

Engine damage: Failure caused by cylinder-head gasket? Actual causes and remedial measures



G O O D E X P E R I E N C E

Recognizing and preventing
typical damage to

Cylinder-Head Gaskets



Das Original

Engine failure caused by cylinder-head gasket?

Rigorously tested high-tech components

The cylinder-head gasket is a high-tech and complex engine component. All the more reason for the rigorous testing on state-of-the-art engine test benches during the development stage at Elring-Klinger and at the engine manufacturers' facilities. In addition, stringent inspection and testing throughout the manufacturing process ensure top quality, thus guaranteeing that the gasket fulfills all necessary technical and design requirements for a perfect seal on the engine.

Cylinder-head gaskets are available in various designs – multi-layer metal gaskets Metaloflex®, metal/soft-material and metal/elastomer. Further information about these designs can be found in the brochure "Cylinder-Head Gaskets". Just ask us to send you a copy.

Engine failure – is the cylinder-head gasket to blame?

When an engine fails – for instance due to overheating or oil/water leakage after installation of the cylinder head - the blame is often put on the cylinder head gasket. And that is understandable from the workshop professional's point of view, since the gasket has usually been installed carefully in accordance with the repair instructions.

The hidden actual causes

Analysis of actual cases through the years clearly shows that the real cause of engine damage is often something entirely different. The cylinder-head gasket is usually the last link in the chain where the damage comes to light – when the gasket can no longer fully carry out its actual task – sealing the engine. So in the end, the cylinder-head gasket is returned to the manufacturer as a defective part.

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What can leak from cylinder-head gaskets?

When we speak of leakage in the sealed area of the cylinder head, we are usually dealing with the media

- gas
- water
- oil

Types of gas leakage

- from the combustion chamber through the sealing web into the neighboring combustion chamber
- from the combustion chamber into the cooling circuit

These leaks usually lead to considerable damage and finally to the destruction of the gasket. Depending on the engine load, the gasket is ruined suddenly or gradually over a longer period of time.

Types of water leakage

- from the interior to the exterior of the engine
- into the oil circuit
- into the combustion chamber

Types of oil leakage

- from the interior to the exterior of the engine
- into the cooling-water circuit

Slight sweating of water or oil (no drops) on the sealing edge or dried coolant does not constitute leakage. Water or oil leakage can arise over a longer period of time and often initially goes unnoticed until for instance water or oil has to be refilled within an unusually short amount of time.

Take warning signs seriously and act

When you detect irregularities in the running condition of the engine such as poor cold-start performance, the engine not running on all cylinders during cold-start, loss of power, cooling water temperature in the red zone, etc., you should immediately undertake appropriate measures such as shutting down the engine and consulting a specialist to determine the cause. At this stage it is still possible to prevent serious damage to the engine, perhaps saving the customer a great deal of money.

Important:

First determine the cause before undertaking any repairs. Otherwise the damage can reoccur after the repairs.

This brochure is intended to be a tool for you.

It will help you find the hidden actual causes of engine damage and ideally prevent damage with appropriate measures before it is too late.

Damage symptoms and causes of gas blow-by

Black discoloration is a clear symptom.

The over blow of combustion gases at the combustion chamber eyelets of the cylinder-head gasket is one of the most common problems making it necessary to disassemble the cylinder head.

A clear indication is visible black discoloration on the metal eyelets or in the adjacent soft-material area of the gasket. Due to the high gas temperature, the soft material at these points is overheated and can even burn. The gases often find their way into the cooling circuit. This is indicated by rising gas bubbles in the cooler or by overheating of the cooling circuit (pressure in the cooling circuit increases and coolant escapes from the pressure relief valve – loss of coolant). In the worse case, the eyelet is entirely destroyed. Uniform discoloration of the combustion chamber eyelet is however normal, and depends on the steel material and the surface coating used.

Most common causes

In many cases, insufficient compression of the gasket in this area, which is subjected to very high temperatures, is a possible cause. This can be caused for instance by failure to comply

with the installation guidelines or the specified tightening torque for the cylinder head bolts, or the use of old bolts. Non-flat (deformed), excessively rough component surfaces also contribute to the insufficient compression of the gasket.

