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Defective timing chains on the VW/AUDI VR6 MPI 3.2 liter Aggregate BDB, BMJ, BUB & BFH, BML



Image source: MTZ 2003

Christian Schlenger & Michael Lorch
2009

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Research into the causes of timing chain elongation and developing solutions for Avoiding renewed chain elongation and Kettenbrüchen beim VW/AUDI VR6 MPI 3.2-Liter Aggregate

15.08.2009
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short version

The timing drive connects camshafts to the crankshaft and drives the engine's valve control. In addition to gear wheels and belts, chains are the most common means of transmission.

Damage to the timing chain drive on the VW/Audi VR6 MPI 3.2 liter unit has been increasing for over 2 years. Engine variants that are frequently affected are the units from Audi AG with the engine codes BDB, BMJ and the BFH and BML used in the VW Group. The damage manifests itself in the form of elongation of the timing chain, abrasive wear and tear on the rails, and in severe cases, especially in vehicles Category VW Golf IV R32 Timing chain fractures. VW and Audi often made improvements in the series by using newer timing chains. The chains from the company Sachs that were installed first were exchanged for chains from the company Iwis. However, this did not lead to any improvement. Only the fractures disappeared. The first signs of a defective timing chain drive are rattling, clicking and scraping noises from the engine, and in some cases the engine check lamp lighting up and error messages stored in the on-board computer. In addition, there is a gradual loss of performance, jerking, increased consumption and soot formation on the ESD.

Due to the sharp increase in the number of defects, especially in 2008, the subject of timing chain elongation was examined intensively in order firstly to find the cause and secondly to develop solutions to avoid such damage.

After extensive research, investigations and analyzes at various laboratories and institutions as well as engineering offices, the following influencing factors were determined that directly or indirectly cause or promote damage to the timing chain drive.

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Influencing factors:

- Oil change in the long-life interval
- Oils according to Longlife specification
- Oil mist separation
- Blowby
- Frequent cold starts, short trips, city cycles
- Silting from Castrol oils
- Increased oil pressure due to defective oil pressure pumps
- Entry of dirt particles in the oil (soot, oil carbon, glass fiber)
- Water ingress in the oil
- Resonant vibrations
- Missing lateral guidance of the rails
- Faulty camshaft sensors
- Corrosion-prone chain materials
- Hydrogen embrittlement
- Word “Sachs” stamped in link plate

At a later point, all of the influencing variables will be dealt with in detail and their relationships explained.

Cause:

If the VR6 MPI 3.2-litre engines of the VW/Audi Group with engine oils according to the long-life specification are used in the long-life service interval, mainly in short-distance operation with many cold start phases, the timing chains, which are susceptible to hydrogen embrittlement, are damaged by aggressive blow-by, water in the engine oil and particles dissolved in the oil (Glass fibers, oil carbon, soot) damaged to such an extent that they can stretch and tear. Older Sachs chains can break due to an embossing in the link plate in connection with increasing loads.

Solution:

An early oil change service (maximum 10,000 km to 15,000 km or 1 year, whichever comes first) using suitable engine oils (e.g. Mobil 1 0W40) and avoiding short distance cycles can prevent timing chains from elongating and breaking, as no corrosive medium can form in the oil, which attacks the chain materials and damages them through hydrogen embrittlement. Furthermore, no foreign particles collect in the oil, which would cause the chain to wear out. The formation of oil sludge is also prevented.

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Continuation:

The collected findings lead to the conclusion that it is not a specific problem of the VW/Audi VR6 MPI 3.2-liter unit.
Rather, one could transfer the summarized knowledge to every engine of the corporations which are driven by means of timing chains and are mainly operated in short-distance operation with long-life service intervals using engine oils according to the long-life specification. Turbocharged engines with low oil volume in the oil circulation system, engines with FSI technology and engines made of light metals such as aluminum etc. should be viewed critically.





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The authors expressly point out that they accept no responsibility whatsoever for damage to engines or vehicles that has occurred as a result of their own conclusions and unauthorized actions after reviewing this elaboration.

The elaboration of the authors merely represents their own knowledge and opinions obtained through experiment, analysis, research and research.

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Table of Contents

1 Introduction..... 9

2. Assignment 10

3. Engine, components and system description..... 13

3.1 The 3.2-litre VR6 MPI engine from the VW/Audi group..... 13

3.2 The chain drive of the engine 19

3.3 The timing chain 21

3.4 The chain tensioners 26

3.5 The running rails 29

3.6 The camshaft adjusters 32

3.7 The oil pump 34

3.8 The oil separator..... 36

3.9 The camshaft position sensors..... 38

4. The Lubricant..... 40

4.1 Das Longlife Interval 40

4.2 The engine oil according to the long-life specification 40

4.3 Topic of engine oils 41

5. Symptoms and diagnosis of chain elongation..... 44

5.1 First signs..... 44

5.2 Use of the workshop diagnostic system..... 45

5.3 The manual visual inspection..... 47

5.4 The noise analysis..... 54

5.5 Tips for buying a used car 65

6. The influencing variables 66

6.1 The oil..... 66

6.2 Blowby: What is it and what are its effects? 67

6.3 Frequent cold starts, short trips and hot operation 71

6.4 Topic of the glass fiber reinforced guide rails of the timing chain drive..... 72

6.5 Entry of dirt particles in the oil (soot, glass fiber, black sludge, etc.) 75

6.6 Water entry in the oil 80

6.7 Resonant vibrations..... 80

6.8 Missing lateral guides of the rails 81

6.9 Vulnerable camshaft position sensors..... 84

6.10 Corrosion-prone chain materials..... 85

6.11 Hydrogen embrittlement 85

6.12 The timing chains of the revision levels in series use..... 89

6.13 Material, volume, inflow and geometry of the motor..... 91

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7. The interaction of all influencing factors 92
8. Professional repairs 96
8.1 Workshops and timing chain damage 99
9. Quotation SWR..... 99
10. Avoidance of damage..... 101
10.1 Workshop for better monitoring / remedy 103
11. Summary and discussion of the results ..... .107
12. Closing words..... 110
13. Literary Picture and source reference 111
14. The DVD for the report 114
15. Appendix..... 115

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1. foreword

This version was created by the authors specifically as an instrument for drivers in whose vehicle a 3.2-liter VR6 MPI unit from the VW/Audi group was installed.

It is intended to help you to identify defects in the timing chain drive at an early stage so that professional repairs can be initiated. This is the only way to avert major damage to the unit.

Furthermore, insights into the installed technology and how it works are given.

The authors also implement the knowledge they have gained in meticulous work over a year and provide the reader with numerous aids and thus possibilities of how they can reduce or avoid the dangerous timing chain elongation through very simple measures. This means that you can still enjoy driving and the engine will be able to run perfectly for a long time.

distance statement

The authors expressly distance themselves from expressing or presenting criticism of the VW/Audi Group in this report. This is not in the sense of this version.
Only the actual structural conditions of the unit are listed here, which have been researched in detail and are verifiable, with the aim of optimizing the existing conditions for drivers of these affected vehicles in order to increase the mileage of their VW/Audi and continue to enjoy the Drive and maintain brand loyalty.



Christian Schlenger



Michael Lorch

In August 2009

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2. task

Timing chain damage on the Audi A3 3.2 quattro with the 3.2 liter VR6 MPI engine from the VW/Audi group has increased in recent times.

The aggregates with the engine codes BDB and BMJ are currently affected.
Spreading to the newer BUB variant is very likely, since AUDI included this engine type in the internal event system in spring 2009.

With the group brother VW Golf R32, especially with the Golf 4 (less Golf 5), these problems have been known for a long time and are up to date every day. You only have to visit relevant Internet forums such as www.Motor-Talk.de or www.R32-Club.de .

In contrast to the R32, where the chains break, Audi A3 owners are lucky in misfortune. The timing chains only lengthen here.
But at a speed that does not correspond to the calculated normal lifespan. Timing chains built in 2003 and 2004 are often between 30,000 and 80,000 kilometers long. Individual cars have less or more mileage.

Annex 1_1 shows a list of affected vehicles .

Drivers notice this from rattling, clicking and scraping noises from areas between the engine block and air filter box and in the driver's side wheel arch.
In the advanced stage, the engine check lamp lights up in the instrument cluster.
Audi specifies the threshold value for lighting up at -8° CA and only speaks of chain elongation from here on.
Other signs are engine jerking, rough running, increased fuel consumption and poor performance, especially in the upper range.

A visit to the authorized Audi workshop was unsuccessful in most cases.
The employees are hardly able to recognize and interpret the noises.
Most customers hear the following statements:

- "...these are typical age-related changes in the sound of the engine"
- "...this is state of the art"
- "...these are gear noises which are normal"

An error diagnosis with the appropriate diagnostic device is usually unsuccessful, since an error is not always generated. This depends on the widely varying camshaft position sensors, which determine the values and forward them to various control units.

If, at some point, there is a positive acknowledgment of the damage, the dispute over the assumption of costs begins. Who is paying? Factory warranty, new car extended warranty insurance, used car insurance? ... Etc.

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Anyone who does not have this is dependent on goodwill from the manufacturer. This is acting inscrutable here. A3 drivers, some of whom have the same mileage and age, receive different goodwill here. In a range of 0% over 50%, 70%, 80% to 100%

A system of who receives what percentage of goodwill is not recognizable.

The SWR TV car magazine RASTHAUS reported specifically in a program about damage to the timing chain on the Audi A3 3.2 quattro and the procedure of the workshops and the group. The report can be seen here: http://www.youtube.com/watch?v=8KvDz2TGJv0

If you ask in the workshops why the chains are getting longer, you get no or only insufficient answers. Neither workshops nor manufacturers could or wanted to give the exact reason. Some of the workshops denied that this problem even existed.

From these points of view, the task for the authors was to investigate why timing chains lengthen and are sometimes destroyed by forced breaks, and what countermeasures can be taken to prevent this.

It was also important to get an instrument that would allow you to easily determine whether your car was damaged or not.

The point of finding countermeasures became even more important at the beginning of March 2009 than at the beginning of this version at the end of January 2009.
The reason lies in the decision of Audi AG, which announced in week 11 / 2009, to completely stop production of the Audi A3 3.2 quattro from week 22 / 2009.
This step came just a few weeks after the decision to only deliver the Audi A3 3.2 quattro with the DSG. The manual gearbox was deleted.

There is a suspicion here that Audi AG and those responsible in the Volkswagen Group want to avoid having to pay larger sums to repair damage.
It is also conceivable that they expect large numbers of conversions and goodwill if the Audi A3 3.2 quattro continues to be produced.

The omission of the manual transmission could be related to the problem of the "throb" in the dual-mass flywheel. In December 2007 there was a court case before the district court of Wiesbaden, in which an expert opinion from Dekra confirmed to the driver that the problem with the dual-mass flywheel is not state-of-the-art, but a design defect that cannot be remedied even by replacing it with a new dual-mass flywheel is.

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This elaboration states that chain elongation not only affects certain engine types such as the BDB, but can affect all engines if there are unfavorable influences such as long-life change intervals, long-life oil, frequent short journeys. This increases the number of vehicles that fall under the goodwill arrangement and cost the group a lot of money.

The many defects with the dual-mass flywheel and the timing chains got around very quickly, which is why the group had to react. It will not be due to the few models sold so far. Large-volume engines with a lot of power are also offered in small numbers in other Group models.

For this reason, it is important to use suitable measures to take care of and maintain the few Audi A3s with the VR6 engine that have been built so far, in order to be able to give them a long service life. Finding a solution to this was one of the main reasons for the task.

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3. Engine, components and system description

3.1 The 3.2-liter VR6 MPI - aggregate of the VW / Audi group

With the new edition of the Audi A3 in 2003, known internally as 8P, Audi introduced a six-cylinder unit in the A segment for the first time. In the group brother VW Golf R32 it was offered a little longer. Here, however, with 241PS instead of the 250PS in the Audi A3. It was only with the introduction of the Golf V that the Wolfsburg car also received a 250hp engine.



Image 3.1_1 - The Audi A3 3.2 quattro

Top engine for the top version:
the new Audi A3 3.2 quattro will have the most powerful version of the 3.2 liter V6 with 184 kW (250 hp) from its market launch in autumn 2003. The V6 mobilizes its maximum torque of 320 Newton meters between 2,500 and 3,000 rpm; it reaches its maximum output at 6,300 rpm. This means a performance increase of 7 kW/ 9 hp. The technical basis for this is a modified exhaust tract. Additional benefit for the driver: a decidedly sporty sound that turns the VR6 into an acoustic treat. The extremely powerful six-cylinder - it is also used in the Audi TT 3.2 with the same performance level - accelerates the top A3 from 0 to 100 km/h in just 6.5 seconds. The A3 3.2 reaches its top speed at 250 km/h (limited). With this performance, the second generation of the A3 qualifies as a top athlete in the field of the premium compact class.

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Modification:

From model year 05, the gear ratios for the 6-speed switch and the DSG software changed. The acceleration values have been improved as follows:

DSG	0 to 100 km/h in 6.2 seconds
6-Gang	0 to 100 km/h in 6.3 seconds

The data sheet for the Audi A3 3.2 quattro is listed in ***Appendix 2_1***
In March 2009, Audi AG announced that production of the Audi A3 3.2 quattro would be discontinued from calendar week 22 until further notice. The reasons are currently unknown.

technology in detail

design type	-- VR	
displacement	cm^3	3189
Hub	mm	95,9
drilling	mm	84,0
compression ratio	-	11,25
connecting rod length	mm	164,0
cylinder spacing	mm	65,0
V-Shop	-	15°
cast	mm +/-	12,5
crankshaft bearing	-	7-small
main bearing diameter connecting rod bearing diameter	mm mm	60,0 54,0
valve diameter - admission - outlet	 mm mm	 33,2 30,2
firing sequence	-	1-5-3-6-2-4
Ventilhub - admission - outlet	 mm mm	 10,0 10,0
fuel	PINK	98/95
ignition	-	single rod ignition coils
rated capacity at speed	kW min/1	184 6300
Max. Torque at speed	Nm min/1	320 from 2500 to 3000
Max	bar	12,60
medium piston speed	m/s	19,8

Table 3.1_1 – VR6 engine data

Engine codes and their approximate period of use
BDB- used from 7/03 - 8/04
BMJ- employed from 9/04 - 10/05
BUB used from 11/05 - week 22/2009

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concept

The six-cylinder engine from Volkswagen's VR engine series is used at AUDI for the first time in the transverse engine platform. The displacement of the further development of the 2.8L VR6 four-valve engine was increased to 3189 cubic centimetres. By optimizing the intake and exhaust system, the specific power and torque values increase. The engine achieves a maximum torque of 320 Nm at 2500 rpm. and achieves 184kW at 6300 rpm. That

In all engine-transmission combinations, the vehicle complies with the exhaust emissions legislation according to EURO 4.

