Overview

Premature failures in pistons, piston rings, cylinder liners, bearings and bushings

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Introduction

All engine parts have a foreseen operational life, which can be longer or shorter, depending on the specific function ascribed to it. Therefore each part has its pre-determined operational life under normal running conditions of the complete assembly, according to what has been expected.

But not always these expectations are maintained, because internal and/or external factors to the engine can impair one of the parts during the engine operation, reducing its operational life. A good mechanic should therefore not limit his action only to the exchange of parts, but he should also diagnose the cause of the reduction of the pre-determined durability.

The failures of internal engine components, which will be analyzed, are:

Pistons

Pistons are parts made usually of cast or forged aluminum, whose function is to transmit by alternate movement the force of expanding gases, which are the result of the combustion of an air/fuel mixture. This force is transmitted to the crankshaft by the pin and the con rod.

Piston rings

Piston Rings are circular elastic elements with high expansive force. They have following main functions: to provide the sealing of the gases in the combustion chamber, to control the lubricating oil film of the cylinder walls and to be a transmitting element for the heat, from the piston to the cylinder.

Cylinder liners

Liners are cylindrical parts of three types: dry, wet and finned. Their main functions are: to provide a sealed system for the expansion of combustion gases and to provide the heat transfer to the cooling liquid that circulates through the engine blocks galleries (in case of dry and wet cylinders) and to the air (in case of finned cylinders). They also allow the re-use/ salvage of the engine block in certain cases.

Bearings

Bearings are steel parts covered by different anti-friction alloys. Their main functions are: to reduce the friction between a movable engine part and a static one connected to it, and to resist the high loads, mainly the high impacts caused by the engine's combustion.

Bushings

Bushings are integral or parted parts, similar to bearings. They differ basically from the bearings in their form, in some cases of terminology and in the composition of their alloys.

Valves

Valves are parts built from materials of one or more types. According to their function, they're divided into two types: intake valves and exhaust valves.

The function of an intake valve consists in admitting the air or air and fuel mixture to the combustion chamber. They're normally mono-metallic or mono-metallic with seat face or wafer-welded tip end.

The function of an exhaust valve consists in allowing the discharge of the combustion gases. They're normally bi-metallic or bi-metallic with seat face. They can be hollow, filled with sodium.

Both types of valves have also the function to seal the combustion chamber and to transmit the heat to the cylinder head and the cooling liquid.

We present you below the most common causes, which could jeopardize the operational life of the above-mentioned parts. It should be important to mention that the operational life of these components could be influenced by one or more causes combined:

- incorrect assembly;
- irregular machining of the dry cylinder housing;
- washing/insufficient lubrication of the cylinder;
- other factors.

The mere replacement of a part with premature failure, will submit the new part to the same causes responsible for the damages caused on the previous one. The mechanic, therefore, should not correct the failure without first discovering what has been the cause(s).

In order to facilitate the understanding, each case in this Manual is analyzed from three different angles:

1. Aspect - A brief description of the part, that is failed due to one or more specific causes.
2. Causes - Description of the destructive process and the factors capable of accelerating the damage.
3. Corrections - Measures to be taken, to correct the premature failure of the part.

Normal conditions, aspect and wear

To have an internal combustion engine running under normal conditions, a starter is required which, turning the crankshaft, provides the admission of the air/fuel mixture to the combustion chamber. In this chamber the mixture is compressed by the piston and will have its volume reduced and its temperature increased. There are two types of ignition:

- forced ignition (by spark plug);
- spontaneous ignition.

The spark of the spark plug starts the forced ignition; the air/fuel mixture, compressed by the piston, enters in combustion and expands, pushing the piston of the corresponding cylinder down (engines of the Otto-cycle-gasoline/alcohol/gas)

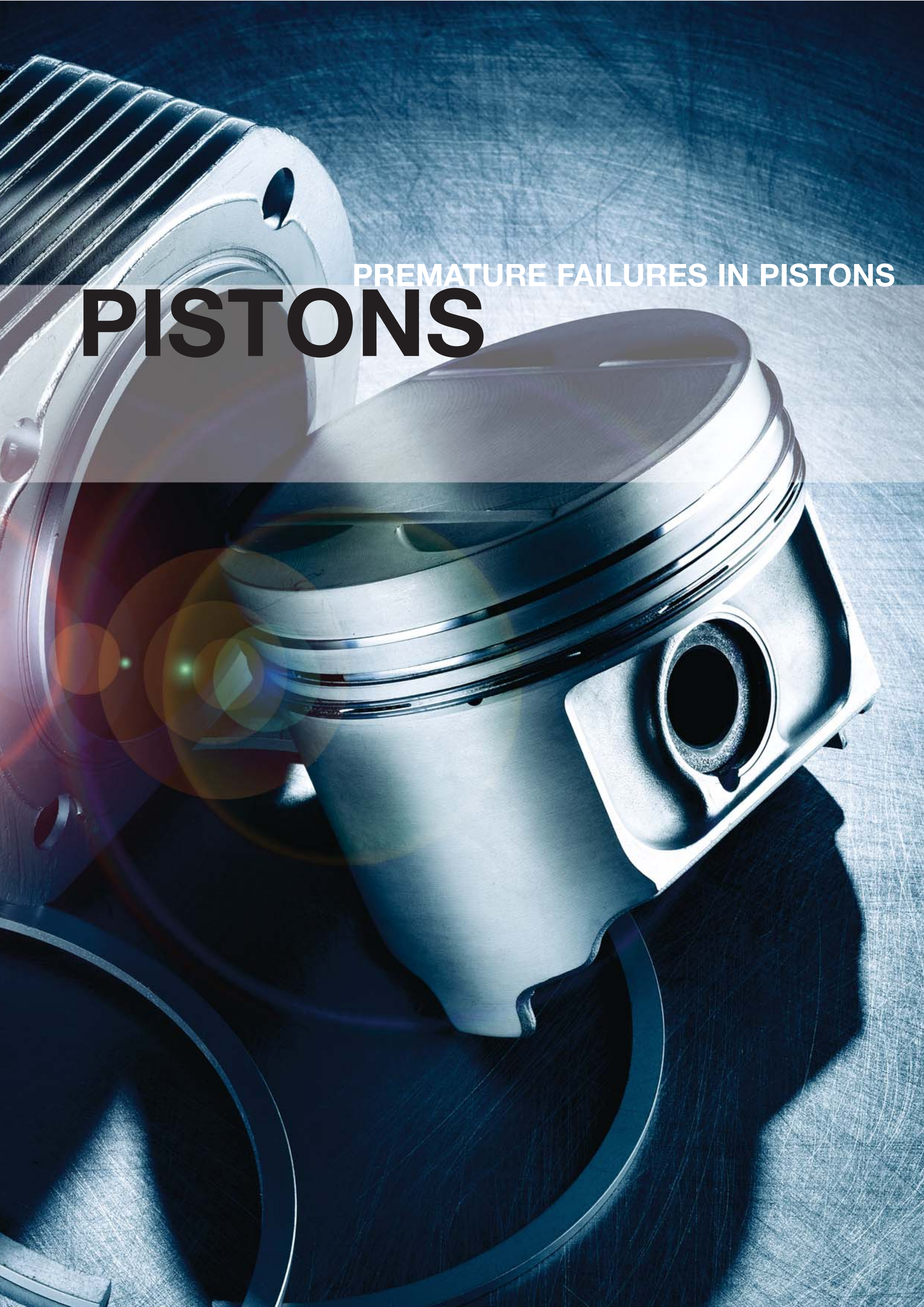
The spontaneous ignition occurs in engines that use diesel fuel. They have a higher compression ratio than the Otto-cycle engines. In these cases the engine admits only air into its combustion chamber and the piston compresses this air until its small volume results in a high temperature increase. At a certain point (injection point) the fuel is injected at the combustion chamber by an injection nozzle. At his moment the combustion of the air/fuel mixture starts (spontaneous combustion), pushing the piston of the corresponding cylinder down (engines of the Diesel-cycle).

IMPORTANT

In this premature failure manual we presented the most common causes that could lead to a failure in pistons, pistons rings, cylinder liners, bearings, bushings and valves. Surely exist several other causes that shoud be analyzed and take into account before assembly new parts during the engine rebuilt.

PISTONS

PREMATURE FAILURES IN PISTONS



Normal running characterstics

The normal wear of a piston occurs when the other engine components also function under normal conditions. The air filter systems, the fuel injection, lubrication and cooling, combined with the normal engine operation, will result in a piston with normal wear during the operational life of the engine.

Piston with normal running characteristics

1. Premature failures in pistons, due to assembling error

1.1 Circlip expulsion

Aspect

- Breakage of the piston pin circlip groove. Generally this occurs due to a composition of forces that pushes the pin against one of the circlips, until its expulsion and/or fracture. Eventually pieces of the fractured circlip cross the inner pin diameter and damage the other end.

Causes

- Bent con rod;
- Cylinders are misaligned in relation to the crankshaft;
- Incorrect circlip mounting;
- Conical crankshaft journal;
- Excessive longitudinal (axial) clearance of the crankshaft;
- Excessive clearance between pin and circlip;
- Non-parallelism between the con rod small end bushing and the bearing.

Corrections

- Correct alignment of the con rods (changing them, if necessary);
- Cylinder rectification correctly aligned with the crankshaft;
- Correct circlip mounting, without deformations during assembly;
- Correct rectification of crankshaft journal;
- Check axial crankshaft clearance.

Fig. 1.1

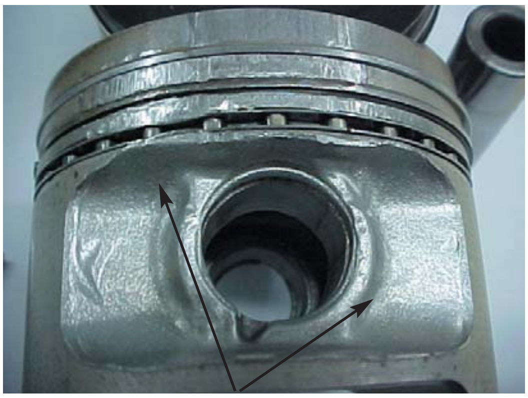


Fig. 1.1.1 Damages caused by circlip

Fig. 1.1.2 Damages caused by circlip

Fig. 1.1.3 Damages caused by circlip

1.2 Insufficient clearance between pin and bushing

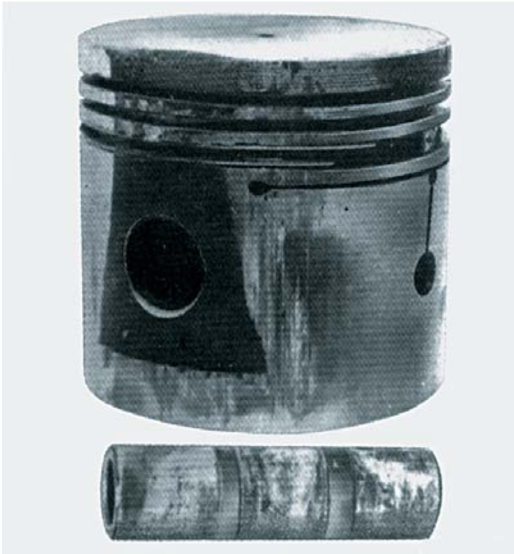


Fig. 1.2

Aspect

- Scuffing zone along the pin bore (bosses).

Causes

- Pin was mounted with insufficient clearance into the pin bore and/or into the con rod small end bushing.

Corrections

- Mount the piston pin with the correct specified clearance at the con rod small end bushing, observing the existence or not of pin and piston pin bore classification.

Fig. 1.3

1.3 Inclined contact area

Aspect

- Inclined contact area in relation to the piston axis.

Causes

- Bent con rod;
- Cylinders are misaligned in relation to the crankshaft.

Corrections

- Get a correct con rod alignment (changing them, if necessary);
- Rectification the cylinder, keeping it correctly aligned with the crankshaft;
- Small end bushing ID boring.

Fig. 1.3.1 Inclined marks at the piston skirt region

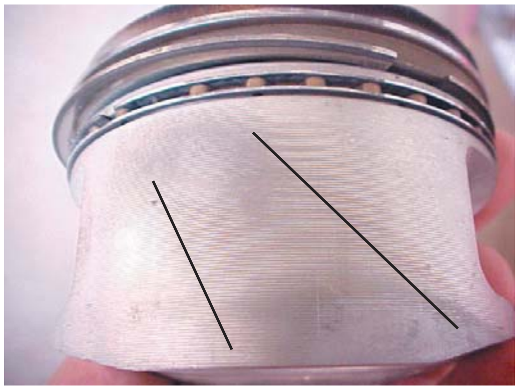


Fig. 1.3.2 Inclined marks

Fig. 1.3.3 Inclined marks

Fig. 1.3.4 Inclined marks at the piston skirt region

1.4 Scuffing caused by cylinder liner deformation

Aspect

- Scuffing in small stripes, generally at the complete circumference of the piston skirt. The stripes tend to enlarge during the running time and result in general engine seizure.

Causes

Deformation of cylinder liners, caused by:

- Irregular engine assembly;
- Expanded o'ring seals during engine operation;
- Housing diameter of o'ring seals out of specification;
- Inadequate torque of cylinder head bolt;
- Deficient cylinder rectification.

Corrections

- Provide correct machining of engine block bores for cylinder liner installation;
- Use o'ring seals of good quality;
- Verify o'ring seal housing dimensins;
- Give correct torque to cylinder head bolts.

Fig. 1.4

1.5 Ring flutter

Aspect

- Destroyed ring grooves.

The problem usually occurs at the first compression ring, which is situated at the most loaded zone of the ring region and therefore is exposed directly to the combustion gases.

Delayed ignition originates heat and overheats this region of the piston. Furthermore the rings don't fulfill its function of transferring heat to the cylinder.

Thus the piston has its resistance diminished, which can originate cracks that happen normally at ring lands.

Causes

- Excessive clearance between ring and groove;
- Use of new rings in old grooves (used pisto);
- Use of rings with incorrect height;
- Excessive deposits of carbon materials.

The overheating of this piston region, plus the abrasion caused by the carbon materials, do result in excessive groove wear, and consequently could cause ring flutter.

Corrections

- During ring changes, the groove conditions should be carefully checked, mainly the first ones, which run the compression rings;
- Keep the clearance between the rings and the grooves within the specified values.

Fig. 1.5.1

Fig. 1.5

Fig. 1.6

1.6 Insufficient assembly clearance

Aspect

- Considerable and generalized scuffing of the piston skirt, mainly at the thrust side, as a consequence of abnormal running, caused by a reduction of the clearance to values smaller than the ones specific in the project.

Causes

- Piston fitted in the cylinder with insufficient clearance.

Corrections

- Observe the piston/cylinder clearance recommended by the engine manufacturer.

2. Premature failures caused by engine malfunction

Fig. 2.1

2.1 Scuffing caused by insufficient cooling

Aspect

- Piston scuffing, mainly over the pin axis (bosses).

The piston/cylinder assembly is mounted with fairly small clearances, which tend to diminish during the heating of the engine, because the piston expansion coefficient is higher then the cylinder coefficient.

Obviously, during the piston project, the engine cooling system is taken into consideration.

Any change in the engine cooling results in higher temperatures of the assemblage, eliminating the project clearances, breaking the lubricating oil film and resulting in a metallic contact between piston and cylinder.

This abnormal operation leads inevitably to piston scuffing.

Causes

- Excessive deposits in the engine block's water conduits, which have not been removed during the last reconditioning. These deposits cause considerable increase to the thermal resistance of the walls, increasing the piston temperature;
- The malfunction of the thermostatic valve, even during short periods, can lead to flow interruptions of the refrigerating water to the radiator, increasing therefore the engine temperature;
- Radiator in bad conditions, especially when internally or externally blocked. The thermal insulation of the radiator core from the exterior is a consequence of excessive deposits, mainly mud, at its external surface;
- A mechanical failure of the water pump can result in insufficient cooling water circulation, which is noted mainly when the engine runs at high power;
- A slack fan belt (slipping in excess),

originates a reduction in air flux through the radiator;
- A faulty radiator cap doesn't offer sufficient water-sealing, and causes the fall in water pressure and frequent water "boiling";
- Draining the cooling system to remove possible air bubbles, when filling the system with additivated water.

The air bubbles should be removed at the correct places and according to instructions given by the manufacturer/producer. For example: theB58, B10M, NL10-340 Volvo vehicles have to be drained by removal of a small plug at the 6th cylinder head, when filling the system with cooling fluid, after all air is removed from the system and before the engine is started.

Corrections
- Revise periodically the cooling system (water pump, radiator, belts, fan and thermostatic valve).

2.2 Damage caused by detonation

Aspect
- Piston crown partially destroyed.

During combustion, when the unburnt gas mixture suffers compression due to the advance of the flame front it could happen that, under certain circumstances, the final portion of the mixture suffers spontaneous combustion.

This combustion could represent a considerable mass, which, instead of burning progressively during the flame's advance and consuming each part of the mass approximately at constant pressure, will react instantly instead and at constant volume. The resulting pressure is much higher than the final pressure achieved under normal combustion. Due to the high speed of this phenomenon, there is no time for the burnt gases to expand, which justifies the hypothesis that this abnormal combustion happens at constant volume.

The increase in the corresponding pressure is limited to the occupied volume by the mass that has spontaneously reacted and given birth to a pressure wave that propagates itself in the combustion chamber at sound's speed.

This wave is repeatedly reflected by the combustion chamber walls, originating a typical noise, which is generally and erroneously called "pin knocking". The correct name of the described phenomenon is 'DETONATION'.

The detonation erodes the piston crown, at he spontaneous combustion side of the gases (normally opposite to the spark plugs) and has its origin in the gases turbulent action, at very high temperatures, against the piston crown.

Furthermore, it can originate in its last stages, excessive wear of the first groove, plus breakage, furrows and seizing of the piston rings.

Fig. 2.2

Causes
- Use of gears and shifting, inadequate to the vehicle load and speed;
- Cylinders running at too high temperatures;
- Incorrect regulation of the carburetor (extremely poor mixture);
- Excessively advanced spark;
- Low quality fuel (with low octane content);
- Incorrect distributor calibration/regulation;

- Engine overload;
- Excessive deposits on piston crown and cylinder head;
- Excessive cylinder head lowering, with resulting increase in compression ratio;
- Use of incorrect spark plugs.

Corrections
- Periodical revision of fuel and ignition systems, maintaining them in working conditions as recommended by the engine manufacturer;
- Avoid engine overloading.

2.3 Damage caused by pre-ignition


Fig. 2.3

Aspect
- Partial destruction of piston ring lands and piston crown;
- Hole in the piston crown.

The formation of a second flame wave, not originated by the spark plug, and having spontaneous ignition, is called pre-ignition.

We have here a new wave front, which isn't an inconvenience in itself, as long as it occurs after the main flame wave, that is, the one that has been ignited by the spark plug.

At the same time in which the temperature of the parts increase, pre-ignition starts to occur earlier and earlier in the cycle, until it happens before the spark plug ignition, reducing the engine power.

If this would happen in an engine with only one cylinder, the power would be reduced progressively, until finally and silently the engine would stop. In an engine with many cylinders however, the other cylinders keep the engine running and the cylinder with pre-ignition will be submitted to combustion temperatures, which will be higher and higher, causing an excessive heat flow to the combustion chamber walls.

Excessive temperatures and pressures, resulting from pre-ignition, can perforate the piston crown.

Causes
- Incorrect spark plugs for the required service;
- Hot spots originated by defective cooling;
- Carbon deposits at very high temperatures (almost incandescent) generating hot spots;
- Valves operating at higher then normal temperatures;
- Detonation or conditions that lead to detonation.

Corrections
- Installation of adequate spark plugs;
- Check the cooling system;
- De-carbonization of the piston crowns and cylinder head, whenever possible;
- Periodical regulation of engine valves, according to instructions given by the engine manufacturer.


