Piston & Rod Orientation

Including a discussion of major and minor thrust

BY **MIKE MAVRIGIAN**

When it comes time to install pistons and connecting rods, orientation of the two components relative to each other and relative to the block can sometimes lead new builders to wonder about direction. This brief article should help.

WHAT DIRECTION DO THE RODS GET INSTALLED TO THE PISTONS?

If the big end of the connecting rod features a larger chamfer on one side, this side must be installed facing the crankshaft's journal radius fillet. If the rods are designed for use on a crank that does not feature a radiused fillet, the rods may not feature a large chamfer on one side. Rod orientation can then be obtained by orienting rod with its bearing tang grooves biased toward the pan rail (outside) or cam side (inside). For example, SBC and BBC bearings tangs are positioned toward the outside (toward the pan rails). Other designs may specify that the tangs are located to the inside. This isn't an issue of the bearings themselves but merely serve to provide a reference for rod orientation.

If there is no noticeable chamfer on either side of the rod big end, the bearing placement on the side of the rod that faces the fillet should be slightly spaced away from the fillet to prevent the bearing from digging into the fillet radius.

SQUIRT HOLES

If an oil squirt hole is featured in one side of the rod's big end, this oil hole is intended to allow oil to be squirted to opposing pistons, so the oil squirt hole in the big ends should be oriented so that they face the cam. These big end squirt holes are not intended to provide camshaft lubrication as some folks have been led to believe. An oil hole in the rod small end (whether on top or at an angle) is to simply allow splash-oil delivery to the wrist pin.

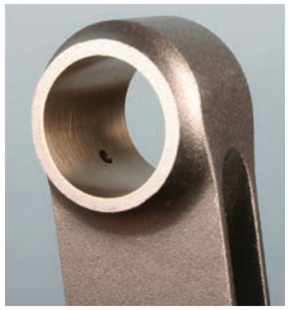
ROD BEARING TANGS

The grooves in the rod big end and cap and the protruding tangs on the rod bearings exist to facilitate bearing installation and are not specifically intended to prevent bearing "spin." The bearing crush that is generated when the cap is properly tightened prevents bearing movement. The grooves in the rod and cap and the tangs on the bearings merely serve as an installation aid in order to align the bearings during assembly (locating upper and lower bearings correctly fore/aft). Bearings as-installed feature the ends slightly protruding beyond the parting line. The bearings are locked in position and secured as a result of radial bearing crush when the cap bolts are fully tightened to specification.

OE engine designs have begin to use tang-less bearings (Chrysler 3.7L and 4.7L engines are an example). Eliminating machining of grooves in the rod and cap and eliminating the tang on the bearings

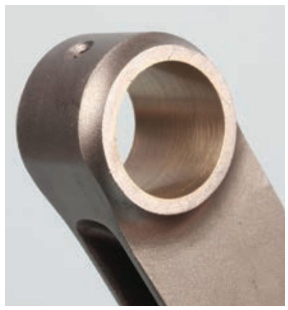
Examples of two opposing-bank asymmetric pistons. Each piston features a wider skirt for the major thrust side and a narrower skirt for the minor thrust side.

Another example of an asymmetric piston. Notice that the pin bosses are closer together to accommodate a shorter (and lighter) wrist pin. While it's difficult to see by eye, the pin centerline is biased 0.020" closer toward the major thrust side in order to tune the pin's pivot point balance in order to compensate for the difference in major and minor skirt size/mass.



An oil squirt hole at the rod small end serves to provide lubrication to the wrist pin.

A view of a small end squirt hole at the exterior of the small end.



A larger chamfered oil hole at the top of the small end on some rod designs provides a "funnel" for improved oil reservoir for floating pin lubrication.

When a piston maker specifies a precise skirt height location for diameter measurement, this represents the area of the skirt "barrel" profile that will experience the highest cylinder wall loading.

Asymmetric pistons may also feature an arrow that indicates piston orientation relative to the front of the engine. This provides a handy visual aid in installing the pistons so that the major thrust side skirt faces the major thrust load within the cylinder bore.