The displacement volume of the 2.8L six-cylinder engine in Volkswagen's V-series has been increased from the previous 2792cm^3 to 3189cm^3. The engine was first used in the Volkswagen Phaeton. After further applications at Volkswagen in the Touareg and Golf R32, the engine is also used at AUDI in the TT and now also in the A3. This means that AUDI is now also using the advantages of the VR series with a cylinder angle of only 15°, which, due to the small width and length of the engine, enables installation at the front across the compact vehicle. A displacement of 3.2 liters would not be possible. The installation space would not be possible. The arrangement of the ancillary units and add-on parts had to be adapted to the requirements of the new fifth-generation A-Class platform from the Volkswagen Group.

basic engine

The new 3.2L engine has the same technical concept as the 2.8L base engine
- Four-valve cylinder head with roller rocker arm valve train
- Continuous intake and exhaust camshaft adjustment
- Resonance variable intake manifold made of plastic
- Cast iron cylinder block
- Individual rod ignition coil for each cylinder

The most important technical data are summarized in the table above. The increase in displacement is achieved by enlarging the piston stroke from 90.3mm to 95.9mm and the cylinder bore from 81.0mm to 84.0mm. In addition to the increase in displacement, the increase in the specific performance parameters is essentially due to the complete redesign of the intake system with the optimization of the flow geometry of the intake manifold and channels in the cylinder head. The cylinder head is a new development compared to the 2.8 liter engine. The focus was on increasing the flow capacity. The intake and exhaust ports have larger flow cross-sections, the diameters of the intake and exhaust valves are increased to 33.2mm and 30.2mm respectively.

The well-known principle of the variable intake manifold in an overhead configuration with separate main and power collectors was adopted by the 2.8-litre engine. In the torque position, the cylinders are supplied with air directly via the main collector and the torque tubes. In the power position, the shift drum releases the connection to the power plenum, so that air is supplied via the power plenum in addition to the torque tubes.

Consistent optimization of details and reduced flow losses lead to an increase in the specific performance parameters. The inlet areas of the suction arms in the collector are of particular importance.

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A pronounced flatness of the pressure wave reflection and a uniform velocity distribution in the muzzle cross-section were achieved. An example is the pronounced equal distribution in the intake process of cylinder 2. In the area of the pipe branching on the power collector, a reduction in pressure losses and good use of the cross-section of the individual intake arms were achieved. The reduced leakage at the shift drum results in a narrow scatter band of the measured maximum torques with high specific values.

Camshaft control

In the 3.2-liter engine, the principle of double camshaft adjustment is expanded to include the potential of continuous adjustment of the exhaust camshaft. The adjustment angle of the intake camshaft is 52° crankshaft, that of the exhaust camshaft here for the first time 42° crankshaft. In the case of the intake camshaft, the basic position when starting the engine is designed for late valve opening.
With the exhaust camshaft, reliable starting in the retarded position was not possible under all operating conditions, especially at low temperatures, due to the wider adjustment range.
The exhaust camshaft adjuster is therefore mechanically locked in the "advanced valve opening" position by means of a locking pin. This means that the engine starts reliably under all boundary conditions with minimal valve overlap, which is also the best operating position for idling.

The extended adjustment range of the exhaust camshaft, in conjunction with a basic position shifted by 7°CA towards "late opening", results in a maximum overlap angle of 47°CA compared to 19°CA in previous applications. This is not fully used in operation, but the overlap area is shifted to later. Instead of expelling the burned gas into the intake port and sucking it back into the combustion chamber (respiratory exhaust gas recirculation), part of the residual gas remains in the cylinder (residual EGR). This results in the following advantages for internal exhaust gas recirculation (EGR).

- Consumption savings through reduced gas exchange work
- increased partial load range with exhaust gas recirculation
- better smoothness
- lower sensitivity to mixture fluctuations
- Exhaust gas recirculation possible even with a cold engine

A reduction in consumption of 4% compared to the 3.2-liter engines previously used and 6.5% compared to the 2.8-liter basic engine is achieved over a wide part-load range. At the operating point Pe=2bar/ n=2000 rpm. the specific fuel consumption is 360g/kWh.

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Exhaust system and emissions of the 3.2 L engine

The double flow in the exhaust system far behind the catalytic converters results in the high maximum torque at a speed of 2500 rpm, which is very low for a naturally aspirated Otto engine. The high specific value of 100Nm/L as in the Golf R32 and AUDI TT is achieved through consistent fine tuning. The exhaust system contains a main catalytic converter and 2 lambda probes per exhaust line. The latest generation of the planar broadband lambda sensor from Bosch, LSU 4.9 with regulated heating, is used in front of the catalytic converters. The lambda control responds very early. The raw gas emissions could be further reduced due to the onset of the residual exhaust gas recirculation at low engine temperatures and the improved leaning ability, especially in the cold start and in the warm-up phase. The twin-jet injectors in the cylinder head are located closer to the intake valves than in the 2.8-l engine. The resulting improvement in mixture preparation also makes the air shroud around the injectors superfluous. The fuel supply to the injectors is demand-controlled and return-free. This reduces the heating of the fuel in the tank and the evaporative emissions are reduced. Secondary air injection supports the early response of the two main catalytic converters under the vehicle floor, each with a volume of 1.0 litres. The emission limit values according to Euro 4 are clearly undercut with both transmission variants.

Engine management of the 3.2L engine

The Motronic ME7.1.1 from Bosch is used as engine control. The processor speed was increased from 32 to 40MHz because of the computational effort for numerous new functions. New functions were required for the continuously controlled exhaust camshaft adjuster with a wider adjustment range. The maps of the camshaft control had to be completely reapplied due to the changes described above. Due to the high exhaust gas recirculation rates, a calculation of the residual gas content in the cylinder was introduced. The results of this in turn improve the calculation of the intake manifold pressure and, as a result, the transient behavior of the mixture preparation significantly.

To reduce noise emissions at low engine speeds, a flap is integrated in the exhaust system, which is opened by the engine control unit depending on the load and engine speed. As in the Phaeton, the radiator fans are controlled via a discrete signal from the engine control unit, which contains the large amount of information required for setting the desired coolant temperature. The mean oil level is calculated in the engine control unit from the current information from the oil level sensor in the oil pan. The result is forwarded to the instrument cluster, where it is part of the maintenance interval display. The engine control, transmission control of the DSG, ABS, ESP, air conditioning, immobilizer and the instrument cluster are networked via the CAN bus.

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Results:
The engine delivers 184kW at 6300 rpm. The maximum torque of 320Nm is already available at a speed of 2500 rpm. reached. The useful mean pressure curve is in the scatter band of comparable engines in the upper range. At the low speeds below 3000 rpm that are relevant for the driving range. there is a significant advantage over comparable engines. The compression ratio of E=11.25 was designed for fuel quality RON 98. RON 95 is covered by the knock control.



Image 3.1_2 - Cutaway model of the VR6

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3.2 The chain drive of the engine

The timing drive connects camshafts to the crankshaft and drives the engine's valve control. In addition to gear wheels and belts, chains are the most common means of transmission.

The 3.2-litre VR6 engine also has a timing chain drive. You can see it in detail in the following pictures.



Image 3.2_1 - The chain drive of the VR6

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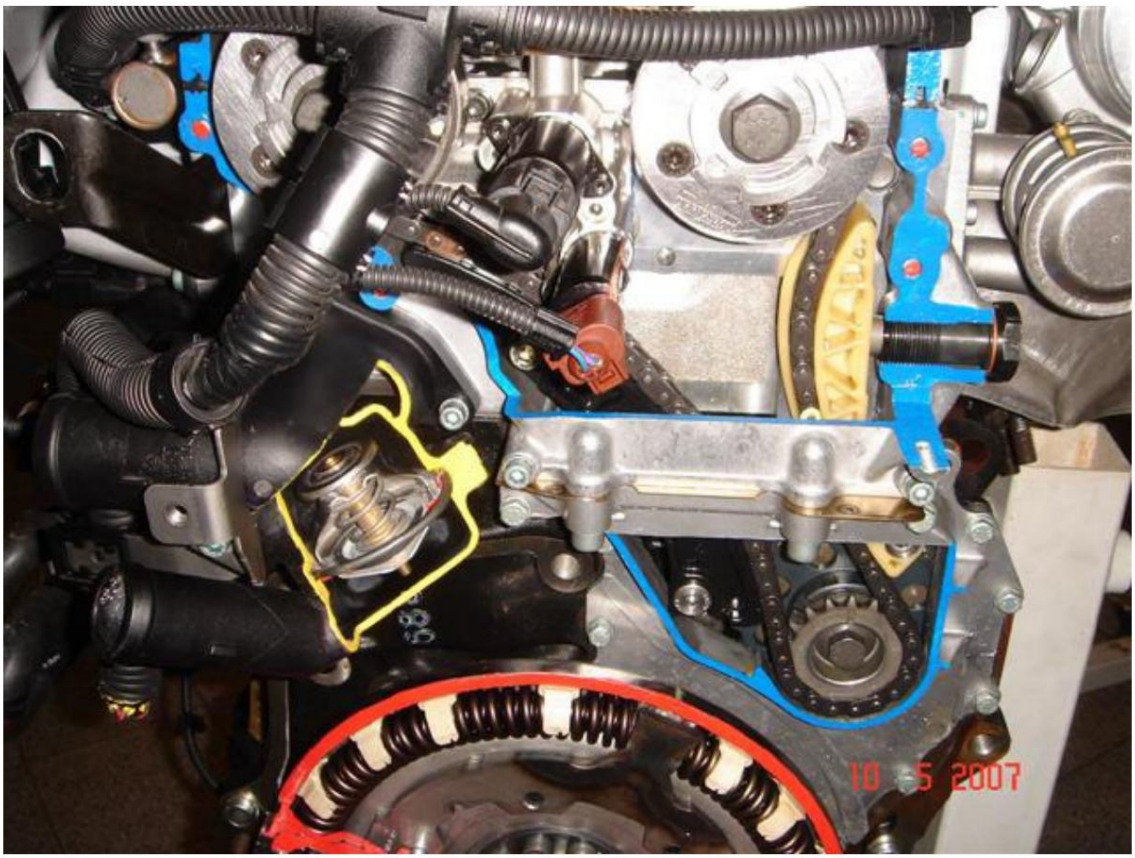


Image 3.2_2 - The chain drive of the VR6



Image 3.2_3 - The chain drive of the VR6

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3.3 The timing chain

The timing drive connects camshafts to the crankshaft and drives the engine's valve control. In addition to gear wheels and belts, chains are the most common means of transmission.

In the 3.2-litre VR6 MPI engine, upper timing chains from the company Sachs were initially installed.
However, these lengthened and some of them broke apart in the Golf 4 R32.
In the course of ongoing product monitoring, Audi made several improvements to the A3. Among other things, by replacing the Sachs chains with chains from the manufacturer IWIS
We are aware of the following change periods.

March 2004
June 2004
January 2005

Unfortunately, the hoped-for success did not materialize because the chains continued to lengthen.

The most recent upper timing chain part number is currently (as of August 2009):
IWIS 03H 109 503



Figure 3.3_1 - New Iwis chain above, old Sachs chain below (dark).

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Image 3.3_2 - Above the new Iwis chain, below the longer Sachs chain in comparison

The timing chain parts are mainly made of carbon steels. The bolts are mostly made of high-alloy steel with vanadium content.
In order to obtain stable chains, they are high-strength tempered. However, this condition is a fine line to walk, since high-strength and tempered steels are very susceptible to hydrogen embrittlement. Section **6.11** and Section **7** provide detailed information on this.

Chains are always subject to a certain amount of wear and tend to elongate. This is no different when used in motorcycles or bicycles than in car engines. However, this should take place within a reasonable period of time, and not after around 30,000 kilometers as in the case of the Audi A3 3.2 quattro.

There are various causes. Abrasion from contact with the sprockets, abrasive wear from particles in the oil (soot, oil carbon, glass fibres), above-average stress from the effects of force as a result of defective oil pressure pumps which allow the chain tensioner to press the chain with increased force. Reduced lubrication due to water ingress in the oil.

All these influences lengthen a chain. In addition, there are additional stresses on the link plates when the chain slides over the rails.

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Figure 3.3_3 - worn Sachs chain

Due to the abrasive wear of parts in oil (soot, oil carbon, glass fiber), all parts of the chain wear all around and become thinner. They are undersized, which means that the fits have more play. The consequence of this is greater lateral deflection and elongation due to the parts that are no longer within tolerance.

Attachment 2.3_1 contains images that illustrate very well the increased lateral play and the lengthening in a comparison of old and new.

Another feature of the previously used Sachs chain was the company logo embossed on the side of the chain link. Initial assumptions suggested that the deep and sharp-edged embossing could have been partly responsible for the breaks in the Golf R32. In the REM analysis, this could be confirmed that it had its impact as a result of the embossing notch effect.

to the Crack formation Original Logo In this case, permanent swelling loads were the cause. Which

See **Appendix 2.3_2**

The average hardness value determined on the link plates of the broken chain was 470HV10.
A hardness value of HRC 43+5 is required as a specification for the production of chains from the Iwis company.
If the hardness values according to Vickers (HV10 according to DIN EN ISO 6507) are compared with the values according to Rockwell (HRC according to DIN EN ISO 6508), the broken chain from the Sachs company would be on average approx. 40-50HV10 above the requirement. i.e. harder/brittle the would be

Note: The comparison of hardness values determined using different methods is also referred to as conversion (see DIN 50150) .

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Later chains were in turn susceptible to hydrogen entry and embrittlement due to the formation of molecular hydrogen in the structure. See **Annex 2.3_3** and **Annex 2.3_4.**
This type of damage can be recognized under the SEM by the typical features that any fracture caused by hydrogen embrittlement has.
This is dealt with in detail under **point 6.11** ***Hydrogen embrittlement .***

Striking were cases of repaired Audi A3s in which, after successful repairs, the chain lengthened again within a very short time and with little mileage, and after mostly 10,000 kilometers they were at -3°KW or -4°KW shift. In addition, the well-known engine running noises reappeared.

This abnormality is dealt with in **point 7 .**

An elongated Sachs chain of a BDB engine from September 15, 2003 EZ was measured.
The results are listed in **Appendix 2.3_5 .**

If you look at **Diagram 1.1_1** in **Appendix 1_1 ,** you will notice the large number of damages in the production month of March 2004. Something must have gone wrong somewhere in the production process. Be it the chain manufacturer Sachs or the engine builders at Audi.
There is no other way to explain such a high number of damages.