Fig. 2.3.1


Fig. 2.3.2

2.4 Cracks on piston crown and pin bosses

Aspect
- Cracks on piston crown;

- Cracks on upper part of the pin bosses.

Causes
- The cracks formed at the piston crown are a consequence of extreme thermal tensions. Should the cracks have been formed in perpendicular direction to the piston pin axis, in addition to the thermal effects, there have occurred also mechanical stresses, subjecting the piston to traction or compression of the crown's surface;
- If the cracks have been originated at the upper part of the bosses, and from there followed in the direction of the top, tending to part the piston in two, there has been an interaction between the boss and the piston pin. High tensions have occurred, above the recommended values, caused by compression, by deformation of the piston pin and by the wedge effect applied to the surface of the pinhole.

Fig. 2.4

Corrections
- The engine reconditioning, the regulation of the injection system, as well as de engine running conditions have to be performed according to the specifications given by the engine manufacturer.

2.5 Failures caused by running at temperatures below normal

Fig. 2.5

Aspect
- Destroyed ring lands between ring grooves;
- Excessive carbonization of ring lands.

Causes
- Incorrect carburetor regulation (incorrect air/fuel ratio - too many fuel);
- Engine running below normal temperature;
- Thermostatic valve blocked in open position and/or non-existent.

Corrections
- Provide correct carburetor regulation, to achieve correct air/fuel ratio;
- Check thermostatic valve working conditions;
- Replace faulty thermostatic valve;
- Avoid to run at high load with totally cool engine.

2.6 Excessive fuel injection

Aspect
- Scuffing stripes from piston crown downwards, generally in the direction of the diesel oil injection, tending to expand later to other regions.

Fig. 2.6

Fig. 2.6a

Causes

- The dilution of the lubricating oil film, existing on the cylinder walls, happens due to fuel injected in excess. This can be the case when the fuel pump inject more fuel than specified and/or when there is an incorrect spraying done by the nozzles.

The oil film dilution generates a metal-metal contact between the piston and the cylinder. The temperature raises substantially due to friction and the piston expands excessively, until it gets scuffed.

Fig. 2.6.1 Spraying occurs partially out of the combustion chamber

Fig. 2.6.2 Spraying occurs partially out of the combustion chamber

Fig. 2.6.3 Irregular spraying done by the nozzle

Fig. 2.6.4 Irregular spraying done by the nozzle

Fig. 2.6.5 Irregular spraying done by the nozzle

Fig. 2.6.6 Irregular spraying done by the nozzle

Fig. 2.6.7 Scuffing started at the top land, followed by rupture at the pin boss

Corrections

- Revise periodically injection pump and nozzles, according to recommendations given by the engine manufacturer.

2.7 Crown damage by erosion

Aspect

- Piston crown eroded, due to mechanical overloads and thermal disintegration.

Causes

- Excessive fuel injection at each cycle;
- Premature injection (anticipated ignition point);
- Incorrect spraying;
- Leaky injectors nozzle.

Fig. 2.7

Corrections

- Regulation of injection pump and nozzles, to achieve correct injection and spraying of diesel fuel;
- Correct fuel injection point.

Fig. 2.7.1 Partial destruction of the combustion chamber

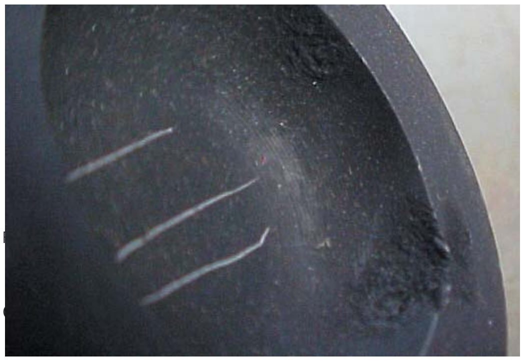


Fig. 2.7.2 Partial destruction of the combustion chamber

Fig. 2.7.3 Scuffing started at the top land, and extended to the piston skirt

Fig. 2.7.4 Scuffing started at the top land

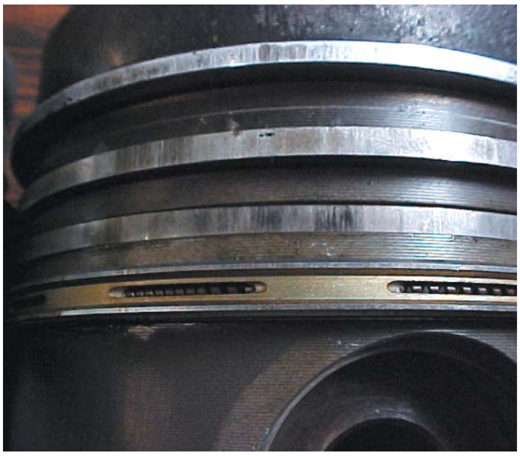


Fig. 2.7.5 Scuffing started at the top land

Fig. 2.7.6 Partial destruction of the crown, due to injection defect

Fig. 2.7.7 Partial destruction of the crown, due to injection defect

Fig. 2.7.8 Scuffing started at the top land

Fig. 2.7.9 Scuffing started at the top land

Fig. 2.7.10 Destruction of the crown and the pin boss region, due to irregular injection

Fig. 2.7.11 Destruction of the crown and the pin boss region, due to irregular function of injection nozzle

2.8 Interference between piston and cylinder head and/or valves

Aspect

- Piston crown is deformed due to knocking against cylinder head and/or engine valves.

Causes

- Piston stroke increase, due to loosening of a con rod bolt;
- The carbon deposits formed at the piston crown are thicker than the top clearance, resulting in piston impacts on the cylinder head;
- Engine block height below specifications;
- Change in piston stroke due to incorrect grinding of crankshaft journal;
- Change in length of con rod;
- Reduction of cylinder head height, without the corresponding adjustment of depth of valve seats;
- Valve floating;
- Incorrect synchronization of camshaft.

Fig. 2.8

Corrections

- Check camshaft synchronization;
- Check if clearances are correct;
- Check if the piston position in the cylinder is correct in relation to the top of the engine block;
- Check the piston crown height in relation to the engine block face;
- When grinding the fournal, keep the piston stroke according to dimensions specified by the engine manufacturer;
- Check the con rod length;
- Correct the depth of the valve seats;
- Don't exceed the speed specified by the engine manufacturer;
- Regulate the injection point;
- Adjust the pump according to instructions given by the engine manufacturer.

Fig. 2.8.1 Valve mark on machined piston crown

2.9 Piston fracture at the pin boss region

Aspect

- Deep cracks at the region of the pin bore or at the inferior skirt part, which could lead to fractures.

Causes

Normally this failure happens when running the engine under scuffing and cylinder crown seizing, caused by:

- Incorrect clearance when fitting piston/ cylinders;
- Engine overload during running-in period;
- Insufficient cooling;
- Insufficient lubrication;
- Abnormal combustion.

When the scuffed piston is moved-on by the other ones, its skirt is torn out, starting at the middle section of the pin bore.

Fig. 2.9

Corrections

- Follow the engine manufacturer instructions for fitting clearance of piston/cylinder;
- Follow the engine manufacturer instructions for engine running-in period;
- Verify if the cooling, lubricating and injection systems are working correctly.

2.10 Cracks at the combustion bowl ring

Aspect

- Radial cracks starting at the bowl rim of the piston of diesel engines with direct injection.

Causes

- A premature and/or excessive fuel injection can result in high thermal and mechanical loads at the piston crown;
- The most heated part of the combustion chamber, surrounded by less heated regions,

Fig. 2.10

can't expand in accordance with its expansion coefficient at high temperature, because the material can't be compressed; the only way out is to expand in the direction of the free surface;

- The elasticity limit of the piston material is low and therefore is easily exceeded at high temperatures. A plastic deformation occurs in form of accumulated material or its concentration on the combustion chamber's periphery;
- Once the piston cools down to ambient temperature, the deformation persists, resulting in tensile stresses, which lead to cracks at the combustion chamber corners.

Corrections

- Regulate the injection point;
- Adjust the injection pump according to instructions given by the engine manufacturer.

Fig. 2.10.1

2.11 Cracks at the piston skirt

Fig. 2.11

Aspect

- In some piston types a crack at the skirt starts at the hole of the oil groove slot and in others, at the slot existing in the skirt.

Causes

This type of crack is characteristic in cases of engine overload and, consequently, overload of the piston. Generally it occurs at the high-pressure side (thrust side), because the most loaded region is the skirt, which in this case is submitted to excessive flexion.

The crack, or the cracks develop in direction of the lower part of the piston skirt, sometimes detaching its central part.

The irregularities that generally cause this overload on engine and pistons, are the following:

- Increase of compression ratio, to values that are higher than the limits given in the project;
- Increase of engine speed, surpassing the limits given by the engine manufacturer;
- Inadequate fuel for the existing compression ratio;
- Inverted piston assembly;
- Excessive piston/cylinder clearance.

Corrections

- Keep the compression ratio and the speed specified by the engine manufacturer;
- Use adequate fuel for the existing compression ratio;
- Observe the piston/cylinder clearance specified by the engine manufacturer;
- Observe the fitting instructions indicated on the piston crown.

2.12 Deformation of upper cylinder liner part

Aspect

- Material detachment at the piston top land.

Causes

The deformation of the upper cylinder part results in damage of the piston's top land. The causes of this type of piston wear can be:

- Cylinder liner deformation, due to irregular cylinder head bolt torque;
- Incorrect cylinder head gasket.

Fig. 2.12

Corrections

- Assemble and fasten the cylinder head bolt according to specifications given by the engine manufacturer;
- Use cylinder head gaskets of good quality, following the instructions given by the engine manufacturer.

2.13 Piston crown machining

Aspect

- Cracks originated along the combustion bowl rim;
- The piston crown shows machining tool marks and absence of piece identification marks.

Causes

- The machining of the piston crown reduces the distance between the first ring groove and the crown (top land height reduction). This reduction, plus the withdrawal of the concordance of the combustion chamber edges radii, results in an increase in piston crown tensions, increase in concentration of tensions at said combustion bowl rim and, consequently, increase in susceptibility for cracks in this region (see fig. 2.13.6).

Fig. 2.13 Machined crown

Corrections

- Use pistons with lower compression height, if available;
- Replace the engine block.

Fig. 2.13.1 Machining marks at piston crown

Fig. 2.13.2 Machining marks on piston crown and valve recesses

2.14 Incorrect con rod fitting

Aspect

- The part presents irregular marks on the piston pin, as a result of overheating. The piston also can present: cracks/fractures at the pin boss region, lubricating oil consumption, aligned ring end gaps and noises.

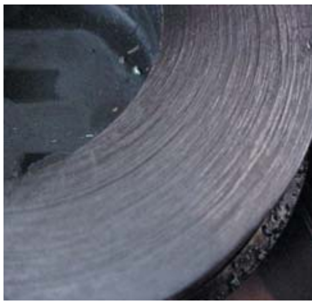


Fig. 2.13.3 Machined crown

Fig. 2.13.4 Machined valve recess

Fig. 2.13.5 Machined valve recess

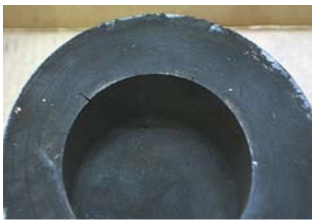


Fig. 2.13.6 Cracks at combustion bowl rin

Causes

- Incorrect position of the con rod in relation to the piston pin;
- Irregular heating of the con rod during fitting process.

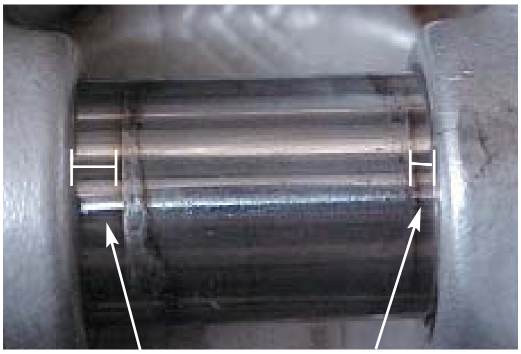


Fig. 2.14 Eccentricity between the con rod and the piston pin

Corrections

- Con rod and piston must be fitted exactly to the specifications given by the engine manufacturer;
- Use adequate tools and electrical furnace, when assembling con rod and piston;
- Be alert to a possible misalignment of the piston pin in relation to the boss, while installing the pin at the piston.

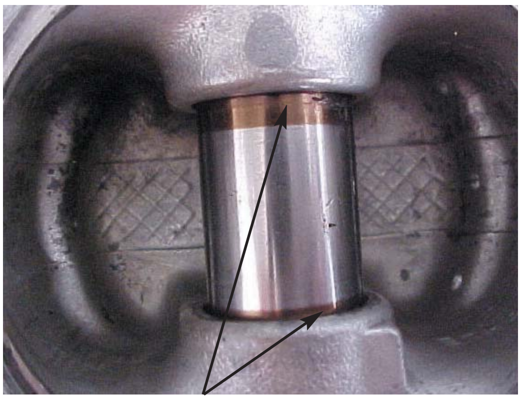


Fig. 2.14.1 Eccentricity between the con rod and the piston pin

Fig. 2.14.2 Irregular piston pin marks on the bosses during con rod fitting

Fig. 2.14.3 Part which has been cracked during con rod fitting

Fig. 2.14.4 Irregular mark, close to the pin boss

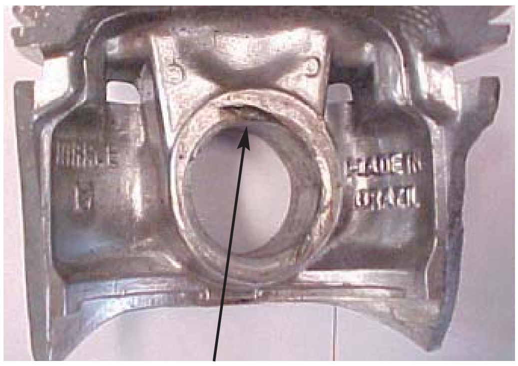


Fig. 2.14.5 Piston pin mark on the pin boss

2.15 Rupture/breakage of ring land

Aspect

- Diesel and Otto-cycle pistons present rupture/breakage at first and/or second land between ring grooves.

Causes

- The rupture of lands between ring grooves is a consequence of a sudden combustion pressure peak. This occurs due to the an increase in admitted fuel volume/mass, due to the decrease in combustion chamber volume in the cylinder head and also due to an incorrect injection/ignition point. Under these conditions the piston is submitted to an increase in mechanical and thermal loads (higher peak pressure), causing the rupture of the lands between the ring grooves. This rupture/ breakage is related to the process called "DETONATION".

Fig. 2.15 Broken lands in piston (Otto-cycle engine)

Corrections

- Keep the cylinder head height according to recommendations given by the engine manufacturer;
- Keep the engine block height according to the recommendations given by the engine manufacturer;
- Keep the projection of the piston in relation to the engine block according to the recommendations given by the engine manufacturer;
- Don't use fuel of bad quality;
- Revise peripheral engine component (injection pump and nozzles, cold start system, starting motor and battery);
- Use heating spark plug correctly (if existent);
- Apply the parts and the components correctly;
- Use correct injection point;
- Check items which could lead to "DETONATION".

Fig. 2.15.1 Broken land in piston (Otto-cycle engine)

Fig. 2.15.2 Fractured lands in piston (Otto-cycle engine)

Fig. 2.15.3 Fractured lands in piston (Diesel-cycle engine)

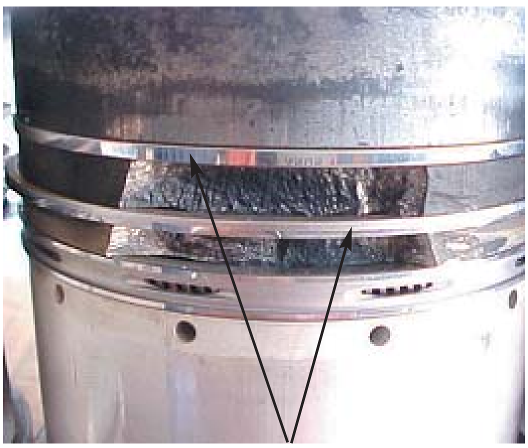


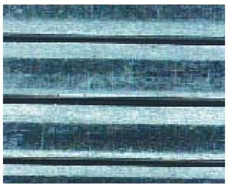
Fig. 2.15.4 Fractured lands in piston (Diesel-cycle engine)

PREMATURE FAILURES IN PISTON RINGS

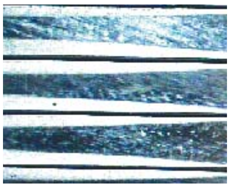
PISTON RINGS

Normal running characteristics

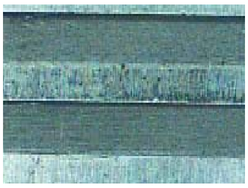
The below piston rings pictures, present normal running characteristics, the ring contact face wear is in accordance to the operational life of the whole engine assemblage.



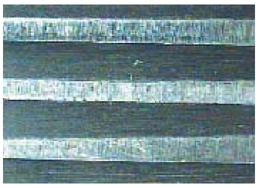
First groove piston ring. Running face - contact zone with cylinder. 180° from gap



End gap



Second groove piston ring. Running face - contact zone with cylinder. 180° from gap



End gap

Third groove piston ring. Running face - contact zone with cylinder. 180° from gap

End gap

3. Premature failures in piston rings, due to assembling error

3.1 Inverted piston ring mounting

Aspect

- The visual appearance of the mounted piston rings indicate that they have been inverted during mounting, that is, with the engraving of the lateral face placed towards the lower piston side.

Causes

- Wrong/inverted mounting of the piston rings in the piston grooves (fig.3.1 and 3.1.1). When this happens, the piston rings don't perform as expected, allowing the combustion chamber gases to leak easily to the carter, forming consequently an irregular air/fuel mixture to be admitted to the combustion chamber. The lubricating oil temperature and the carter pressure increase. Furthermore the inverted mounting of the piston rings increases the lubricating oil consumption, because instead of scraping the oil down, the piston rings will pump it up, to be burnt together with the air/fuel mixture in the combustion chamber. It can also increase the lubricating oil contamination by gases, which will reduce the operational life of the lubricant and produce damages to other engine components (main and con rod bearings, and bushings).

Fig. 3.1 Piston ring mark mounted towards the lower side

Fig. 3.1.1 Piston ring mark mounted towards the lower side

Corrections

- Replace the ring set and fit the new one with its markings directed to the piston crown.

3.2 Overlapped coil spring or expander ends mounting

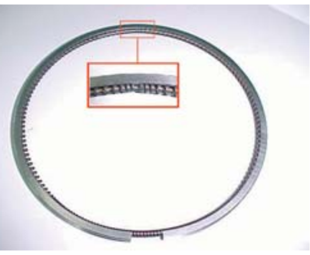


Fig. 3.2

Aspect

- Coil spring or expander ends are mounted overlapped.

Causes

- The mounting of overlapped coil spring (fig.3.2) or expander (fig.3.2.1) ends during the oil ring assembly affects the radial piston ring pressure, and consequently its function, which is to control the excess in lubricating oil of the cylinder walls. This radial pressure reduction will result in a considerable increase in oil consumption.

Piston rings with coil spring must have the coil ends positioned at 180° from the gap.

In the case of 3-piece oil rings, the ends must be displaced by 90° from each other.

Corrections

- The spring-ends of a 2-piece oil ring have to be mounted at 180° from the gap. The overlapping of the expander ends in a 3-piece oil ring should by all means be avoided.

