N2

Motor Trade Theory

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Module 1

Engine measurement

What is covered?

In this module, we cover engine measurement, including measurements taken on parts in the engine block and the cylinder head. The components in the engine block which need to be measured are cylinders, pistons, piston rings, crankshaft and bearings. The parts in the cylinder head which need to be measured are the face surface of the cylinder head, valve guides and stems, and the valve springs.

Learning Outcomes

After studying this module, you should be able to:

- Understand where to measure the cylinder bore for size taper and ovality
- Explain how all the measurement are taken on the piston
- Explain how all the measurements are taken on the crankshaft, both inside and outside the engine block
- Explain how the measurements are taken on the connecting rod
- Explain how the measurements are taken for thickness and warpage
- Explain how all the measurements are taken for wear on the valve guide and valve stem
- Explain how to check the seating of the valves
- Explain how to measure valve spring height and spring tension.

Unit 1: Engine block

LEARNING OUTCOMES

- Understand where to measure the cylinder bore for size taper and ovality
- Explain how all the measurement are taken on the piston
- Explain how all the measurements are taken on the crankshaft both inside and outside the engine block
- Explain how the measurements are taken on the connecting rod.

Introduction

After extended engine operation and high mileage, it is necessary to service an engine block. Worn piston rings can cause engine smoking, high oil consumption and low compression during combustion. Worn bearings can lead to low oil pressure, bearing knock and complete part failure.

To service a cylinder block, it is necessary to measure the cylinders for wear, inspect the cylinder wall for damage, install core plugs and hone a cylinder. To determine the **serviceability** of parts, the pistons, piston rings, cylinders, crankshaft and bearings need to be measured. These measurements need to be compared to the manufacturer's specifications to determine whether they are still able to be of service or useful.

Keyword
Serviceability when something is still able to be of service or useful

Measure a cylinder bore for size taper and ovality

If a cylinder is not badly scratched, you have to measure the cylinder to ensure that the new rings will seal properly. Piston rings cannot seal in a worn, out of round or tapered cylinder. The cylinder measurement will help you to determine the piston to cylinder clearance. Cylinder taper and ovality or out of roundness are measured with an inside micrometre or a cylinder bore gauge.

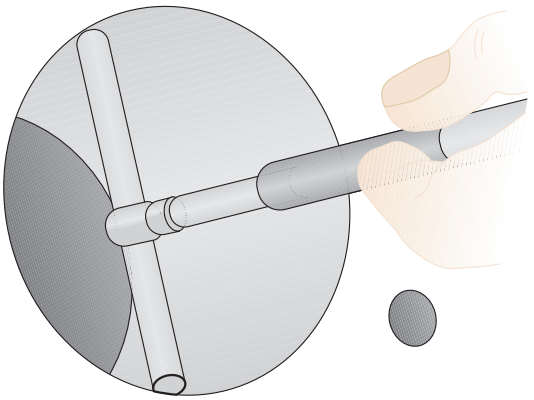


Figure 1.1 The bore dial gauge

When measuring the diameter of a cylinder with a telescopic gauge, the gauge is extended and locked to measure the inside cylinder after which measurements are made using a micrometre.

Cylinder taper is the difference in diameter between the top of a cylinder and the bottom of the cylinder. Cylinder taper is caused by less lubricating oil at the top of the cylinder and more oil splashing at the bottom. Cylinder taper should not **exceed** the manufacturer's specifications, which means it should not go beyond bounds or limits. The manufacturer's service manual should be consulted for exact specifications. Use a bore gauge or inside micrometre to measure the inside diameter of a cylinder.

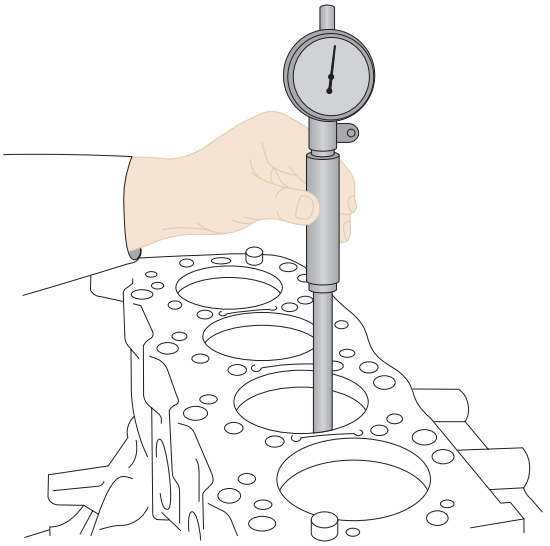


Figure 1.2 The telescopic gauge

Keyword

Exceed to go beyond bounds or limits

Cylinder ovality or cylinder out of roundness is the difference in diameter between a cylinder being measured side to side and from the front to the rear in the block. Piston thrust action makes the cylinders wear more at the right angles to the centre line of the crankshaft. The positions where to measure a cylinder bore for size taper and ovality is illustrated in Figure 1.3.

Measure the diameter of the cylinder at the top and the bottom of the cylinder. Then calculate for cylinder taper and ovality as illustrated in Figure 1.4. Compare the amount of taper and ovality to the manufacturer's specifications to determine whether the cylinder is acceptable or if the engine block needs to be bored.