Unusually high engine loads in operation can also result in excessive thermal stress and the subsequent destruction of the combustion chamber seal.

An example:

The full-load operation shortly after the cold start generates extreme shifting motion between the crankcase (gray cast iron) and cylinder head (aluminum), subjecting the gasket to extreme stress. In addition, the clamp forces of the cylinder-head bolts under these conditions are low, thus increasing the dynamic sealing gap motion towards the crankcase and cylinder head.

Very often, especially on truck engines, the specified liner protrusion was not provided due to lack of knowledge or was adjusted incorrectly during installation, the liner seating surface in the engine block was not refinished or the liner was not press-fit sufficiently, causing the liners to drop with the consequence that the required sealing compression is lost. The path is opened up for the combustion gases to the rear part of the gasket, where they can then destroy the elastomer sealing elements or the soft sealing material on the water and oil passages.

1. Failure of the cylinder-head gasket on commercial vehicles due to gas blow-by

Damage symptoms:

Between cylinders two and three (exhaust area) there is extreme gas over blow. The soft material of the gasket has been destroyed in the area of the water holes.



Cause:

The cylinder-head gasket was not compressed sufficiently because the bolts were not tightened in compliance with the method specified by the manufacturer. This caused gas blow-by into the cooling water, resulting in increased coolant pressure and loss of coolant as well as the destruction of the cylinder-head gasket.

Other possible causes:

- Cylinder liner has sunk.
- Components have become distorted.
- The surfaces of the engine components cylinder crankcase and cylinder head were too rough.
- Start of delivery was not adjusted properly, producing excessive ignition pressure.

Measures:

- Use only new cylinder head bolts to ensure quality and safety.
- Tighten cylinder-head bolts with the tightening torque as specified by the manufacturer.

Damage symptoms

The elastomer sealing element has separated from the gasket carrier at the tappet opening, as well as at the water opening (small arrow). The result is significant loss of water.



Cause:

An uneven cylinder head surface caused gas blow-by (large arrows). The elastomer sealing elements were pressed away from the carrier plate by the strong gas pressure. The destructive process was accelerated by the constant full-load operation of the engine.

Other possible causes:

- Insufficient compression forces generated by the cylinder-head bolts.
- Liner protrusion not adjusted properly.

Measures:

- Carefully check the flatness of the component sealing surfaces before installation. If necessary, resurface.

Damage symptoms and causes of gas blow-by

2. Failure of the cylinder-head gasket on passenger cars due to gas blow-by

Damage symptoms:

Sealing web between combustion chambers one and two burnt through.



Cause:

The gasket was not compressed sufficiently in the destroyed section because the specified bolt tightening torque was not observed or the old cylinder-head bolts were used, resulting in gas blow-by. Overheating then destroyed the sealing web.

Other possible causes:

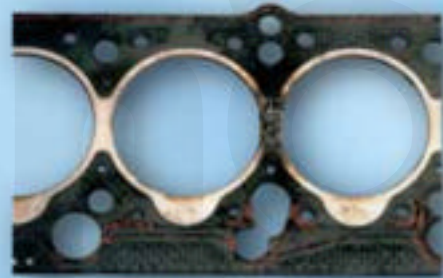
- Engine components not flat; sealing web deformed on the engine block and cylinder head.
- Engine not properly adjusted, resulting in overheating.

Measures:

- Follow the specified installation instructions closely.

Damage symptoms:

Combustion chamber eyelet and soft material between cylinders three and four scorched. The start of dark discoloration between cylinders three and four.



Cause:

Uncontrolled combustion process lead to overheating and ultimately the destruction of the sealing material.

Other possible causes:

- Cylinder-head bolts not tightened as specified.
- Engine components not flat.
- Error in cooling system, defective thermostat.

Measures:

- After installation, check injection adjustment.
- Check injection valve carefully and test for leakage.