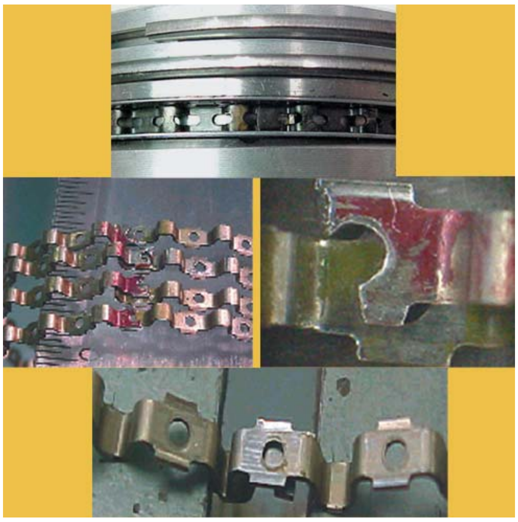


Fig. 3.2.1

3.3 Mounting with odd materials

Aspect

- The piston rings have odd material impregnated at its running and side surfaces (fig.3.3).

Causes

- The piston ring contamination by odd material occurred during the engine assembly. The use of adhesives for engine sealing, close to the cylinders, is a procedure which no manufacturer/producer recommends. In this case the contaminated piston rings had its sealing function reduced, because the pressure at the periphery has been unevenly distributed, due to the "wedge" provided by the adhesive. This reduces the operational life of the piston rings, causing an increase in lubricating oil consumption and irregular wear at the cylinders.

Fig. 3.3

Corrections

- Mounting has to be done according to recommendations given by the engine manufacturer;
- Clean all internal components with materials void of dirt and impurities, by using the adequate procedure.

3.4 Piston ring mounting with inadequate or damaged tools

Aspect

- The piston ring is twisted (with displaced butts) and deformed (fig. 3.4.to 3.4.2).

Causes

- By mounting the piston rings at the piston grooves without the adequate tools (ring pliers) the rings will suffer undesirable tensions and deformations, and get a spiral configuration. As a consequence, the mounted piston ring ends will present localized pressure against the lateral piston groove faces, wearing these areas, on top of reducing the lateral sealing. Due to these conditions the piston rings will not rotate in the groove, starting irregular wear at its running face and at the cylinder walls, increasing the oil consumption and the blow-by (flow of combustion gases to the carter).

The tool used to close the piston rings when mounted on the piston, and being fitted in the cylinder, is a strap called "ring compressor". If the compressor doesn't close completely the piston rings in the groove, their side faces will collide with the cylinder edge (which should have a small chamfer to facilitate the mounting). This can result in damage or even breakage of the piston ring (see fig.3.4.2).

The recommended gap opening, during the piston ring installation, shall not exceed 8,3 times the radial width of the piston ring. For example: a piston ring with radial width of 3,00 mm has a maximum gap opening allowance of 3,00 x 8,3 = 24,90 mm.

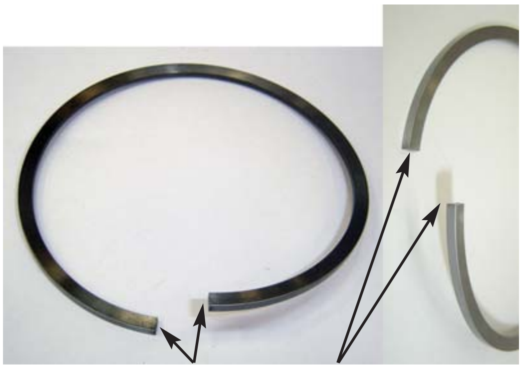


Fig. 3.4 Displaced butts due to incorrect mounting

Corrections

- Don't use your hands when opening the gap ends;
- Mount the rings using adequate tools and in good working conditions, mainly the expander ring pliers;
- Use adequate ring compressor for each engine, when fitting the piston/piston ring assembly into the cylinder.

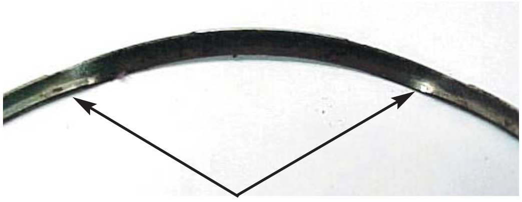


Fig. 3.4.1 Ring was twisted during mounting

Fig. 3.4.2 Chipped contact face

3.5 Odd particles in aspirated air

3.5.1 Contamination by abrasives

Aspect

- The piston rings present scratches and premature wear at the running face (fig.3.5.1, 3.5.2, 3.5.3, 3.5.6 and 3.5.7), as well as on side faces (fig.3.5.4 and 3.5.5). The oil rings present a large and plain running face (in some cases even inexistent).

Causes

- Solid particles of different sizes are present in the air. These particles, such as sand (silica), dust, carbon, among others, when aspirated by the engine, cause serious damage to the piston rings, resulting in: premature wear of the coating on the running and side faces, reduction in radial thickness, increase in gap clearance, pressure reduction and deep scratches on the cylinders and on the piston skirt.

The piston ring contamination by abrasives can occur due to:

- **Deficient air filter system** - saturated or incorrectly applied filter elements, holes or cracks in air hoses, damaged clamps, and damaged seals on the intake manifold;
- **Machining residues** - insufficient cleaning of abrasive particles resulting from honing operation, particles swept by the wind and those originated by shot blashing of engine components, such as, for example, the cylinder head;

- **Fuel filter system** - incorrect application of fuel filters and use of bad quality fuel.

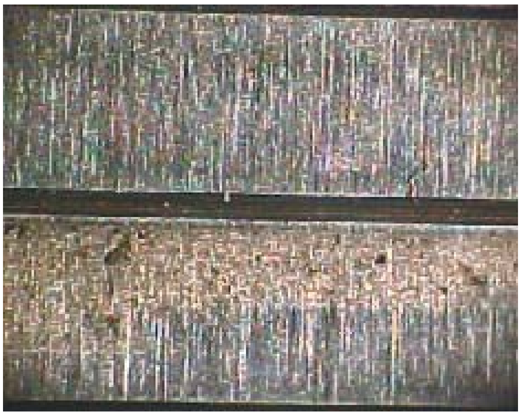


Fig. 3.5.1 Piston rings with scratches on running face

Corrections

- Use only filters according to the recommended applications, verify them and change them according to recommendations given by the engine/ vehicle manufacturer;
- Make a periodical check-up of the filter system (hoses, clamps, seals, etc);
- Prepare and clean correctly the internal components before assembling them on the engine;
- Use fuel of good quality, as well as correct filter elements and separation filters.

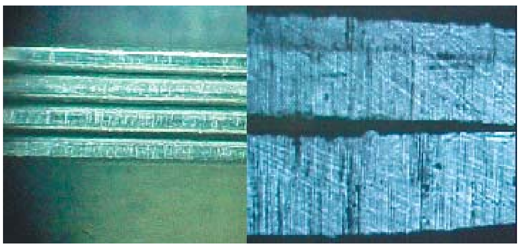


Fig. 3.5.2 Damages/scratches on piston ring contact face

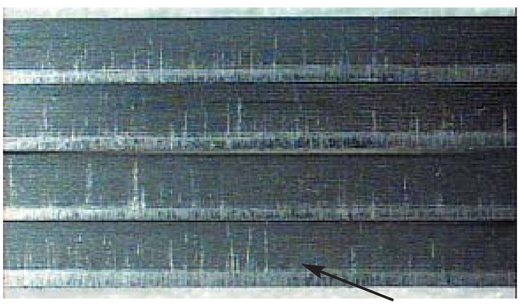


Fig. 3.5.3 Piston ring with scratches on contact face

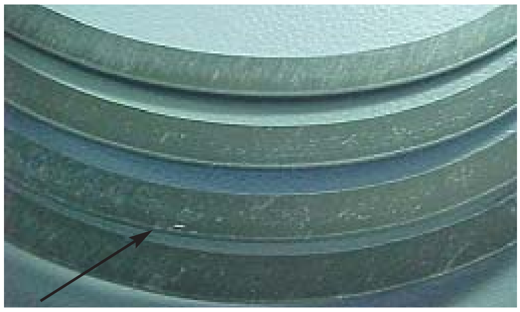


Fig. 3.5.4 Piston ring with scratches on lateral face

Fig. 3.5.5 Piston ring with abrasive particles on lateral face

Fig. 3.5.6 Worn-out piston ring of the third groove

Fig. 3.5.7 Considerable wear on the third groove

3.6 Insufficient lubrication

3.6.1 Cylinder washing

Aspect

- The rings present scuffing signals on the running surface (fig.3.6.1 to 3.6.5).

Causes

- The lubricating oil has a series of functions, two of them are: to participate on the cooling of the internal engine components and to reduce the friction between moving parts. When the combustion occurs at the piston crown, the generated heat is dissipated by the piston rings (mainly by the ring in the first groove). The rings transmit this heat to the cylinder walls and to the existing lubricating oil. The oil film formed between the piston rings and the cylinders reduces considerably the friction, avoiding the direct metal-metal contact.

The washing away of the lubricating oil from the cylinder walls has following main causes:

- Injection system and/or carburetion deficiencies - the main causes for the cylinder washing are connected to an incorrect regulation of the injection pump and nozzles, resulting in a series of changes: quantity of delivered diesel fuel, injection-pump rotation, synchronization between governor and pump, synchronization among pump elements, opening pressure and projection of the injection nozzles out of recommendation, and the height of the piston crown, in case of Diesel-cycle engines. For the Otto-cycle engines the "big villain" is the carburetor with bad application and/or regulation. All of this will wash the lubricating oil from the cylinder walls. Both the Diesel and the Otto-cycle engines, in presence of insufficient oil lubrication of the cylinders, will increase the friction and the heating of the piston rings, which can result in flaking-off (fig.3.6.5) and can initiate a scuffing process, seizing of the cylinders, or also can wear the cylinders in excess;
- Lubricating system deficiencies - a worn-out lubricating oil pump will reduce its pumping capacity, having as a consequence, the reduction in pressure in the oil circuit, and jeopardizing the engine lubrication, originating in this way the above-mentioned damages.

Fig. 3.6.1

Corrections

- Keep the injection system and the carburetor always regulated, following the recommendations given by the manufacturer/producer;
- Check periodically the engine oil lubricating system;
- Check and maintain the original turbine.

Fig. 3.6.2

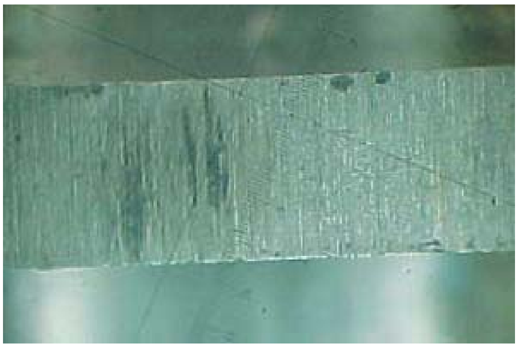


Fig. 3.6.3

Fig. 3.6.4

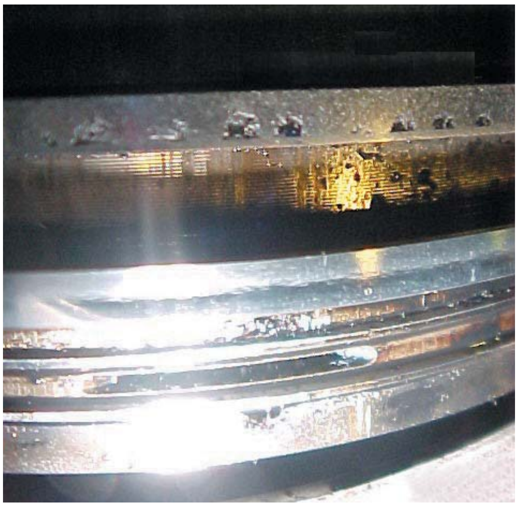


Fig. 3.6.5 Flaking-off of the piston ring coating

3.7 Other factors

3.7.1 Honing

Aspect

- The piston rings present scratches on the running surface, mainly the ones in the first groove (fig.3.7.1).

Causes

- The main cause is related to the finish of the cylinders after honing. Too high roughness will result in high wear and will be a risk to the running face of the piston ring. Too low roughness makes piston ring seating difficult and retains less lubricating oil on the cylinder walls.

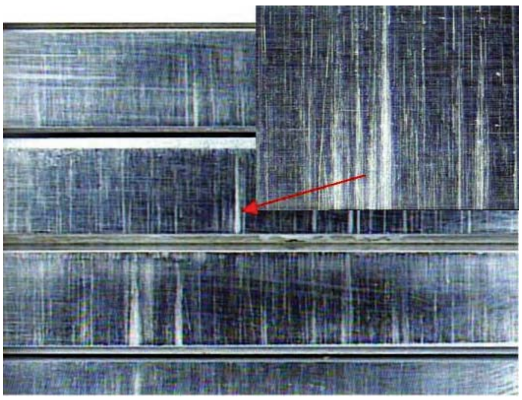


Fig. 3.7.1

Corrections

- Honing the cylinders according to recommendations given by the engine manufacturer, following the correct honing angle and specified roughness.

3.7.2 Piston ring adulteration

Aspect

- Rings of the first, second and third grooves have signs of adulteration at the butt ends.

Causes

- The reworking of the piston ring butt ends is done to reduce its external diameters and to adapt them for different applications then theones for which they have been recommended by the engine manufacturer. The change in the constructive characteristics of piston rings is not recommended by MAHLE and cancels any product warranty.

Corrections

- Don't make any kind of rework at the piston rings;
- Use the piston rings only for the indicated applications given by the engine manufacturer.

Rings of the first groove

Face/external edge of the butt ends (figs. 3.7.2 to 3.7.2.3).

Adulterated butts - ground, eliminating external chamfer/irregular finish

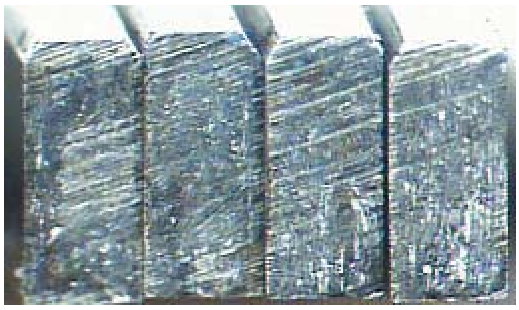


Fig. 3.7.2

Fig. 3.7.2.1

Non-adulterated butts - original finish, with external chamfer on the chromed face

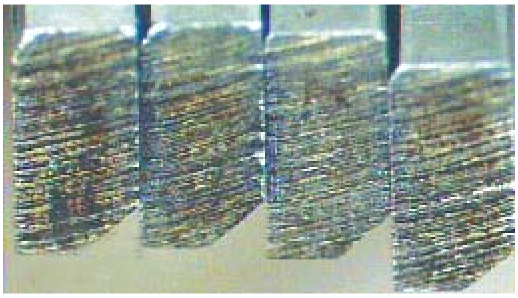


Fig. 3.7.2.2

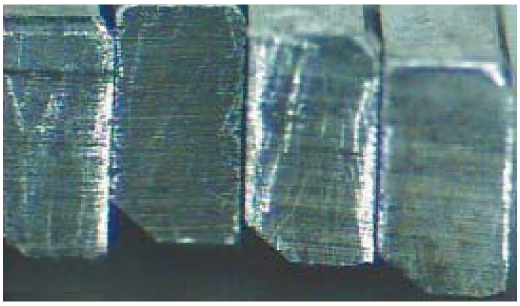


Fig. 3.7.2.3

Rings of the second groove

Butt faces (figs .3.7.2.4 and 3.7.2.5).

Adulterated butts - ground, absence of phosphate/surface treatment

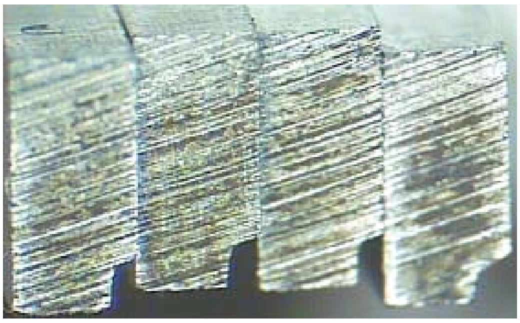


Fig. 3.7.2.4

Non-adulterated butts - original finish, with surface treatment

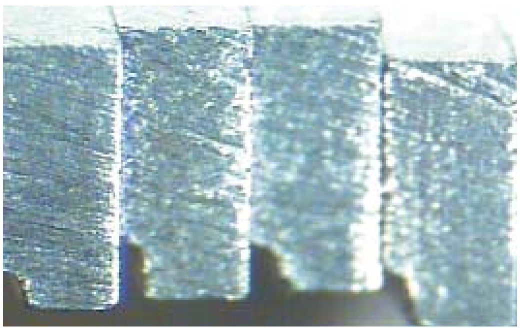


Fig. 3.7.2.5

Rings of the third groove

Butt faces (figs. 3.7.2.6 and 3.7.2.7).

Adulterated butts - ground, absence of phosphate/surface treatment

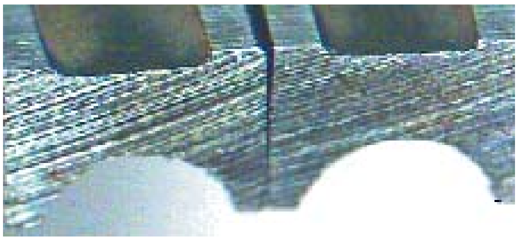


Fig. 3.7.2.6

Non-adulterated butts - original finish, with surface treatment

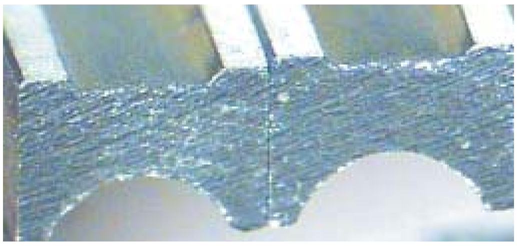


Fig. 3.7.2.7

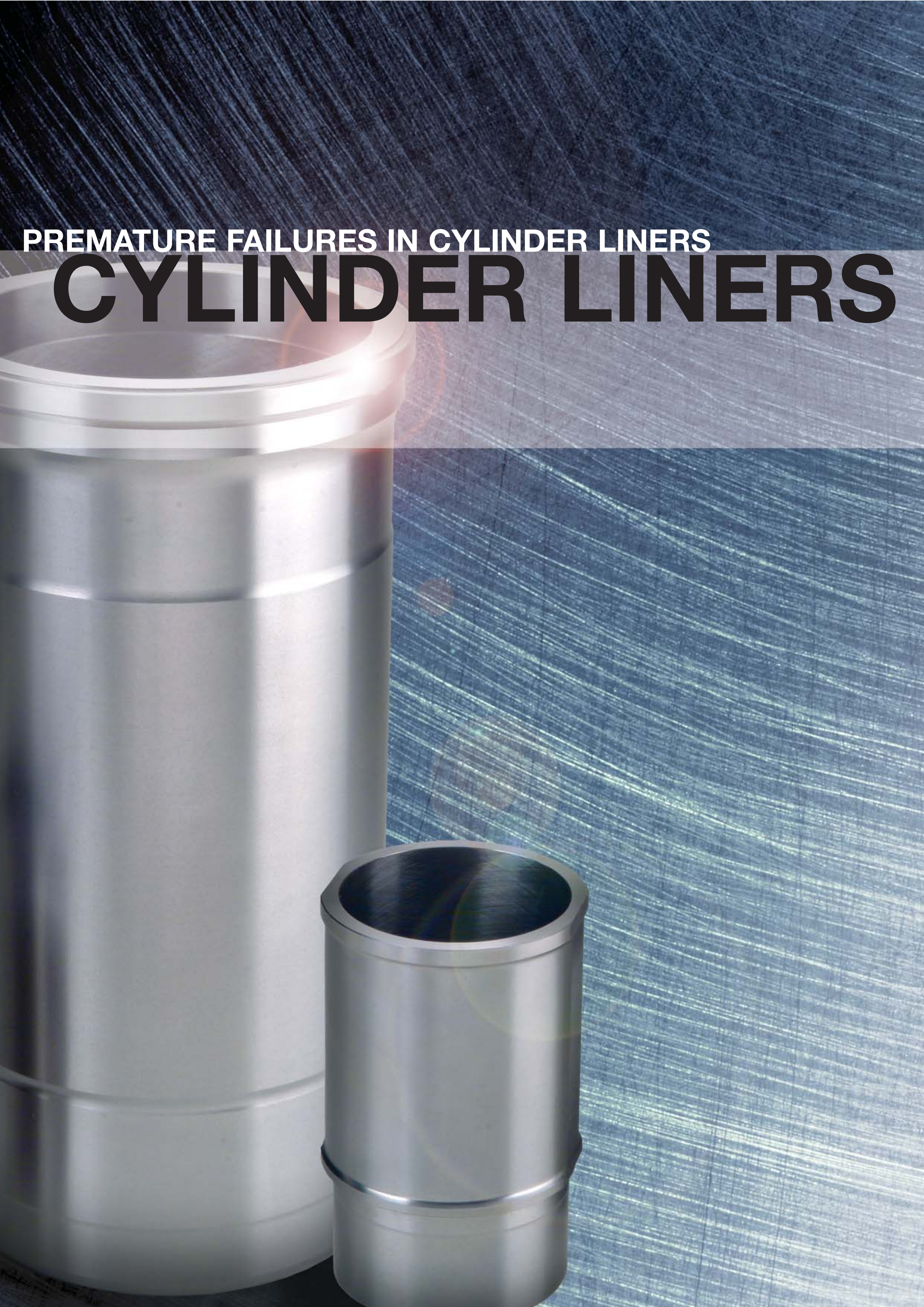
Aspect of the expander ends (figs. 3.7.2.8 and 3.7.2.9.).