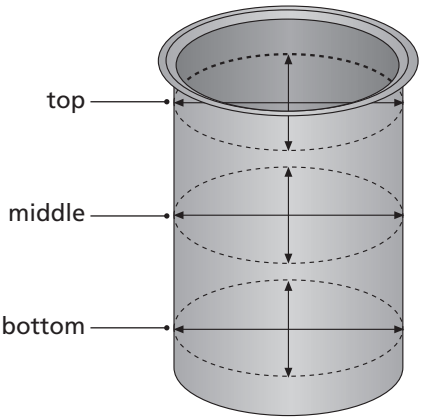
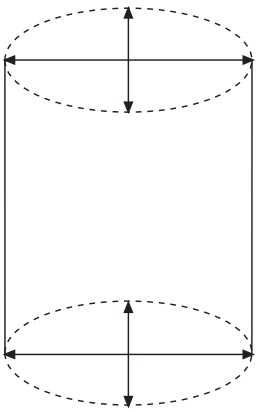


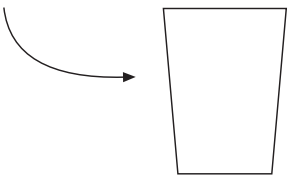
Figure 1.3 Measurements of the cylinder bore for size taper and ovality



3.987
– 3.981
0.006

Subtract the two top measurements from each other to calculate the cylinder out of round.

When a cylinder is tapered, either the top or bottom is larger in diameter than the other.



Subtract the top and bottom readings from each other to calculate the taper.

Figure 1.4 Calculations for cylinder taper and ovality

ACTIVITY 1.1

1. Discuss the terms 'ovality' and 'taper' in a cylinder.
2. A four-cylinder diesel engine's bore diameter specifications are 86,49 mm–86,53 mm. The specified maximum out of roundness and taper is 0,01 mm. Calculate the taper and out of roundness for the following measurements taken from a four-cylinder diesel engine to determine if the engine is still within the manufacturer's specifications.

Table 1.1 Cylinder bore measurements

	Cylinder diameter at the top		Calculations		
Position inside cylinder	**In line with the crankshaft centre line (*Dx*)**	**Across crankshaft centre line (*Dy*)**	**Ovality**	**Taper in line with crankshaft centre line (*Dx*)**	**Taper across crankshaft centre line (*Dy*)**
Top	86, 55	86, 65	$D_y - D_x$ = 86,65 – 86,53 = 0,12 mm	$D_{top} - D_{middle}$ = 86,55 – 86,53 = 0,02 mm	$D_{top} - D_{middle}$ = 86,65 – 86,56 = 0,09 mm
Middle	86,53	86,56	$D_y - D_x$ =	$D_{middle} - D_{bottom}$ =	$D_{middle} - D_{bottom}$ =
Bottom	86,52	86,54	$D_y - D_x$ =	$D_{top} - D_{bottom}$ =	$D_{top} - D_{bottom}$ =

Measure a piston

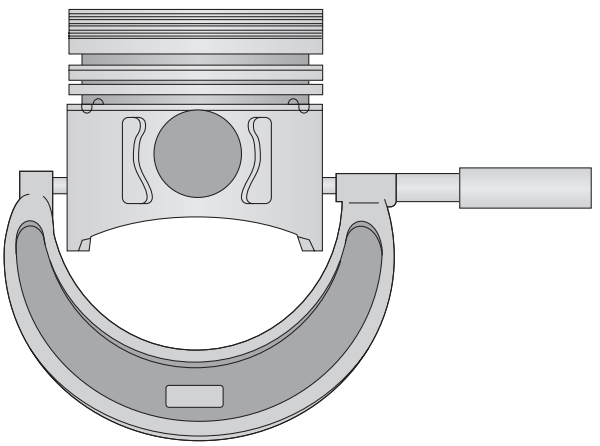
Pistons are made of aluminium and are easily damaged and worn. When servicing an engine's bottom end, it is important to check every piston thoroughly. Look for cracked skirts, worn ring grooves, pin bore wear and other problems.

Piston size is measured using a micrometre on the piston skirt just below the piston pinhole. Adjust the micrometre for a slight drag as it is pulled over the piston.

Piston taper is measured by comparing the piston diameter at the piston pin centre with the diameter at the bottom of the skirt. The difference between the two measurements equals the piston taper. Compare this measurement with the manufacturer's specifications. If the piston taper is not within manufacturer's specifications, the piston should be replaced.

Piston clearance is measured by subtracting the cylinder bore diameter from the piston diameter. The difference between the bore diameter and the piston diameter equals the piston clearance.

Piston taper-measure at piston pin centre and bottom of skirt



Piston size-measure ¾ in. below centre line of piston pin hole

Figure 1.5 Measuring piston taper

Alternatively, the piston clearance can be measured by placing the piston inside the cylinder and measuring the clearance with a feeler gauge. Place a long feeler gauge blade on the piston skirt and push the piston into the cylinder. Use a spring scale to pull the feeler gauge out of the cylinder. When the spring scale reading equals the manufacturer's specifications, the size of the feeler gauge equals the piston clearance.