Figure 3.3_4 - The word "Sachs" embossed in the link plate

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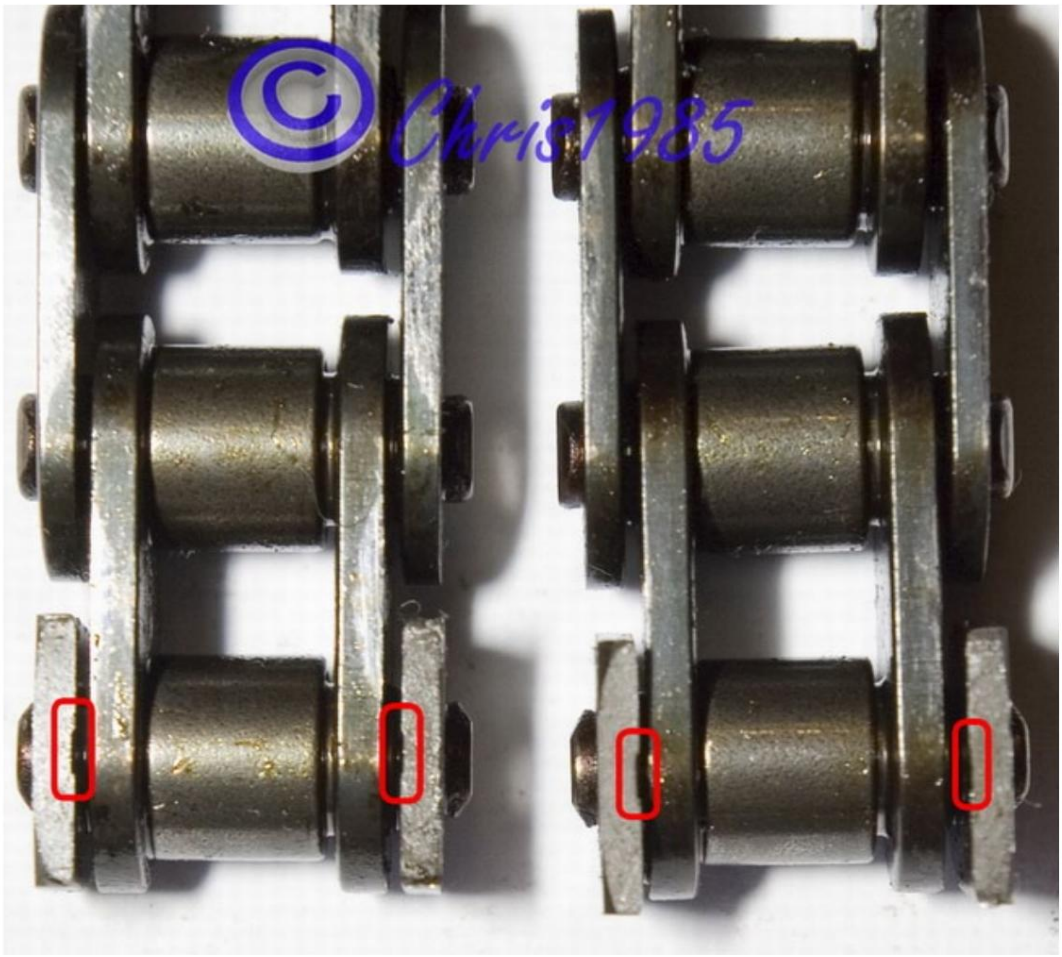


Figure 3.3_5 - The word "Sachs" embossed in the link plate.
You can clearly see how deep the embossing is (red frame).

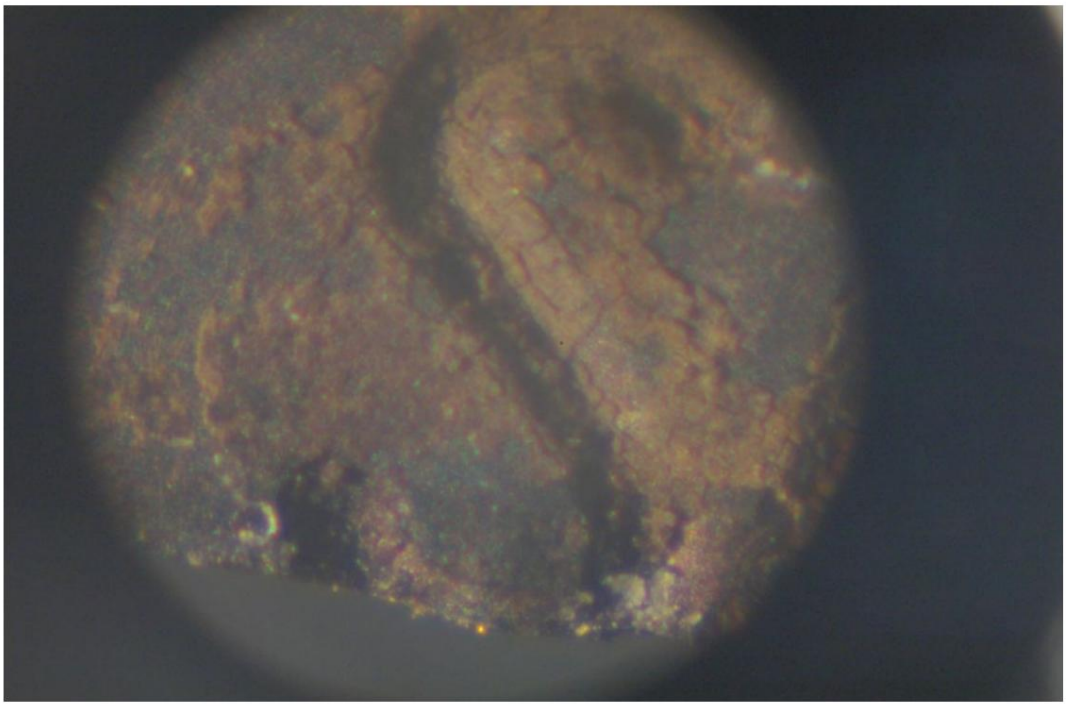


Figure 3.3_6 – Embossing (Sachs letter S) with fracture surface

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3.4 The chain tensioners

Chain tensioners fulfill many important tasks in chain drives.
They keep the chain at the previously calculated pretension, but at the same time dampen vibrations.
Two different types are used in the VR6 engine.

The upper tensioner is designed in the form of a screw and is screwed into the block from the outside.
He presses inside on a running rail attached to a pivot point and thus tensions the chain
before.

The lower tensioner is located in the middle of the chain drive and cannot be accessed from the outside.
The cylinder presses on a rail on the tensioner itself, which pretensions the lower chain. The cylinder is
designed in such a way that the extent of the elongation can be determined via the piston travel.



Figure 3.4_1 - Lower chain tensioner

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Figure 3.4_2 - Lower chain drive of the 3.2 liter VR6 engine



Figure 3.4_3 upper chain tensioner

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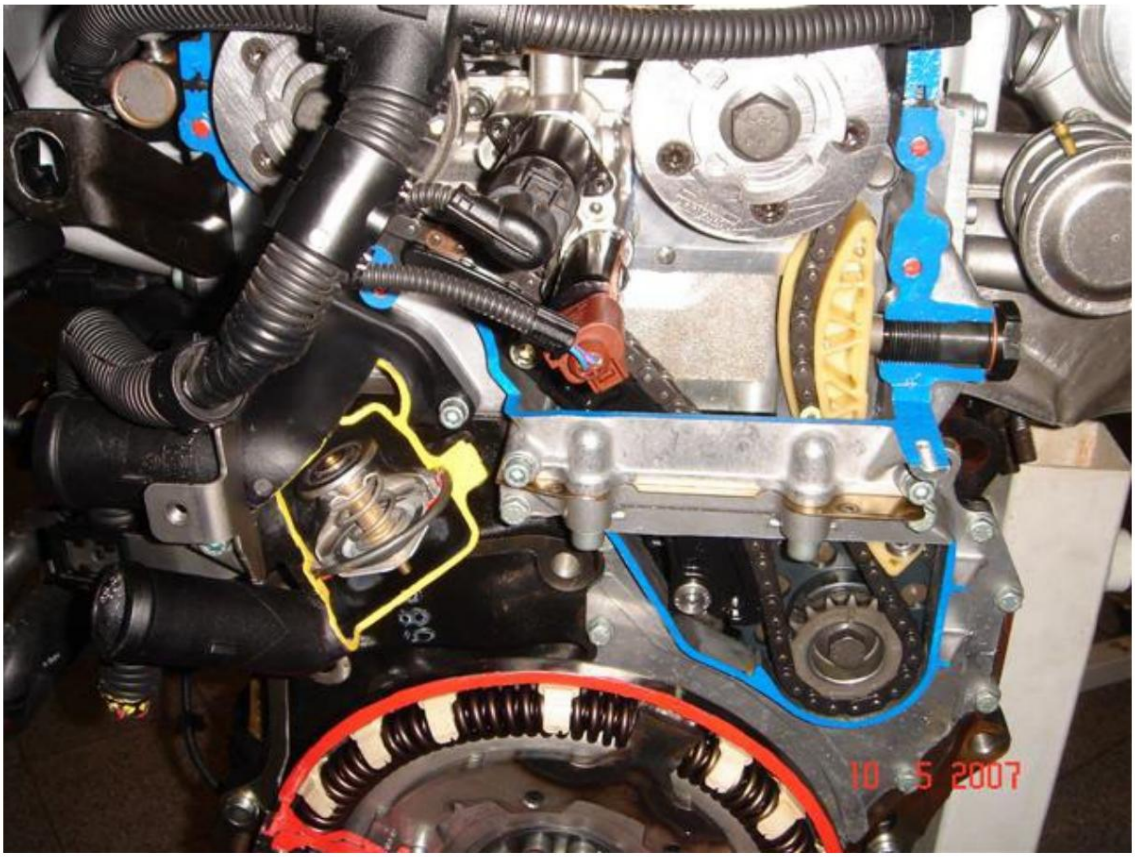


Figure 3.4_4 upper chain drive of the 3.2 liter VR6 engine

At the beginning it was suspected that a defect in the tensioners caused the chain to be pressed with increased force.

Any larger carbon particles entrained in the oil flow could have collected in the fine oil channels and formed bottlenecks, which could have led to malfunctions. To rule this out, the chain tensioners were examined radiographically.
No internal impurities were found.

The X-rays are in **Appendix 2.4_1.**

An above-average wear could not be determined here.
The functionality of the cylinder was not affected.

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3.5 The running rails

A chain drive requires not only clamping elements but also guide rails for perfect operation.
They should support and guide the chain. There must be no swinging, as the chain tension would no longer be guaranteed and the chain could possibly skip a tooth on the sprocket. The result would be that the control times would no longer be correct and the synchronous operation of the valves and pistons would be disturbed. The downward opening valve would hit the piston crown rushing upwards. The result would be major engine damage.

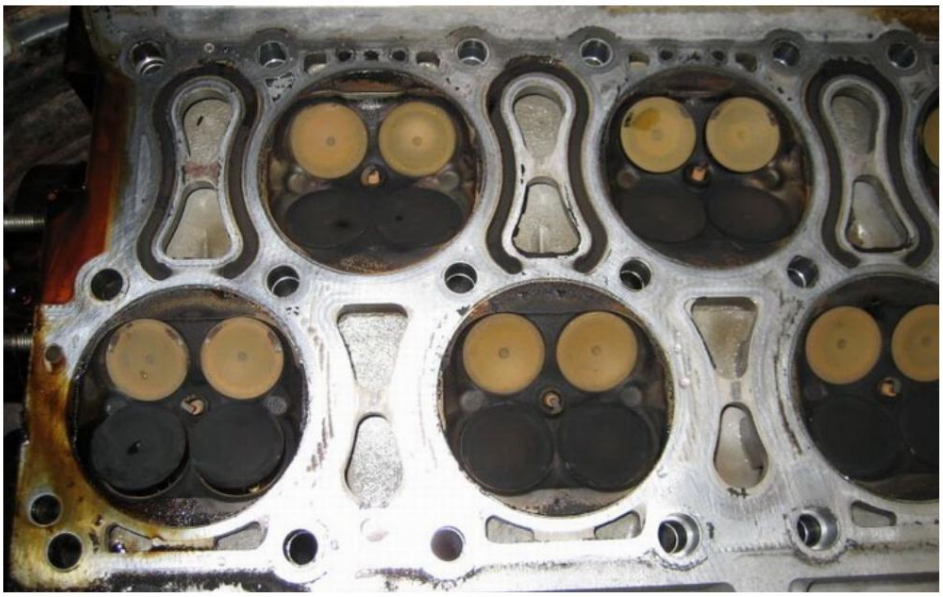


Image 3.5_1 - Engine damage after a broken timing chain on the VR6

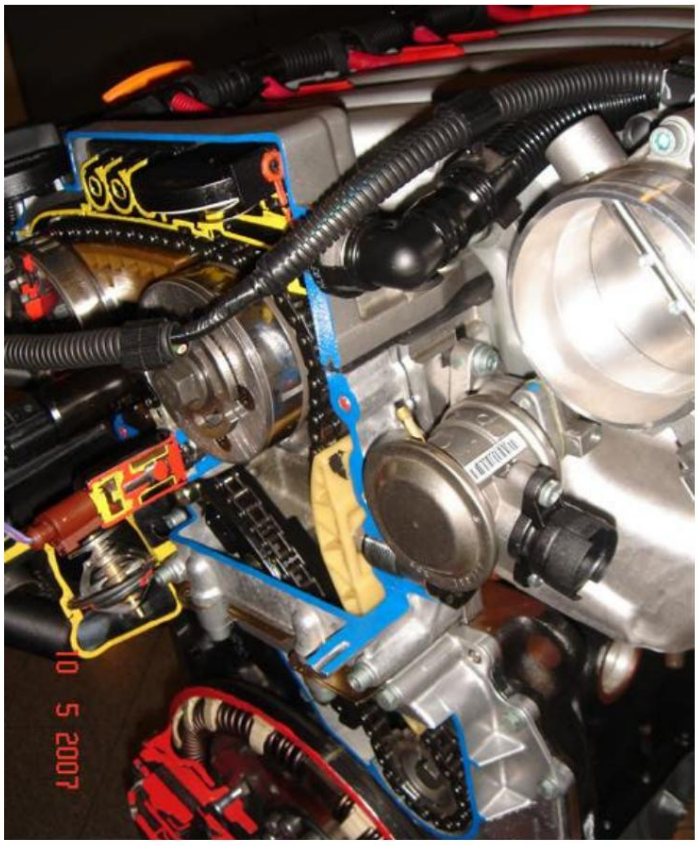


Image 3.5_2 - View of the chain drive of the VR6

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The removed rails showed different degrees of wear.



