MEASURING THE ACTUAL COMPRESSION RATIO OF AN XK ENGINE

by Ray Livingston
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This document describes simple procedures for measuring the actual compression ratio of any 3.8 or 4.2 litre XK engine, with the head both off and on. With the head off, more accurate readings can be taken, but the difference, when done properly, will be less than one tenth of a point of compression.

If you have any questions, or run into any problems, feel free to contact me by E-mail or phone:

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I'll be happy to provide whatever assistance I can. When you're all done, I'd love to hear how it went. I'd be ***very*** interested in hearing what compression ratio you came up with and what type of head gasket your engine has.

DISCLAIMER:

I developed this procedure for my own use, and I am offering it to others as a courtesy only, and on a strictly AS-IS basis. USE THIS INFORMATION STRICTLY AT YOUR OWN RISK!! I will accept absolutely no responsibility or liability for anything that happens as a result of your use of the information presented here.

OVERVIEW:

I first developed these procedures to diagnose and correct a severe pinging problem that my 3.8L engine had since being rebuilt. Pinging is a significant problem for a large percentage of E-type owners, and can seriously detract from overall enjoyment of the vehicle. However, it is a problem that has a relatively easy cure. It is my belief that pinging can ***always*** be addressed by selection of the proper head gasket, which will lower the compression ratio to a level appropriate to the available fuel. In my case, it required having a custom head gasket made by Bill Terry (owner of Terry's Jaguar), but this was not particularly expensive, and Bill was extremely helpful in deciding what the appropriate thickness should be.

Based on my personal experience, and that of many fellow E-type owners I've talked to, it appears to me that XK engines are prone to pinging at only about a 9.3:1 compression ratio on 91 octane fuel. The 93 octane available in some parts of the country should allow compression to be perhaps 9.5:1 before problems occur. However, having the head milled only 0.025" is enough to raise the compression of a stock 9:1 XK engine to 9.5:1. As many heads, like mine, have been milled more than once over the years, I suspect many people simply live with the problem I had. For this reason, I *strongly* recommend that compression be measured as a routine part of rebuilding ***any*** XK engine, and use this information to choose a head gasket with a thickness appropriate to maintain compression ratio below 9.3:1.

In my case, I first measured the compression ratio with the head on, both on my engine, and on a friends nearly identical 3.8. These preliminary readings indicated my compression was in the neighborhood of 10:1! I subsequently removed the head, and took more accurate readings with the head off, which showed my actual compression to be, in fact, 9.91:1. Based on what I learned by removing the head, I refined the "head on" compression ratio calculations, and achieved near perfect correlation with the "head off" readings. Both methods of calculation are summarized in the Excel spreadsheet associated with this document. There is one very minor factor the spreadsheet does not take into account, and that is the bore of the head gasket, which is often somewhat larger than the cylinder bore itself. This is a minor factor, so I simply chose to neglect it.

MEASURING COMPRESSION WITH THE HEAD ON:

This will always be the first step in any investigation of compression ratio, unless you are taking the engine apart anyway for a rebuild. If this measurement indicates your compression is at a reasonable level, you need not proceed any further, your problem lies elsewhere.

WHAT YOU'LL NEED:

You'll need the following tools:

- A good quality 100cc burette. This is available from any place that sells chemistry lab supplies. This is a tall glass cylinder, accurately marked in cc, with a small valve at the bottom, to allow you to control the flow of liquid from the bottom. You will use this for putting a carefully measured volume of oil into the cylinders of your engine through the spark plug hole.
- A large syringe. Suitable ones are usually available from auto parts stores, designed for filling/draining transmissions and differentials. You'll use this for removing the oil you put into the cylinders of your engine, to avoid damage due to hydraulic lock. It should have a length of tubing to go over the nozzle, to reach down into the cylinder far enough to reach the top of the piston.
- A dial indicator. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=33675
- Magnetic base for dial indicator. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=5646
- A length of 3/8" dowel, or something similar. This needs to be able to insert into the spark plug hole, and extend far enough to rest on the top of the piston, with the piston at TDC, and have the dial indicator rest on the exposed end.
- At least 100cc of clean engine oil.

