6-cylinder Double Vanos Rattle Procedure

Introduction

“Vanos” is BMW’s name for its variable valve timing units. Vanos units take on various shapes and design according to car year and model (engine model). The vanos discussed here is BMW part # 11-36-1-440-142. It’s a double vanos; meaning both the intake and exhaust valve timing is varied. This vanos unit is part of BMW 6-cylinder engines M52TU, M54, and M56. These engines were incorporated into a wide range of car models during years 1998-2006. They are found in the 3-series E46 98-05, 5-series E39 99-03 / E60 & E61 02-05, 7-series E38 98-01 / E65 & E66 02-05, Z3 E36 98-02, Z4 E85 02-05, X3 E83 03-06, X5 E53 00-06.

This vanos, like most vanos designs, can develop a rattle. The vanos rattle is caused by wear in the variable valve timing helical (slanted) gears. These gears are found on the camshaft, camshaft sprocket, and splined shaft which attaches to the vanos. The helical gear wear allows the camshaft to have lash movements that engage the splined shaft axially. At certain RPMs these movements resonate and engage axial play (free space) and cause associated components to hit and rattle. The axial play that facilitates the rattle is found on the helical gears and the vanos piston bearing. Replacing the helical gear components is expensive and the gears will wear again and the rattle will return. Removing the vanos piston bearing axial play significantly reduces the rattle to the point where it’s barely heard or not heard at all in the passenger compartment. Performance cams like the cams on the US E46 ZHP or aftermarket performance (Schrick) cams create stronger camshaft lash forces and thus are more susceptible to causing a rattle.
Beisan Systems provides a vanos rattle repair kit which has a replacement component for the vanos piston bearing to remove the bearing axial play. An associate special tool is also provided to facilitate the repair.

Below is a more detailed explanation of the rattle cause and solution.

Technical background

To understand the cause of the vanos rattle some understanding of the BMW variable valve timing system is needed.

Variable valve timing is the modifying of the engine valve opening/closing timing dynamically. BMW's variable valve timing implements a time shift (phase shift) scheme. The camshaft cam is not modified, thus all the characteristics of the opening and closing of the valve remain the same. What changes is the time when the valve opening/closing occurs relative to the crankshaft timing. The camshaft relative rotational position to the crankshaft is modified (shifted). Advancing (clockwise) the camshaft advances (earlier) the valve timing (opening/closing) relative to the crankshaft. Retarding (counter clockwise) the camshaft retards (later) the valve timing (opening/closing) relative to the crankshaft.
Helical (slanted) gears are utilized to physically implement this mechanism. Due to their nature, helical gears require a rotation to insert onto each other. This characteristic of helical gears is utilized to implement the relative rotation of the camshaft to the crankshaft dynamically while the engine is running.

[picture]
The camshaft and camshaft sprocket are not mounted directly to each other. The sprocket has a hole at its middle that's larger than the camshaft end. Opposing slant helical gears are mounted at the sprocket hole and camshaft end. There is an independent splined shaft with a cup and helical gears on the inside and outside of the cup walls. The splined shaft cup inner helical gears match the camshaft helical gears and the splined shaft cup outer helical gears match the sprocket helical gears. The splined shaft cup is inserted onto and mates with the camshaft and sprocket helical gears. Thus the splined shaft connects the camshaft and sprocket. Inserting and withdrawing the splined shaft axially in/out of the camshaft and sprocket requires the rotation of a component due to the helical gears. The sprocket rotation is fixed by the timing chain. The splined shaft can't rotate due to the opposing helical gear slants on its cup inside and outside. Thus it's the camshaft that rotates when the splined shaft is manipulated axially.

[picture]
Inserting the splined shaft axially onto the camshaft and sprocket causes the camshaft to advance (rotate clockwise) and cause advanced (earlier) timing.

[picture]
Withdrawing the splined shaft axially from the camshaft and sprocket

causes the camshaft to retard (rotate counter clockwise) and cause retarded (later) timing.

The vanos is a hydraulic actuator. Its function is to dynamically position the splined shaft axially to cause camshaft advance or retard rotation which enacts variable valve timing.
The vanos utilizes two cylinders and a piston. There is an oil chamber at the fore and aft of the piston. Controlling the oil pressure in the two oil chambers manipulates the axial position of the piston. Seals on the piston allow the piston to reciprocate axially along the cylinder walls while maintaining a tight oil seal on the two oil chamber. The splined shaft is mounted to the vanos piston. Thus manipulating the axial position of the piston also manipulates the axial position of the splined shaft. The piston has a bearing at its center. The splined shaft is mounted to this bearing. The piston bearing allows the splined shaft to rotate with the camshaft and sprocket while not rotating the piston.

Cause of rattle

Due to the nature of helical gears, not only does the axial positioning of the splined shaft cause the rotation of the camshaft, but also reciprocally the rotation of the camshaft causes the axial positioning of the splined shaft. Over time and use the helical gears on the camshaft, sprocket, and splined shaft develop wear along the gear spline side contact surfaces. This wear creates excessive play between the helical gears. This causes excessive play in the fit of the splined shaft to the camshaft and sprocket. This manifests in axial play between the splined shaft and camshaft and sprocket.
As the camshaft rotates the cam nose rolls onto the valve seat and compresses the valve spring to open the valve and rolls off the valve seat and decompresses the valve spring to close the valve. The resistance force of the valve spring compression creates an opposing force to the forward rotation of the camshaft. The recoiling force of the valve spring decompression creates an additive force to the forward rotation of the camshaft.
Due to the splined shaft axial play, as the cam compresses the valve spring the camshaft will slightly retard in relative rotation to the crankshaft and as the cam decompresses the valve spring the camshaft will slightly advance in relative rotation to the crankshaft. These movements of the camshaft are due to camshaft least resistance path of movement. Due to the splined shaft axial play there is less resistance to the camshaft retarding than compressing the spring and less resistance to the camshaft advancing than containing the decompressing spring. These movements manifest into camshaft lashes which engage the splined shaft axially. The greater the helical gear wear the greater the splined shaft axial play the stronger the