Piston ring side clearance is the space between the compression ring and the ring groove. Ring groove wear increases this clearance, and if wear is enough, the ring will not be held square against the cylinder wall. To measure ring side clearance, slide a feeler gauge between the ring and its groove. The largest feeler gauge that fits between the ring and its groove indicates the ringside clearance. Compare this to the manufacturer's specifications.

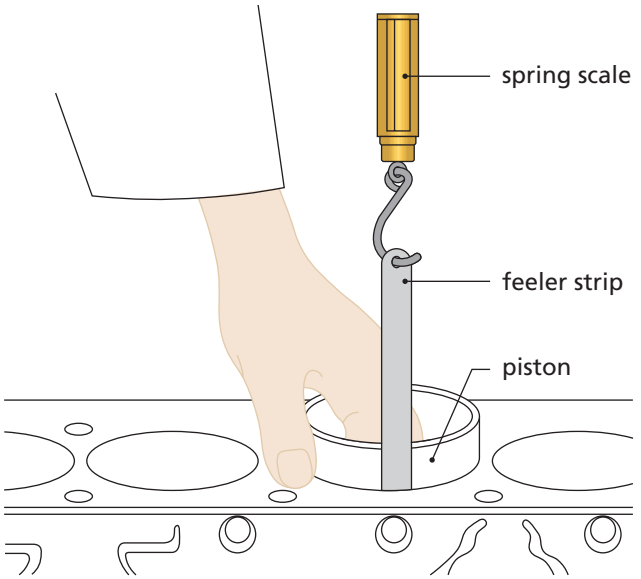


Figure 1.6 Measuring piston clearance

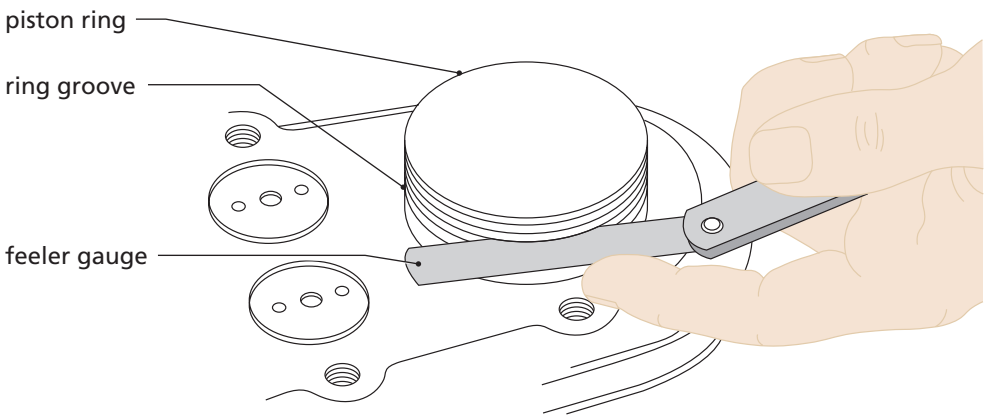


Figure 1.7 Measuring piston ring side clearance

Piston ring gap clearance is very important. If the ring gap is too small, the ring could lock or score the cylinder upon heating up and **expanding**. If the gap is too large, the ring tension against the cylinder walls can be too low, causing blow-by. Check the ring gap clearance by pressing the ring into its cylinder. Press the ring in deeper using the piston to square the ring inside the cylinder. The ring gap is then measured with a feeler gauge and compared against the specifications.