The underside of this piston features an "L" suffix, indicating that this piston is intended for the left bank of a V engine. Pistons intended for the right bank will feature an "R" suffix.

reduces manufacturing cost. Again, the locking tangs only exist to provide assembly alignment. When installing no-tang bearings, they must be centered on the rod and cap bearing bore surfaces. We'll be seeing more and more of these applications from the OEM side.

ROD OFFSET

Offset designed into a rod places either the large or small end centerline slightly offset from the centerline of the rod beam. This is to accommodate engine designs where the centerline of the cylinder bore is slightly offset from the fore/aft intended location of the rod bearing radial centerline. Depending on the specific engine deign, the rod may feature an offset of as much as 0.100" or more.

If in doubt, during test fitting, verify that the small end of the rod is centered on the wrist pin between the pin bosses.

DO REVERSE ROTATION ENGINES GET PISTONS INSTALLED BACKWARDS?

On a reverse-rotation engine (where the crank rotates counterclockwise when viewed from the front of the engine), rods are installed similar to a clockwise rotation engine, where the larger chamfer side of the big end faces the fillet. However, if the pistons feature an offset pin, the piston must be installed "backwards" relative to installation in a clockwise engine. The pin offset is biased toward the major thrust side of the piston. In a clockwise-rotating engine, the major thrust side is at the intake side on the left (driver) bank and the exhaust side on the right (passenger) bank. In a reverse-rotation engine, the thrust sides are opposite: the major thrust side will now be at the exhaust side of the left bank and the intake side of the right bank. If the pistons are symmetric and do not feature an offset pin location, piston orientation won't matter, as long as the valve pockets (if any) are located appropriate to the valve locations.

SKIRTS AND MAJOR/MINOR THRUST

The shape, area of mass and weight of a piston's skirts play a major role in managing friction and in stabilizing the piston during TDC and BDC transitions. Here we'll discuss the role of the major and minor thrust sides of a piston and the development of asymmetric skirt designs intended to minimize weight while maximizing efficiency.

Piston skirts are not perfectly round, and each side of the piston experiences different levels of loading, relative to the intake and exhaust sides of the cylinders. Skirt design plays a major role in accommodating these forces in terms of durability and performance, as well as piston weight.

The piston skirt area is slightly "barrel" shaped to provide an adequate surface load against the cylinder wall while reducing friction. The amount of surface area must accommodate the load, while providing piston stability to minimize rocking relative to the pin axis as the piston moves down from TDC and back up from BDC.

The piston experiences a "major" and "minor" thrust force at opposing sides of the piston skirts. The major thrust face is the side of the piston that receives the thrust on the power stroke. As viewed facing the front of the engine, if the crankshaft is rotating clockwise, the major thrust face is on the left side of the cylinder (the exhaust sides of the right/passenger cylinders; and the intake sides of the left (driver) side cylinders. The minor thrust side experiences force on the compression stroke.

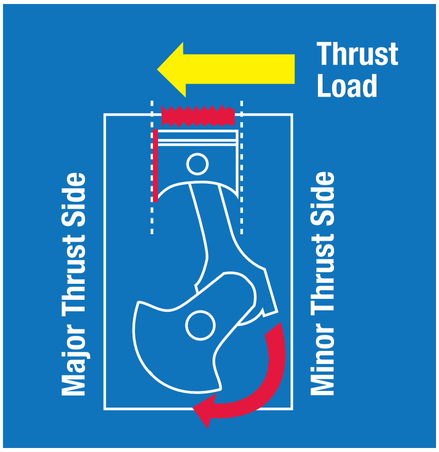
This difference in force at each side of the piston is caused in part by the operating angles of the connecting rod during its travel.

During the firing cycle, the load experienced on the major thrust side skirt can be as much as 10 times greater than the load experienced on the minor thrust side skirt. The difference in skirt loading will vary depending on variables such as crankshaft stroke, connecting rod length and peak cylinder pressures.

Since asymmetric pistons are bank-specific, each piston will be labeled for right or left bank position. The dome may also feature a laser-etched arrow that indicates piston orientation toward the front of the engine.