camshaft lashes.
At certain engine RPMs these camshaft movements resonate. This causes stronger camshaft lashes which cause more powerful engagements of the splined shaft axially. This causes strong axial movements of the splined shaft. Any axial play in the splined shaft vicinity is engaged and can cause a rattle.
There are two locations of axial play. The helical gears themselves have axial play that’s engaged and rattles and the vanos piston bearing has axial play that’s engaged and rattles.

Testing has been performed to assess and attempt to reduce the rattling. The vanos piston bearing radial play was modified and the results indicated little to no change in the rattling. The vanos piston bearing axial play was increased and this resulted in a proportional increase in the rattling. The vanos piston bearing axial play was decreased and this resulted in a proportional decrease in rattling.
The testing results show that removing the vanos piston bearing axial play significantly reduces the rattling.
Some owners have had the dealership replace their helical gears (splined shaft, camshaft, sprocket) and this resolved all the rattle. These owners eventually developed the rattle again and to the same level as before. This is due to the new helical gears wearing and creating the splined shaft axial play.

Engines with higher lift (performance) cams are more susceptible to having a vanos rattle, and the rattle is likely to be worse. The higher lift cams compress the valve springs further and thus cause higher spring forces. This causes stronger camshaft lashes which engage the splined shaft and axial play components harder.
This affects US 3-series E46 ZHP performance package cars and cars with aftermarket performance cams (Schrick)

<u>Rattle solution</u>

As noted above removing the vanos piston bearing axial play significantly reduces the rattle. Also replacing the helical gear components (splined shaft, camshaft, sprocket) is expensive and the helical gears will wear again. Thus removing the vanos piston axial play is a practical approach to addressing the rattle problem. Furthermore, per bearing specification and consultation with bearings companies, there should be no bearing axial play and a notable axial pre-load (tightness) should be present.

The vanos piston bearing is made of a thick washer and two thrust (roller) bearings. The washer if mounted to the splined shaft and the two thrust bearings sandwich the washer facilitating the washer to rotate at camshaft speed. The washer and two thrust bearings are incased in a ring and two ring outer washers. The complete bearing is housed inside a piston cavity and is closed off with a piston bolt/cap.

Removing the bearing axial play requires modifying or replacing at least one bearing component. The thrust bearings are a standard part and are manufactured to tight tolerances. It’s not feasible to modify or replace them. The ring and center washer are non standard parts and are manufactured to loose tolerances. The ring height can be reduced or the center washer height can be increased to remove the bearing axial play. The ring has been found to have a large height variation and the washer has been found to have a smaller height variation. Due to these findings, it’s more effective to replace the ring. A bearing adjustment can be made at installation to address any minor axial fit variation.

The bearing ring and center washer were assessed by a metallurgical consulting firm. The parts were assessed for their material makeup, hardness including micro depth hardness, manufacturing process and finish.

As a solution to the vanos rattle problem a replacement vanos piston bearing ring is manufactured to the same specification as the original bearing ring but with a shorter height and a very tight height tolerance. The other ring dimensions are also manufactured to tight tolerances.
The bearing ring is a difficult and expensive component to manufacture. It’s made from a special bearing steel and hardened to a high hardness. All its surfaces are ground. This technique allows for machining hard parts to a high dimensional tolerance and a polished surface.

The double vanos rattle repair kit includes two replacement vanos piston bearing rings.

<u>Repair techniques</u>

To replace the piston bearing ring the piston bolt/cap that retains the bearing must be removed. This is difficult due to the need to counter hold the piston to open the bolt/cap and the small size of the piston.

The piston has fins that allow for counter holding the piston to open the bolt/cap. But manufacturing a special tool for this purpose and providing it for a one time use is cost prohibitive. A vice can be used to counter hold the piston. A standard vise would damage the soft aluminum piston. Common aluminum and rubber coated aluminum vise jaw liners would also risk damaging the piston. Softer nylon vise jaw liners have been tested and found to hold the piston effectively without the risk of damaging it. Soft vise jaw liners are provided as an associate tool for the repair. The liners can also be useful for other delicate component work.

Due to the small diameter of the piston the piston will spin in the vise jaws with soft vise jaw liners when attempting to remove or install the piston bolt/cap. An impact wench easily removes and installs the piston bolt/cap without risk of piston damage. Thus an impact wrench and impact socket is needed to perform the repair.

Symptoms

Vanos rattle at a certain RPM range, often 1800-2200 RPM. Rattle can also occur at idle.

This vanos is manufactured with loose piston bearings. Thus all vanos units can rattle. For the vanos to rattle a resonance needs to be achieved in the camshaft lash and associate parts movements. Some car models are more susceptible to achieving this resonance and rattle than others.
Models susceptible to experiencing vanos rattle:
3-series E46 320i, 323i, 330i
5-series E39 520i, 523i, 530i
5-series E60 530i
Z3 all models.
This list will be updates as more data is collected.

Note: All models can and have experienced the vanos rattle.

Repair Procedure

The following is a double vanos piston bearing rattle repair procedure.