3. Failure caused by gas blow-by on 2-layer metal gasket

Damage symptoms:

The metal stopper layer and the functional layer show significant black discoloration near the cooling duct. Gas has leaked between the stopper layer and the functional layer.



Functional layer, head side

Stopper layer, engine block side

Cause:

The bolt tightening torque was too low, generating insufficient sealing compression.

Other possible causes:

- Engine components not flat (deformed by overheating).

Measures:

- During installation, ensure that the specified bolt tightening torque is applied.

4. Failure due to pressure build-up in the cooling system as a result of gas blow-by

Damage symptoms:

On the multi-layer metal cylinder-head gasket, clear linear impressions can be seen in the area of the water ducts. These come from the cylinder head sealing surfaces and run in the direction of the combustion chamber. The water passages have an obvious light coloration.

Cause:

The surface structure of the cylinder head was machined either insufficiently or not at all, resulting in the blow-by of combustion gases into the cooling circuit and overheating (pressure build-up).

Other possible causes:

- The air was not removed entirely from the cooling system so the coolant did not circulate.
- Cooling circuit was interrupted (water pump, thermostat, fan).
- High exhaust back pressure caused engine to overheat (e.g. defective catalytic converter).

Measures

- Check the condition of the sealing surfaces very closely before installation and ensure that the cylinder head is flat (very fine structure, permissible surface roughness values for the cylinder head machining $R_z 11 \mu\text{m}/R_{\text{max}} 15 \mu\text{m}$).



Damage symptoms and causes of gas blow-by

5. Failure of the cylinder-head gasket due to pressure build-up in the cooling system as a result of gas blow-by

Damage symptoms:

Clear linear impressions visible on the multi-layer metal-elastomer cylinder-head gasket. These impressions were made by the cylinder-head sealing surfaces and run in the direction of the combustion chamber.



Cause:

The surface structure of the cylinder head was machined either too coarsely or not at all. This caused combustion gas blow-by into the cooling circuit and overheating (pressure build-up).

Other possible causes:

- The air was not removed entirely from the cooling system so the coolant did not circulate.
- Cooling circuit was interrupted (water pump, thermostat, fan).
- High exhaust back pressure caused engine to overheat (e.g. defective catalytic converter).

Measures:

- Check the condition of the sealing surfaces very closely before installation and ensure that the cylinder head is flat (very fine structure, permissible surface roughness values for the cylinder head machining $R_z 11 \mu\text{m}/R_{\text{max}} 15 \mu\text{m}$).

Damage symptoms and causes of overheating

Destructive heat

In many cases, damage to cylinder-head gaskets induced by overheating is caused by an engine component that stops functioning. This can be the water pump, a thermostat that does not open or a radiator plugged with calcium deposits (no circulation). Insufficient water in the cooling circuit or an improperly vented cooling circuit after the installation of a cylinder head can however also be the cause.

There may however be other destructive factors that are the source of the problem, and these perhaps are not even considered in the initial assessment of damage.

For instance, the exhaust system can also be responsible for overheating. A loose component in the muffler or a melted catalytic converter can for example lead to a restricted exhaust duct

cross section. This increases the exhaust back pressure, in turn leading to overheating of the engine parts and cylinder-head gasket and the loss of engine power.

A cylinder-head gasket which has failed due to overheating is easy to recognize. A sure sign is for instance the swollen waviness of the soft material near the water passages.

In the case of overheating of the cooling system, coolant penetrates into the soft material matrix of the gasket where it vaporizes due to the adjacent hot engine parts, pressing the soft material away from the metal carrier. The result is the waviness of the material.

One should not underestimate the consequences of using antifreeze and anti-corrosion agents that have not been approved or the use of pure water as coolant. The metal carrier plates of the gasket suffer massive decomposition as a result of corrosion, resulting in the destruction of the gasket.