Image 3.5_3 - Running rail with running tracks of the timing chain

Many running strips in the chain drive showed significant depressions. Caused by the chain digging into the material of the guide rail. This topic is examined in more detail under **point 6.4 .**

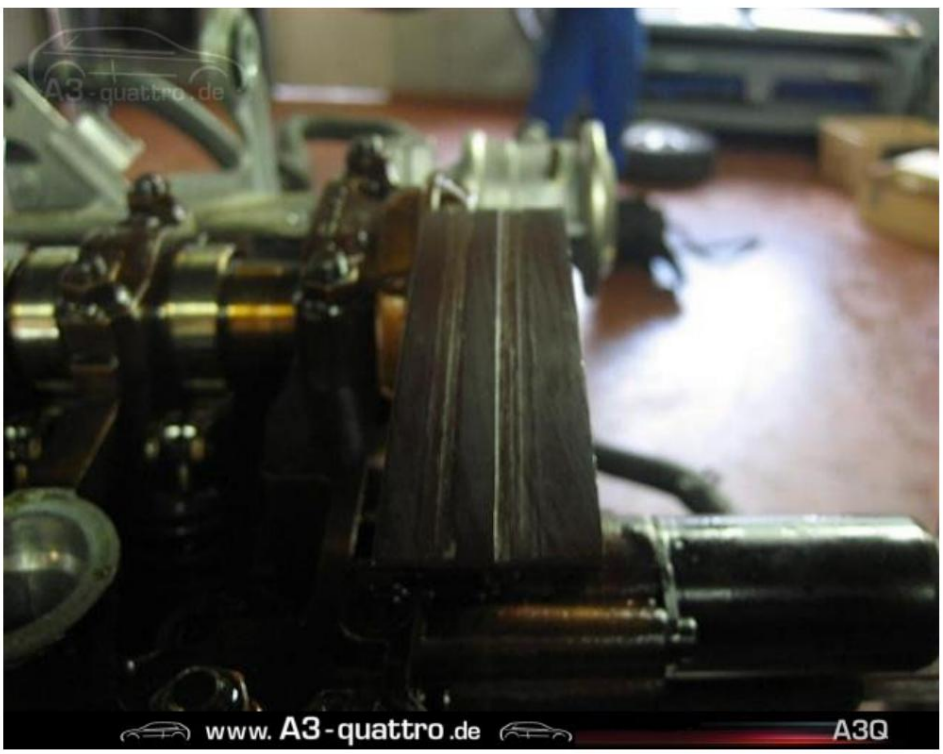


Image 3.5_4 - severely damaged running rail

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Image 3.5_5 - severely damaged running rail

If you take a closer look at the geometry of the rails installed in the VR6, you can see a crucial weak point, especially compared to other engines.

Some of them are too short, and there are also no really good side guides that prevent the chain from slipping sideways and keep it on track.
In addition, such a skipping could be prevented.

The chain drive could be optimized by running rails with good lateral guidance of the chain.

More pictures of the scroll bars are in **Appendix 2.5_1.**

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3.6 The camshaft adjusters

They sit on the camshafts to influence the valve control times. Through a
integrated ring gear, they are driven by the upper timing chain. Inside there are vane cells and chambers which can be controlled hydraulically.



Image 3.6_1 - Old and new NWV

They have a direct influence on the running of the engine and have been replaced several times in the series with improved variants. Cases of engine bucking and loss of power were increasing. In particular, these symptoms appeared after inadequate repairs were carried out on A3 drivers.

More precisely, it happened very often that workshops only replaced the upper timing chain without replacing the camshaft adjusters. Rails and tensioners were mostly exchanged. Only after a delay did the engine start to jerk and run rough. There were frequent fluctuations in speed. These problems only disappeared after the customer insisted on replacing the camshaft adjusters, and the engine ran smoothly and hung on the gas bitingly. Informed by the workshops, Audi made improvements with newer camshaft adjusters and also listed this in internal workshop instructions. As soon as a workshop replaces defective timing chains, it has to check the construction status of the adjusters installed ex works. If older versions are available, newer ones must now be installed.

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part numbers the old and first built camshaft adjuster:
022 109 087 E
022 109 088 G

Part numbers of the new camshaft adjusters to be installed:

Up to chassis number 8P 6A085000
022 109 087 J
022 109 088 J

And from chassis number 8P 6A085001
022 109 087 H
022 109 088 L

Initially, there was a suspicion that particles in the oil were putting the hydraulically operated parts out of operation. This was the reason to subject the NWV to an X-ray inspection in order to be able to see inside. However, deposits, particles or blocked oil channels could not be localized on the examined part.

Annex 2.6_1 shows the X-ray images of the NWV.



Image 3.6_2 A camshaft adjuster of the VR6

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3.7 The oil pump

The oil pump is the central element of the lubrication of an engine.
Many components in the engine are supported by plain bearings and require a constant flow of oil to maintain lubrication. Oil pressure is also required to tension the chains and compensate for the valve clearance using hydraulic tappets.

A gear pump is used in the VR6 engine, which pumps the oil from the oil pan through two meshing gear wheels and pumps it into the engine's pressure channels.
The pump is installed at the bottom of the engine block so that it can suck the oil directly from the oil pan. This is done by a suction tube attached to the lower part of the pump. The oil is pre-filtered through a coarse-meshed metal mesh (oil strainer).
The oil is trapped in the tooth gaps and guided through the pump on the outside of the housing wall.

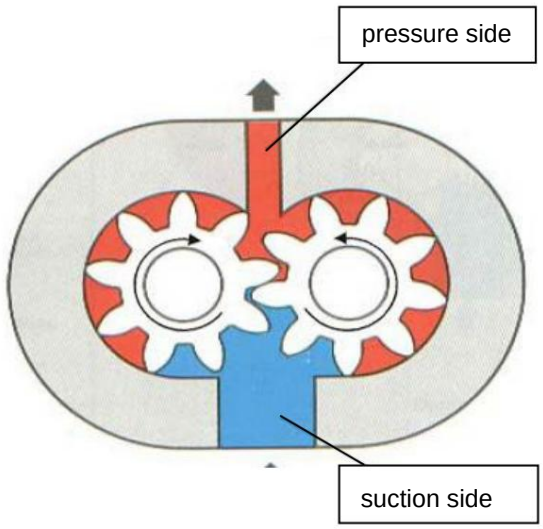


Figure 3.7_1 – Functional principle of a gear pump

Only one of the two gears is driven. At the same time, the meshing of the gears creates a seal between the pressure and suction sides.
The mechanical drive is via the lower timing chain, which is connected to the oil pump via the intermediate shaft, an angular gear and another shaft.
Furthermore, a pressure control valve is integrated in the oil pump to limit the oil pressure in the system. A pressure control bolt is installed in the lower part of the oil pump for this purpose. The maximum permissible pressure of approx. 6 bar is determined by a spiral spring which presses against the bolt. As soon as the pressure approaches this value, the control bolt is pushed back and releases an overflow channel that allows the oil to flow back into the oil pan.
This procedure reduces impermissibly high oil pressure and keeps the pressure in the system at a constant level.

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The following picture shows all the components of an oil pump from a VR6 3.2l.

- On the left in the picture the lower part of the pump including the pressure control valve and oil strainer
- In the middle the upper case with the gears
- On the right the second non-driven gear

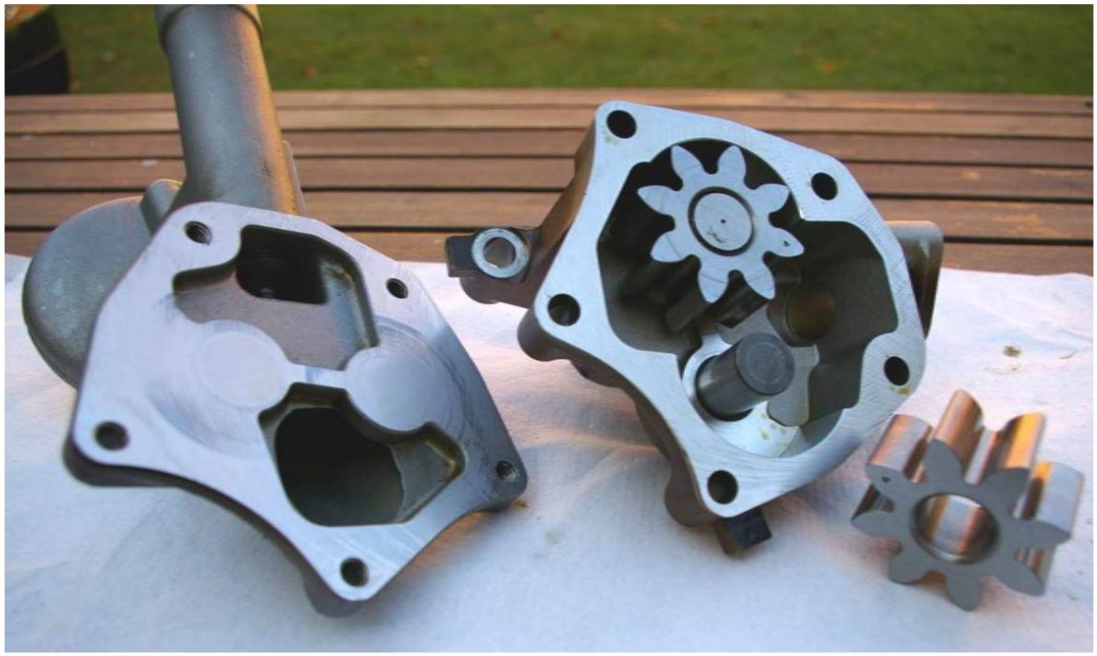


Figure 3.7_2 - Parts of the oil pump from a VR6 3.2

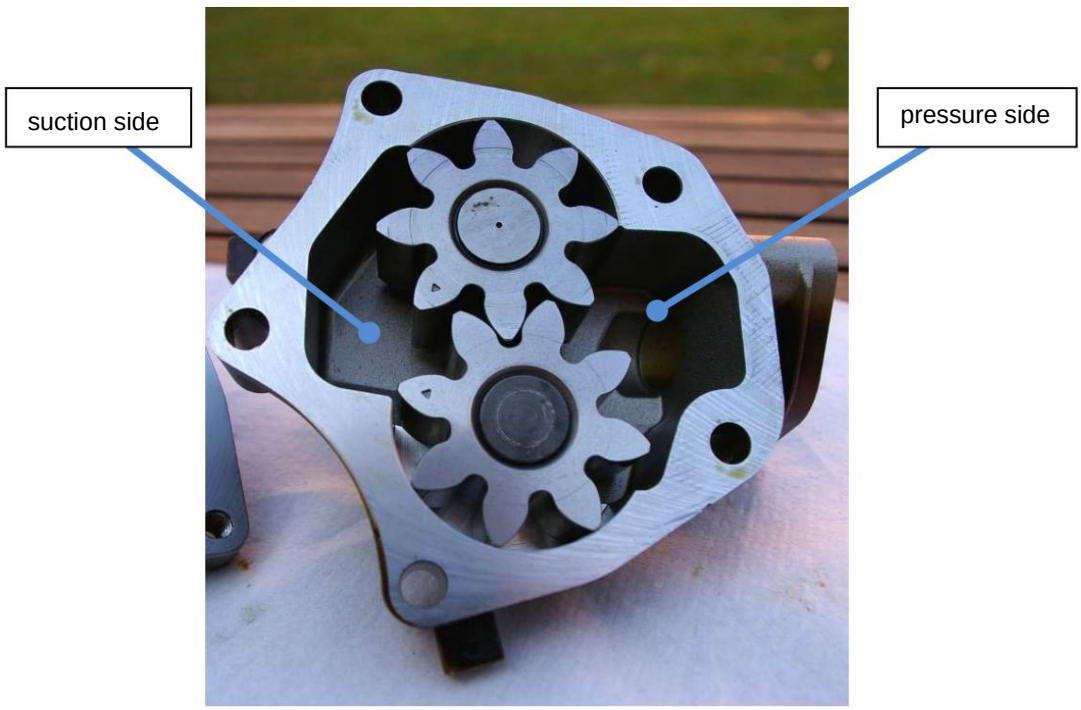


Figure 3.7_3 - Gears in mesh

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3.8 The oil separator

The oil separator is used to separate the oil contained in the air flow of the crankcase ventilation from the air and to feed it back into the engine circuit.

The oil separator is integrated into the cylinder head cover and cannot be replaced individually. There are two different designs for the 3.2l units. On the Golf Mk4 R32, the separator is on the right-hand side of the cylinder head cover, in the direction of travel. All newer vehicles (such as Audi A3, Golf 5 R32) have a modified cylinder head cover. Here the separator is on the left-hand side.

In the Golf4, there is a metal mesh in the cylinder head cover for separation, where the oil is caught and then drips off.
In the Audi A4 and Golf 5 R32, so-called cyclone separators are used to separate the oil. They are based on the mass inertia principle. The oil-gas mixture enters the separator tangentially and is set in rotary motion there. Due to the inertia of the solid components, they are thrown to the outer wall and can flow off from there. The remaining gas is led out of the separator through a central pipe and then into the intake manifold of the engine. With this type of separator, it is important to ensure a defined air flow. If this is too high, oil particles are entrained and get into the engine despite the separator.

For this purpose, the oil separator is preceded by a vacuum valve, which limits the vacuum in the intake manifold to a permissible level.
The oil separator is shown in section below.

- In the red area you can see the cyclones and the vacuum valve
- In the yellow area, the return of the gas into the intake manifold

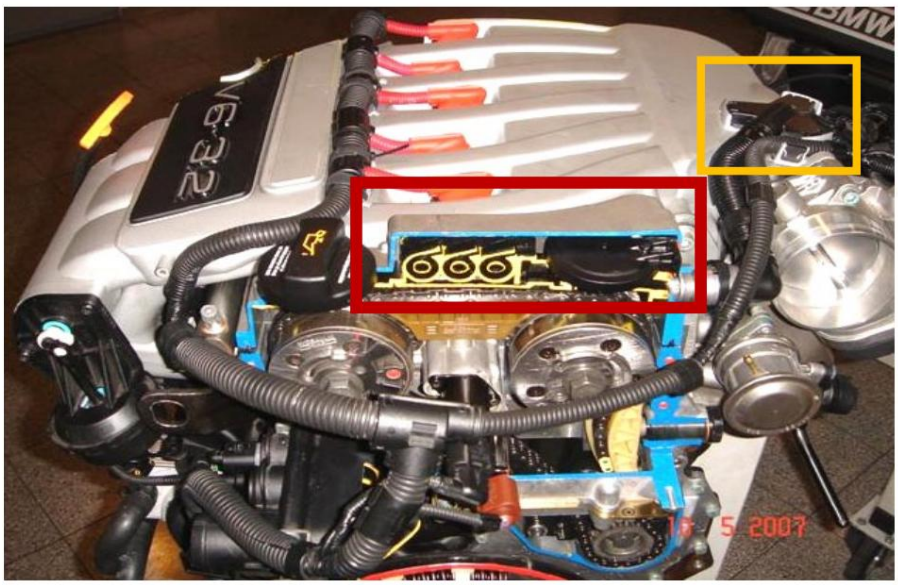


Bild 3.8_1 –Ölabscheider im Audi A3 3,2l

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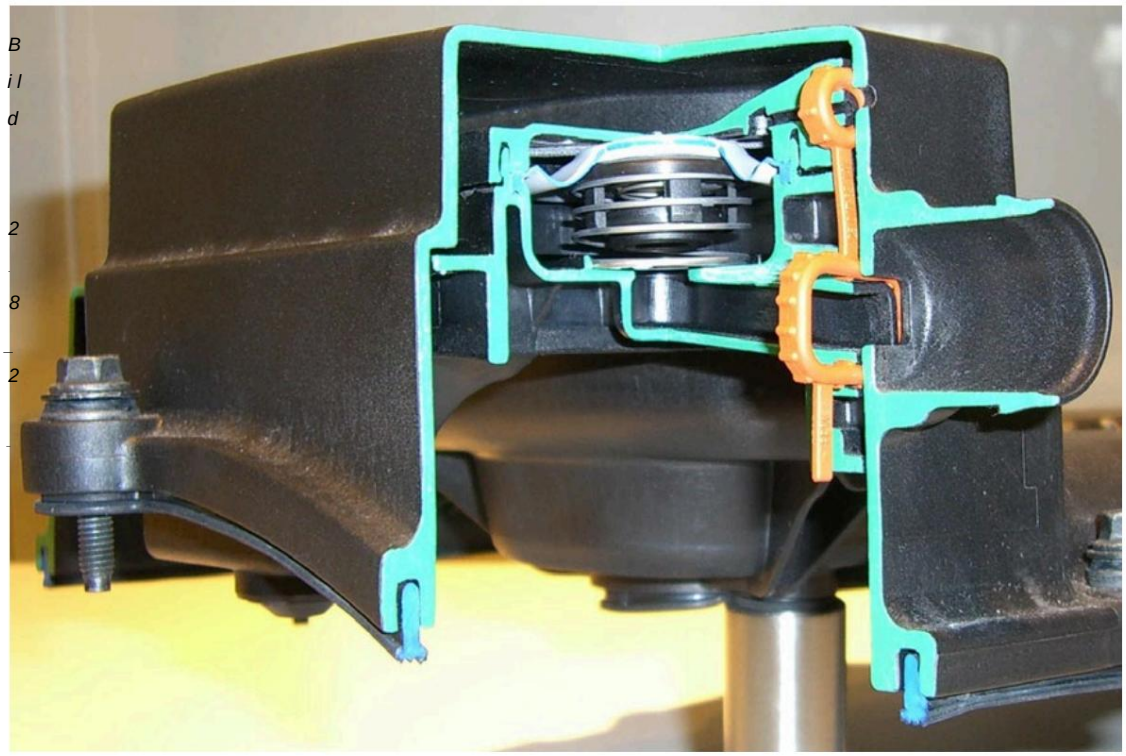


Figure 3.8_2 – Oil separator VR6 FSI 3.6l in section

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3.9 The camshaft position sensors

When idling, the measured value blocks 208 + 209 show the assignment of the crankshaft to the camshaft for the intake and exhaust camshaft.