This repair should be performed with the double vanos seals repair. The rattle repair should be performed before the new vanos seals are installed.
Double Vanos Seals Procedure

Repair time: .5 hours mechanic, 1+ hours DIY.

Parts, Tools, and Shop Supplies

Double vanos rattle repair kit (BS002) $60/each (www.beisansystems.com), soft vise jaw liners (BS091) $15/each (www.beisansystems.com)

Caution: Beisan soft vise jaw liners are critical to performing repair. They are fully nylon and will allow tightening vise without damaging piston. Other types of jaw liners, including aluminum and rubber coated aluminum, can damage piston.

4”, or larger, swivel vise (Harbor Freight, 4” at store $45)

Note: Vise must be mounted for use.

1/2” impact wrench (Harbor Freight, http://www.harborfreight.com/12-electric-impact-wrench-68099.html on sale at store $40)

24mm impact socket 1/2", T30 torx bit socket 1/4”, 90 degree pick tool, magnet pickup, 1/4” ratchet

Paper towels, brake cleaner, oil spray
~400 grade sandpaper (not shown)

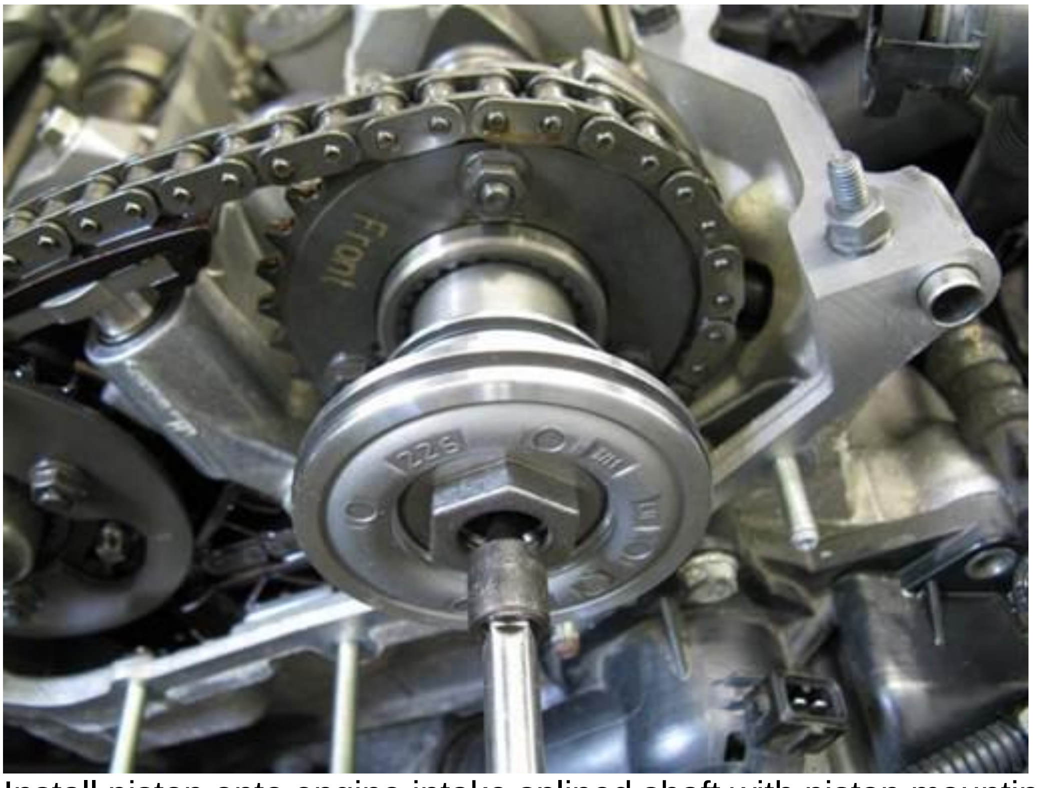
Repair

Repair is performed once vanos is removed from engine and vanos cylinder covers are removed. Refer to double vanos repair procedure, Double Vanos Procedure
Replace vanos piston seals after this procedure.

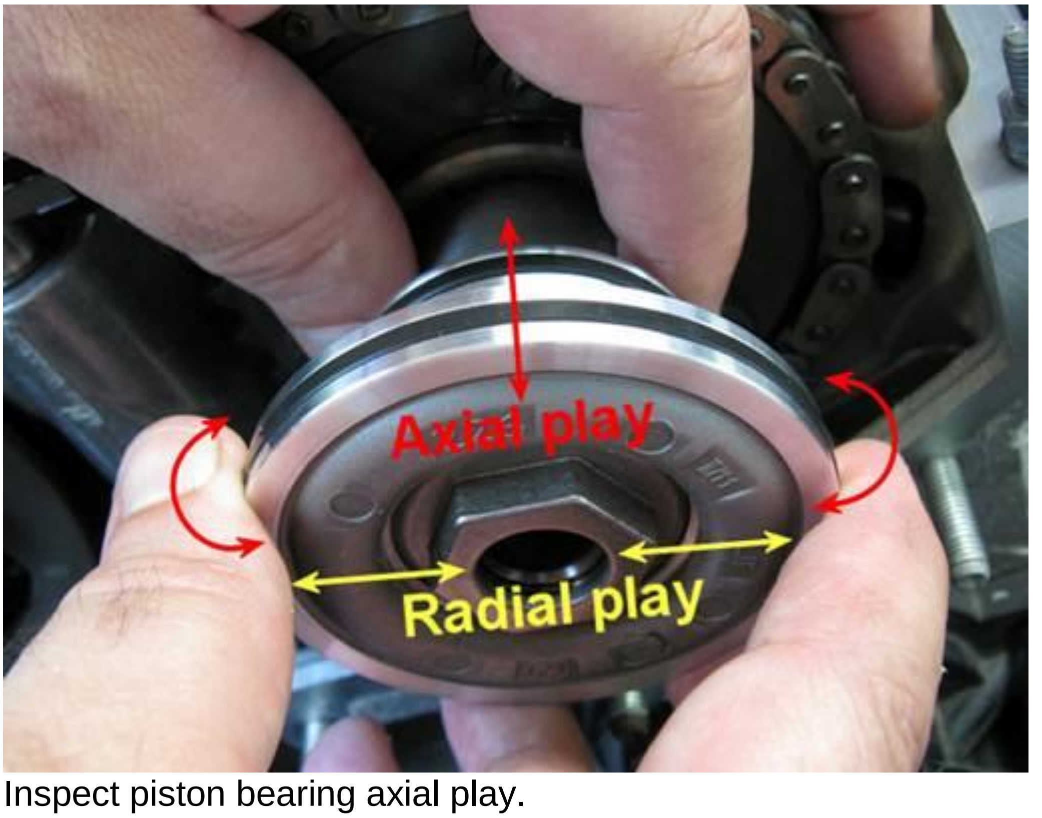
For each vanos piston perform following procedure.