Fig. 3.7.2.8 Adulteration on one of the ends

Fig. 3.7.2.9 Form and colors in new expanders (without rework)

PREMATURE FAILURES IN CYLINDER LINERS

CYLINDER LINERS



Normal running characteristics

The characteristics here presented correspond to normal running conditions. The wear on honing and the possible scratches are a consequence of the contamination by odd materials during the normal operational period.

Cylinder liner with normal running characteristics

4. Premature failures in cylinder liners, due to assembling error

4.1 Cylinder fitting with glue/adhesive

Aspect

- Visual inspection indicates the use of glue/adhesive at the cylinder liner seat on the engine block.

Causes

The use of glue/adhesive, after it dries, causes uncontrolled deformations on the cylinder liner walls, and can reduce its operational life. The consequences can be:

- Ovality;
- Local and uncontrolled deformations, which wont let the compression rings have its complete sealing effect and which will not scrap the lubricant oil via the scraper rings;
- Local and uncontrolled deformations, which will change the clearance between the piston skirt and the cylinder walls, leading to scuffing;
- Glue/adhesives could run into, and obstruct lubricating channels;
- Insufficient seat of the cylinder head (non-perpendicularity between the cylinder liner seat and the cylinder head).

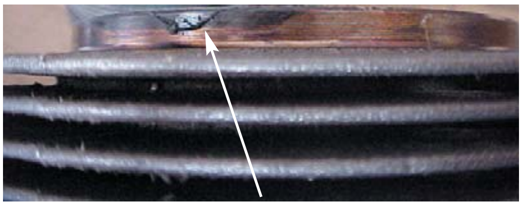


Fig. 4.1 Cylinder liner fitted with glue on the cylinder head seat (upper cylinder liner side)

Corrections

- Follow correctly the recommendations given by the engine manufacturer with respect of the use or no-use of glue/adhesives.

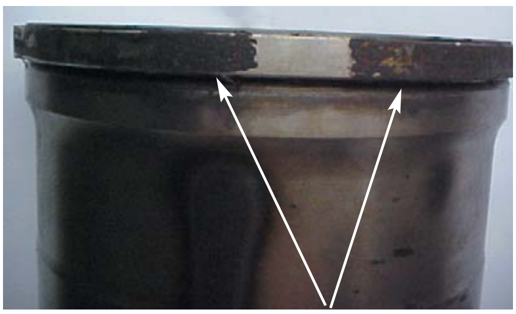


Fig. 4.1.1 Glue at the collar region of the cylinder liner

Fig. 4.1.2 Silicone at the lower base of the cylinder liner

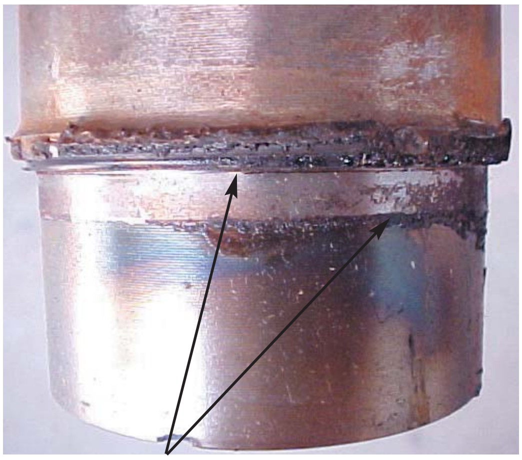


Fig. 4.1.3 Glue at the region of the cylinder liner seat on the engine block

Fig. 4.1.4 Cylinder head was fitted with glue at its lower base

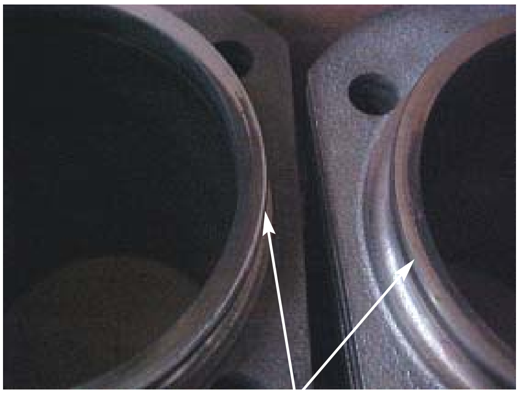


Fig. 4.1.5 Irregular cylinder liner seat on the cylinder head

5. Irregular machining of engine block and/or cylinder head

5.1 Fitting of cylinder liner on irregular seats

Aspect

- Flange fracture of the cylinder liner and/or insufficient sealing with the cylinder head.

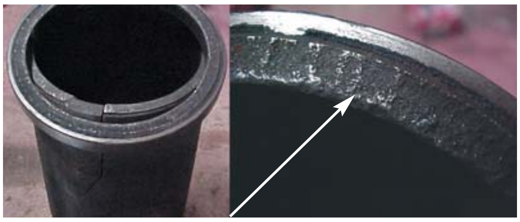
Causes

- Both wet and dry cylinder liners need to be installed according to instructions given by the engine manufacturer, specifically when it refers to the seat of the liner on the engine block. An irregular seat leads to irregular distribution of tensions along the whole cylinder liner perimeter due to the torque applied to the bolts during cylinder head fastening to the engine block. In engines using dry cylinder liners, if the applied tensions happen to be higher then the ones recommended by the engine manufacturer, a flange fracture could also occur.

Corrections

- Keep the dimensions of the cylinder liner seat at the engine block according to recommendations given by the manufacturer/producer;
- Follow the engine manufacturer recommendations when fitting the cylinder liners at the engine block;
- Machine correctly the cylinder liner seat at the engine block;

- Lower de cylinder head without lowering the cylinder liner housing seat depth at the head (for example: the VOLVO TD-102 FS cylinder head).



Figs. 5.1 and 5.1.1 Wet cylinder liner. Fractured and carbonized flange region

Figs. 5.1.2 and 5.1.3 Dry cylinder liner. Carbonized flange region

Fig. 5.1.4 Flange region of a carbonized cylinder liner

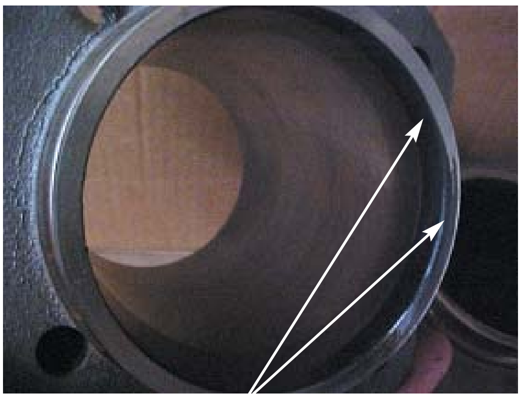


Fig. 5.1.5 Irregular seat between the upper cylinder liner part and the cylinder head

5.2 Fitting of cylinder liner on irregular engine block

Aspect

- Dry cylinder liner with irregular contact marks on external liner side and engine block housing. In engines running with wet cylinder liners, scuffing and/or deformation at the region next to the sealing rings housing installed in the cylinder block.

Causes

In engines running with **dry cylinder liners**, existing irregularities of the engine block housing, due or not due to machining, can cause:

- Irregular contact between the cylinder liner and the housing can impair the thermal exchange between the two and, consequently, can result in scuffing between the piston and the cylinder liner;
- Reduction in sealing effect of the piston rings, with possible increase in lubricating oil consumption or even blow-by (gas leakages) to the carter.

In engines running with **wet cylinder liners**, irregularities on the engine block housing, O'rings and even the displacement of these rings during the fitting of the cylinder liner, can cause:

- Change in clearance between the piston and the cylinder liner, due to deformations, with possible scuffing originated by the displacement of material from the piston skirt region, at the area where the O-rings are installed in the engine block. Scuffing could expand later to the piston ring region. If necessary, remove the cylinder liner and re-install it, eliminating excessive deformations.

Fig. 5.2 cylinder liners with machining marks from engine block

Corrections

- Machine the cylinders according to milling instructions given by the engine manufacturer;
- Install the cylinder liner, either wet or dry,

according to instructions given by the engine manufacturer;

- After installation of the wet cylinder liner in its housing, measure the internal diameter with specific instruments and search for any cylinder liner deformation.

Fig. 5.2.1 Dark marks on internal side of cylinder liner, identifying the lack of interference with the housing

Figs. 5.2.2 and 5.2.3 Scuffing originated by O'ring displacement. Impurities in the cylinder liner O'ring housing

Fig. 5.2.4 O'ring has been cut during cylinder liner fitting in engine block

5.3 Insufficient lubrication/dilution of lubricating oil

Aspect

- The dilution of the lubricating oil of the inner cylinder liner wall results in a premature lapping wear done by the piston rings, and generates vertical scratches and scuffing marks, with material removal.

Causes

- Incorrect injection pump and nozzle regulation;
- Turbo charger ;
- Incorrect projection of the injection nozzles, in relation to the cylinder head;
- Incorrect injection/ignition points;
- Bent camshaft or with defect cams;
- Incorrect carburetor regulation;
- Incorrect engine running-in period.

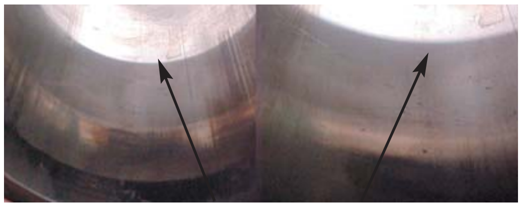


Fig. 5.3 Cylinder liner with bore polishing, due to constant speed

Corrections

- Regulate injection pump and nozzles, according to recommendations given by the engine manufacturer;
- Keep the correct injection point;
- Check the camshaft and its cams;
- Regulate correctly the carburetor;
- Apply correctly the internal components (pistons, cylinder liners and piston rings);
- Avoid constant engine speed during the running-in period.

Figs. 5.3.1 and 5.3.2 Scuffing originated by dilution of lubricating oil existent on inner cylinder wall

6. Other factors

6.1 Corrosion - scales - cavitation

Aspect

- Little holes and/or formation of scales.

Causes

- Electrolytic corrosion or electrolysis - originated by the chemical metal decomposition, which results from small electrical currents, which appear when two different metals, like iron and copper, enter in contact with water. This electrical current, although weak, after some time attacks the external cylinder walls. Modern engines have a brass ring installed below the cylinder liner collar, which leads the current to the engine block and from there, to the chassis, via a ground wire;

- Chemical corrosion - is the result of an attack to the cylinder liner iron, done by the oxygen present in the water, forming iron oxides or rust. This phenomenon is accelerated by higher oxygen content in the water, due to faulty sealing of the cooling system, which allows air to enter through hoses and connections, defective caps, low water level, among other things. The chemical corrosion is also accelerated by the use of untreated water, water with presence of corrosive materials, acid or alkaline waters, or because of the absence of corrosion inhibitors as recommended by the manufacturer/producer of the engine;

- Scale formation - scales are formed by minerals found in the untreated water of the cooling system. These minerals will get deposited at the external heated cylinder walls in form of scales. These scales slowly form a thermal barrier, which reduces the heat transfer and generates hot spots, which tend to wear and excoriate the inner cylinder walls and produce scuffing of pistons and piston rings;

- Cavitation - During the engine running, the cylinder liners are submitted to pulsations, which are the consequence of the air/fuel combustion in its interior. When the combustion occurs, the cylinder wall expands fractions of a millimeter, due to the pressure of the expanding gases against the inner walls. Once the gas expansion is over, the cylinder walls return to its normal dimensions. This return happens in a very small space of time; the cooling water has not sufficient time to fill the resulting space, and originates very small vacuum bubbles, which implode against the cylinder wall, tearing off small particles and at the end perforating it.

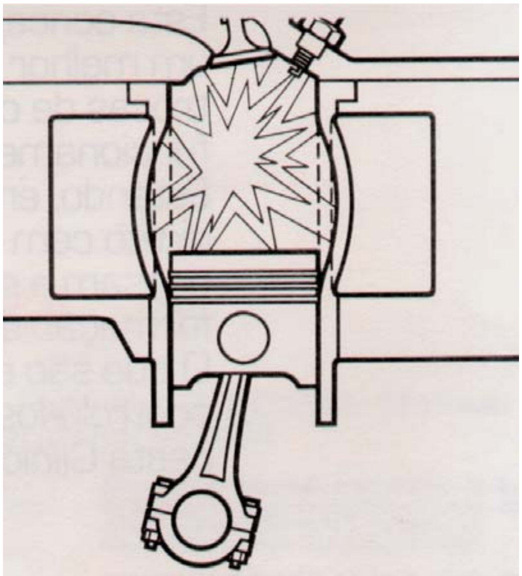


Fig. 6.1 Cylinder liner in expansion phase

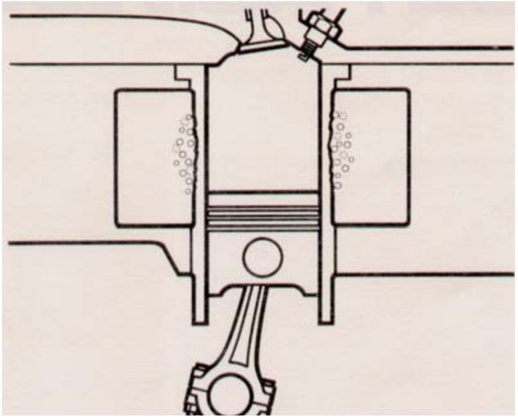


Fig. 6.1.1 Bubbles around the cylinder liner

Corrections

- Keep all cooling system components (reservoir and/or radiator cap, hoses and clamps, thermostatic and pressostatic valves, water pump, etc.) in normal running conditions, compatible with the engine project;
- Always use the corrosion inhibitor additives and the anti-freezing fluids, as recommended by the manufacturer/producer of the engine;
- Keep the correct water level in the reservoir and/or radiator. When there is a refilling need in the water system, follow the recommendations given by the engine manufacturer, with regard to quantity of additives to be used;
- Assemble the engine according to recommendations given by the manufacturer/producer with regard to eventual changes in pistons, injection system or any other.

Fig. 6.1.2 Cavitation and scales

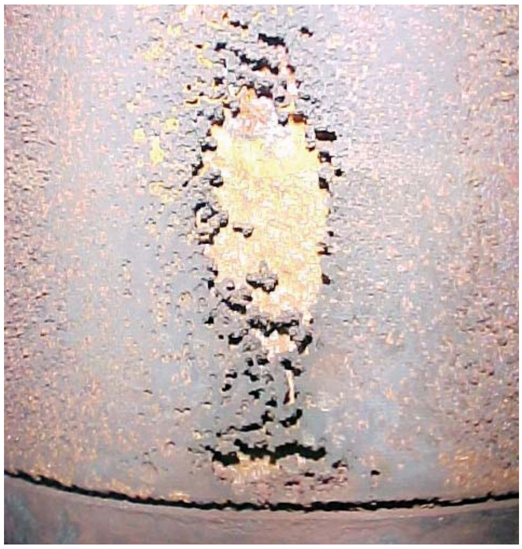


Fig. 6.1.3 Cavitation without corrosion

Fig. 6.1.4 Scales

Fig. 6.1.5 Cavitation

Fig. 6.1.6 Cavitation

6.2 Circlip expulsion

Aspect

- The cylinder liner has an internal mark indicating its contact with the piston pin.

Causes

- Lack of parallelism between the bushing housing center and bearing housing center on the con rod;
- Bent and/or twisted con rod;
- Incorrect con rod fitting;
- Incorrect position of the circlip in its groove;
- Conical con rod journal of the crankshaft.

These factors cause misalignment and generate lateral forces, by which the con rod "pushes" the piston pin against the circlip. Once the circlip is expelled, the piston ring will start to move until it touches the cylinder liner. The expelled circlip, due to the vertical up-and-down piston movements, will wear the region (aluminum) until it manages to get free.

Fig. 6.2 Piston wear, at the bosses and crown region, caused by the circlip

Corrections

- Keep the parallelism between the bushing housing center and the con rod bearing housing center;
- Fit the con rod according to recommendations given by the engine manufacturer;
- Install and locate correctly the circlip in its housing;
- Gronding the crankshaft and keep the journal according to the patterns recommended by the engine manufacturer.

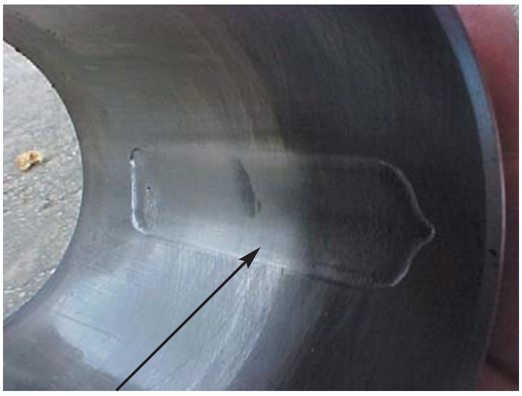


Fig. 6.2.1 Mark originated by the piston pin displacement after the circlip expulsion

6.3 Contamination by abrasives

Aspect

- The cylinder liner presents excessive wear at the upper region.

Causes

- Blocked and/or damaged air filter or non-operative safety valve;
- Damaged air intake hose;
- Incorrect cylinder cleaning during engine assembly;
- Bad sealing of air intake filter housing, due to deformation or damages.

Corrections

- Always replace filters according to maintenance recommendations given by engine/vehicle manufacturer;
- Inspect periodically the air hoses;
- Clean cylinders correctly.

Fig. 6.3 Wear and scratches formed by solid particle admission into the cylinder

PREMATURE FAILUERS IN BEARINGS

BEARINGS

Normal running characteristics

A major portion of the normal bearing wear occurs during the engine start or during its initial operation. After that, the wearing rate is considerably reduced. Under adequate preventive maintenance, only the very small and non-retained particles will be present in the abrasive process at the bearing surface. Under these circumstances, the bearings will have a fairly long life cycle.

A major evidence, that the operational life of the bearings has been exceeded, is the appearance of engine noises ("gusts") and the reduction of lubricating oil pressure.

Normal wear is generally indicated by a small quantity of scratches on the bearing surface, resulting from small particles, which haven't been retained by the oil filter. The scratches present no problem, unless they reach the base-alloy. If operation continues, these scratches might even disappear.