Keyword
Expand to increase in extend, size or volume

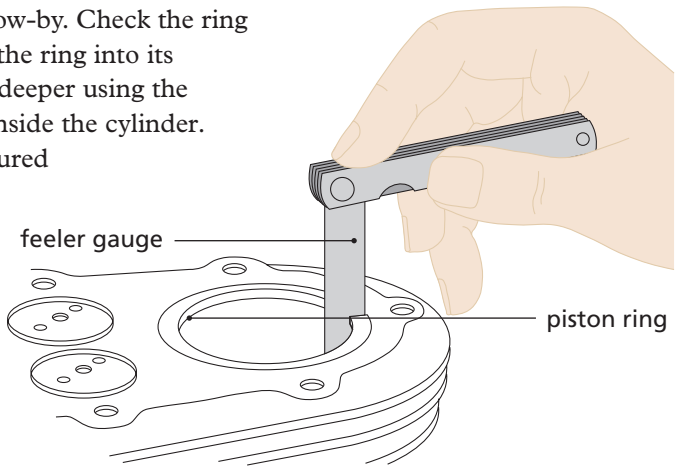


Figure 1.8 Measuring ring gap clearance

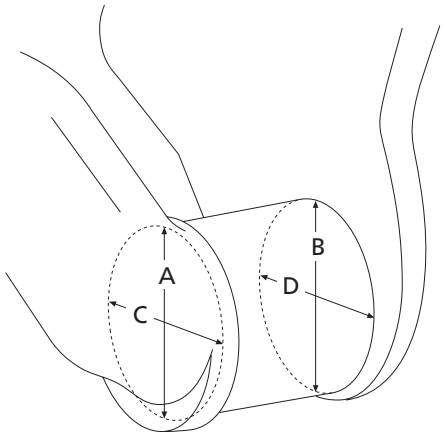


Figure 1.9 Measuring the crank journal for taper and ovality

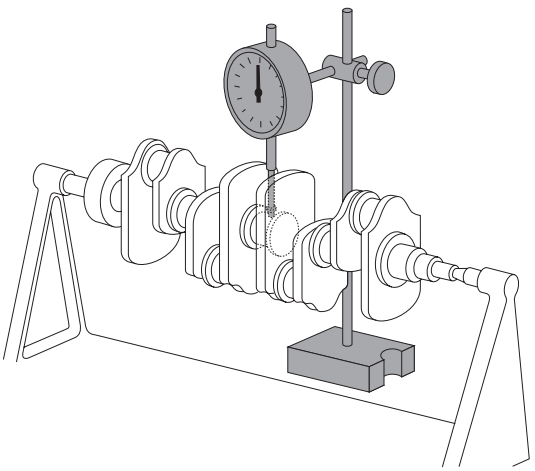


Figure 1.10 Checking a crankshaft for straightness

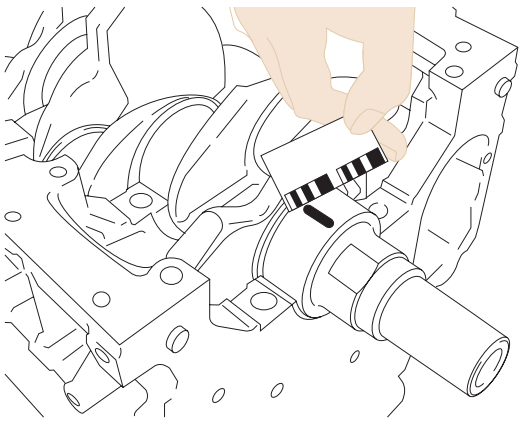


Figure 1.11 Checking oil clearance with a plastic gauge

Measure a crankshaft

A crankshaft needs to be perfectly clean before installing it. Inspect the big end and main bearing journals carefully for any scratching, scoring or signs of wear. Blow out oil passages with compressed air.

Measuring a crank journal for taper will show if one side of the crank journal is worn more than the other. Use an outside micrometre to measure both ends of the journals. The two measurements should be subtracted from each other and compared to the manufacturer's specifications. Taper beyond the manufacturer's limits requires crankshaft turning.

Measure a crank journal for out of roundness or ovality by measuring the crank journal form side to side and from top to bottom. Subtract the two measurements from each other and compared to the manufacturer's specifications. If the ovality is not within the manufacturer's limits, the crankshaft should be sent for machining.

To calculate crank taper, use the following formula:
Taper 1:= $D_A - D_B$ and Taper 2: = $D_C - D_D$

To calculate crank journal out of roundness, use the following formula:
Out of roundness 1: = $D_A - D_C$ and Out of roundness 2: = $D_B - D_D$

Check crankshaft straightness by mounting the crankshaft on V-blocks and mounting a dial indicator against the centre journal. Slowly turn the crank while watching the dial indicator. Dial indicator movement indicates a crankshaft is bent. The crankshaft can also be placed into the block main bearings instead of using V-blocks.

Check main bearing oil clearance

To check the oil clearance for the main bearing and big end bearings, you can either use a plastic gauge or bearing nip or crush. Wipe off any oil on the crank journal surfaces and install the crankshaft by using the manufacturer's torque specifications.

Use a plastic gauge to check the oil clearance between the crankshaft and the main bearing. First, remove the bearing cap and place a small bead of plastic gauge across the surface of the unoiled crankshaft. Replace the bearing cap and tighten the bolts according to the manufacturer's specifications. Loosen the bolts again to remove the bearing cap. Then compare the smashed bead of the plastic gauge to the paper scale. If the clearance is not correct, check the crank journal sizes and bearing sizes.

To check bearing nip or crush, make sure the bearing cap bolts have been torqued according to the manufacturer's specifications. Then loosen one of the bolts and check the

clearance underneath the bearing cap using a feeler gauge. Compare the measurement with the manufacturer's specifications.

Crankshaft end play is the amount of front to the rear movement of a crankshaft in the engine block. Crankshaft endplay is controlled by the clearance between the main thrust bearing and the crankshaft thrust surface. Mount a dial indicator on the block to measure endplay. Place the dial indicator stem parallel to the crank's centre line and prise the crank back and forth. The dial indicator movement equals crankshaft endplay. Compare the endplay with the manufacturer's specifications. If endplay is incorrect, check the thrust bearing.

Crankshaft end play can also be checked by using a feeler gauge. Press the crankshaft to the one side and insert the feeler gauge at one of the main bearing journals. The largest feeler gauge that enters the gap equals the crankshaft end float.