Removal of piston bearing


Clean vanos piston (brake cleaner & towels).



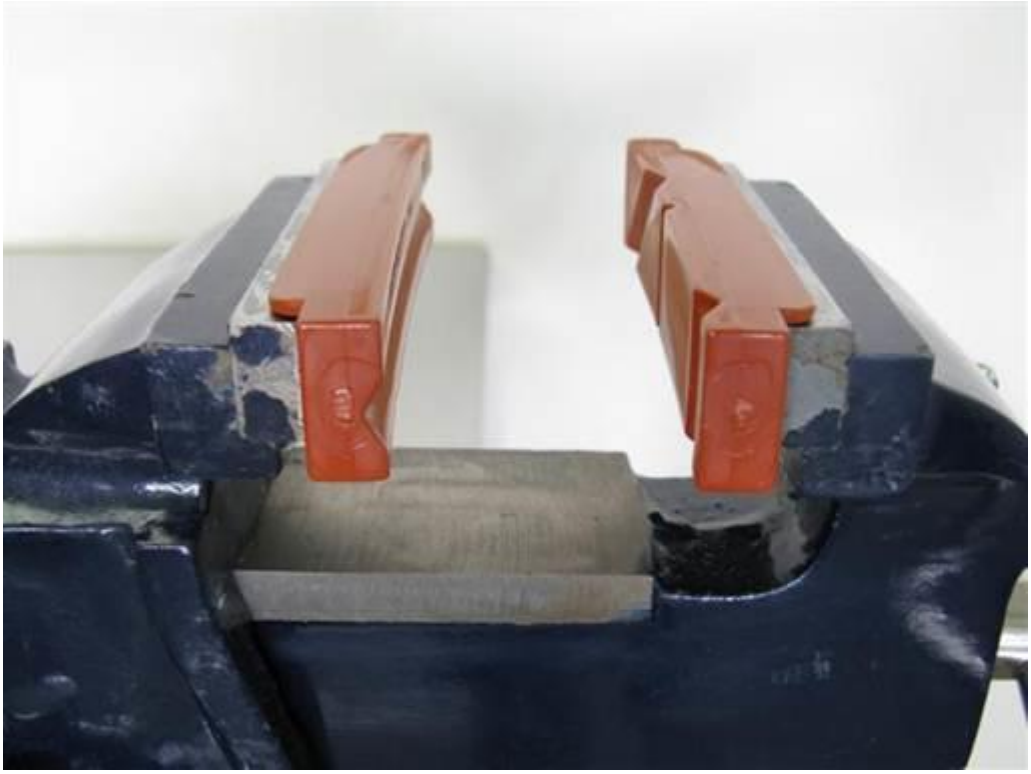
Install piston onto engine intake splined shaft with piston mounting bolt; <u>left hand thread</u> (T30 torx bit socket 1/4” / 1/4” ratchet & extension).
Lightly tighten.



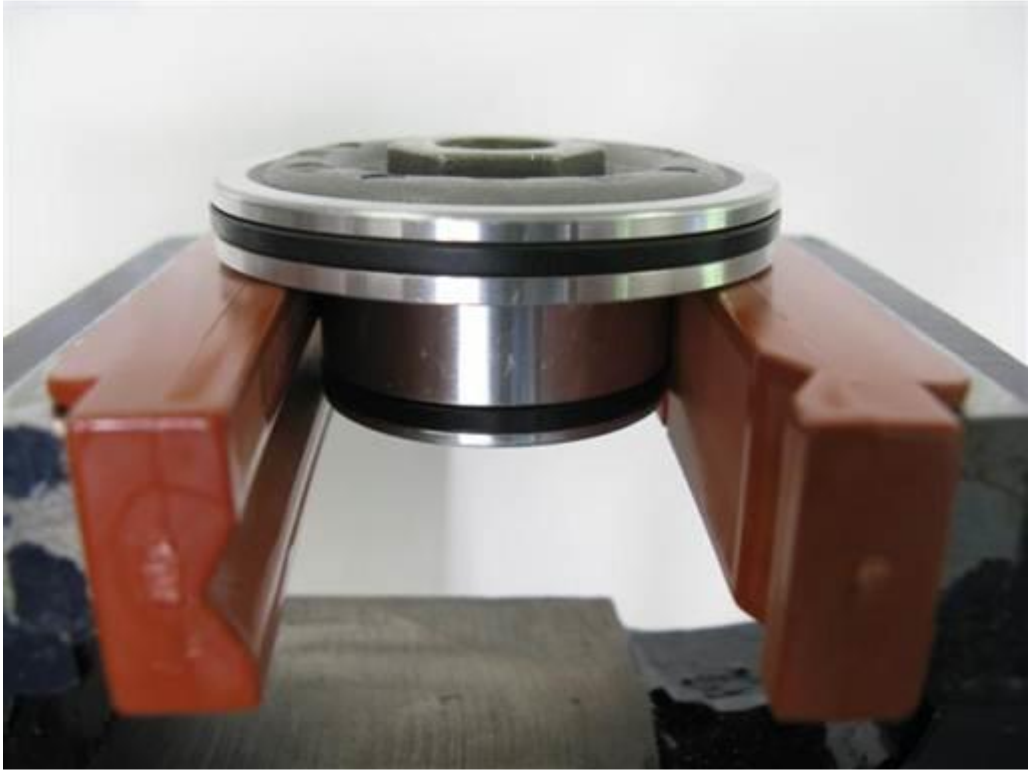
Inspect piston bearing axial play.
Hold helical shaft and tilt (rock) piston to each side to note bearing axial play (free space).
Axial play can also be checked by repeated insertion and withdrawal of