7. Premature failures in bearings, due to malfunction

7.1 Corrosion

Aspect

- The typical aspect of corrosion can be identified by dark composites and small pits, which are formed at the bearing surface.

Causes

- Corrosion is a chemical attack at the bearing alloy, originated by components that exist in the lubricating oil. These components can be strange to the lubricating system, such as water, or can be produced during the engine running, as a result of the lubricant's oxidation. This harmful action develops when a bearing operates in a corrosive atmosphere, and it can result in the removal of one or more elements from the alloy or the formation of fragile oxides over the sliding surface.

In the first case, the attacked metal is removed from the matrix, leaving it fragile with respect to its loading capacity, and resulting in fatigue. A fragile oxide layer over the sliding surface can also be removed by fatigue or even by erosion, in view of the difficulty which odd particles have to remain fixed at these surfaces.

The lubricating oil industry has developed additives that inhibit the oil oxidation during long running periods, minimizing considerably this type of damage, but haven't yet eliminated it completely. The heat generated by the engine operation accelerates the oxidation process. Contributions are also given by the exposure of the bearings to air and water, and to other materials, which might exist in the oil, including certain metals that can produce catalytic effects. Other contributing factors include the passage of gases to the carter (blow-by) and the combustion of fuels with high sulphur content, plus the possibility of inorganic acid formation.

Fig. 7.1

Corrections

- Change lubricating oil according to specifications given by the engine manufacturer;
- Should the corrosion be a result of blow-by (gases flow to the carter), change the piston rings and rebuilthing the engine, if necessary.

Fig. 7.1.1

Fig. 7.1.2

7.2 Hot short

Fig. 7.2

Aspect

- Great areas of the bearing's anti-friction layer are torn out, leaving the steel shell exposed.

Causes

- When a running bearing heats up to values higher than the lead (326ºC) or tin (231ºC) fusion temperatures, and is subjected to considerable dragging forces by the shaft, the anti-friction material reaches a point of fragility by heat. Under these conditions, the lead or tin can move, separating itself from the copper, and the surface layer looses its adhesion with the steel shell, resulting consequently in material detachment. The fragility by heat condition is a consequence of excessive heat increase in some bearing zones. The excessive heat can be the result of insufficient radial clearance, impurities, crankshaft journal deformation, or misalignment of the engine block and/or the crankshaft.

Corrections

- Fit the bearings with the clearance recommended by the engine manufacturer;
- When changing lubricating oil, observe absolute cleanliness and when assembling the engine, eliminate all machining residues and any existing dirt;
- Before fitting new bearings, inspect carefully all journal dimensions of the crankshaft;
- Verify the alignment between engine block and crankshaft.

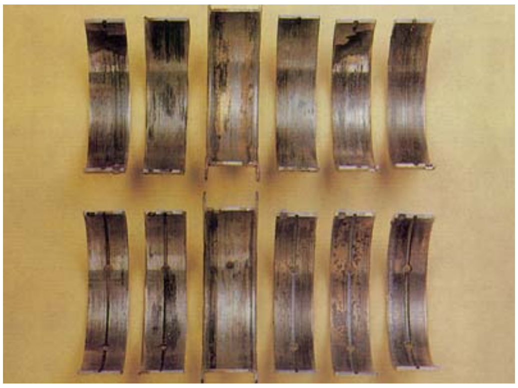


Fig. 7.2.1

7.3 Generalized fatigue

Aspect

- The bearing surface presents irregular areas with detached anti-friction material.

Fig. 7.3

Causes

- Fatigue damages can be caused by abnormal and cyclical stresses, in other words, by load peaks (fig. 7.3.1).

Fatigue fractures are initiated by excessive loads, and have a perpendicular propagation to the bearing surface. Before reaching the bonding line between the bearing alloy and the support material (steel), the fracture changes its direction, propagating itself parallel to the bonding line.

These fractures can get united to each other, which will result in bearing material detachment. One of the most common types of fatigue occurs at the upper layer of tri-metallic bearings, where the fractures, after perpendicular penetration, propagate in parallel to the nickel barrier, causing its removal in reduced areas (fig. 7.3.2).

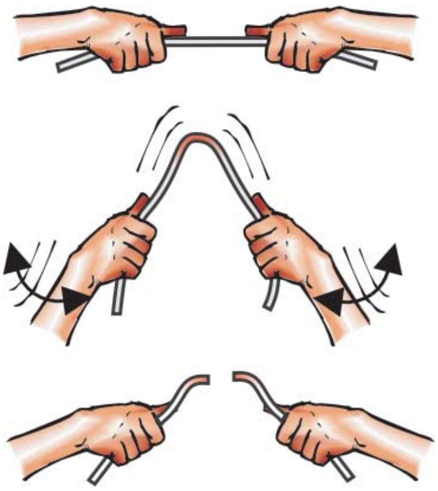


Fig. 7.3.1 Fatigue

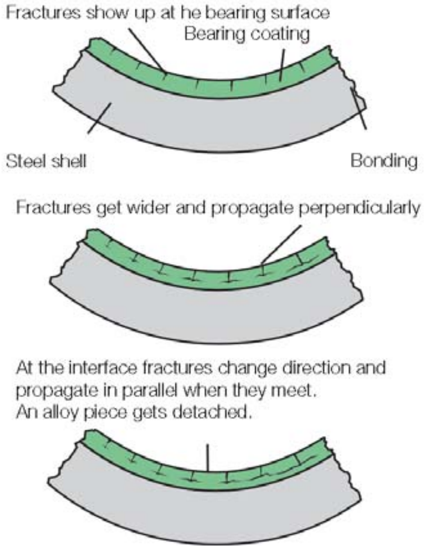


Fig. 7.3.2

Corrections

- If the bearing's operational life has been lower then expected, check the temperature and load conditions in which the engine has been running, and eliminate eventual existing defects;
- Avoid operational engine over-loads, observing the recommendations given by the engine manufacturer.

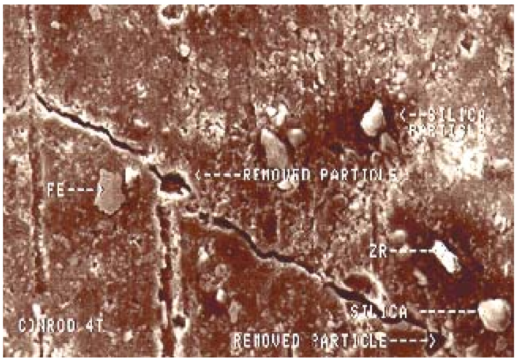


Fig. 7.3.3 Magnified 350 X

7.4 Insufficient oil in bearing

Aspect

- When a bearing fails because of insufficient or diluted lubricating oil, its running surface can get shiny fig. 7.4.2). In the case of complete lack of lubrication, the bearing will present excessive wear by dragging off material along the axle, at the contact zone of the bearing sliding surface, with the journals of the crankshaft.

Fig. 7.4

Causes

Insufficient or diluted lubricating oil film between the bearing and the axle, will wear the electrodeposited layer. It is normally caused by:

- insufficient vertical clearance;
- lubricating oil dilution;
- engine running at low speed during long periods.

The lack of lubricating oil leads to metal-metal contact between the bearing and the crankshaft journal, and to excessive wear, due to dragging away of anti-friction material. It is normally caused by:

- Partially clogged oil galleries;
- Incorrect choice of bearing under-size;
- Inverted mounting of the main bearings (lower part versus upper part);
- Bad functioning of the oil pump or the relieve valve.

Fig. 7.4.1

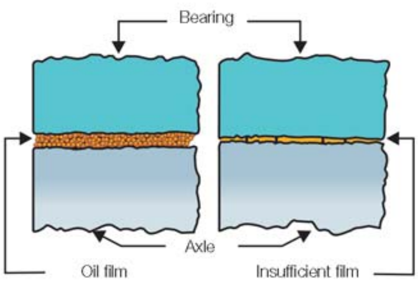


Fig. 7.4.2 Insufficient oil at the bearing

Corrections

- Check the journal dimensions when choosing new bearings;
- Grinding the crankshaft journals, if necessary;
- Check the oil pump and relieve valve's running conditions. Recondition or change them, if necessary;
- Check if the bearing oil holes are in-line with the corresponding holes on the engine block and con rods;
- Avoid engine running at low speed for long periods;
- Check de dilution of lubricating oil by the fuel or the cooling liquid.

7.5 Erosion by cavitation

Aspect

- Some regions of the bearing surface are eroded. In some cases the erosion can cross the whole material depth of the bearing alloy and reach the steel shell.

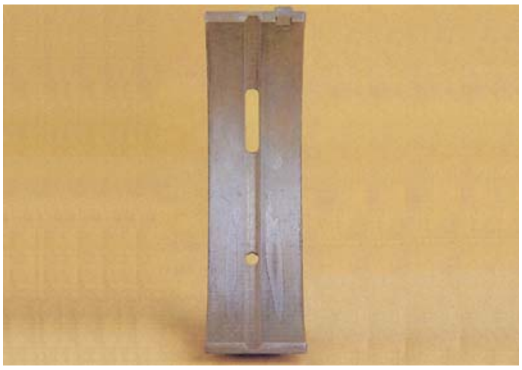


Fig. 7.5

Causes

- The erosion by cavitation is a type of damage caused by the instantaneous explosion of low pressure oil vapor bubbles, against the anti-friction alloy of the bearing. Loads on an engine bearing fluctuate rapidly, both in intensity and in direction, during an engine's running cycle. This results in rapid changes in hydrodynamic pressure of the bearing oil film.

The change in pressure gets higher each time there is a high deformation between the bearing and the corresponding journal.

The bearing erosion can also be caused by high velocity of the oil flux through the crankshaft holes and by flux variations given by discontinued surfaces, such as recesses, channels and sharp corners.

Bearing erosion by cavitation can be divided into four main groups:

- Erosion by suction cavitation - occurs behind the axle movement;
- Erosion by discharge cavitation - occurs in front of the axle movement;
- Erosion by flux cavitation;
- Erosion by impact cavitation.

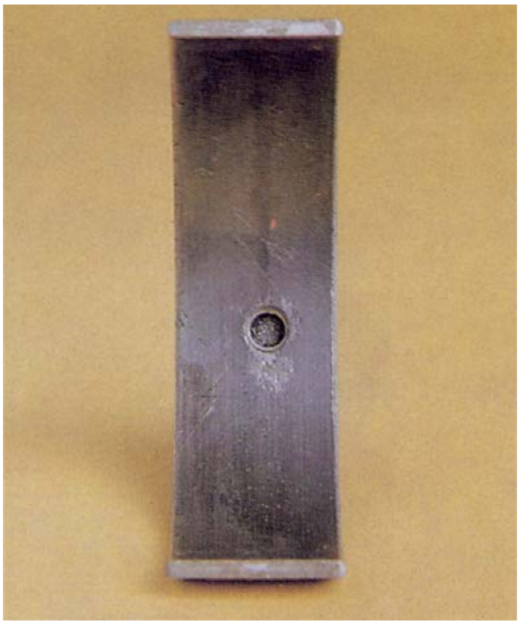


Fig. 7.5.1

Corrections

- Use lubricating oil with viscosity recommended by the engine manufacturer;
- Check the oil pressure;
- Avoid lubricating oil contamination;
- Check the assembly clearances.

7.6 Excessive clearance

Aspect

- The piece has scratches, originated by particles and resulting from deformation/ migration of the anti-friction alloy to a region close to the lateral bearing border.

Causes

- If the crankshaft or journal dimensions are below the recommended minimum, as well as the diameter of the bearing housing is bigger than the recommended maximum, this will result in a higher than permitted maximum lubricating oil clearance. Excessive clearance doesn't give hydrodynamic support to the axle. This results in a contact between the axle and the bearing surface, causing fusion and surface deformation of the bearing's anti-friction alloy (figs. 7.6 to 7.6.3).

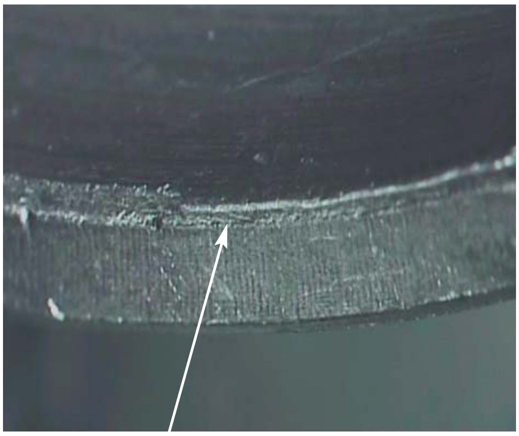


Fig. 7.6 Yield of material

Corrections

- Check the diametrical dimensions of bearings, con rods and crankshaft throws;
- Apply always the correct torque to the bolts and substitute them whenever recommended by the manufacturer/producer;
- Use adequate lubricating oil in your engine, as recommended by the manufacturer/ producer.

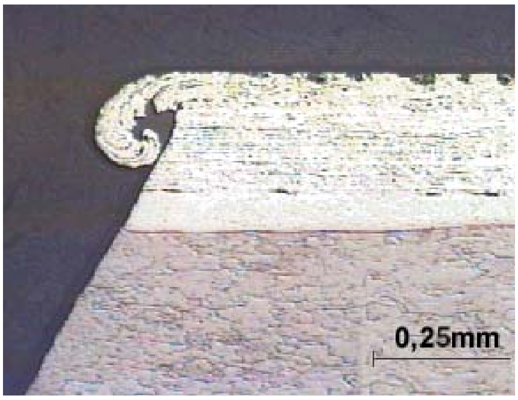


Fig. 7.6.1 Yield of material (enlarged photo)

Fig. 7.6.2 Yield of material

Fig. 7.6.3 Yield of material

8. Premature failure in bearings, due to fitting error

Fig. 8.1

8.1 Insufficient axial clearance (longitudinal)

Aspect

- Excessive wear on flange outside and in the region of the inner bearing surface, at the higher axial load side, while the other side has normal running aspect. In worn areas occur fusion and anti-friction alloy detachments.

Causes

- Insufficient clearance, caused by incorrect mounting or by incorrect placement of the clotch plate and the plateau, results in a crankshaft forcing against the bearing flange, to such an extent, that the resulting friction and the lack of lubricating oil film, increase the temperature to levels which separate the lead from the copper in the alloy, damaging completely these areas.

Corrections

- Obey to the assembly clearance specified by the engine manufacturer;
- Check the correct positioning of the connecting elements between engine and gear box.

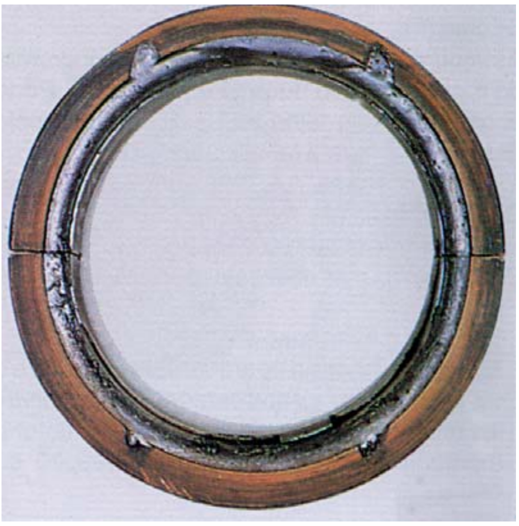


Fig. 8.1.1

Fig. 8.1.2 Totally worn-out flange

Fig. 8.1.3 Bearing flange front side without wear and back side with wear

8.2 Solid impurities

Aspect

- Foregein particles get imbued in the anti-friction alloy, resulting in material displacement. Scratches on the bearing surface can also be found.

Fig. 8.2

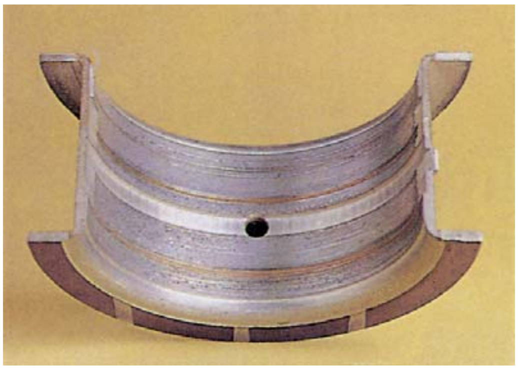


Fig. 8.2.1

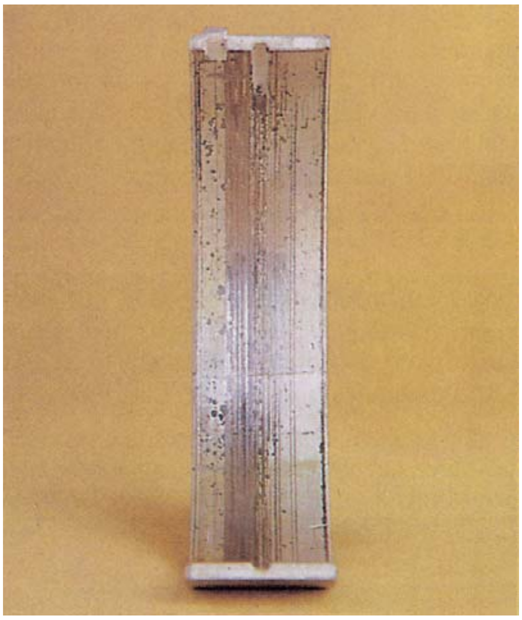


Fig. 8.2.2

Fig. 8.2.4 Contaminated main bearings with circumferential scratches

Causes

- Dust, dirt, abrasives and metallic particles, present in the oil, are absorved on the bearing surface, displacing the anti-friction alloy. The projection of this alloy or these particles can touch the axle, creating local friction points and disrupting the oil film (fig.8.2.3).

Incorrect engine cleaning, before or after assembly, can leave impurities. Worn-out metallic parts can also generate bad running conditions.

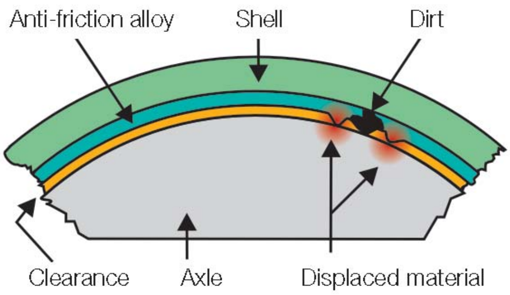


Fig. 8.2.3 Solid impurities

Corrections

- Install new bearings, following carefully the recommended cleaning instructions;
- Grinding the axle, if necessary;
- Recommend the operator to change periodically the oil and its filter, at the intervals specified by the engine manufacturer. Keep the air filter and the breather crankcase clean.

Fig. 8.2.5 Enlarged photo of a channel opened by an odd solid material, strange to the bearing

Fig. 8.2.6 Contaminated con rod bearing with circumferential scratches

Fig. 8.2.7 Enlarged photo of scratches and odd materials on a bearing

Fig. 8.2.8 Contaminated con rod bearing and circumferential scratches in the lubricating hole direction

Fig. 8.3

8.3 Housing dirt

Aspect

- Localized worn areas at the alloy's surface, corresponding to a mark caused by the presence of odd particles at the bearing back.

Fig. 8.3.1

Causes

- Particles between the housing and back of the cause bearing the inadequate contact and impair the heat flow. The heating and local loads give rise to fatigue in these areas and detaches the material (fig. 8.3.2).

Corrections

- Clean carefully the housing, eliminating all burrs, dirt and solid particles, before installing new bearings;
- Check the crankshaft journal and grinding them, if necessary.

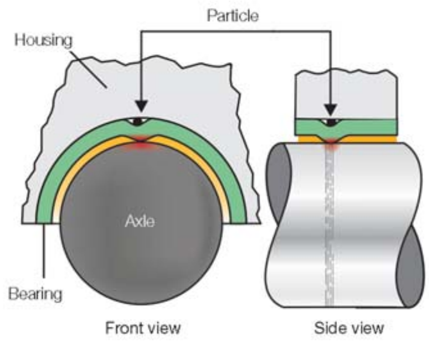


Fig. 8.3.2 Dirt in housing

8.4 Oval housing

Aspect

- Areas with excessive wear close to the bearing partition line.