MEASUREMENT PROCEDURE:

1. Remove all six spark plugs
2. Rotate the engine to raise the piston in the cylinder you are to measure to close to TDC on the ***compression*** stroke. You can detect this either by looking at the rotor position in the distributor, the cam positions, or by placing your finger over the spark plug hole, while turning the engine, and feeling for pressure in the cylinder as the piston comes up.
3. Insert the dowel into the spark plug hole, so it is resting on the top of the piston, and extending straight vertically out of the spark plug hole.
4. Setup the dial indicator and base so the tip rests on the end of the dowel, so you can read the height of the dowel.
5. Slowly rotate the engine by placing the transmission in 4^{th} gear, and gently rolling the car. Watch the dial indicator, and position the engine so the piston is at the very top of the stroke. With care, you should easily be able to get the piston within 0.001" of TDC. Accuracy is important here!
6. Remove the dowel.
7. Fill the burette with your regular motor oil, then drain off enough to bring the level down to the highest calibrated marking (probably 100cc).
8. *Slowly* open the valve on the burette, and allow oil to flow into the sparkplug hole, while carefully watching the level. The spark plug hole is located off-center within the domed combustion chamber, so if you look carefully, you'll see the hole is slightly higher on the side closest to the center of the chamber than the other. Close the valve on the burette when the oil level ***just*** reaches the bottom of the higher side of the spark plug hole.
9. Look at the final oil level in the burette, and calculate ***and write down*** exactly how much oil was actually put into the cylinder. For a typical 9:1 compression engine, this should probably be around 70-75cc for a 3.8L, and 75-80cc for a 4.2L. Yours may be slightly above or below these numbers.

10. ***This is the most important step of this process!! If you do not do this, you risk serious damage to your engine due to hydraulic lock!!*** Using the syringe, suck out as much of the oil from the cylinder as possible. You don't need to get it all, but you do want to get out as much as you can. ***Do not rotate the engine until you do this!!*** I was able to easily get out at least 50cc, which is enough.
11. You can now replace the spark plugs, and start the engine. It should start right up, but will smoke some for the first few minutes, as it burns off the residual oil in the cylinder. It will almost certainly smoke quite a bit after it fully warms up. Much of the oil left in the cylinder will be pumped into the exhaust system, where it will sit until it gets hot enough to start burning. You'll be amazed at how much smoke such a small amount of oil can make, and how long it take to fully burn off, so don't be surprised if it continues to smoke for a half hour or more. It will eventually burn off, and stop smoking.
12. Now open the spreadsheet, and select the "Head On" worksheet. Enter the volume of oil you measured above into cell B2, the over-bore (if known) into cell B3. If you don't know the overbore, you'll just have to guess. Standard sizes are 0.000, for an unmolested, or re-sleeved engine, 0.020", 0.030", and, sometimes, 0.040". The overbore is a minor factor, so even if you guess wrong, it will not drastically change the final result. Finally, enter your engine displacement (either 3.8 or 4.2) into cell B4.
13. Cell B13 now displays your calculated compression ratio. If you find this to be above 9.3:1, you may have a problem. If you'd like to see what it would take to drop this to a more acceptable level, change the number in cell B16, to see how much additional head gasket thickness would be required to drop your compression ratio down to any level you're comfortable with.
14. Standard head gaskets are available in three thicknesses, depending on where you buy them. The old-style "tin" gasket is 0.015". The newer Payen composite gasket is 0.035", while most other composite gaskets appear to be 0.050". Beyond that, you'll have to contact Bill Terry, and ask him about his all-steel custom gaskets, which can be ordered in any thickness up to a whopping 0.120"! With this selection, it should be possible to reduce the compression on ***any*** XK engine down to where pinging is completely eliminated.
15. Determining the final gasket thickness required will necessitate removing the head to measure the existing gasket. In my case, the measured cylinder volume was 69.0cc, with 0.020" overbore, on a 3.8L. This worked out to 9.92:1 compression. I already knew I had the 0.015" tin gasket, so entering 0.060 into cell B16 told me I needed a new gasket of 0.015 + 0.060 = 0.075" to drop the compression to 8.9:1, which is where I wanted to be.
16. At this point, if you feel you need to lower your compression, the next step is to remove the head, and take the "Head Off" measurements outlined below, to more accurately calculate your compression ratio before making your final gasket selection.

MEASURING COMPRESSION WITH THE HEAD OFF:

This procedure should be followed if you have the head off your engine, or you are undertaking a rebuild.

WHAT YOU'LL NEED:

You'll need the following tools:

- A good quality 100cc (or larger) burette. This is available from any place that sells chemistry lab supplies. This is a tall glass cylinder, accurately marked in cc, with a small valve at the bottom, to allow you to control the flow of liquid from the bottom. You will use this for putting a carefully measured volume of oil into the cylinders of your engine through the spark plug hole.
- A large syringe. Suitable ones are usually available from auto parts stores, designed for filling/draining transmissions and differentials. You'll use this for removing the oil you put

into the cylinders of your engine, to avoid damage due to hydraulic lock. It should have a length of tubing to go over the nozzle, to reach down into the cylinder far enough to reach the top of the piston.