Audi defines as follows:
If the upper timing chain is too long, the values fall below -8° CA and are often between -9° and -10° CA.

If no value is displayed, the chain has also been stretched in this case and must be replaced.

The values are stored in the measured value blocks.
In addition, a code is stored in the data memory.

For the 1st cylinder bank this is 17748
For the 2nd cylinder bank this is 17755

It is stored there that the NW sensor/KW sensor has an incorrect assignment. Sometimes also sporadically.

Unfortunately, you cannot rely 100% on the sensor display for diagnosis.
There are cases of timing chain elongation where reading out the fault memory did not produce a positive result. The engine, however, rattled and rattled. The manual visual inspection clearly showed that the control cams were in the wrong position and the control times were therefore shifted.

How is this possible?
In addition, unfortunately, almost every workshop only relies on the diagnostic device. In this case, that would be to the detriment of the customer. He would have to continue driving with a defective chain drive because the workshop found nothing in the error memory. So the car is fine for them. Despite the rattling noise.

The cause is the narrow tolerances of these NW sensors. Due to their design, they scatter very strongly from one another right from the production stage. Experienced master mechanics cross-swap the sensors during installation in order to bring the values towards the zero position.

Only the real zero setting during installation ensures that the entered value is also the correct one later when it is read out and does not deviate by a few degrees.
This could be very disadvantageous for the customer, since the chain could actually be at -10° CA, but only -6° CA is displayed due to the tolerance.

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Here, the repairs require a great deal of experience on the part of the workshop staff in order to install this properly. A post-installation check readout can help the customer and workshop personnel verify the correct value and mark the actual zero position. So you know later how far the chain is actually stretched.



Figure 3.9_1 - Camshaft position sensor (Hall sensor) in close-up



Figure 3.9_2 - Camshaft position sensor (Hall sensor) in close-up

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4. The Lubricant

4.1 Das Longlife Interval

In models of the current series, the inspection and oil change intervals are carried out as so-called maintenance interval extensions, WIV for short.
In order to offer customers the greatest possible intervals between inspections, the oil change interval for petrol engines has been extended to up to 30,000km or 2 years (whichever comes first).

In the meantime, an interval of up to 50,000 km has been implemented for TDI vehicles, but this is no longer found in current vehicles.

The special feature of the long-life interval is its flexibility. The timing of the oil change is calculated by the engine control unit. Among other things, data about the driving condition (rpm, engine oil temperature, speed, consumption) and the number of cold starts are entered here. Based on this, the time of the oil change is individually calculated. A direct monitoring of the oil condition does not take place here.

If the mileage is approaching the calculated maintenance time, a message is issued via the instrument cluster, which signals to the driver that the next service is imminent. The report also includes a remaining mileage until service; usually between 2000 and 3000km, depending on the model.

4.2 The engine oil according to Longlife specification

In order to achieve corresponding mileage, long-life oils are prescribed by the manufacturer.

These oils are classified according to the manufacturer's special oil standards. Today, long-life oils are mainly found with a viscosity of 5w-30 and are produced using the hydrocracking process.
The oil is referred to as Longlife 3.
The previously used Longlife 2 oil, on the other hand, had other special features. The HTHS was limited to a range of 2.9 to 3.5 by the manufacturer standard. The reason for this was an improved consumption value. The oil with a reduced HTHS value offers less resistance and therefore easier running of the components. However, the unstable lubricating film has a disadvantage. The result is an increased susceptibility to wear.
Today's Longlife 3 oils have again been set at a level above 3.5 in their HTHS.

Another special feature are oils that are offered as so-called “Low SAPS”. These are limited in their proportion of sulfated ash, sulfur and phosphorus. The reason for this lies in the diesel particulate filters used, which become clogged with ash contamination. Soot is automatically broken down by a special cleaning program. The ash, on the other hand, remains in the filter and thus renders it unusable.

The lower sulfur and phosphorus content, on the other hand, benefits the catalytic converters in petrol engines. This puts less strain on them.
In order to achieve the prescribed values, additives containing ash, sulfur and phosphorus are reduced in their proportion.

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4.3 Topic of engine oils

General explanations:
Oil is commonly referred to by its viscosity grade. 5w-30 / 0w-40 /
5w-40 / 5w-50 etc.

The first digit indicates the temperature up to which the oil can still flow independently to the oil pump.
A 5w is capable of doing this down to -30°C, a 0w down to -35°C.
The 2nd digit indicates the dynamic viscosity at exactly 100°C. The higher the value, the tougher the oil at 100°C.

The problem here is that the two values do not say much about a good or bad oil. A whole series of other key figures are necessary for this.

A much more meaningful value is the HTHS viscosity.
This value indicates how stable the oil film is at 150°C and under shear stress. The abbreviation HTHS stands for **ÿ** High Temperature High Shear If you now look at the temperature gradient in the engine, it quickly becomes clear where this value is important:

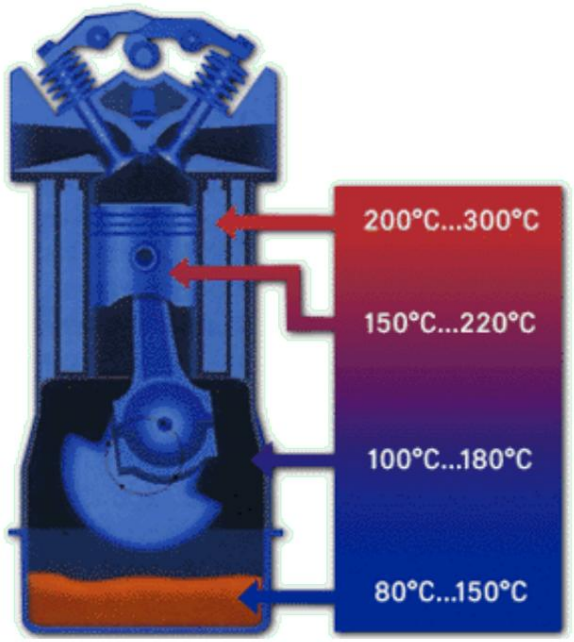


Figure 4.3_1 - Temperature gradient in the internal combustion engine

At the piston or between the piston rings and the cylinder wall, there are both high temperatures and high shear stresses, to name an example in the engine. The consequence of an insufficient HTHS would then be excessive wear of the components.

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However, it must be said that the HTHS value alone is not responsible for the wear properties of the oil. If an oil only consisted of the base oil, this would still apply to a limited extent. So you can't directly say that an oil with a high HTHS is always better than one that just has a lower value; as a point of reference, however, this is still useful and much better than the viscosity class.

If you look at the composition of motor oils today, there is actually no longer any oil that is not alloyed; so has no additives.
In modern oils, the proportion of additives is around 20% and more.
Among other things, these additives also improve wear protection and can
separate lubricating parts from each other even if the base oil would no longer be able to do so.

In addition to the anti-wear additives, there are also so-called EP additives that improve pressure stability. These properties are important in places where there is high surface pressure but little relative movement between the friction partners, i.e. where no hydrodynamic lubricating wedge can form. Examples here are the piston pin, gears, valve on cam, hydraulic lifter.

Motor oils also consist of cleaning and anti-corrosion additives, dispersants (they keep fine deposits in suspension), and viscosity index improvers.

However, the additives are not available in unlimited quantities. They are used up in the engine and lose their effectiveness with use.

The viscosity index (VI) indicates how much an oil thins out with increasing temperature. The viscosity of oils depends on the temperature, the higher the temperature, the more fluid the oil is.
The optimum would be an oil that is equally viscous (tough/flowable) at all temperatures. But since that is not possible, special additives are used to try to get as close as possible to the optimal oil. The higher the VI, the less an oil thins out. So an oil with a high VI can flow well at cold temperatures and at the same time does not become too thin at high temperatures.

Oil that thins out too much, for example in the plain bearings, becomes problematic. The principle of plain bearings is clearly explained on the basis of aquaplaning. At high speeds, the components to be stored form a so-called hydrodynamic lubricating wedge. This separates the parts from each other and prevents mechanical friction. During the start-up phase, however, there is always a short period of mixed friction until the lubricating wedge has completely built up. In order to build up lubrication in the engine as quickly as possible after a cold start, it is therefore advantageous to use an oil that has the lowest possible dynamic viscosity; So a 0w or 5w.

If an oil becomes extremely thin when it is hot, higher relative speeds are required between the friction partners in order to completely separate them from one another.
If you !!exclusively!! in terms of lubrication, an engine can never rev high enough. The faster the bearings rotate, the more stable the lubrication becomes. However, this is limited by the component strength of the connecting rods, pistons, gudgeon pins, etc.

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Next, for oils, there is the TBN (Total Base Number). The value indicates how long an oil can neutralize acidic components.
Figuratively speaking, one can understand that oils have a kind of reserve to neutralize acid. The more an oil becomes contaminated with acidic combustion residues, the more the TBN is degraded.

This task is taken over by the alkaline additives. These include the cleaning and anti-rust additives. The TBN is therefore a factor that shows how long an oil can remain in the engine.

Evaporation loss is another characteristic of oils. When the engine oil gets on the hot cylinder surfaces, part of it evaporates and is burned as well. The evaporation loss indicates how much an oil tends to evaporate and which proportions are evaporated in the process.

Since passenger cars have been equipped with DPF (diesel particle filters), manufacturers have been demanding oils with a particularly low proportion of sulfate ash. Ash is produced when you burn the oil in the engine. This then gets into the DPF and clogs it. The DPF cannot regenerate itself from these deposits.

These oils are referred to as low-SAPS oils and have a sulfate ash content of between 0.6 and 0.8%. (depending on the required standard).

A few more sentences on the general behavior of oil. If you read in forums, you often come across statements like "don't be 0w-**, that'll run through all your gaskets".
From a technical point of view, however, this is not sustainable.
If you look at the viscosity of all oils, there is none!! thinner when cold than at operating temperature. The "0w" only indicates the temperature up to which the oil still flows independently. At 100°C, the oils are many times thinner than at the temperatures described by the first digit.

In fact, it's almost the other way around. A 0w-40 will not thin out as much with increasing temperature as a mineral 15w-40 and is therefore still more stable at 100°C.

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5. Symptoms and diagnosis of chain elongation

5.1 First signs

Timing chain elongation is a gradual process and therefore very treacherous. This
Changes in the sound of the engine do not occur in full force overnight, but rather they slowly become louder and more concise over a long period of time. The ear gets used to it and you only recognize these noises if you have had anything to do with timing chains before. One of the reasons why many workshop employees have problems with the diagnosis. The VR6 3.2 liter engines are not often represented. Hardly any car dealership has a used or new car on site to get a comparison. Again, many did not have one at all in their yard or in the workshop, since the large number of vehicles sold tends to show smaller engines.

In addition to the changes in the sound of the engine, another phenomenon is the decrease in performance. People get used to certain situations too quickly. This also applies to the driving situation with a 250hp Audi A3. You drive it every day and don't notice that the performance is constantly decreasing. You would probably notice this more quickly if 20-30 hp were suddenly missing here overnight. It is not so.

Yet it is measurable. 3 performance logs are listed in the appendix. With one measurement each when new, during the defect just before the repair and after the repair. The drops in power and torque are clearly visible, as well as the shaky course of the curves in the case of the measurement that was determined with a defective timing chain. In the last area you can see that the engine wants to adjust to the performance, but cannot do it because of the adjusted control times. The following diagrams are in the appendices.

Annex 4.1_1 : Performance measurement of the A3 after the repair.
Annex 4.1_2 : Performance measurement of the A3 without rattling (new condition)
Annex 4.1_3 : Performance measurement of the A3 with rattles (with defective timing chains)

Other signs are increased fuel consumption and an uneven, rough running of the engine.
Can be heard particularly well when it is cold and idling. All drivers who have been repaired report reduced fuel consumption and a silky smooth sound. Just how a six-cylinder should sound.

So here are some more videos for comparison:

Before the repair with a defective chain drive AFTER the repair

From the front	From the front
Laterally	Laterally
About engine	About engine
In the wheel arch	In the wheel arch

All files are also included on the multimedia DVD that accompanies the printed version of this report or can be downloaded from www.A3quattro.de .

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5.2 Use of the workshop diagnosis system

If the timing chain is suspected to be stretched, the workshop will first read out the fault memory with its diagnostic device. If a chain is stretched, the control times change in the "retarded" direction. The camshaft position sensors register this.
Write down the determined value in the measured value blocks 208 + 209.

When idling, the measured value blocks 208 + 209 show the assignment of the crankshaft to the camshaft for the intake and exhaust camshaft.

Common diagnosis: Check engine light comes on in conjunction with trouble codes 17755 and 17748

These error codes indicate an elongated upper roller chain.

Unfortunately, these values scatter so widely, caused by the production tolerances, that these values can only be used as a guide. **Point 6.9** refers to this topic . In many cases, the timing chain is actually stretched and the workshop finds no or only insufficient values. In this case, the workshop should definitely carry out the manual visual inspection. By removing both Hall sensors, you can see the position of both control cams on the intake and exhaust side and the degree of elongation.

The manual visual inspection is dealt with in **point 5.3**

Appendix 4.2_1 shows a diagnosis printout of the measured value blocks 208 + 209



Figure 5.2_1 – Diagnostic device

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Figure 5.2_2 – Diagnostic device connector in the socket of the Audi A3

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5.3 The manual visual inspection

The safest method of detecting an elongation of the upper timing chain is the so-called manual visual inspection.