Major thrust side

When the piston is pushed down during the power stroke, it experiences resistance as it attempts to turn the crankshaft. As load increases, the amount of resistance increases. During this resistance, the



A view of the major thrust side. Note the width of the skirt. (Courtesy JE)

By contrast, this is a view of the minor thrust side of the same piston. Note the reduced width of the minor-side skirt. (Courtesy JE)

A rod big end's non-chamfered side faces the adjacent rod big end.

If a large chamfer is present as shown here, this side of the rod faces the radius fillet of the crank journal.

piston side load is forced to one side (the major thrust side), which places more force (with subsequently increased friction and potential wear) on the thrust side of the cylinder wall. If the piston dome features a reference dot or other mark, it's critical to install the piston with this mark facing the appropriate direction (usually the mark indicates the side of the piston that should face forward). The piston side loads on the major side tend to increase with the use of longer stroke and with forced/boosted induction pressures. Again, assuming a clockwise-rotating crankshaft, the major thrust side will be at the exhaust side of the engine's right bank and the intake side of the left bank.

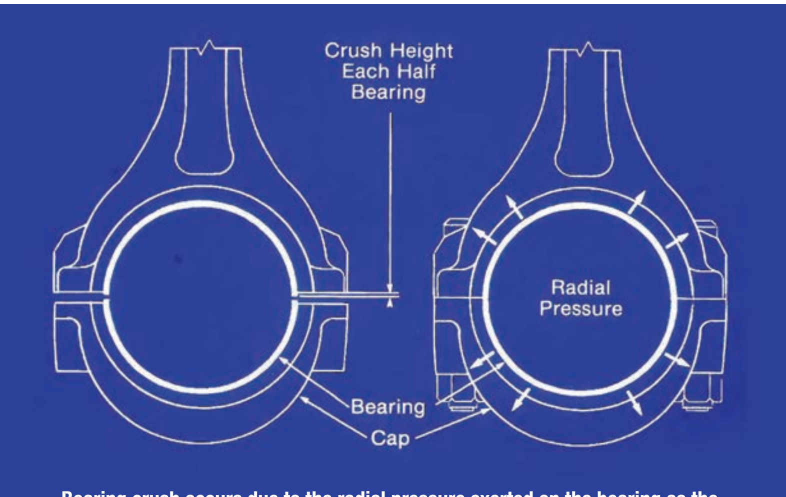
Minor thrust side

The piston's minor thrust side is directly opposite of the major thrust side. The minor thrust side is forced to the opposite side of the cylinder wall as it moves up on the compression stroke, due to the resistance generated by meeting the air/fuel mixture. The role of the minor thrust side is basically to provide piston stability, with the major thrust side taking the brunt of the cylinder wall contact. Due to its "less force" role, the minor thrust side skirt can be narrower, saving weight, without sacrificing strength.

In order to address, or "fine tune" these forces between the major and minor thrust sides, asymmetric pistons have been developed that feature two different-size skirts.

This style of pistons is specifically designed with a larger (wider) skirt on the thrust side and a smaller skirt on the minor thrust side. This provides a greater "footprint" for the major thrust side, where it's needed the most to handle a higher degree of thrust loading, and allows

Bearing tangs register to the tang grooves in the rod and cap simply to provide a locating aid to place the bearings in the correct fore-aft position, to eliminate potential mistakes in bearing location. Bearing crush that results from cap tightening serves to lock the bearings in place to prevent bearing spin. Note how this bearing is registered slightly biased away from the chamfered side to prevent the bearing from digging into the crank fillet.