- A dial indicator. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=33675
- Magnetic base for dial indicator. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=5646
- An “telescoping gauge” with a 3”-4” range. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=5649
- An micrometer with a 3”-4” range. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=37173
- A small vernier caliper. A suitable one is available from Harbor Freight: http://www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=5647
- A reasonable quantity (perhaps a quart) of clean Mineral Spirits
- A 6”x6” square of Plexiglas, Lexan, acrylic or other solid, transparent plastic
- A small quantity of clean wheel bearing grease

MEASUREMENT PROCEDURE:

1. With the head upside-down and slightly off-level length-wise on a bench, lay the piece of plastic over one of the chambers, and mark the centers of the four surrounding head stud cavities, and mark one additional location near the edge of the chamber, on the higher side.
2. Remove the piece of plastic, and drill holes at the marked locations, somewhat larger than the stud diameter. Drill two additional holes adjacent to the location marked near the edge of the chamber. One of these will be used as a fill hole, the other as a vent.
3. ***Carefully*** rotate the cam(s) to ensure the valves in the cylinder you intend to measure are fully closed. Be ***extremely*** careful in rotating the cams, as the exhaust and intake valves can collide, causing damage, when rotating the cams individually like this.
4. Place a thin bead of grease around the gasket surface of the head, just outside the chamber you intend to measure. Just “paint” it on with your finger, or an acid brush.
5. Place the piece of plastic over the chamber, and press it down so the grease forms a tight seal between the plastic and the head.
6. Fill the burette with clean Mineral Spirits, then drain off enough to bring the level down to the highest calibrated marking (probably 100cc).
7. *Slowly* open the valve on the burette, and allow oil to flow into one of the holes in the plastic, into the chamber, while carefully watching the level. Close the valve on the burette when the Mineral Spirits ***just*** fills the chamber completely.
8. Look at the final oil level in the burette, and calculate ***and write down*** exactly how much Mineral Spirits was actually put into the cylinder. For a typical engine, this should probably be around 100cc. Yours may be slightly above or below this.
9. Using the syringe, suck out as much of the Mineral Sprits from the chamber as possible, then remove the plastic, and mop up the rest with a rag.
10. Using the telescoping gauge and micrometer, carefully measure, ***and write down***, the exact bore of the cylinder you intend to measure. Measure about one inch down from the top, to ensure you are not measuring the ridge, if any. Take several readings, and make sure you get good correlation.
11. Now get the dial indicator and magnetic base, and place them on the gasket surface of the block, with the point of the dial indicator resting on the flat part of the piston you intend to measure.
12. Rotate the engine very slowly, and, watching the dial indicator, bring the piston up to the top of it’s stroke. You should be easily able to get it within 0.001” of TDC.
13. Using the tail of the vernier caliper, carefully measure the deck height, which is the distance from the gasket surface of the block, to the flat part of the piston. This should be roughly 0.015”.

14. Again using the dial indicator, ***carefully*** rotate the engine to drop the piston ***exactly*** one inch from the deck.
15. Using your finger or a small acid brush, apply a thin bead of clean grease around the perimeter of the piston, to seal up the small gap between the piston and the bore.
16. Using your finger or a small acid brush, apply a thin bead of clean grease on the gasket surface around the perimeter of the bore.
17. Take the piece of plastic used above, and slide it over the studs, and down onto the gasket surface over the cylinder, so the two holes are located on the higher side of the cylinder, so air can easily escape. Press it down firmly, so the grease forms a good seal between the plastic and the block.
18. Using the same procedure as above for measuring the chamber, measure the exact volume of Mineral Spirits required to ***completely*** fill the cylinder. This should be roughly 125cc. Yours may be slightly above or below this.
19. Using the syringe, suck out some of the Mineral spirits, then remove the plastic, and use a rag to mop up the rest. Remove as much of the grease from the perimeter of the piston as possible.
20. Now open the spreadsheet, and select the “Head Off” worksheet. Enter the volume you measured for the combustion chamber into into cell C3, the cylinder volume into cell C4, the bore diameter into cell C5, the deck height into cell C6, and the head gasket thickness into cell C7.
21. Cell C25 now displays your calculated compression ratio. If you find this to be above 9.3:1, you may have a problem. If you’d like to see what it would take to drop this to a more acceptable level, change the head gasket thickness in cell C7, to see what head gasket thickness would be required to drop your compression ratio down to any level you’re comfortable with.