The effort is minimal and you are on the safe side, in contrast to diagnosis via OBD and reading out the error memory. **Point 6.9** describes this inaccuracy . All in all, the manual visual inspection takes less than 30 minutes, including the creation of images.

The car is slightly raised on the lifting platform to guarantee free wheel travel.
Now turn until you have correctly set the TDC point on cylinder bank 1 (intake side). In order to gain insight, the air filter box must now be removed.
At the level of the oil filler neck, the cable harnesses that run on the side of the engine are loosened and both Hall sensors are removed

Now you can look through the window (location of the removed Hall sensors) into the engine.
Audi gave the workshops repair instructions in which 2 pictures with the "normal position" are shown. If the control cams on the car deviate from the pictures, they must be repaired because the chain has lengthened. According to Audi specifications, the “critical” limit value measured would be: -8° CA.

From here the group speaks of a chain elongation that needs to be repaired.

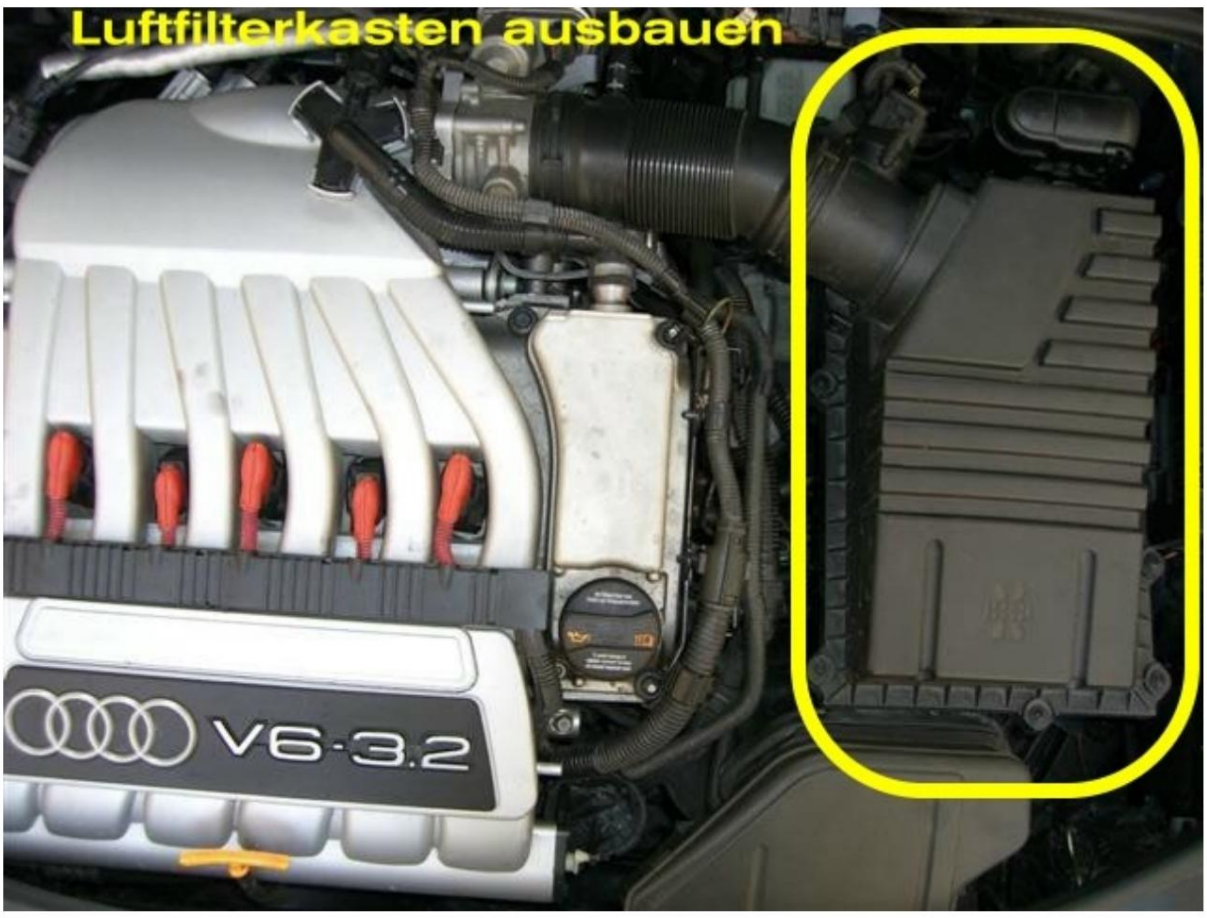


Figure 5.3_1 - Air filter box removal

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Figure 5.3_2 – Detaching the cable harnesses



Figure 5.3_2 - Location of the Hall sensors



Figure 5.3_3 - Removal of the Hall sensors

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Image 5.3_4 – Hall sensor cylinder bank 2



Figure 5.3_5 - before removing the Hall sensors

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Figure 5.3_6 - View of the Hall sensors

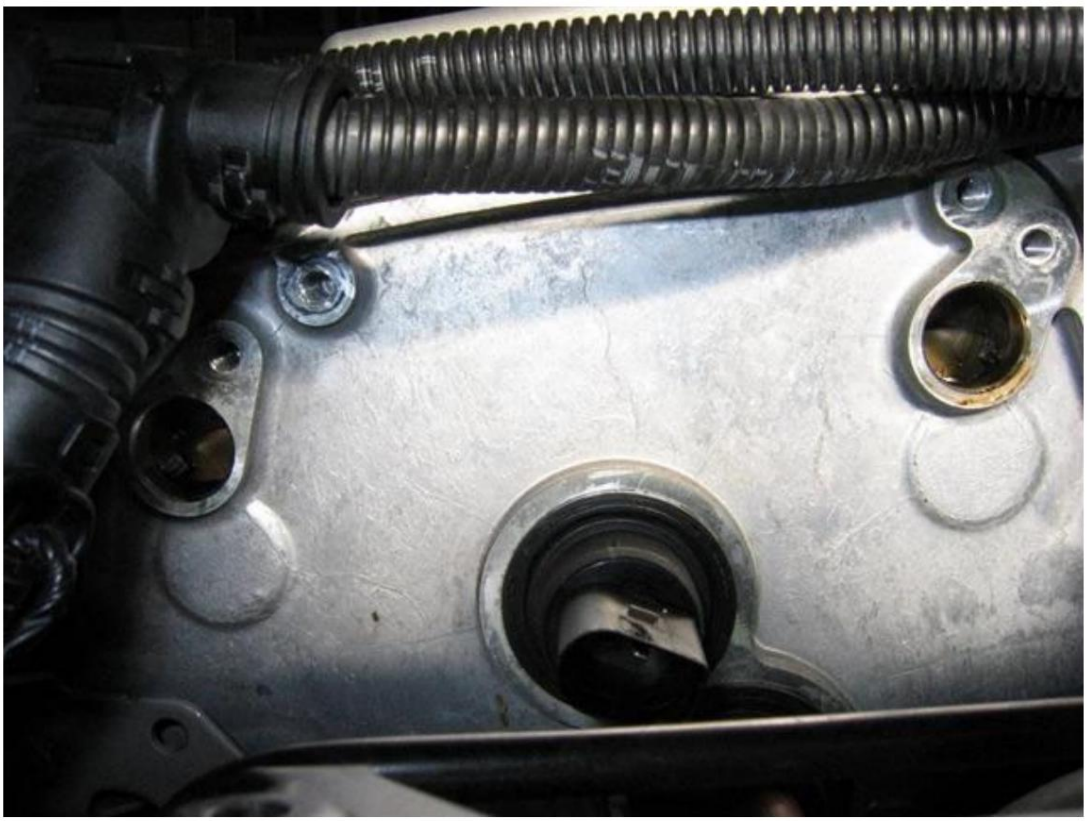


Figure 5.3_7 - open viewing windows

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Figure 5.3_8 - Close-up of the Hall effect sensor



Figure 5.3_9 - Control cams in the viewing window (cam position = example recording)

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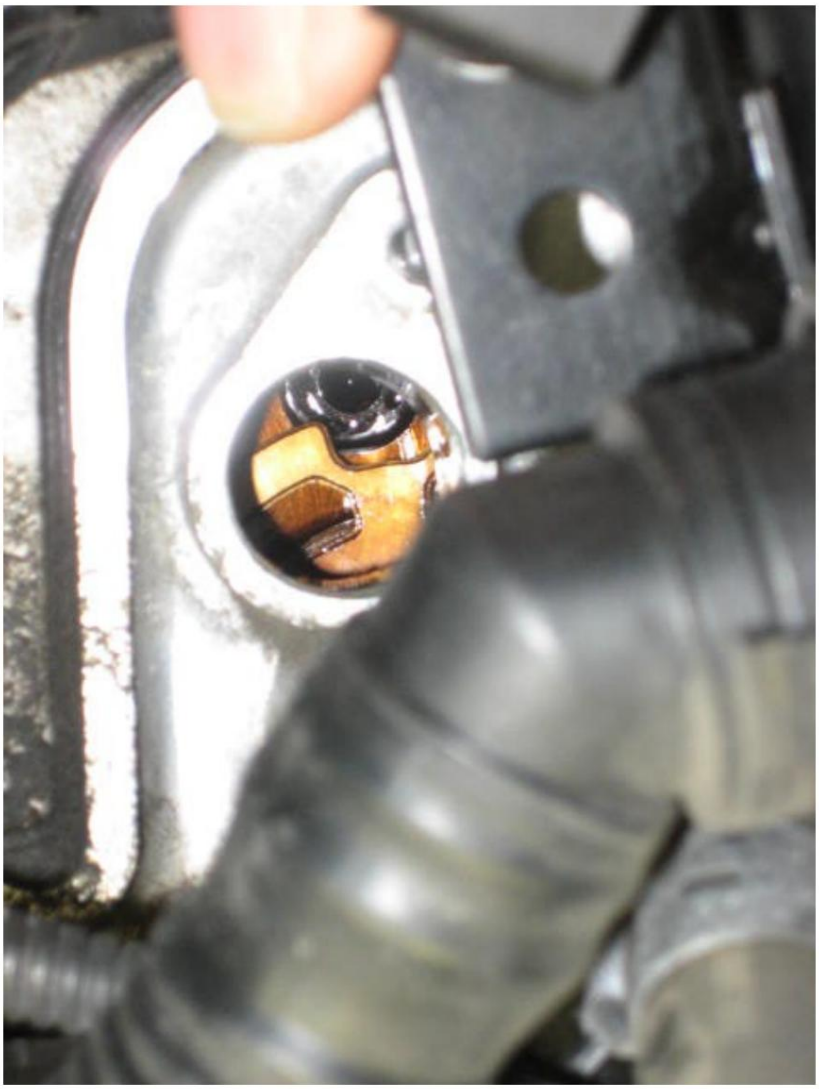


Figure 5.3_10 - Control cams in the viewing window (cam position = example recording)

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Here is a picture showing how to set the TDC point of the first cylinder bank

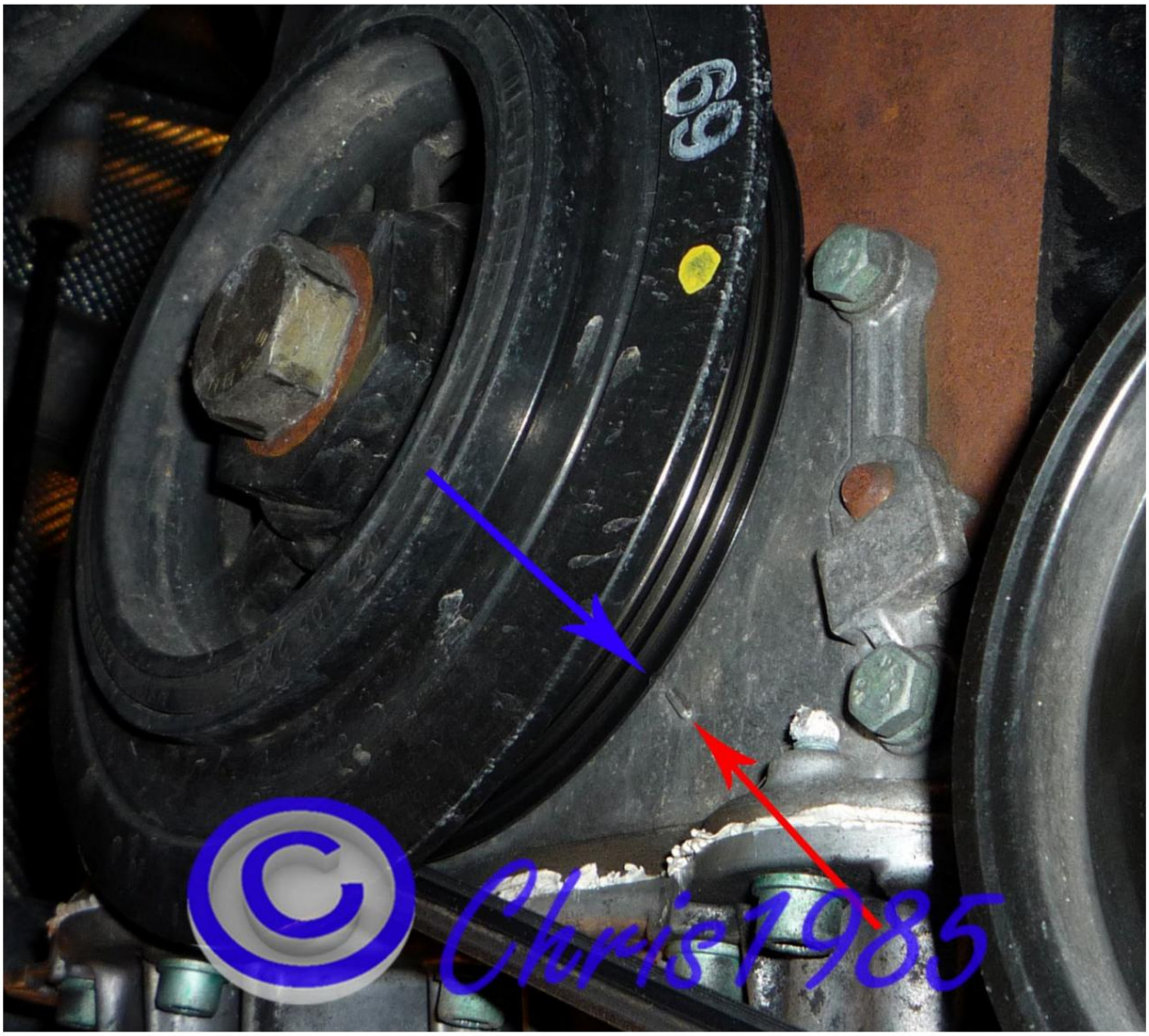


Figure 5.3_11 - Belt pulley at TDC position of the 1st cylinder bank

On the pulley on the left side of the engine (belt drive side / seen from the front) there is a small embossing in the form of a small semicircle (approx. 3-4 mm).

There is also an oblique marking on the engine block.
Now you should turn the pulley so that the marking on the pulley is aligned with the marking on the motor.