Bearing crush occurs due to the radial pressure exerted on the bearing as the cap bolts are tightened. (Courtesy MAHLE Clevite)

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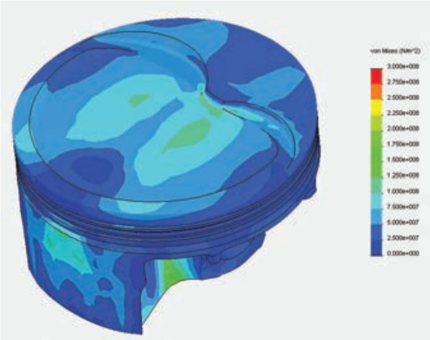
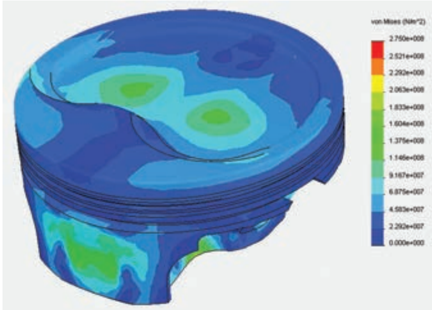
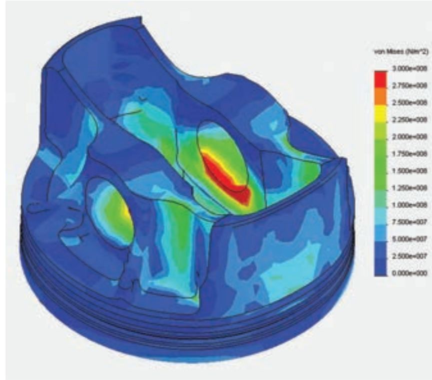


This FEA (finite element analysis) view shows even stress forces at both major and minor thrust sides (note the dark dome areas), even though skirt areas differ in area. The offset location of the wrist pin aids in balancing-out the pivot point. (Courtesy JE)



FEA takes a snap shot of the piston's stress levels at the worst case scenario and differ greatly from an engine that's at part throttle. The image represents a stress level plot. The high stress areas are shown in red in accordance with the chart on the right. This is a simulation of stress under firing. (Courtesy JE)



The stress of the piston under major stress. (Courtesy JE)

the piston weight to be slightly reduced by featuring a small footprint on the opposite/minor thrust side where the force is less. During the power stroke, when the piston changes direction at top dead center, combustion pressure pushes the piston down, and at the same time pushes the thrust side of the skirt towards the cylinder wall.

Citing JE Pistons' "asymmetric" design as an example, in their FSR (forged side relief) line, a wider skirt area is featured on the major thrust side, and the pin bosses are relieved at the outboard sides to allow the use of a shorter (and lighter) wrist pin.

The asymmetric piston design concept was initially developed years ago for specific racing applications. While it didn't get much OE backing then, there is renewed interest in it now and its use has trickled down to street applications, with the GM LS platform as a good example.

Another benefit to the asymmetric approach with regard to skirt mass and profile is increased piston ring sealing and ring stability. Basically, the dedicated major and minor thrust skirt design coupled with a slightly offset wrist pin directly addresses ring performance in addition to reduced wall friction.

Offset pin

Asymmetric pistons will also feature an offset wrist pin, with the pin centerline biased from zero towards the major thrust side by 0.020". This slight offset tends to balance the piston to accommodate the difference in skirt mass and to compensate for and alter the effect of rod angle, transferring a bit of force away from the major thrust side.

Again citing JE's development in this area, the asymmetric design allows the use of shorter, stiffer and lighter wrist pins. According to JE, a typical weight savings is in the 10 gram range.

NOTE: The contact pressure FEA images show contact pressure specifically between the skirt panel and the bore. It's important to analyze both skirt profiles on an asymmetrical piston design even though the minor thrust experiences a much lower amount of pressure. On a symmetrical design, typically only the major thrust is analyzed. Stress images show how the stress at the skirts affects the rest of the piston.

Hopefully, this article on piston and rod orientation helps you. Remember, it's best to mark rods before disassembly. AERA's tech team often receives questions regarding this topic and they asked me to write an article to better explain. Answering questions and helping with technical issues regarding engines is AERA's main mission. Toll-free access to four full-time tech experts is just one of the many benefits of an AERA membership. To learn more about AERA, visit www.aera.org and join today. You'll be glad you did and most likely thank me tomorrow!■

An anti-friction coating on the skirts aids in oil retention and provides additional friction reduction especially during cold starts. While this can more prominently benefit the major thrust skirt, applying the coating to both major and minor skirts provides a lubricity "back-up."

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