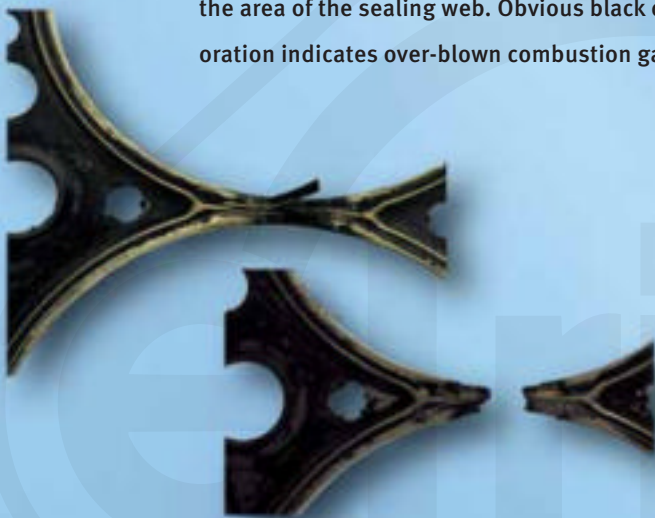


Damage symptoms and causes of overheating

1. Cause of failure – overheating on 2-layer metal gaskets

Damage symptoms:

The metallic functional layer into which the combustion chamber seal is integrated is broken in the area of the sealing web. Obvious black discoloration indicates over-blown combustion gas.



Cause:

Part distortion resulted in over-blown combustion gases, which in turn overheated the metal layers and led to their destruction.

Other possible causes:

- Low quality fuel (insufficient octane rating).
- Excessive compression ratio.
- Engine tuning (sparkplugs with incorrect heat rating).
- Insufficient bolt clamp force (bolt quality, tightening of bolts).

Measures:

- Check parts carefully for distortion and surface condition before installation.

2. Cause of failure – overheating of the metal/soft-material cylinder-head gasket

Damage symptoms:

The exposed soft materials on the gasket are heavily swollen at the water passages.



Cause:

After installation of the engine, the cooling system was not vented sufficiently. The engine overheated because of excessive coolant temperature. Vaporization led to the swelling of the soft material of the gasket in the area of the water duct, thus separating the soft material of the gasket from the metal carrier.

Other possible causes:

- The function of the cooling circuit was restricted by water pump or thermostat.
- Water circulation in the cooling system (e.g. in the radiator) was restricted due to calcium deposits.

Measures:

- After installation, ensure that the air is vented fully from the cooling system.

Damage symptoms and causes of oil and coolant leakage

Careful inspection: Just where is the leak?

Many engine failures that are blamed on the gasket were often actually caused by some other factor, for instance crankcase ventilation lines, boost-pressure tube or misaligned parts (timing-gear case on the cylinder block, etc.). Before assuming that the gasket has caused the damage, the technical surroundings of the engine must be inspected closely. For instance, wind from the ventilator or relative wind can blow oil or water away from where it actually originated. The blame is then put on the gasket for not providing a proper seal.

Cylinder head installed professionally?

After repairs, complaints about oil and coolant leaks are very common. In many cases however, these leaks were caused by improper installation of the cylinder head, for instance if the installation instructions specified by the engine and component manufacturer are not followed closely.

If the gasket is not aligned when the cylinder head is put in place because for example the centering pins or sleeves are missing, leakage can occur since the sealing elements of the cylinder-head gasket are not positioned exactly where they were designed to be. Cylinder-head gaskets

installed in this way can often be recognized by deformation of the bolt openings. If the cylinder-head gasket is misaligned, leaks are especially common on the pressure oil bores. If the sealing elements are not positioned exactly at this point, leaks often occur at peak pressure values up to 10 bar.

Cylinder-head gaskets for commercial vehicles: It's a matter of the groove

Various gasket designs are used on engines in commercial vehicles. In most cases, these are metal-elastomer gaskets with mounted or vulcanized elastomer sealing elements. Depending on the design, grooves are recessed in the cylinder block and cylinder head such that the sealing elements function reliably under all engine operating conditions.

On such types of gaskets, it is especially important that these grooves are cleaned carefully of dirt and residues before installation. If this is not done, leakage will occur.