See arrow marks in Figure 5.3_11

If the TDC point is set correctly, the control cams should be similar to those in Figure 5.3_9 and Picture 5.3_10 appear in the viewing windows.

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5.4 The noise analysis

The first "bigger" signs of timing chain elongation and defects in the timing chain drive are usually these typical noises. Some still don't notice it as it is a gradual process and the noise slowly increases and gets louder. From time to time, drivers first notice the warning light or the loss of power and jerking of the engine.

The first thing you notice is the noise. And one has always wondered, how can they arise?
No one could say anything more specific.
"It just comes from the broken parts..." was said. Yes, sure. Just how ???

What noises are there? One can group the whole spectrum of all sounds into 3 parts:

Part 1:

Cylinder head cover with crankcase ventilation box (near the oil cap) up to the level of the Hall sensors. Often you have such a hard, metallic clicking sound. The TÜV expert from the Rasthaus TV report spoke of needle-like tacker noises.

Part 2:

The area of the chain case up almost to the height of the gearbox. Here you can hear a slight grinding.

Similar to the noise that occurs when wood is smoothed with sandpaper.

Part 3:

A tinny scraping noise. part grinding. Very audible in the lowest area, almost at the height of the oil pan. You can hear it well if you turn the steering completely to the left and then listen in the wheel arch on the driver's side. An opening can be seen in the wheel arch paneling. There you can see a cover that comes from the manual gearbox. Things can look different with the DSG.



Figure 5.4_1 – Driver's side wheel housing / view of the manual gearbox

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Because of this, most garages say the noise is from the transmission.
But WRONG. They come from the chain drive.

For clarification, the 3 areas have been marked in the following image.

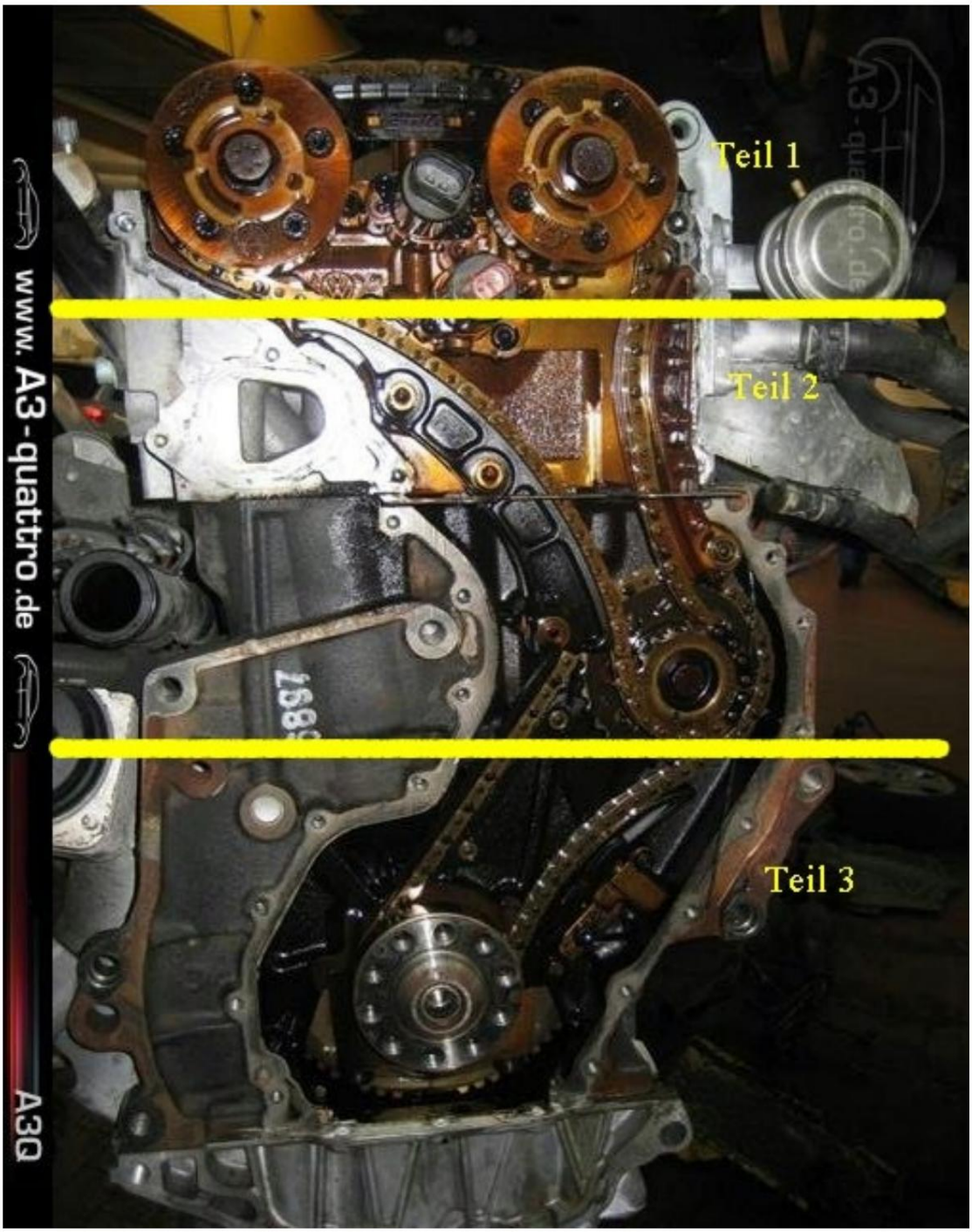


Figure 5.4_2 - Open VR6 engine with the three noise zones

In this case, you can't get any further without illustrative images.

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If you were to measure the sound intensity, you could use the evaluation to precisely localize which parts are generating noise at a certain speed.
The representation would be in the form of a false color image. Red areas radiate a lot, blue areas little noise. The next picture shows what it might look like.

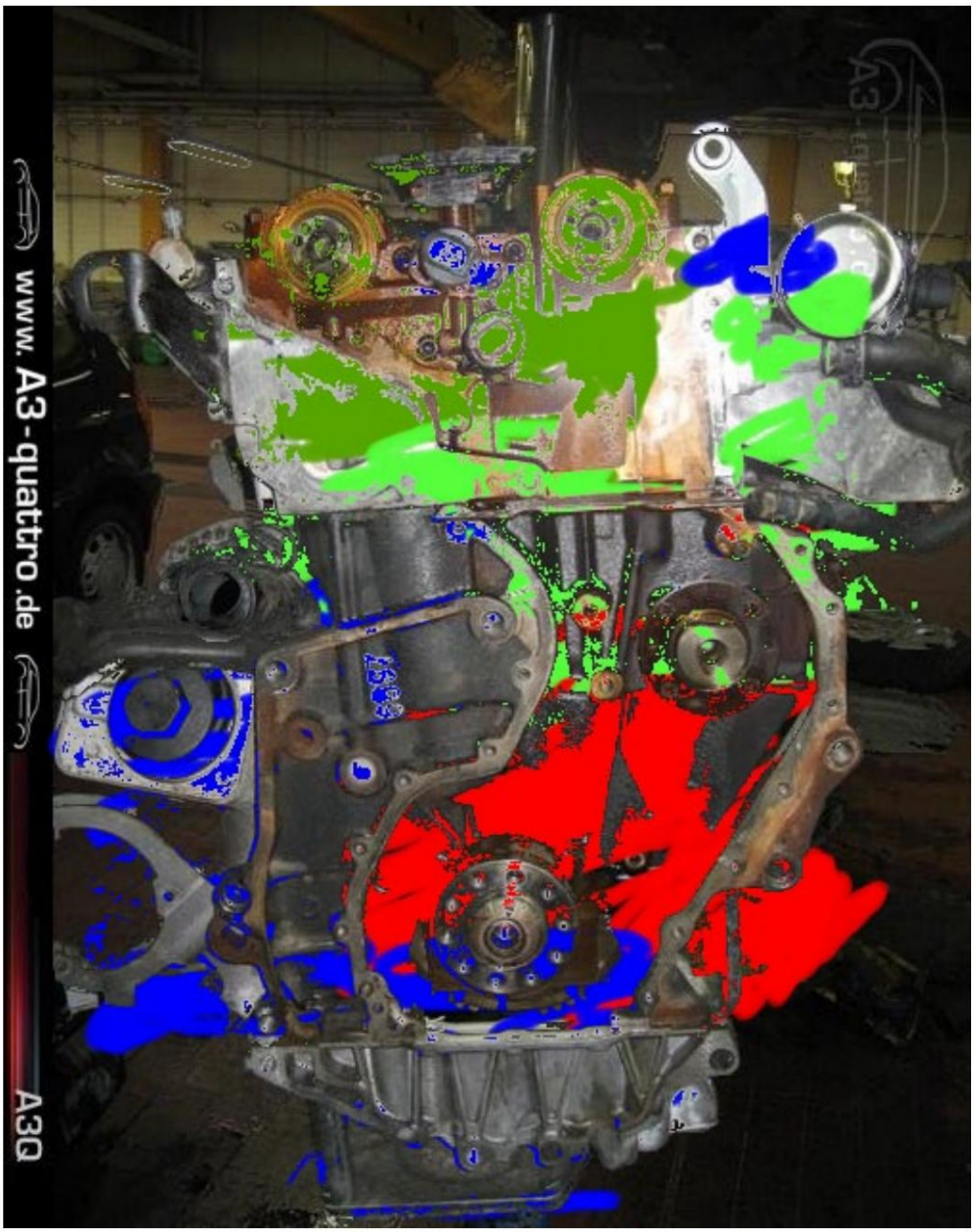


Figure 5.4_3 – simulated sound intensity distribution in the chain drive area

An intact timing chain drive runs harmoniously and quietly. It only has the typical chain running noises, which are however quiet.

Now let's assume that the chain itself is weakened. Due to abrasive wear of impurities dissolved in the oil, such as soot, glass fibers, etc. This also makes it visible from the side
more flexible. This can be seen in the comparison shots of the old Sachs chain with the new Iwis chain. So she has lateral play. See **Annex 2.3_1.**

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A motor generates a lot of vibrations. This includes the most diverse motor orders as well as various natural frequency oscillations of the most diverse components and add-on parts. Always dependent on the engine speed.
What the natural frequency can do was seen in the best-known example of the steel age.

Der Tacoma Narrows Bridge
http://www.youtube.com/watch?v=j-zczJXSxnw

If you run a component at its natural frequency, it doesn't take long before it is destroyed. If you move in the excitation spectrum just before or after this critical frequency, the part is not immediately destroyed, but rather pre-damaged. Parts that are not fastened knock out the mounting holes, damage threads, etc.

If the chain case were made of plexiglass and the engine was running, you could use a stroboscope to illuminate the built-in parts and see the vibration of each part.

We assume that this is partly to blame for the wear and tear. The oscillating and weakened chain is stimulated and its basic vibration is strengthened, which means that it no longer runs smoothly and smoothly. The proof would be the rail in the following picture.

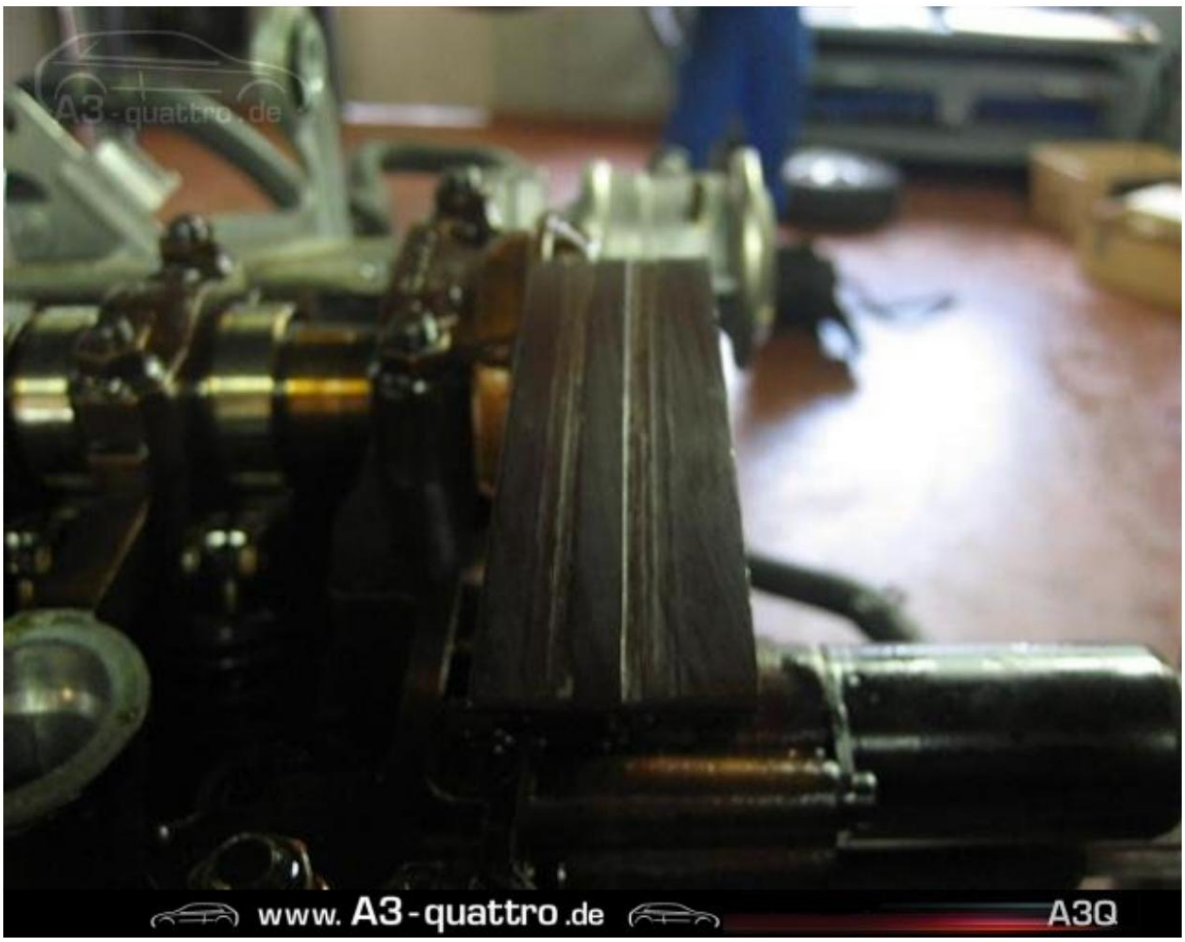


Figure 5.4_4 - Damaged track

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If the chain ran properly in its track, you would only have 2 tracks. Similar to the railway tracks. On the upgraded track, however, you can see many tracks, including sloping ones. We therefore assume that the weak chain makes certain jumps on the track, depending on the speed and current natural frequency. It might even hit you lightly.