piston in/out of splined shaft.
Note: Radial play, side to side movement, is normal and necessary. This should not be confused with axial play, in/out movement.

Remove piston and piston mounting bolt from intake splined shaft; <u>left hand thread</u> (T30 torx bit socket 1/4” / 1/4” ratchet & extension).



Attach soft vise jaw liners to vise jaws.
Open vise jaws as far as necessary to insert piston shaft.



Insert piston shaft into vise and let piston sit on vise jaw liners top surface. Strongly tighten vise.
Note: Vise jaw liners are soft and will not damage piston surfaces.

Caution: Do not clamp on piston without use of soft (nylon) vise jaw liners. Other types of jaw liners, including aluminum and rubber coated aluminum, can damage piston.


Loosen (break seize) piston bolt/cap (24mm socket 1/2” / 1/2” impact wrench).
If available, set impact wrench power to lowest setting.
Engage impact wrench in reverse for 1 second intervals at a time until bolt/cap loosens (seize breaks).
Note: Do not press down on impact wrench. This will hinder bolt/cap removal.
Note: Piston will spin slightly in vise jaws. If piston excessively spins, further tighten vise jaws.

Once piston bolt/cap loosens (seize breaks), loosen vise jaws to release pressure on piston.

Remove piston bearing bolt/cap (hand).

Remove bearing top washer (magnet pickup).
Note: Washer is often bound to bolt/cap with oil and comes off with bolt/cap.

Remove bearing top thrust (roller) bearing (magnet pickup).

Remove bearing center washer (magnet pickup).

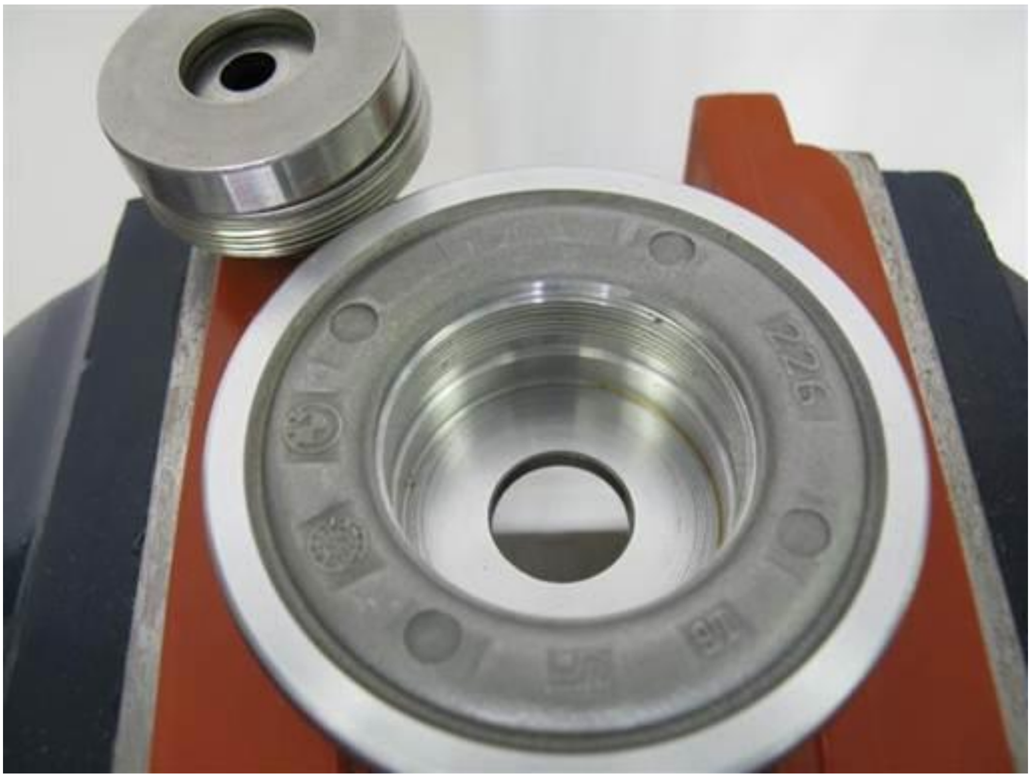

Remove bearing bottom thrust (roller) bearing (magnet pickup).