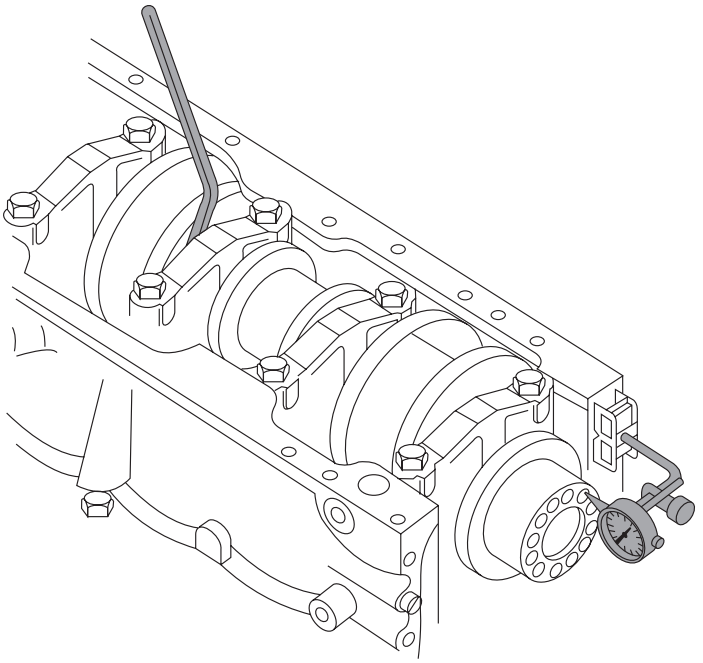


Figure 1.12 Measuring the crankshaft end play with a dial gauge

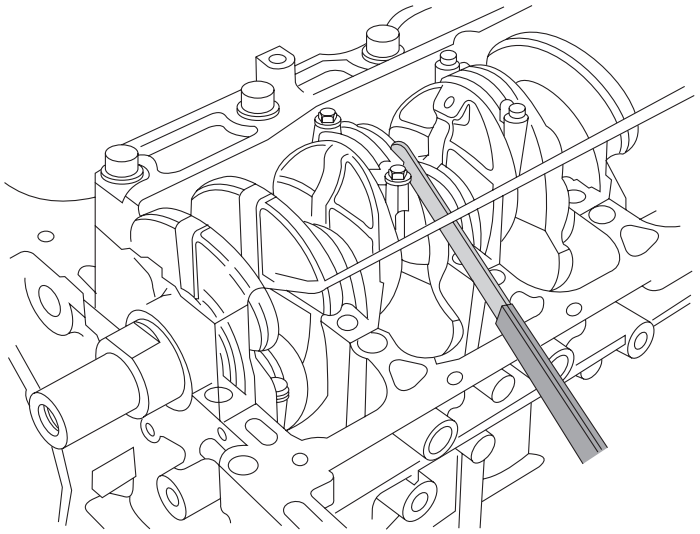


Figure 1.13 Measuring the crankshaft end play with a feeler gauge

ACTIVITY 1.2

1. Explain how to measure piston taper.
2. Explain the two methods to measure for piston clearance.
3. The manufacturer's specifications for the diameter of the main bearings of a diesel engine are 56,980 mm–56,995 mm. The maximum allowed out of roundness is 0,015 mm, and the maximum taper is 0,005 mm. Calculate the taper and out of roundness for the journal if the measurements taken are as in the table below. Refer to Figure 1.9.

Journal no.	Journal diameter				Calculations	
	D_A	D_B	D_C	D_D	Ovality	Taper
1.	56,99	56,94	56,99	56,89	$D_A - D_C = 56,99 - 56,94 = 0,05$ mm $D_B - D_D = 56,99 - 56,89 = 0,1$ mm	$D_A - D_B = 56,99 - 56,99 = 0,00$ mm $D_C - D_D = 56,94 - 56,89 = 0,05$ mm
2.	56,98	56,95	56,99	56,92	$D_A - D_C =$ $D_B - D_D =$	$D_A - D_B =$ $D_C - D_D =$
3.	56,99	56,92	56,98	56,90	$D_A - D_C =$ $D_B - D_D =$	$D_A - D_B =$ $D_C - D_D =$
4.	56,99	56,96	56,99	56,93	$D_A - D_C =$ $D_B - D_D =$	$D_A - D_B =$ $D_C - D_D =$

Measure a connecting rod

The connecting rod is subjected to tons of pressure during engine operation and can wear, bend or break. The old piston and bearing inserts may indicate the condition of the connecting rod. If any piston or bearing abnormalities are found, there may be something wrong with the connecting rod.

The small end is measured with a telescopic gauge and a micrometre. If the small end is worn, the rod bush should be replaced in a machine shop and the pin fitted.

The connecting rod big end is checked after removing the bearings and replacing the bearing cap. Once the bolts are torqued to the manufacturer's specification, measure the rod bore diameter on both edges and in both directions. Any difference in edge diameter equals taper of the big end. Any difference in cross diameters equals connecting rod big end out of roundness.