Damage symptoms and causes of oil and coolant leakage

Damage in the form of crushed elastomer sealing elements can arise already during the installation process if care is not taken when the cylinder head is put in place on the cylinder block.

An actual case:

A truck engine experienced water loss that could not be detected from the outside. The cause: the cylinder liner had a porous area that was visible only under a microscope. When the engine was in operation, water got into the combustion chamber and vaporized. The cylinder-head gasket was not to blame in this case either. Instead, a material flaw in the form of a blowhole in the cylinder liner was the cause.

It's a matter of the surfaces

The condition of the component surfaces plays a decisive role for the seal. The various types of cylinder-head gasket designs such as metal/soft-material, metal layers and metal-elastomer have specific requirements for the component surfaces.

For instance, the surfaces of the cylinder block and cylinder head must be machined very finely and may not have any irregularities. The transitional areas from component to component – for instance when a timing-gear case is flanged – are especially crucial. Great care is required so that there is no raised edge or distortion at the joint that could prevent a force-locked seal.

Use only approved antifreezes and anti-corrosion agents

When considering all the factors that lead to loss of fluid, the chemical impact of the operating media must also be taken into account. This includes antifreezes and anti-corrosion agents. Many operating media available on the market have not been approved by the engine manufacturers. These media contain aggressive additives that destroy the sealing material and lead to leakage. The leak-stoppers that are added to the cooling water also have the same effect. Chemi-



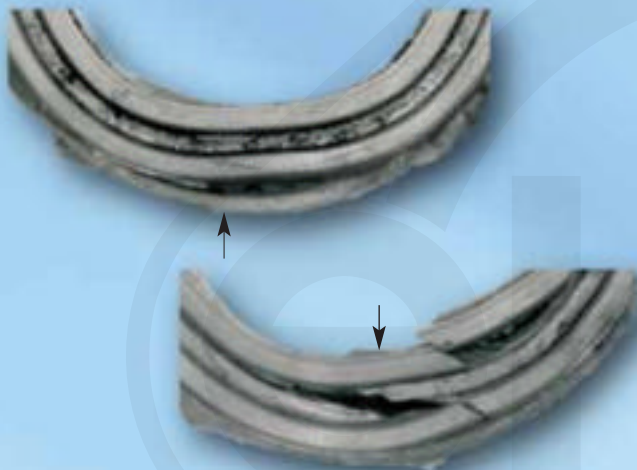
cal plasticizers make the sealing materials swell, destroying the gasket in a short period of time.

Additional sealing compounds that are applied to cylinder-head gaskets can also have a negative effect, since they can hinder the sealing function of the sealing elements integrated in the cylinder-head gasket. Elring cylinder-head gaskets are designed in general such that they do not require any additional sealing compounds.

1. Cause of failure – oil leakage, sealing element destroyed during installation of the cylinder head (truck)

Damage symptoms:

The elastomer sealing elements have been pressed away from the carrier plate and cut/torn.



Cause:

The cylinder head had to be lowered several times during installation because it was originally positioned incorrectly. As a result, certain areas of the sealing element were compressed heavily or cut by the edges of the cylinder head.

Other possible causes:

- Sealing element was pressed away by gas blow-by.
- Sealing element was compressed excessively due to insufficient liner protrusion.

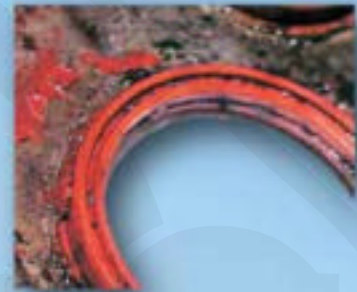
Measures:

- Use great care in preparing and carrying out the installation. If the cylinder head needs to be repositioned, the gasket must be inspected for damage.

2. Cause of failure – oil leakage, sealing compound on sealing element (truck)

Damage symptoms:

The elastomer sealing element has been pressed away from the carrier plate. Dirt particles are in the sealing groove.



