stories engines that completed several laps without losing oil pressure or causing other damage.

Whether coated bearings are right for you or not depends on the kind of engines you're building (stock, performance or even diesel) and how much your customers are willing to spend for the added protection afforded by coated bearings. For most applications, a coating adds less than $100 to the cost of the bearing set. That can be cheap insurance considering what a warranty claim due to a dry start or loss of oil pressure might cost. **EMPG**