Remove bearing outer ring.
Clean bearing ring while still mounted in piston (brake cleaner & towels).
Insert right and left index fingers into bearing ring. Press against ring inner right and left walls and wiggle and pull ring out of piston.
If ring is stuck, place pick tip between ring inner bottom and bottom washer and pry ring to break ring/washer seize (90 degree pick).

If ring tilts and binds in piston, press ring down to fully mount at bottom of piston and repeat removal attempt. If necessary, hit ring down to break bind and fully mount at bottom of piston (90 degree pick handle butt).
Note: If bearing ring difficult to remove, loosen vise jaws.

Set aside bearing ring as it will not be reinstalled.

Remove bearing bottom washer.
Place pick tip between washer inner bottom and piston and pry washer out (90 degree pick).
Note: Washer is difficult to perceive until removed.

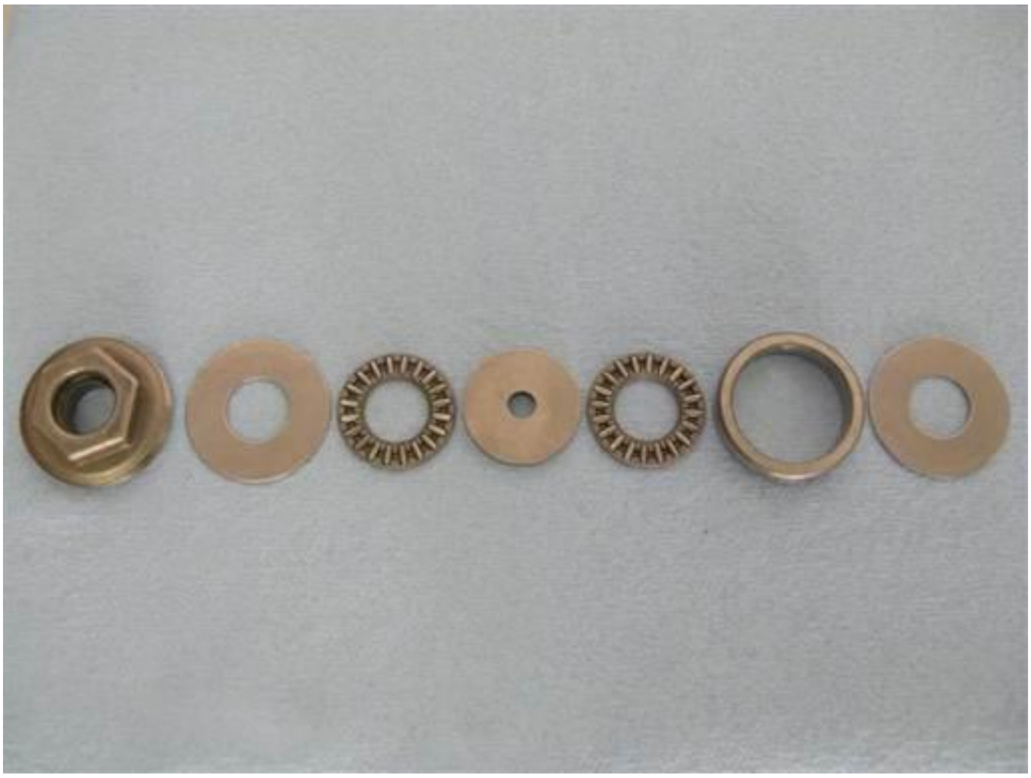


Cleaning of parts

Clean bearing parts (brake cleaner & towels).
Note: It is important bearing parts are thoroughly cleaned. This is needed to properly assess new bearing axial fit.

Clean piston bearing cavity and bolt/cap (brake cleaner & towels).

Installation of piston bearing



Bearing parts installation sequence from right to left.
Bearing parts from left to right: Bolt/cap, top washer, top thrust bearing, center washer, bottom thrust bearing, ring, bottom washer.

Insert bearing bottom washer in piston (fingers).
Note: Piston bearing top and bottom washers are interchangeable. Also

washer faces are same thus washer can be inserted in either orientation.
Manipulate washer side to side while slightly pressing down to fully insert (fingers).

Insert new bearing ring in piston (fingers).
Note: New ring is marked “BS” on outer perimeter.
Initially insert ring in piston.
Insert right and left index fingers into ring. Press fingers against ring inner right and left walls and manipulate ring side to side while slightly pressing down to facilitate ring full insertion.
Note: If bearing ring difficult to install, loosen vise jaws.

Rotate position of fingers 90 degrees and repeat ring insertion to verify full insertion.
Note: Ring should fully mate with bearing washer (picture).

Insert bearing bottom thrust (roller) bearing in piston bearing ring.
Note: Piston bearing top and bottom thrust bearings are interchangeable. Also thrust bearing faces are functionally same thus thrust bearing can be inserted in either orientation.

Insert bearing center washer in piston bearing ring.
Note: Center washer faces are same thus washer can be inserted in either orientation.

Insert bearing top thrust (roller) bearing in piston bearing ring.
Note: Thrust bearing faces are functionally same thus thrust bearing can be inserted in either orientation.

Insert bearing top washer on top of piston bearing ring.
Note: Washer faces are same thus washer can be inserted in either orientation.

Manipulate washer side to side while slightly pressing down to fully insert (fingers).