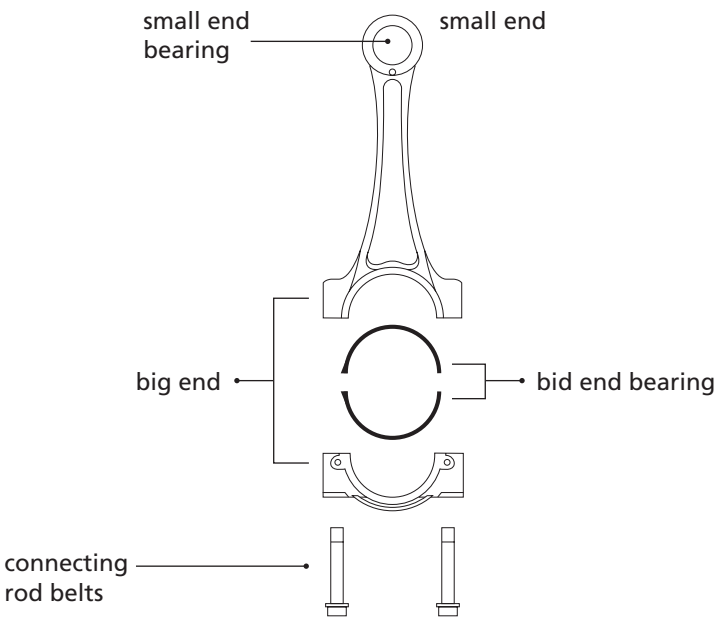


Figure 1.14 The connecting rod assembly

Unit 2: Cylinder head

LEARNING OUTCOMES

- Explain how the measurements are taken for thickness and warpage
- Explain how all the measurements are taken for wear on the valve guide and valve stem
- Explain how to check the seating of the valves
- Explain how to measure valve spring height and spring tension.

Introduction

The cylinder head and valve service are very important for engine performance and service life. The valves, cylinder head and cylinder head gasket, work together to contain the heat and pressure from combustion. Cylinder heads may become warped or cracked which may lead to coolant leaking into the engine oil and the overheating of the engine. When valve guides and valve stem seals are worn, the engine oil will leak past the valve stem into the combustion chamber, which leads to exhaust smoke and oil consumption. Poorly seated, burnt or bent valves negatively influence combustion pressure and causes a misfire. It is thus important to carry out certain checks and measurements on a cylinder head to ensure an engine performs at its best.

Measure a cylinder head for thickness and warpage

A warped cylinder head has a bent deck surface which results from engine overheating. Use a straight edge and feeler gauge to measure cylinder head **warpage**. Lay the straight edge on the head and try to slip different feeler gauge blade thicknesses under the straight edge. The thickest blade that fits under the straight edge equals the head warpage.

Keyword

Warpage to bend or twist out of shape

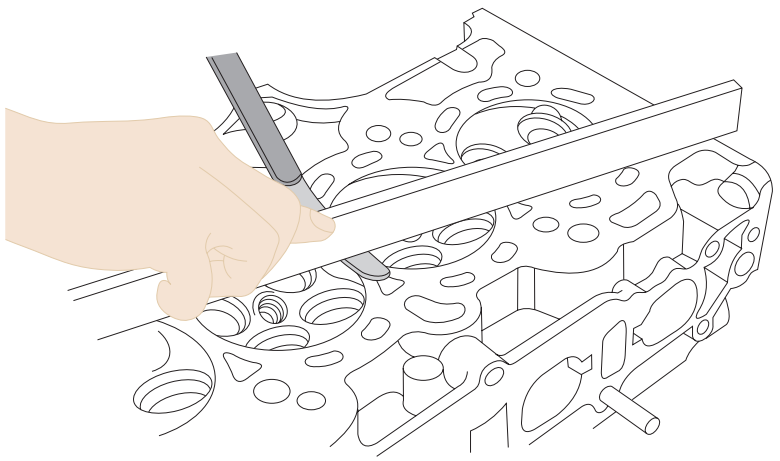


Figure 1.15 Measuring cylinder head for warpage

If the warpage exceeds the manufacturer's specifications, the cylinder head needs to be machined by doing cylinder head milling in a machine shop. When servicing a cylinder head, it is important to also check for cracks in the cylinder head. Usually, dye penetrant is used to find cracks on aluminium components at machine shops.

Measure a cylinder head for wear on the valve guide and valve stem

Valve guide wear is a common problem, and it allows the valve to move sideways during operation. To check valve guide wear, slide the valve into its guide and try to wiggle it from side to side. If the valve moves in any direction, the valve guide or stem is worn. The amount of play can be measured using a dial gauge, as illustrated in Figure 1.16.

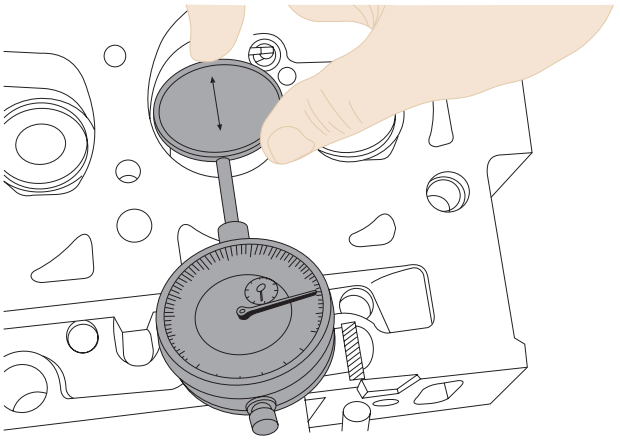


Figure 1.16 Using a dial gauge to measure valve guide and stem wear

Mount the dial indicator stem against the side of the valve head and wiggle the valve sideways while reading the indicator. Valve guide wear can also be measured by using a small hole gauge, as illustrated in Figure 1.17.