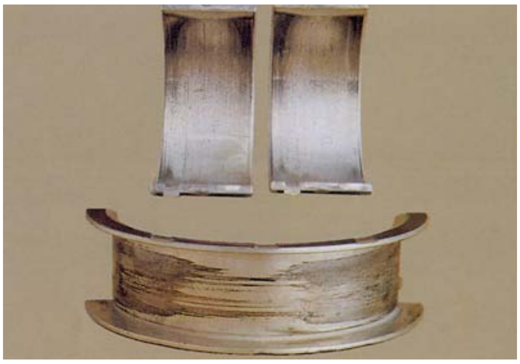


Fig. 8.4

Causes

- Due to the con rod flexure under alternate loads, the housing can get an oval form. The bearings tend to acquire this form, producing therefore a non-cylindrical internal surface. The clearance gets considerably reduced close to the partition line, due to the housing deformation, and this can result in metallic contact of the anti-friction alloy with the crankshaft journals (fig. 8.4.1).

Corrections

- Check the housing circularity of the bearing, and should it be out of specifications, recondition it or change the con rod;
- Check the camshaft journals, grinding them, if necessary.

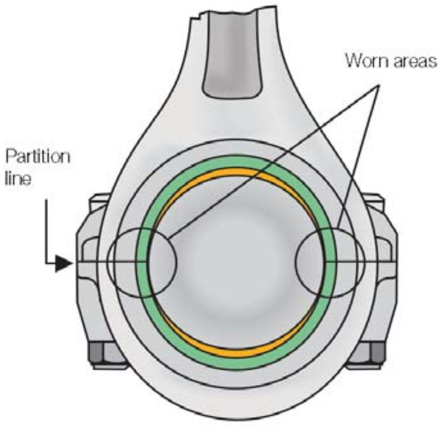


Fig. 8.4.1 Oval housing

Fig. 8.4.2 Marks of contact between crankshaft and bearings

8.5 Insufficient part line height

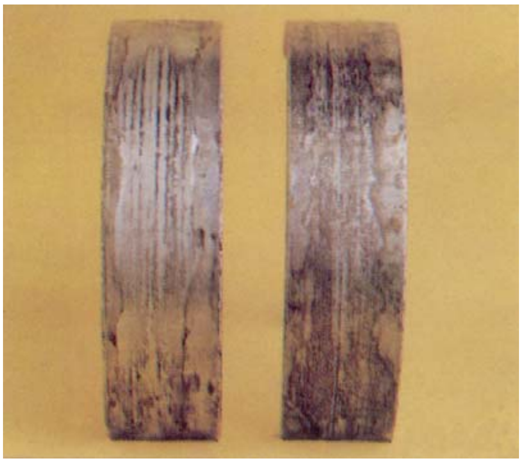


Fig. 8.5

Aspect

- Shiny areas (polished) are visible at the bearing back and in some cases, also at the part line surface.

Causes

- Insufficient fastening doesn't permit the formation of the necessary radial pressure to retain the bearing in its housing.

With inadequate contact, the heat flow gets difficult, and at the same time the additional friction caused by the bearing pulsation, increases the generated heat (fig. 8.5.3). The causes for an insufficient part line height:

- Part line surface reworked;
- Cap distanced from bearing, due to dirt or burrs in the part line surface;
- Insufficient torque;
- Interference between bolt and the end of screwed hole;

- Bearing housing diameter higher than specified diameter.

Corrections

- Clean the part line surfaces before fastening nuts and bolts;
- Check housing dimensions and general conditions, boring it, if necessary;
- When fastening nuts and bolts, apply the torque recommended by the engine manufacturer.

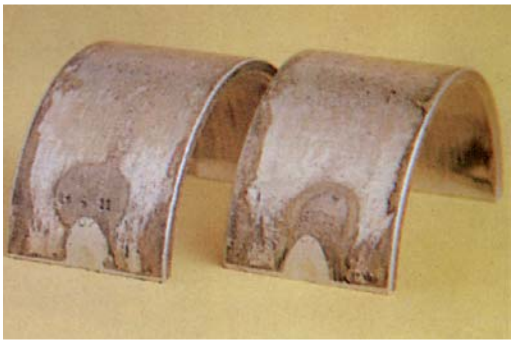


Fig. 8.5.1

Fig. 8.5.2

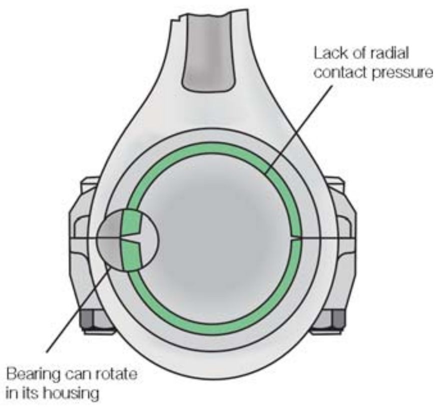


Fig. 8.5.3 Insufficient part line heigth

8.6 Excessive part line heigth

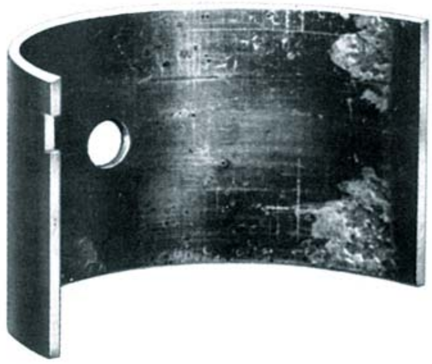


Fig. 8.6

Aspect

- Areas with excessive wear near the part line, in one both bearings.

Causes

- When fitted in the housing, the bearing remains salient at the part line. When the cap bolts are torqued, it will be forced against the housing, providing a good radial contact pressure.

In the presence of an excessive part line height, the resulting radial contact pressure will deforming the bearing close to the part line (fig. 8.6.1).

The most common causes are:

- Part line of the housing re-worked;
- Excessive torque.

Corrections

- Should the shell's partition line, the engine block or the con rod have been milled, re-machine the housing in order to obtain a perfect circularity;
- After the correct fastening of the cap bolts with a torque wrench, check with Prussian blue or any other adequate process (bore gauge, etc.), if the oval form is in its permitted limits;
- When fastening the bolts and nuts, the torque has to be according to the recommendations given by the engine manufacturer.

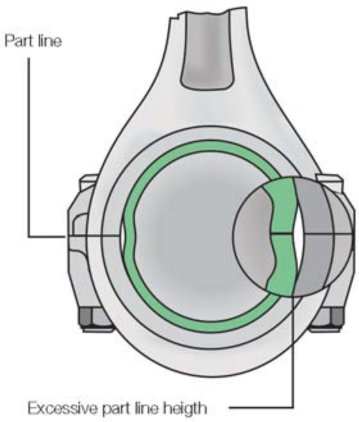


Fig. 8.6.1 Excessive part line heigth

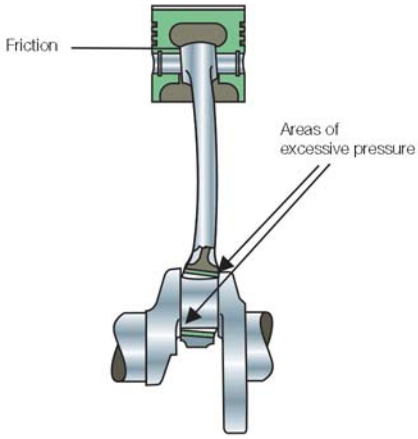


Fig. 8.7.1 Bent con rod

8.7 Bent or twisted con rod

Aspect

- Excessively worn-out areas on diagonally opposed sides of each bearing.

Fig. 8.7

Causes

- In a bent or twisted con rod, the housings are misaligned, originating areas of high pressure and even metal-metal contacts between the bearing and the crankshaft journal. Con rod bending can be caused by forced fitting of the piston pin, by fastening of the cap bolts while the con rod is fixed incorrectly on the vise, or by hydraulic rock (fig. 8.7.1).

Corrections

- Check the con rod and replace it, if necessary;
- Avoid torsion loads on the con rod.

8.8 Displaced cap

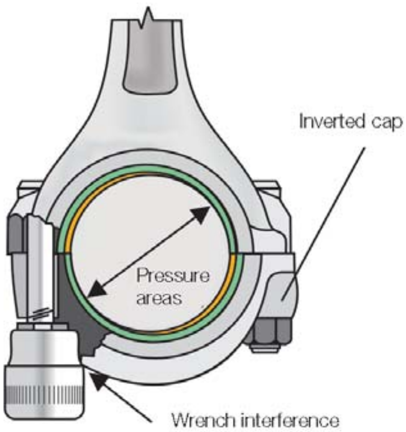


Fig. 8.8 Displaced cap

Aspect

- Areas with excessive wear on diagonally opposed sides of each bearing, close to the part line surface.

Causes

The bearing cap was displaced, forcing one side of each bearing against the camshaft (fig. 8.8). This can happen, due to following causes:

- Use of inadequate wrench when fastening the bolts;
- Cap inversion;
- Altered holes, pins or other centralizing systems;
- Crankshaft center displacement during milling operation;
- Re-use of con rod and/or bearing bolts.

Corrections

- Choose adequate wrench and fasten bolts alternatively in order to get a perfect cap seating;
- Be sure the cap position is correct;
- Check if the cap centralizing system is not altered nor damaged, and replace it, if necessary;
- Replace the con rod and/or housing bolts according to the recommendations given by the engine manufacturer;
- Machine the crankshaft according to specifications given by the engine manufacturer.

Fig. 8.8.1

Fig. 8.8.2 Premature wear

Fig. 8.8.3 Premature wear

8.9 Deformed crankshaft

Aspect

- A well-defined wear strip can be observed at the upper or at the lower main bearing set.

The extension of this wear can change from bearing to bearing, but generally it is more accentuated at the center bearing.

Causes

- The deformed crankshaft submits the main bearings to excessive loads. The highest pressures are achieved at the highest distortion points.

At these points the clearance also is reduced and metal-metal contact can occur between the bearing and the crankshaft journal (fig. 8.9).

The crankshaft can be deformed due to inadequate handling, incorrect storage or extreme operational conditions.

Corrections

- Check, by adequate process, if the crankshaft is deformed;
- Unbend the crankshaft.

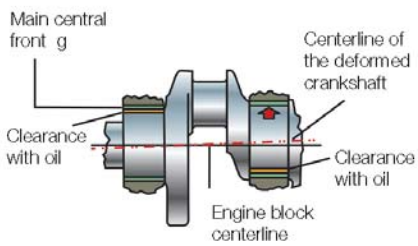


Fig. 8.9 Deformed crankshaft

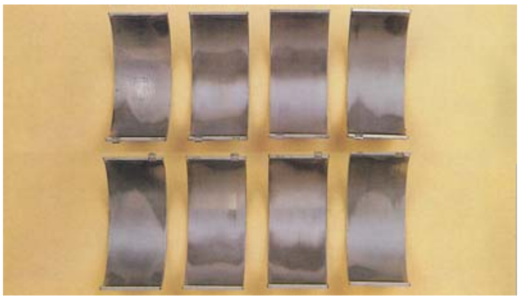


Fig. 8.9.1

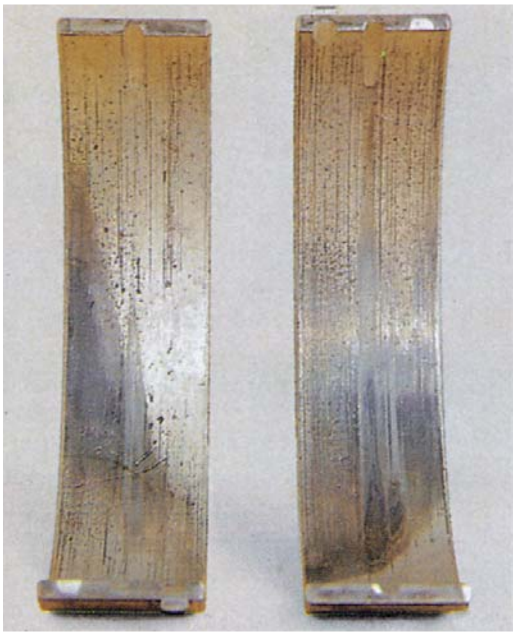


Fig. 8.10

8.10 Deformed engine block

Aspect

- A well-defined wear strip can be observed at the upper or at the under main bearing set.

The extension of this wear can change from bearing to bearing, but in general it is more accentuated at the center bearing.

Causes

The sudden heating and cooling of the engine is one of the causes for engine distortion, when it operates without thermostatic valve. The engine block deformation can also be caused by:

- Unfavorable operating conditions (for example, operational overload of the engine);
- Incorrect fastening procedure of the cylinder head bolts (fig. 8.10.2)

Corrections

- Check for the existence of deformations, by an adequate process;
- Bore the main housing;
- Install a thermostatic valve.

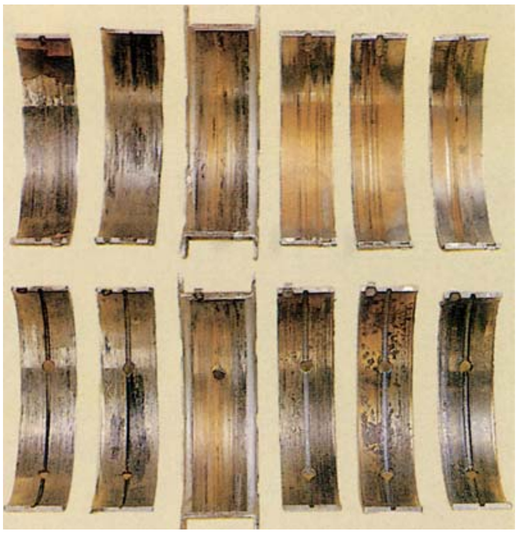


Fig. 8.10.1

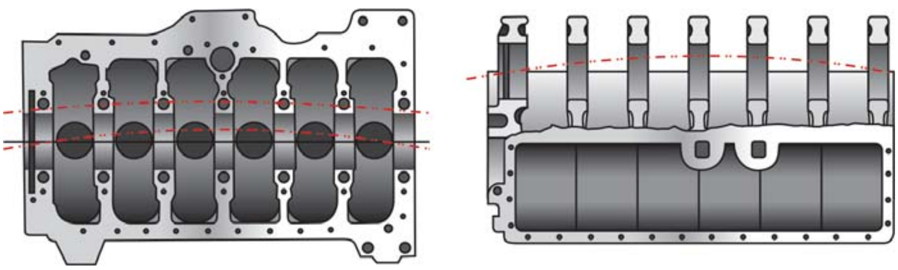


Fig. 8.10.2 Deformed engine block

Fig. 8.10.3 Irregular bearings marks

8.11 Non-cylindrical crankshaft journals

Aspect

- Unequal wear strip on bearing. Depending on the regions where the highest pressures have been active, three main aspects can be distinguished, which correspond respectively to form defects of the illustrated crankshaft journal (fig. 8.11 - A, B and C).

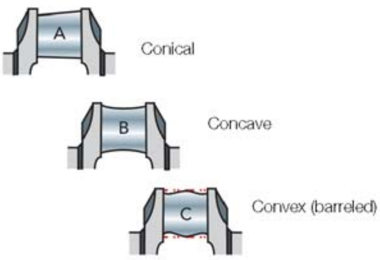


Fig. 8.11 Non-cylindrical crankshaft journal

Causes

- Non-cylindrical crankshaft journals impose an irregular load distribution over the bearing surface, generating higher heat levels in certain areas and accelerating wear. Clearances can result insufficient and metal-metal contact can then occur between the bearing and the crankshaft journals.

In other cases clearances will be excessive. The conical, concave or convex (barreled) journal profiles, plus the con rod bearing housing's conical form are always due to incorrect rectification.

Corrections

- Grind correctly the crankshaft journals and the housings.

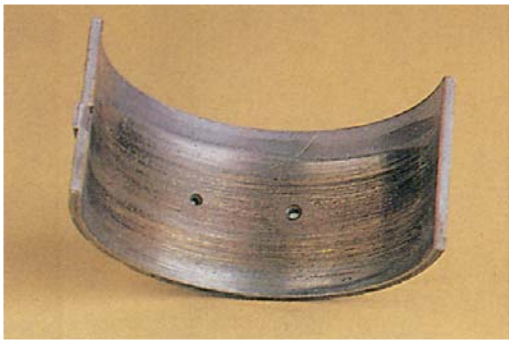


Fig. 8.11.1

Fig. 8.11.2

Fig. 8.11.3

Fig. 8.11.4

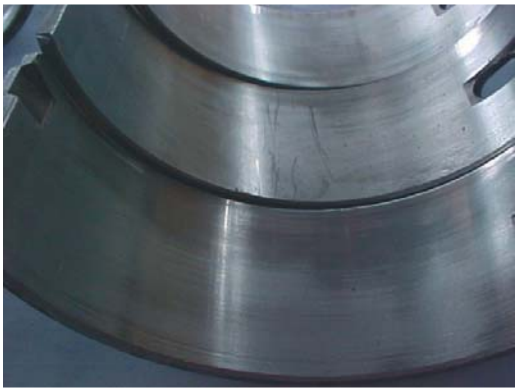


Fig. 8.11.5

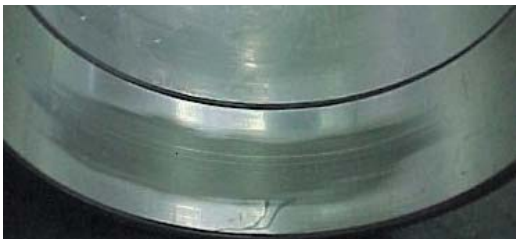


Fig. 8.11.6

8.12 Incorrect radius conformity

Aspect

- Areas with excessive wear along the bearing's lateral faces.

Causes

- Incorrect fillet radius, creating metal-metal contact along the bearing's lateral faces (fig. 8.12). This will result in excessive wear and premature localized fatigue.

Corrections

- Grind the crankshaft journals, observing the correct radii fillet radius;
- Leave no sharp corners because they will weaken the crankshaft, due to tensions which will concentrate on these already loaded areas.

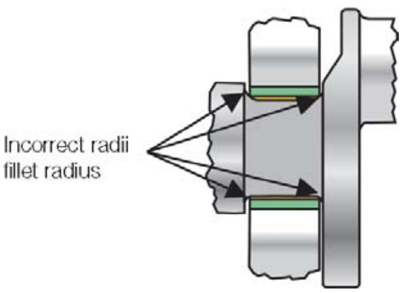


Fig. 8.12 Incorrect radii fillet radius

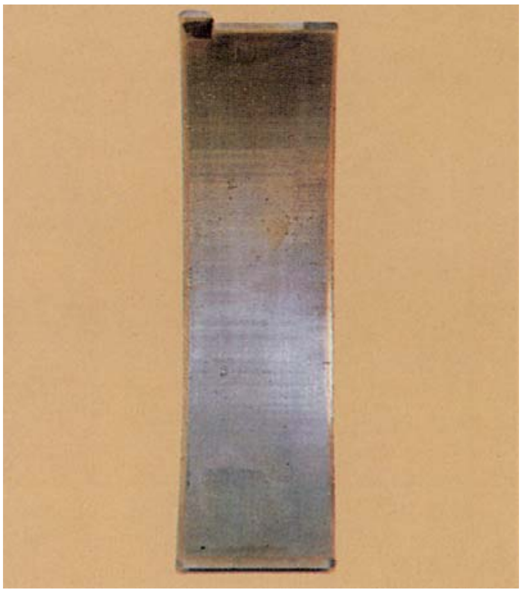


Fig. 8.12.1

8.13 Incorrect torque and application of glue/adhesive

Fig. 8.13 Glue/adhesive on bearing's external lubrication channel

Aspect

- The part presents deformation near the part line of engine block, and has its external lubrication channel partially obstructed by glue/adhesive.