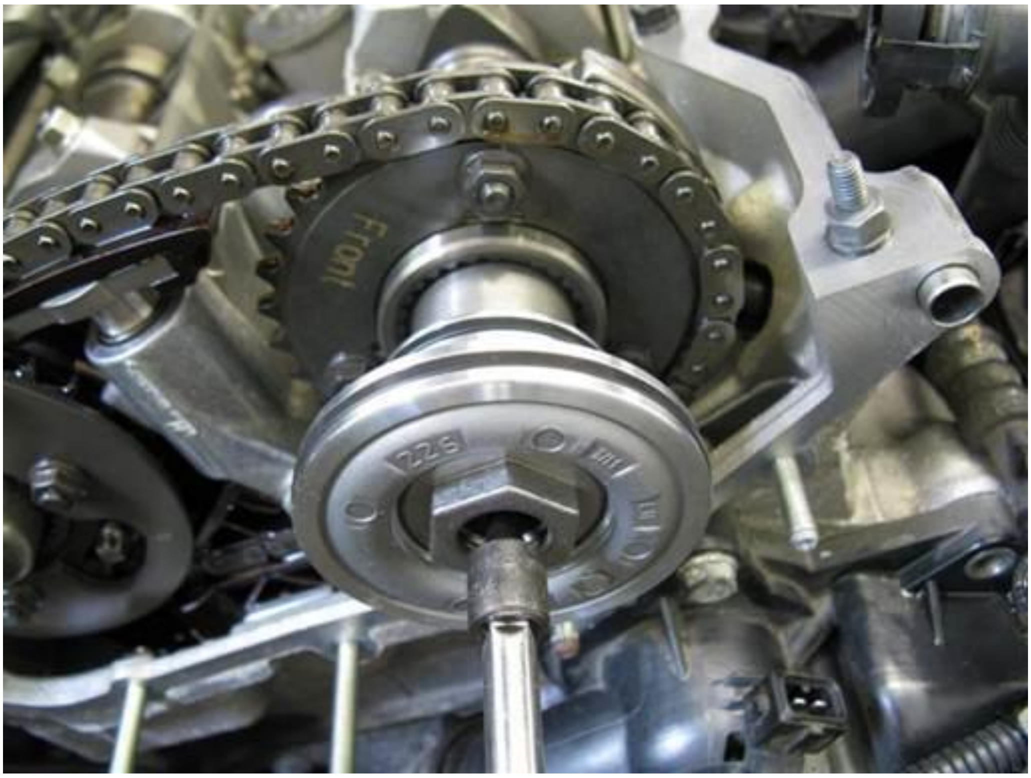
Install piston bolt/cap (hand).
Hand tighten bolt/cap.

Strongly tighten vise onto piston shaft.
Note: Vise jaw liners are soft and will not damage piston surfaces.

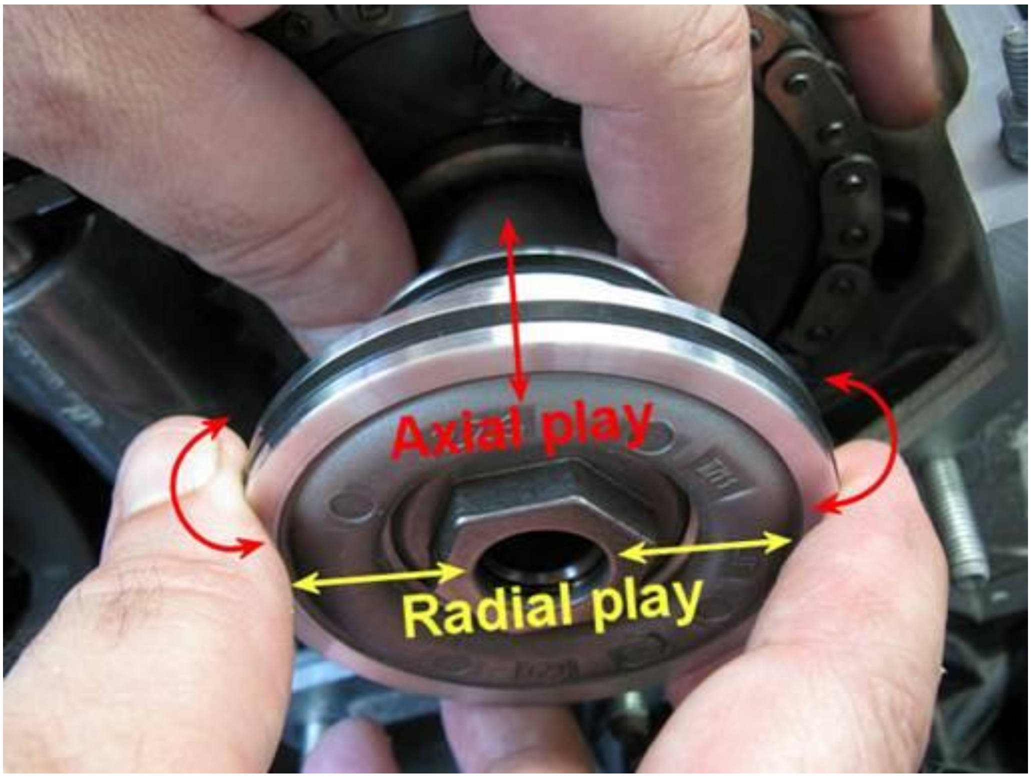
Fully tighten piston bearing bolt/cap (24mm impact socket 1/2” / 1/2” torque wrench).
If available, set impact wrench power to lowest setting.
Engage impact wrench in forward for 1 second interval 3 times to fully tighten bolt/cap.
Note: Do not press down on impact wrench. This will hinder holt/cap tightening.
Note: Piston will spin slightly in vise jaws. If piston excessively spins, further tighten vise jaws.

Loosen vise jaws and remove piston from vise.