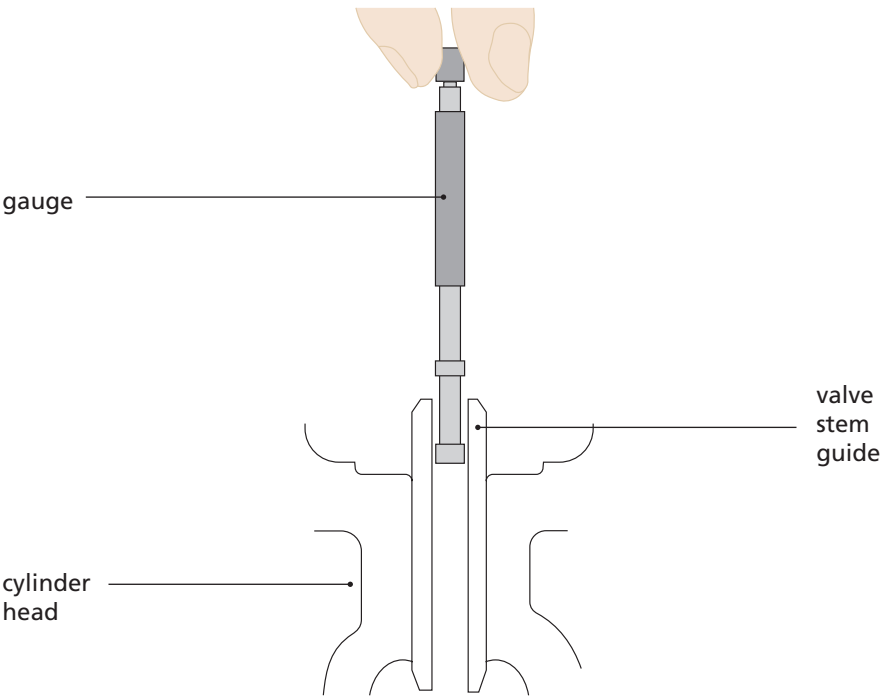


Figure 1.17 Using a small hole gauge to measure valve guide

The small hole gauge is used to determine the inside diameter of the valve guide and then measured by using an outside micrometre.

Valve stem wear is checked by using an outside micrometre, as illustrated in Figure 1.18.

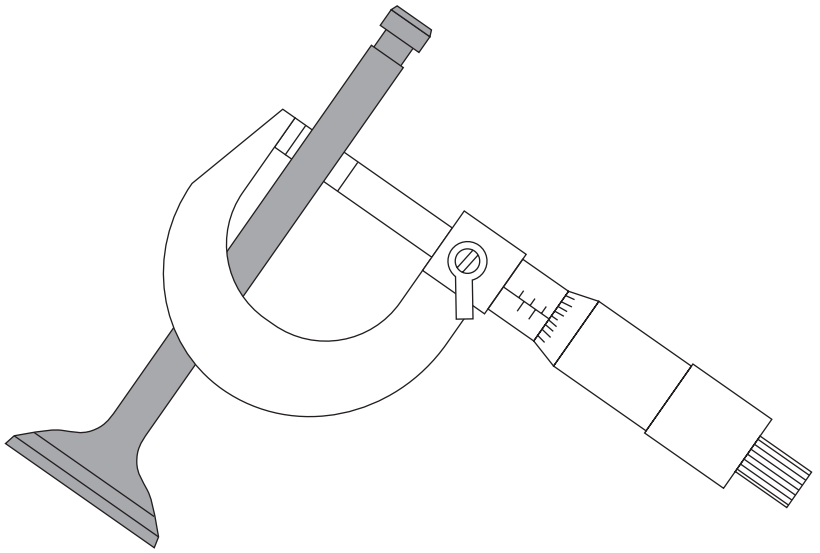


Figure 1.18 Using a micrometre to measure valve stem wear

Check the seating of valves

The measurements on the valve stem should be taken at the top, middle and bottom of the valve stem.

Valve seats and valve faces should be checked for burning, pitting, and wear from opening and closing. To test if a valve is seated correctly and seals effectively, the cylinder head can be turned upside down. Pour paraffin onto the valves to check if any paraffin leaks into the intake or exhaust ports. The valve to seat contact should also be checked, as illustrated in Figure 1.19.

The contact width between the valve's face and the seat of an intake valve should be approximately 1,6 mm. The valve to seat contact of an exhaust valve should be approximately 2,4 mm. The specifications should, however, be checked according to each manufacturer.