Causes

- The torque applied to the engine block studs/bolts, when exceeding the specification given by the engine manufacturer, tends to deformations and consequently to metal-metal contact. This contact generates sufficient heat to start the fusion and dragging of materials. Another factor leaving to fusion will be found in the partial obstruction of the external lubrication channels (fig.8.13) by glue/ adhesive.

The incorrect/displaced position of the retainer also can result in piece deformations, compromising the oil clearance (fig. 8.13.1).

Corrections

- Check/revise the wrench periodically;
- Apply the torque recommended by the engine manufacturer;
- Assemble the engine according to recommendations given by the engine manufacturer, specifically with regard to the use or no-use of glue/adhesive.

Fig. 8.13.1 Pin mark on external bearing side

9. Incorrect fitting, due to lack of attention

- Bearings will not work adequately if incorrectly fitted or if they suffer changes in their project. Incorrect fitting almost always leaves to a premature bearing failure.

The figures below show the most common fitting mistakes.

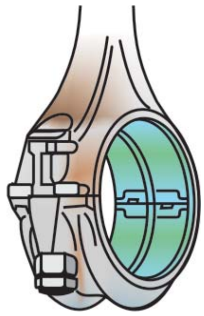


Fig. 9.1 Inverted or swapped caps

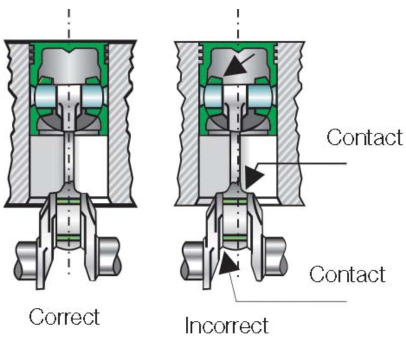


Fig. 9 Asymmetrical con rod

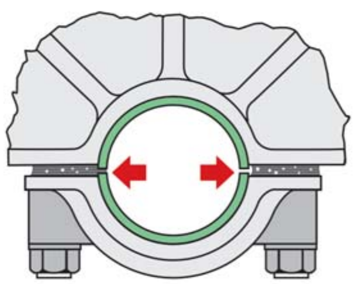


Fig. 9.2 Inadequate shims

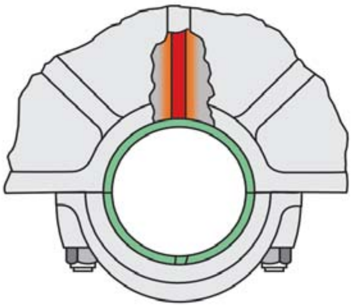


Fig. 9.3 Swapped bearings

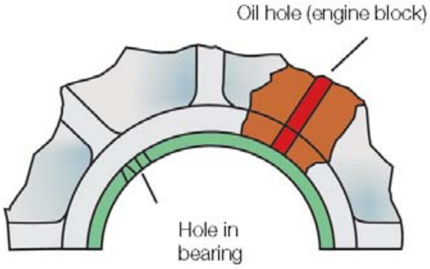
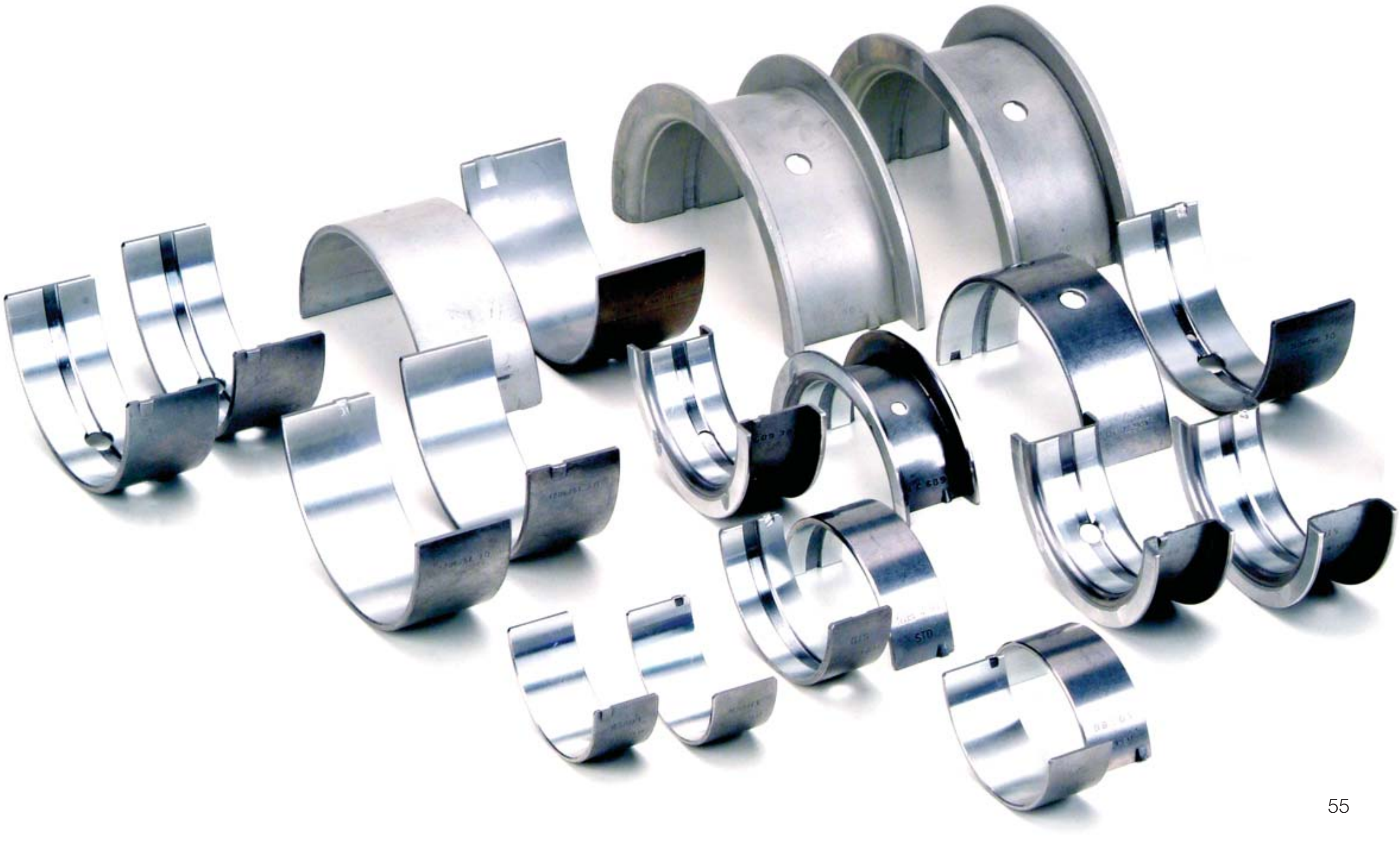


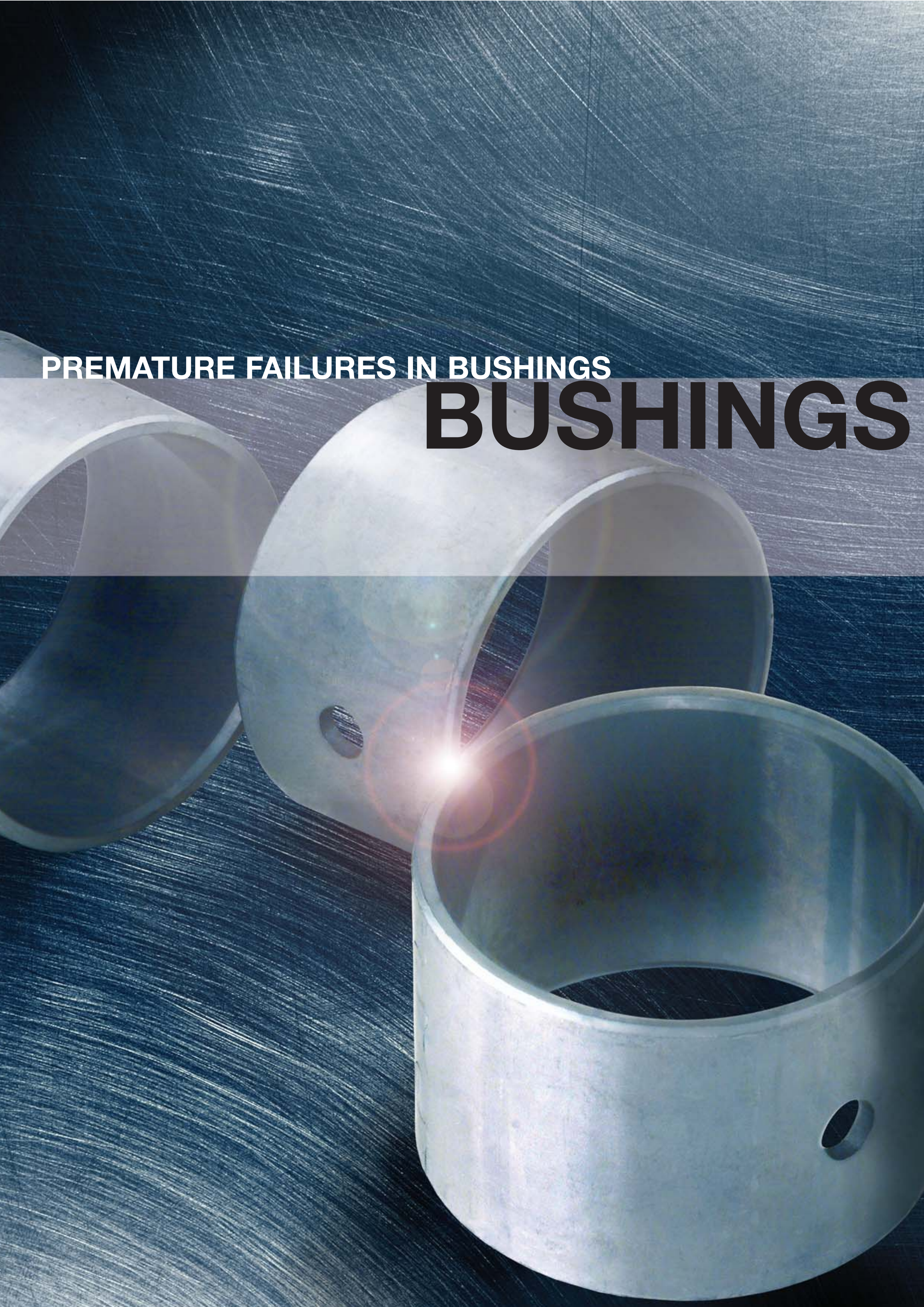
Fig. 9.5 Non-aligned oil hole

Fig. 9.4 Interference between the bearing lug the housing lug



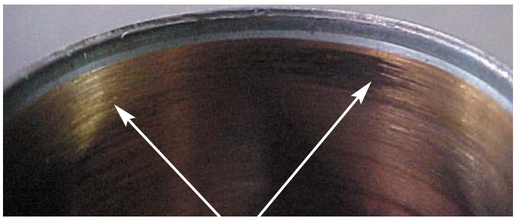
PREMATURE FAILURES IN BUSHINGS

BUSHINGS



Normal running characteristics

Bushings, same as bearings, have the highest wear under normal running conditions, when the engine is started. To reduce this wear to a minimum, oil lubrication filter and air filter changes have to be done according to instructions given by the engine manufacturer. It is also important to pay attention to any problem with the oil pump, and to other systems, such as lubrication, air filter, fuel admission/injection and cooling systems during the engine's operational life.



Normal scratches and correct wall thickness

10. Premature failures in bushings, due to assembling error

10.1 Incorrect assembly clearance

Aspect

- The external bushing surface presents deep circumferential scratches.

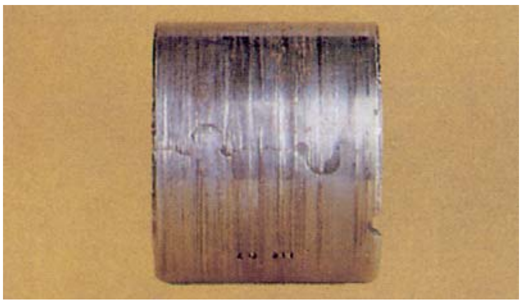


Fig. 10.1

Causes

- Insufficient diametric clearance, the axe was fitted on bushing. The axe gets "stuck" at the bearing and rotates in its housing.

Corrections

- Use the fitting clearance specified by the engine manufacturer.

10.2 Deformed housing

Aspect

- The external bushing surface presents areas of little contact with the housing. On the internal surface the piece presents anti-friction alloy detachment.

Fig. 10.2

Causes

- The manufacturing process adopted by MAHLE Metal Leve S.A. for camshaft bushings is called "G Die" (progressive stamping). In this process the bushing in formation gets a cylindrical form with tolerances for a perfect adjustment after being mounted on the cylinder block housing.

The housing form tolerances are specified by the manufacturer of the engine.

Should the housing form tolerances not comply with the tolerances given by the engine manufacturer, the contact area between the bushing and the housing will be reduced, resulting in a bad seating of the bushing. This doesn't allow a good dissipation of the heat generated by the bearing operation, and can result in a fusion of the bushing alloy. It can also result in a form error on the internal diameter, after the bushing has been fitted, interrupting the lubricating oil film and consequently causing fatigue, scuffing and material detachment.

Corrections

- Check the housing circularity before mounting a new bushing;
- In the case of a highly deformed housing, rectify it and use bushings with external oversize;
- Keep the clearance and interference specifications between the bushing and the housing, as recommended by the engine manufacturer.

Fig. 10.2.1 Alloy detachement

Fig. 10.2.2 Alloy detachement

Fig. 10.2.3 Alloy detachement

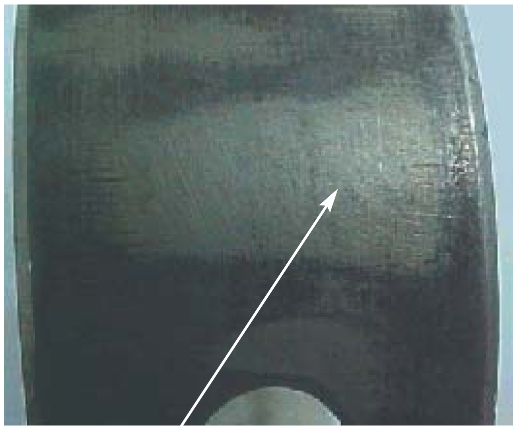


Fig. 10.2.4 Mark of irregular bushing seat in the housing

Fig. 10.2.5 Internal mark formed by odd material

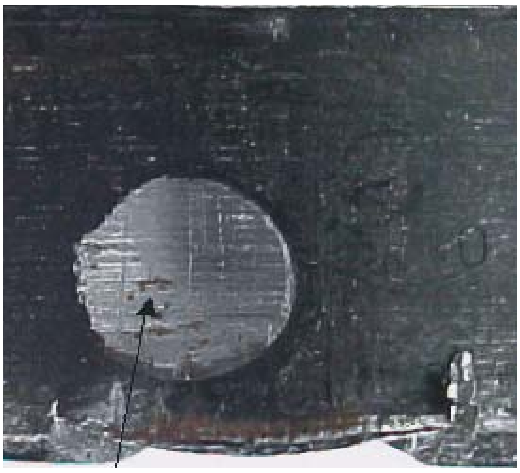


Fig. 10.2.6 External mark formed by odd material

10.3 Incorrect bushing assembling

Aspect

- The external bushing surface presents deep marks.

Fig. 10.3

Causes

- When the installation of a bushing in its housing is prepared, there can occur a misalignment between the bushing center and the housing, generating a certain inclination of the bushing. Considering that the piece is installed with interference on the external diameter, the bushing will not be correctly seated in the housing. There are possibilities that cracks can appear in the bushing material, due to involved stresses when the engine is running.

Corrections

- Use adequate tools for bushing mounting in the housing;
- Don't use deformed pieces.

Fig. 10.3.1 Incorrect bushing mounting mark

Fig. 10.3.2 Inclined bushing mounting mark

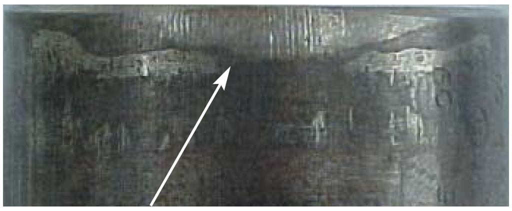


Fig. 10.3.3 Inclined bushing mounting mark

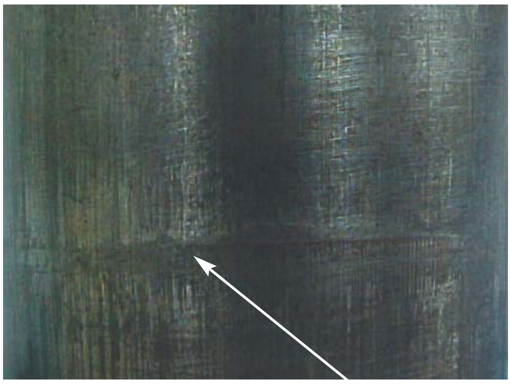


Fig. 10.3.4 Incorrect bushing mounting mark

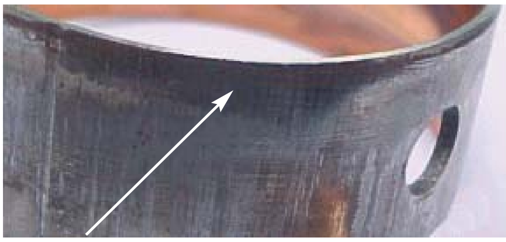
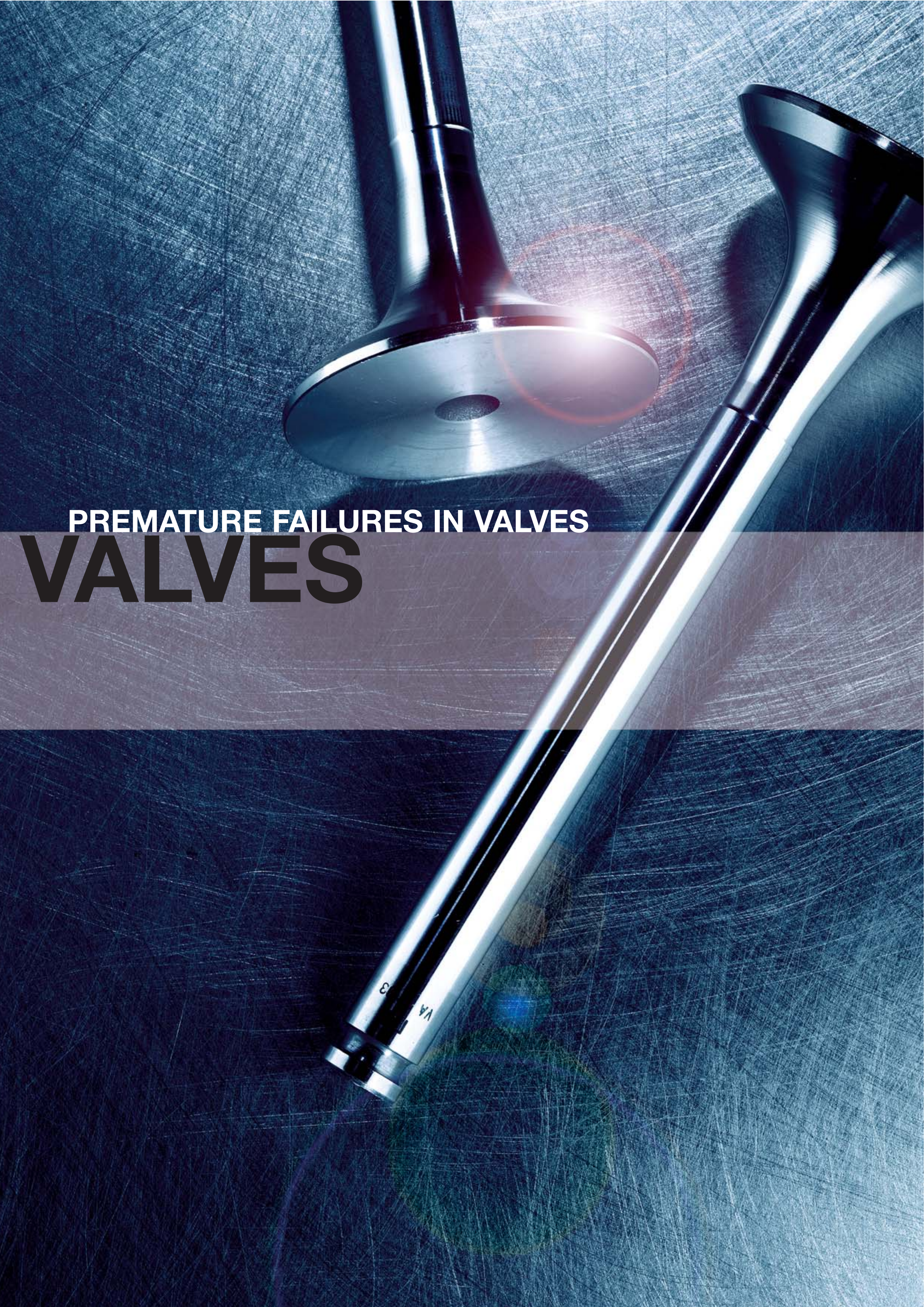


Fig. 10.3.5 Inclined bushing mounting mark



PREMATURE FAILURES IN VALVES

VALVES

Premature failures in valves

The working life of the valves is in proportion to the other engine components. The fuel injection, lubricating, cooling and air filter systems, as well as the operation of the equipment (vehicular, agricultural, stationary, industrial or naval), when done in normal working conditions, lead to the normal wear of the valves.