Cause:

Additional sealing compound was applied to the metal carrier plate. As a result of vulcanization, the elastomer sealing element was subjected to additional pressure and pushed back, causing oil leakage. The damage was accelerated by dirt particles that accumulated from the oil.

Other possible causes:

- The sealing element was damaged during installation/positioning of the cylinder head.

Measures:

- Do not use sealing compounds.
- Inspect the surface quality of the components carefully.
- Change oil regularly.

Damage symptoms and causes of irregular combustion process

“Knocking” damages the gasket

Damage to cylinder-head gaskets as a result of an irregular combustion process is very common in practice.

Very often this is knock damage on gasoline engines, whereby uncontrolled combustion processes occur. This is problematic because of the resulting thermal and mechanical overload on the components. The cylinder head gasket is one of the most prone engine parts and can withstand this extreme stress for only a short period of time. The uncontrolled combustion process generates shock waves accompanied by extremely rapid increase in pressure (over 100 bar) and also high temperatures (well over +3700°C). Crushed combustion chamber eyelets often indicate knock damage on cylinder-head gaskets.

Possible causes:

- Use of non anti-knock fuel with insufficient octane ratings.
- Sparkplugs with incorrect heat rating.
- Excessive compression ratio.
- Gasoline mixed with the diesel.

On diesel engines:

- Start of delivery not adjusted properly.
- Fuel dribble from injection nozzles.
- Cylinder-head gasket not installed with correct thickness; piston standout not taken into account when selecting the cylinder-head gasket.
- Poor fuel quality.

1. Cause of failure – uncontrolled combustion process on multi-layer metal gaskets

Damage symptoms:

Initial black discoloration in the sealing web area of the functional layer indicates the start of destruction, which is complete in the second picture (right).



Cause:

An uncontrolled combustion process generated high-frequency vibrations. The resulting shock waves destroyed the sealing web.

Other possible causes:

- Poor fuel quality (insufficient octane rating).
- Excessive compression ratio.

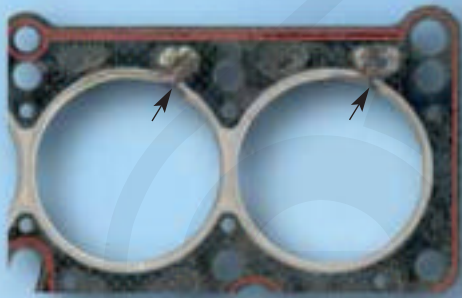
Measures:

- Be certain to use the engine parts (sparkplugs) specified by the manufacturer.

2. Failure of the cylinder-head gasket due to knock damage

Damage symptoms:

Dents and deformations can be seen clearly on the metal combustion chamber eyelets. Melting of the eyelet and the soft material. The metal on the combustion chamber eyelet is usually bright in this area, and the soft material shows signs of scorching.



Cause:

Engine not tuned (pre-ignition) as specified by the manufacturer, leading to uncontrolled combustion process. High-frequency vibrations and the resulting shock waves destroyed the metal sealing element of the combustion chamber and as a consequence, also the soft material.

Other possible causes:

- Poor fuel quality (insufficient octane rating).
- Excessive compression ratio.
- Sparkplugs with incorrect heat rating.

Measures:

- Check engine settings immediately after installation.

Damage symptoms:

The combustion chamber eyelet is clearly dented. Damage of the combustion chamber eyelet ranging from initial signs to complete destruction of eyelet and the sealing material.

Cause:

The use of fuel with insufficient anti-knock properties leads to an uncontrolled combustion process. This in turn results in thermal and mechanical overload on the engine. The uncontrolled combustion generates shock waves with extremely high pressure and temperatures, overstressing the engine components. Damage can be found most commonly on pistons and the cylinder-head gasket.

Other possible causes:

- Incorrect spark adjustment.
- Excessive compression ratio.
- Sparkplugs with incorrect heat rating or defective sparkplugs.

Measures:

- Use anti-knock fuel.



Damage symptoms and causes of mechanical factors

Damage from loose parts

The engine can be damaged seriously by mechanical factors, and of course in this case the cylinder-head gasket also suffers considerable damage.