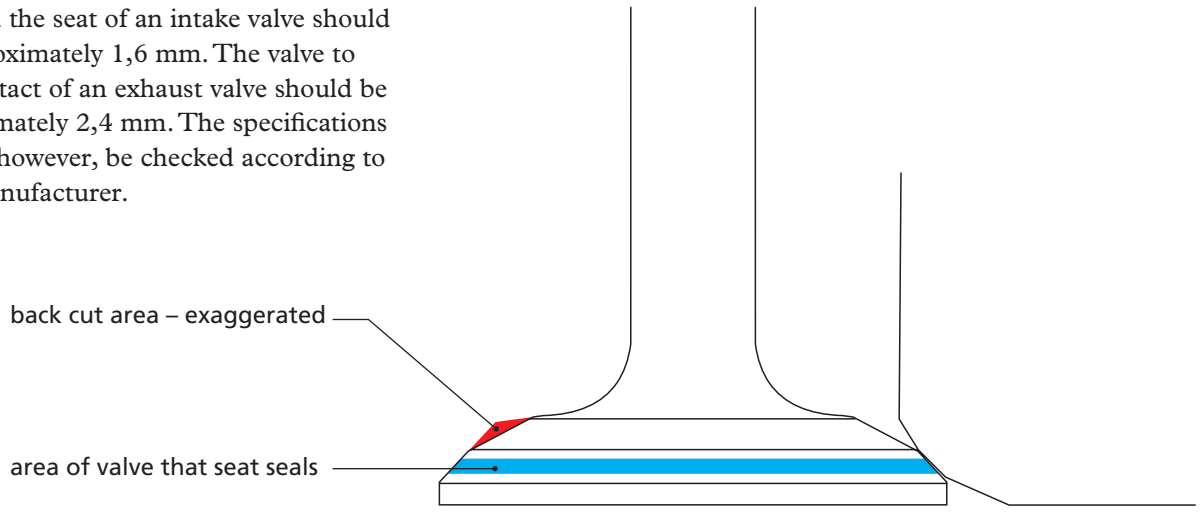


Figure 1.19 Checking the valve to seat contact

Measure spring height and spring tension of a valve

To check for **valve spring squareness** and **valve spring height**, use a combination square. Place each spring next to the square on a flat surface. Rotate the spring and check for a gap between the side of the spring and the square. If the spring is not square, too long or too short, it should be replaced.

To check for **valve tension**, use a valve spring tester, as illustrated in Figure 1.21.

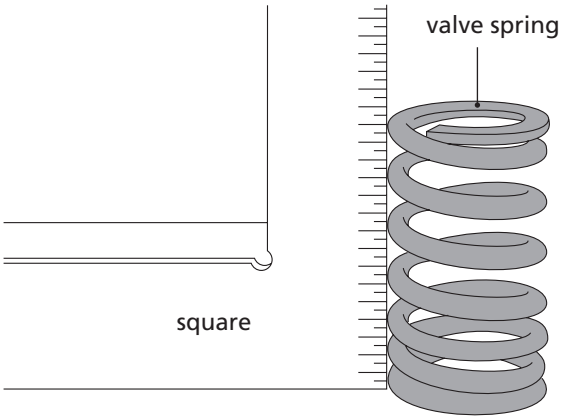


Figure 1.20 Measuring valve spring squareness and height

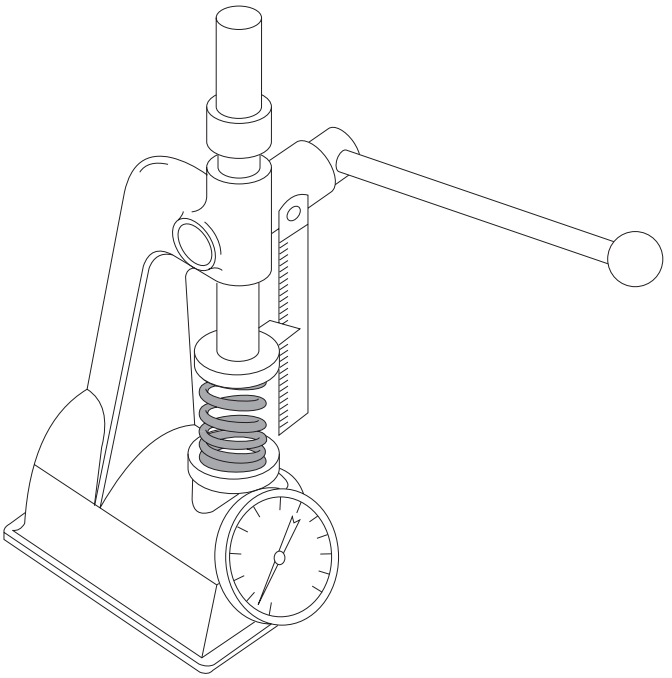


Figure 1.21 Measuring valve spring tension by using a valve spring tester

ACTIVITY 1.3

1. Discuss how you will measure the gasket surface of a cylinder head for warpage.
2. Explain how a blown cylinder head gasket influences engine performance.
3. What will you look for when doing a visual inspection of a valve face and seat?

Module summary

- After extended engine operation and high mileage, it is necessary to service an engine block.
- Worn piston rings can cause engine smoking, high oil consumption and low compression during combustion.
- Worn bearings can lead to low oil pressure, bearing knock and complete part failure.
- To service a cylinder block, it is necessary to measure the cylinders for wear, inspect the cylinder wall for damage, install core plugs and hone a cylinder.
- The cylinder head and valve service are important for engine performance and service life.
- The valves, cylinder head and cylinder head gasket, work together to contain the heat and pressure from combustion.
- It is important to carry out certain checks and measurements on a cylinder head to ensure an engine performs at its best.

Exam questions

1. Describe the TWO measurements you would make on the cylinders of an engine using a sketch. (4)
2. Explain how you will measure piston clearance. (2)
3. Name THREE engine problems expected from having too much clearance between the cylinder and the piston rings? (3)
4. Explain how a crank journal is measured for out of roundness or ovality. (2)
5. Name the TWO methods for checking crankshaft bearing oil clearance. (2)
6. Sketch to illustrate the positions in which you will measure warpage on a cylinder head. (3)

[16]