<u>Inspection and adjustment of piston bearing</u>



Install piston onto engine intake splined shaft with piston mounting bolt; <u>left hand thread</u> (T30 torx bit socket 1/4” / 1/4” ratchet & extension).
Lightly tighten.

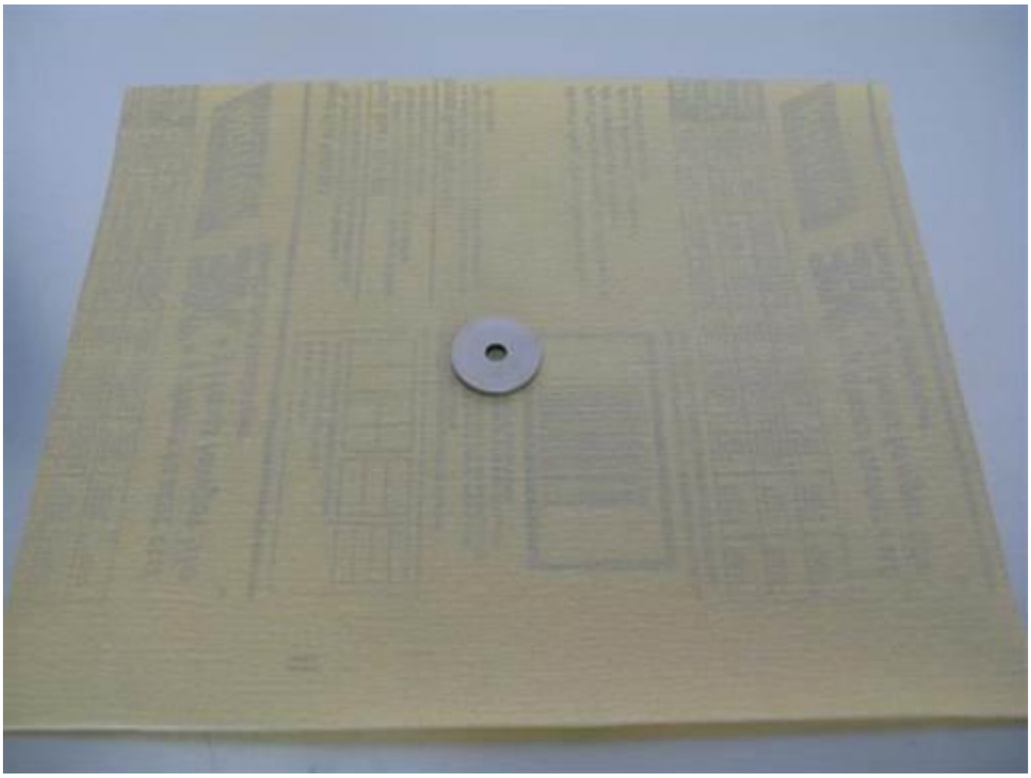


Inspect piston bearing axial play.
Rotate piston to note resistance to rotation.
Hold splined shaft and tilt (rock) piston to each side to note bearing axial play (free space).
Note: Axial fit cannot be properly assessed until piston bolt/cap is fully tightened.
Note: Radial play, side to side movement, is normal and necessary. This should not be confused with axial play, in/out movement.

If piston binds and cannot be rotated then axial fit it too tight and loosening adjustment is needed.
If piston has any tilt movement then axial play is present and tightening adjustment is needed.
Any level of resistance (pre-load) in piston rotation indicates no axial play and is considered an optimal fit.

Note: US 3-series E46 ZHP performance package cars and cars with aftermarket performance cams (Schrick) must have no bearing axial play and bearing should have resistance to rotation (pre-load) to achieve optimal results.

Remove piston and piston mounting bolt from intake splined shaft; <u>left hand thread</u> (T30 torx bit socket 1/4” / 1/4” ratchet & extension).



Bearing loosening adjustment.
If splined shaft binds and cannot be rotated then axial fit it too tight and loosening adjustment is needed.
Disassemble piston bearing per above procedure.
Place sandpaper (~400 grade) on flat table top. Place bearing center washer on sandpaper.
Slide washer side to side on sandpaper ~6” back and forth while moderately pressing washer on sandpaper. Perform sanding for 10 seconds.
Rotate washer 90 degrees and repeat sanding process.
Flip washer to opposite side and repeat above sanding procedure; 10 seconds sanding, rotate 90 degrees, 10 seconds sanding.
Clean washer (brake cleaner & towels).
Reassemble piston bearing per above procedure and reassess bearing axial fit.
Note: Washer is made from hardened steel and does not easily wear. Sanding procedure will remove ~.005mm washer height. Washer might need max .015mm height adjustment.

Bearing tightening adjustment.
If splined shaft has any tilt movement then axial play is present and tightening adjustment is needed.
Disassemble piston bearing per above procedure.
Place sandpaper (~400 grade) on flat table top. Place bearing ring on sandpaper.
Slide ring side to side on sandpaper ~6” back and forth while moderately pressing ring on sandpaper. Perform sanding for 10 seconds.
Rotate ring 90 degrees and repeat sanding process.
Flip ring to opposite side and repeat above sanding procedure; 10 seconds sanding, rotate 90 degrees, 10 seconds sanding.
Clean ring (brake cleaner & towels).
Reassemble piston bearing per above procedure and reassess bearing axial fit.
Note: Ring is made from hardened steel and does not easily wear. Sanding procedure will remove ~.005mm ring height. Ring might need max .015mm height adjustment.

Once piston bearing fit is assessed and adjustment is performed if needed, spray oil into bearing from both ends of piston/bearing (oil spray).
Rotate bearing to distribute oil (finger).
Repeat procedure for second piston.