11. Premature failures in valves

11.1 Valve stem scuffing

Aspect

- The valve stem has marks due to scuffing done by the valve guide. This can result, in certain cases, in material being dragged.

Causes

The scuffing of the stem by the valve guide occurs when the clearance between these parts is jeopardized by failures related to:

- Incorrect alignment between disc/spring, guide and valve seats. The misalignment results in excessive clearance in certain regions and in others compromises the clearance between the stem/guide, to the point of causing its scuffing (fig.11.1.1);
- Incorrect clearance between the stem/guide and the oil/seals. Both the stem clearance with the valve guide, as well as incorrectly applied oil/seals, jeopardize the oil film which exists between the valve stem and the valve guide, resulting in scuffing, followed by material dragging. (fig.11.1.2);
- Inadequate engine operation. When the engine works under inadequate overload/ speed for the working conditions, the lubricating oil film, which exists between the valve stem and the guide, can be disrupted;
- Incorrect synchronization. The valves interference in the piston top due to incorrect synchronization, can cause bending of the stem, resulting in inadequate clearance between stem and guide. This problem can also jeopardize the sealing between the valve and the valve seat in the cylinder head (fig.11.1.3);
- Combustion residues. Carbon residues,

generated by the combustion of the mixture, when deposited on the lower part of the valve stem, can jeopardize the clearance between the stem/valve guide in this region and start the seizing (fig.11.1.4).

Corrections

- Check the alignment between the components: spring/disc/valve guide/seat. Clearance and correct applications shall be checked;
- Check synchronization and avoid excessive engine speed;
- Follow the engine manufacturer's recommendations, with respect to the engine's regulation of the fuel injection system (alcohol, petrol, diesel).

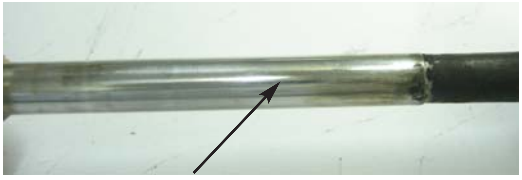


Fig. 11.1.1 Scuffing at the lower valve region

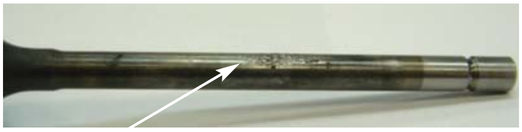


Fig. 11.1.2 Scuffing with material dragging

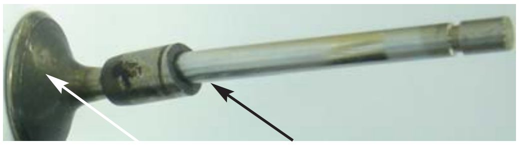


Fig. 11.1.3 Stem bending due to valve interference in the piston top

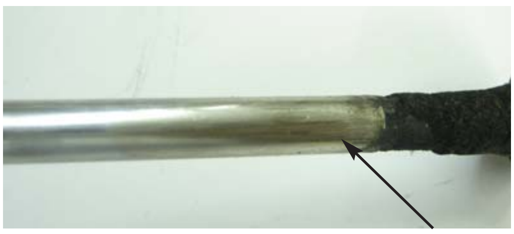


Fig. 11.1.4 Scuffing due to insufficient clearance between valve and valve guide

11.2 Valve seat wear

Aspect

- The valve seat presents excessive wear in channel form, along the whole seat diameter.

Causes

- The wear at the valve seat region is caused by the misalignment between the cylinder head valve seat and the guide. The use of fuels that are inadequate to the valves can also be the cause of this wear. Deficient valve springs can also cause wear in the valve seat region. High camshaft rotation results in valve floating (the valve almost doesn't close and open again) when the valve is "weak" (fig.11.2.1, fig. 11.2.2).

Corrections

- Check the alignment between the valve seat und valve guide.

The valve springs have to be tested according to the engine manufacturer's recommendations.

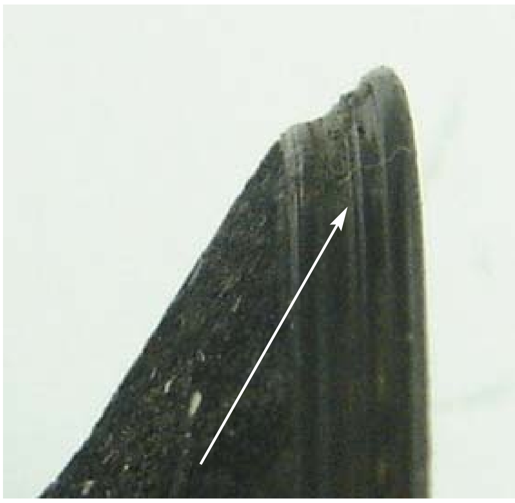


Fig. 11.2.1 Wear in the seat region

Fig. 11.2.2 Wear in the seat region

11.3 Valve fractures and breakages

Aspect

- The valve presents fracture and total head breakage in the radius and stem region. This type of failure is related to mechanical causes.

Causes

- The breakage on the radius and stem region is related to an excessive increase of the cyclic tension on the stem. The valve opening movement is done by the cam, which forces this opening and also compresses and closes the spring. The valve closing is done by the smaller cam part of the camshaft and mainly by decompression and opening of the springs. The increase of the tensions is related to deficient springs and subsequent valve floating. High rotations also causes floating and the increase in tension at the radius/stem region. The valve interference to the piston top, due incorrect engine syncronization, and also the incorrect use of engine-breaking, are factors that jeopardize the normal working conditions of the valves (fig. 11.3.1 and 11.3.2).

Corrections

- The valve springs shall be tested as to dimensions when load is applied. The recommendations for permitted limits shall be followed. Distribution synchronism, excessive speed and/or use of engine breaking shall all follow the limits recommended for each engine/vehicle manufacturer.

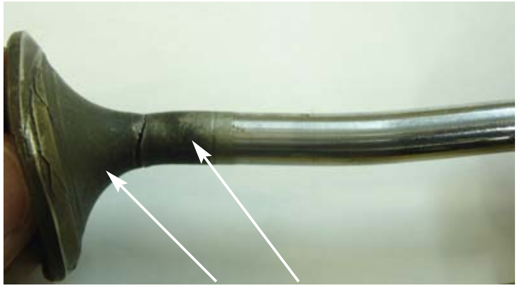


Fig. 11.3.1 Deformed and broken valve at the radius and stem region

Fig. 11.3.2 Broken valve head at the radius and stem region

11.4 Fracture at the keeper groove region with the stem

Aspect

- The valves present cracks/fractures or wear in the keeper groove region. This type of failure is related to mechanical causes.

Causes

- During the valve replacement not only the springs shall be inspected and tested, as formerly informed, but also the keepers. Irregular and damaged keepers can be considered as causes of this type of failure, as well as excessive clearance during adjustment of the valves and also valve floating (fig.11.4.1, 11.4.2, 11.4.3, 11.4.4).

Corrections

- Replace keepers and test the valve springs, as well as adjust correctly the valve clearance.

Fig. 11.4.1 Breakage at the keeper groove region

Fig. 11.4.4 Wear at the keeper groove channel caused by irregular keeper

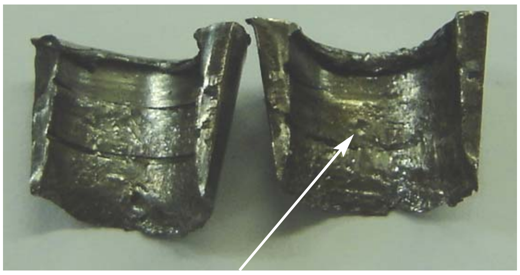


Fig. 11.4.2 Damaged keeper

Fig. 11.4.3 Breakage at the keeper groove region

11.5 Crack and/or fissure in the valve seat region

Aspect

- The valves present a crack/fissure at the head seat region. This type of failure is related to thermal causes. Should the fissure increase, part of the head will detach as show in the item 11.6.

Causes

- The start of the fissure is given by a thermal shock caused by unequal heating, which results in thermal fatigue. Misalignment between valve steam and valve seat and insufficient contact (valve/valve seat) lead to inadequate cooling. The incorrect operation of the vehicle, as well as the use of uncoupling during descents (gear box in the neutral position) also contribute to thermal fatigue (fig. 11.5.1 and 11.5.2).

Corrections

- Correct the alignment of valve steam and valve seat, seat sealing (valve and valve seat) as well as operate the vehicle according to the manufacturer's recommendations.

Fig. 11.5.1 Broken head

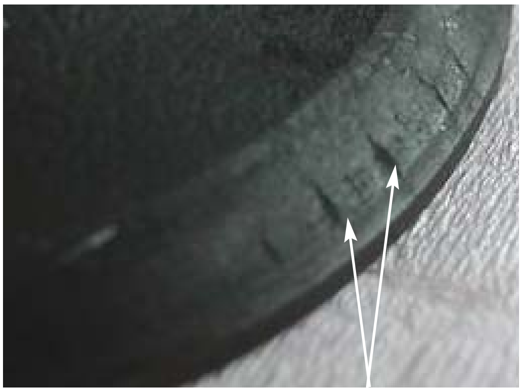


Fig. 11.5.2 Fissures on the valve seat

11.6 Fracture at the valve head region

Aspect

- The valve has a partially broken head. This type of failure is related to thermal loads causes.

Causes

- The partial valve head breakage starts with fissures at the valve seat region and is originated by the increase of combustion pressure and temperature in the combustion chamber and at the valves. This type of failure occurs only on exhaust valves. The increase in combustion chamber and valve temperature is related to the use of inadequate fuel, incorrect ignition/injection timing, inadequate spark plugs, excessive carbon deposit and incorrectly applied valves. The incorrect bedding of the valve on its seat can be the origin of this type of fractures (fig. 11.6.1. and fig.11.6.2).

Corrections

- Keep the original characteristics of the engine, use the adequate fuel, correct ignition or injection timing, adequate spark plugs and correct the valves in relation to its seats.

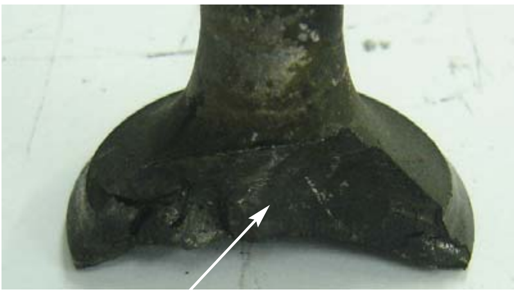


Fig. 11.6.1 Breakage of part of the head

Fig. 11.6.2 Breakage of part of the head

11.7 Generalized wear on the valve head

Aspect

- The valve presents wear at the head region and the valve seat. This type of failure is related to thermal causes.

Causes

- Wear is related to the increase in valve closing forces, combined with high operational temperatures and combustion pressures. Pre-ignition, detonation, poor fuel mixture and inadequate compression ratio are factors that affect and wear the valve head (fig. 11.7.1.and 11.7.2).

Corrections

- Keep the original engine characteristics, as well as the compression ratio, ignition/injection point and use adequate fuel, in correspondence with the engine specifications.

Fig. 11.7.1 Wear at the valve head region

Fig. 11.7.2 Wear at the valve head region

11.8 Burnt valve seats with localized wear

Aspect

- The valve presents a channel that starts at the seat and extends itself in direction of the radial region.

Causes

- Excessive localized heat at the head region, as well as gas escape concentrated at one only point, will result in local disintegration. Irregular valve seat sealing with cylinder head seat, carbon residues generated by irregular combustion (poor mixture) will appear at the seat region and will jeopardize the sealing between the valve and its seat. Deficient refrigeration is another factor, due to partial obstruction of the cylinder head cooling. As a consequence, the valve is cooled inadequately. Incorrectly valve clearance is another factor to jeopardize the sealing and to cause this type of failure (fig. 11.8.1 and 11.8.2).

Corrections

- Provide the correct seating, as well as keep the air/fuel mixture as homogeneous, and clean the cylinder head cooling galleries with products recommended by the engine manufacturer. Avoid long working cycles under idle condiction.

Fig. 11.8.1 Localized disintegration at the seat region

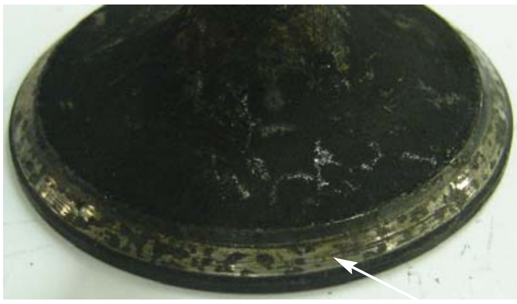


Fig. 11.8.2 Points at the valve seat are contaminated by carbon residues

11. 9 Various types of irregularity

Aspect

- Valves with contaminated valve seats, displaced seating marks, excessive carbon at the valve base, irregular marks at the valve top.

Causes

- Irregular seating marks are due to lack of perpendicularity between the cylinder head valve seat center and the valve guide center. This deficiency will increase the valve pressure at the seat in the region of major incline and permits the gases to pass where the pressure is the lowest. Excessive carbon results from excessive clearance between the valve guide and the stem, damaged or jeopardized retainers, or incorrect height of the guide in relation to the cylinder head.

Irregular marks at the valve top are due to irregularities at the rocker arm. This deficiency doesn't permit the valve to rotate. Another problem could be found in the incorrect height of the cylinder head, caused by inclined action of the rocker arm over the valve, if taken in relation to the cylinder head valve seat axle. It should also be mentioned that the cylinder head seats should be rectified, taking angles and minutes into consideration. The different values between the valve seat and the cylinder head seat permit the valve to be bedded correctly during the cylinder combustion (fig.11.9.1; 11.9.2; 11.9.3; 11.9.4).

Corrections

- Keep perpendicularity between the cylinder head valve seats and the guides. Keep the clearances recommended by the engine manufacturer and also protect the oil seal in order to avoid damages in the keeper grooves during mounting. Replace rocker arms and don't rectify them; replace also the cylinder heads when necessary.

Fig. 11.9.1 Irregular seating area

Fig. 11.9.2 Inlet valve contaminated by lubricating oil due to excessive clearance between valve and valve guide or malfunction of oil seal

Fig. 11.9.3 Contaminated inlet valve with lubricating oil crust due to excessive clearance between valve and valve guide or malfunction of oil seal

Fig. 11.9.4 Marks indicating that the valve hasn't rotated. Rocker arm deficiency

12. Torque conversion table

mkgf.	ft.-lbs.	ft.-lbs.	mkgf.	mkgf.	ft.-lbs.	ft.-lbs.	mkgf.	mkgf.	ft.-lbs.	ft.-lbs.	mkgf.
1	7,23	1	0,1382	31	224,22	31	4,2859	66	477,38	66	9,1248
2	14,47	2	0,2765	32	231,46	32	4,4242	67	484,61	67	9,2631
3	21,70	3	0,4118	33	238,69	33	4,5624	68	491,84	68	9,4013
4	28,93	4	0,5530	34	245,92	34	4,7007	69	499,08	69	9,5396
5	36,17	5	0,6913	35	253,16	35	4,8384	70	506,31	70	9,6778
6	43,40	6	0,8295	36	260,39	36	4,9772	71	513,54	71	9,8161
7	50,63	7	0,9678	37	267,62	37	5,1154	72	520,78	72	9,9544
8	57,86	8	1,1060	38	274,85	38	5,2537	73	528,01	73	10,0926
9	65,10	9	1,2443	39	282,09	39	5,3919	74	535,24	74	10,2309
10	72,33	10	1,3825	40	289,32	40	5,5302	75	542,48	75	10,3691
11	79,56	11	1,5208	41	296,55	41	5,6685	76	549,71	76	10,5074
12	86,80	12	1,6591	42	303,79	42	5,8067	77	556,94	77	10,6456
13	94,03	13	1,7973	43	311,02	43	5,9450	78	564,17	78	10,7839
14	101,26	14	1,9356	44	318,25	44	6,0832	79	571,40	79	10,9221
15	108,50	15	2,0738	45	325,35	45	6,2215	80	578,64	80	11,0604
16	115,73	16	2,2121	46	332,72	46	6,3597	81	585,87	81	11,1987
17	122,96	17	2,3503	47	339,95	47	6,4980	82	593,11	82	11,3369
18	130,14	18	2,4886	48	347,18	48	6,6362	83	600,34	83	11,4752
19	137,43	19	2,6268	49	354,42	49	6,7745	84	607,57	84	11,6134
20	144,66	20	2,7651	50	361,55	50	6,9128	85	614,81	85	11,7517
21	151,89	21	2,9034	51	368,88	51	7,0510	86	622,04	86	11,8899
22	159,13	22	3,0418	52	376,12	52	7,1893	87	629,50	87	12,0282
23	166,36	23	3,1799	53	383,35	53	7,3275	88	636,50	88	12,1664
24	173,59	24	3,3181	54	390,58	54	7,4658	89	643,74	89	12,3047
25	180,83	25	3,4564	55	397,82	55	7,6040	90	650,97	90	12,4429
26	188,06	26	3,5946	56	405,05	56	7,7423	91	658,20	91	12,5812
27	195,29	27	3,7329	57	412,28	57	7,8805	92	665,44	92	12,7195
28	202,52	28	3,8711	58	419,51	58	8,0188	93	672,67	93	12,8577
29	209,76	29	4,0094	59	426,75	59	8,1570	94	679,90	94	12,9960
30	216,99	30	4,1476	60	433,98	60	8,2953	95	687,14	95	13,1342
				61	441,21	61	8,4336	96	694,37	96	13,2725
				62	448,45	62	8,5718	97	701,60	97	13,4107
				63	455,68	63	8,7101	98	708,83	98	13,5490
				64	469,91	64	8,8483	99	716,07	99	13,6872
				65	470,15	65	8,9866	100	723,30	100	13,8255

1 ft.-lbs. = 0,138255 mkgf.   1 mkgf. = 7,2330 ft.-lbs.

1 mkgf. = 10mN (Metronewton)