1. Failure of the cylinder-head gasket due to loose precombustion chamber

Damage symptoms:

The multi-layer metal cylinder-head gasket has been damaged seriously by mechanical factors.



Cause:

The whirl chamber for the first cylinder loosened during operation and fell into the combustion chamber. The result was serious damage to the cylinder head and pistons and in the valve gear.

Other possible causes:

- Protrusion at the whirl chambers did not correspond to manufacturer's specifications.

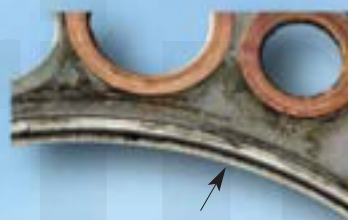
Measures:

- Before the cylinder head is installed, ensure that the whirl chambers are solidly mounted and check the protrusion.

2. Failure of a cylinder-head gasket on a commercial vehicle due to improper installation

Damage symptoms:

The metal combustion chamber eyelet of the cylinder-head gasket has been pressed entirely together on the inside by the collar of the liner. The extreme forces that arose when the engine was started blew off the collar of the liner, resulting in serious engine damage.



Cause:

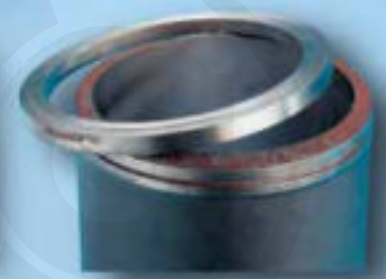
When the cylinder-head gasket was installed, the combustion chamber diameter of the gasket was not checked. A gasket was used that appeared to match the gasket which had been removed, but it had a smaller combustion chamber diameter.

Other possible causes:

- A low quality reproduction was used instead of the original Elring cylinder-head gasket.

Measures:

- Ensure that no force is required when placing the cylinder-head gasket on the liner.



Professional installation of the cylinder-head gasket in seven steps

Please follow the engine manufacturer's general instructions for installation.

1. Carefully clean and degrease the sealing surfaces of the parts (cylinder head and block), removing all remnants of coating and gasket.

2. Clean the threaded holes for the cylinder-head bolts carefully of all dirt and oil. Ensure that the threading is not damaged and that the bolts can be turned easily.

3. Inspect the part surfaces:

- Use an oilstone to remove any material protrusions.
- Check the flatness over the entire surface of the parts using a straightedge ruler: longitudinal = 0.05 mm; lateral = 0.03 mm.
- Depressions must be removed (resurfacing by a specialist).

Parameters	Metal/soft-material	Multi-layer metal	Metal-elastomer
R_z	15 - 20 μm	11 μm	11 - 20 μm
R_{max}	20 - 25 μm	15 μm	15 - 20 μm
W_t	8-10 μm		

4. Center the cylinder-head gasket on the engine block (without any additional sealing compound). Be careful not to damage the coating.

5. Place cylinder head on the gasket.

- Avoid scratching the sealing surface.

- Ensure that there are no remnants such as metal filings that could get onto the gasket from the cylinder head.

6. Cylinder-head bolts

6.1

- Recommendation of the vehicle manufacturer: Always replace cylinder-head bolts and washers.
- Apply a **small** amount of oil to threading and seating surface beneath the bolt head.



6.2

- If a washer is also to be installed, oil the area between the washer and the bolt head.
- Note: Do not apply oil to the seating surface of the washer facing the cylinder head.



7. Tightening of bolts

- Tighten the bolts in the sequence specified by the manufacturer (from the center either cross-shaped or spiral-shaped towards the outside).
- Tightening torque/tightening angle: apply gradually in accordance with instructions.
- Follow any existing instructions for retightening.

The information provided in this brochure, based upon many years' experience and knowledge, does not claim completeness. No liability is assumed for damage claims on the basis of this information. All parts must be installed by trained and specialized staff. Product range and technical specifications subject to modification. No liability assumed for errata.

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