Below is a sketch for clarification:

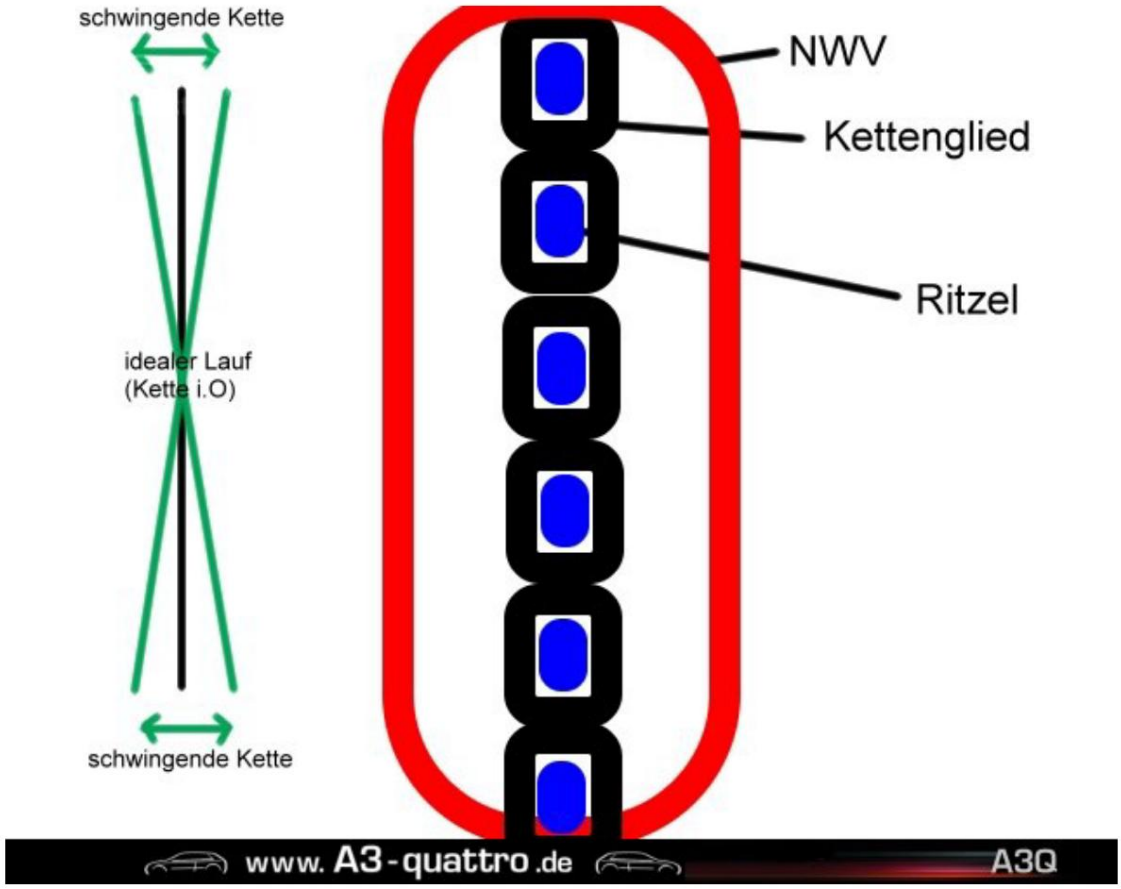


Figure 5.4_5 - Noise development due to the non-ideal running of the chain

You know that from cycling. It's similar there when you pedal hard.
So much for the theory, and on to explaining the sounds in areas 1 to 3.

Part 1.
That hard clack.

The chain may occasionally lie slightly at an angle on the camshaft adjuster sprocket. The run would no longer be free and clean if the sprockets engage in the free spaces in the chain. It would be canted over the pinion of the camshaft adjuster
run, sometimes jump up a bit, which could lead to the sprocket flanks being washed out. As a result, as a result:

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Hard clicking noises.

It's similar when cycling when you change gears and the chain lies diagonally on the sprockets while pedaling hard at the same time.

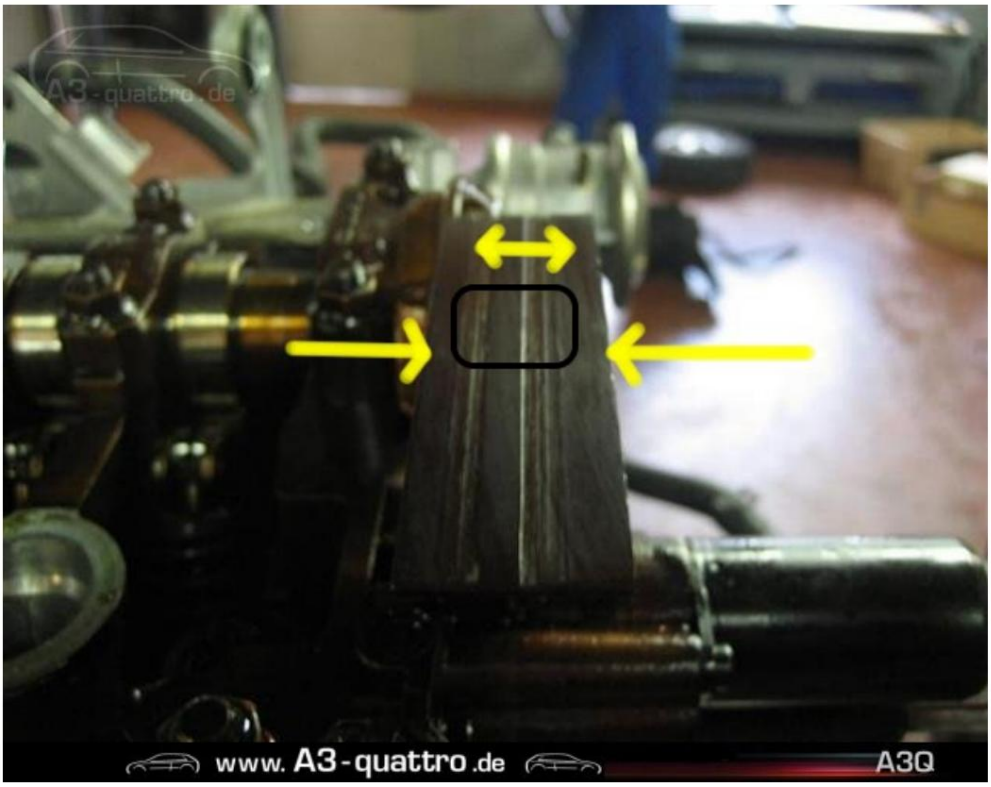


Figure 5.4_6 - Running track

Part 2:

In the middle area there are actually only longer running and sliding rails which have no lateral guides, which narrow the chain and "force" it to run straight. No, it can again be stimulated by vibrations and slide back and forth on the rail. It could be that distinctive loop.

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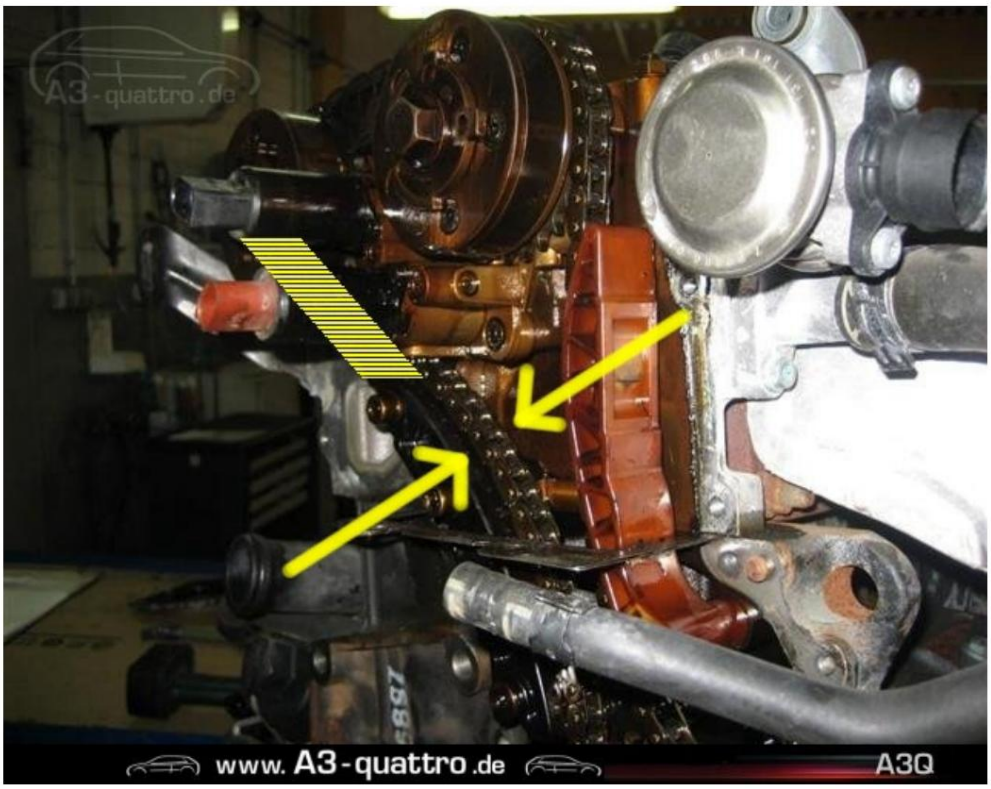


Figure 5.4_7 - simulated lateral movement of the chain

part 3

The tinny scraping noise could be a mix of running on the lower tensioner with the integrated rail. The X-ray image clearly shows the structure of the part. Here we suspect the strongest influence of the resonances. You could excite the weak metal springs and tin lugs, then we would have already determined the tinny noise.

Natural vibration behavior plus pulsating oil flow inside.

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Picture 5.4_8 - lower chain tensioner

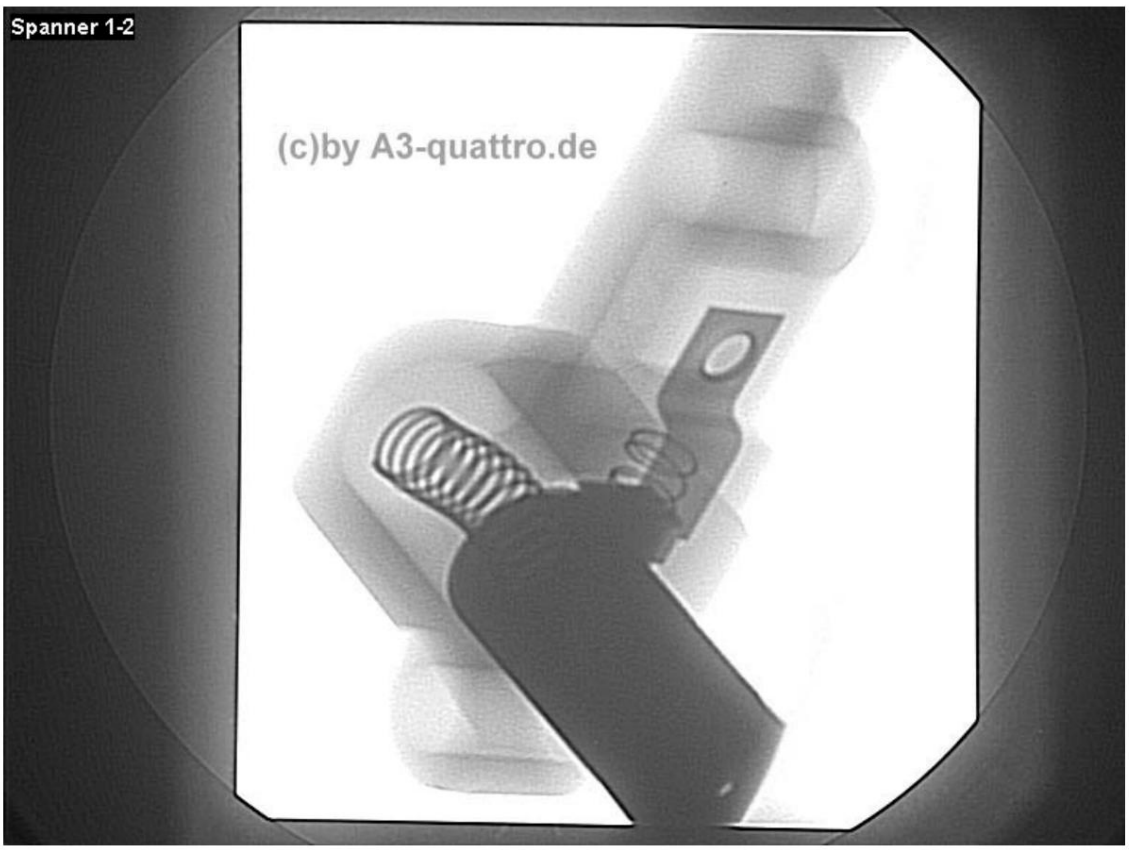


Figure 5.4_9 - radiograph of lower chain tensioner

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More pictures are in **attachment 2.4_1**

Finally, some examples of the typical sounds.

Defective chain drive, example 1
Defective chain drive, example 2
Defective chain drive, example 3
Defective chain drive, example 4

The VR6 3.2 engine can be viewed here in picture and film.

Slideshow VR6 Motor
Video of the cut VR6 engine

All files are also included on the multimedia DVD. More under **point 14.**

At this point, many thanks to Mr. Markus Hofer / University of Graz for creating and processing the photo and video material.

Annotation:

There are cases of repaired Audi A3s that still produce noise under certain influences.

In the normal, well warmed up state, no noise can be detected.
If these vehicles were subjected to extreme driving loads, noises suddenly occurred.
This could be brought about by the following parameters:

-pull up quickly in the aisles
-driving in low gears at high engine speeds
-Driving close to the limit, approx. 6000 rpm.

Usually a good quarter of an hour was enough to be able to hear noises. These are expressed in the form of slight scraping and scratching noises in the wheel housing on the driver's side, as well as very slight clicking noises from the upper chain case.

If you parked this car for about 2-3 hours and started it again. The noises described were gone.

Other A3 and Golf R32 made no noise after driving under the same load.
So where is the cause? The components were the same. And new. So there must be other influences.

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Increased oil pressure due to a defective oil feed pump as well as blow-by and water entry in the oil, which could result in a break in the lubricating film, are obvious. As a result of these influences, the chain can hit and in turn, due to the aggravated conditions such as insufficient lubrication, oscillations, vibrations, etc., it can deviate from the optimum running track and jam / run at an angle. This can generate noise.
If the system is allowed to calm down, the chain runs again in its original straight track with optimal running, which does not produce any noise.

In this case, you should definitely check whether the oil pressure is correct and how long the oil has been in the engine.

The phenomenon is familiar from motorcycles. If the chain is too tight, it will start to flap. Only with reduced chain tension does it run smoothly.

The following figure 5.4_10 shows a sketch which illustrates the situation of the skewing.

If the timing chain runs perfectly straight in the track without hitting the ground or being set into lateral movements by vibrations, the area exposed to wear from the chain links is almost equal to the width B of the chain times the contact length L (WxL). The affected area is the smallest that can exist in the system. The damage is limited. The glass fiber discharge is minimal. The noises that are generated are also low.

However, if the chain runs at an angle and always oscillates slightly left-right, as can happen due to various influences, the loaded area is larger. In our sample image, that would be (Wx2)xL . There's more wear, more fiberglass washout, and back and forth through that
Slipping (sliding) of the chain on the guide rail of course also more and louder noises.

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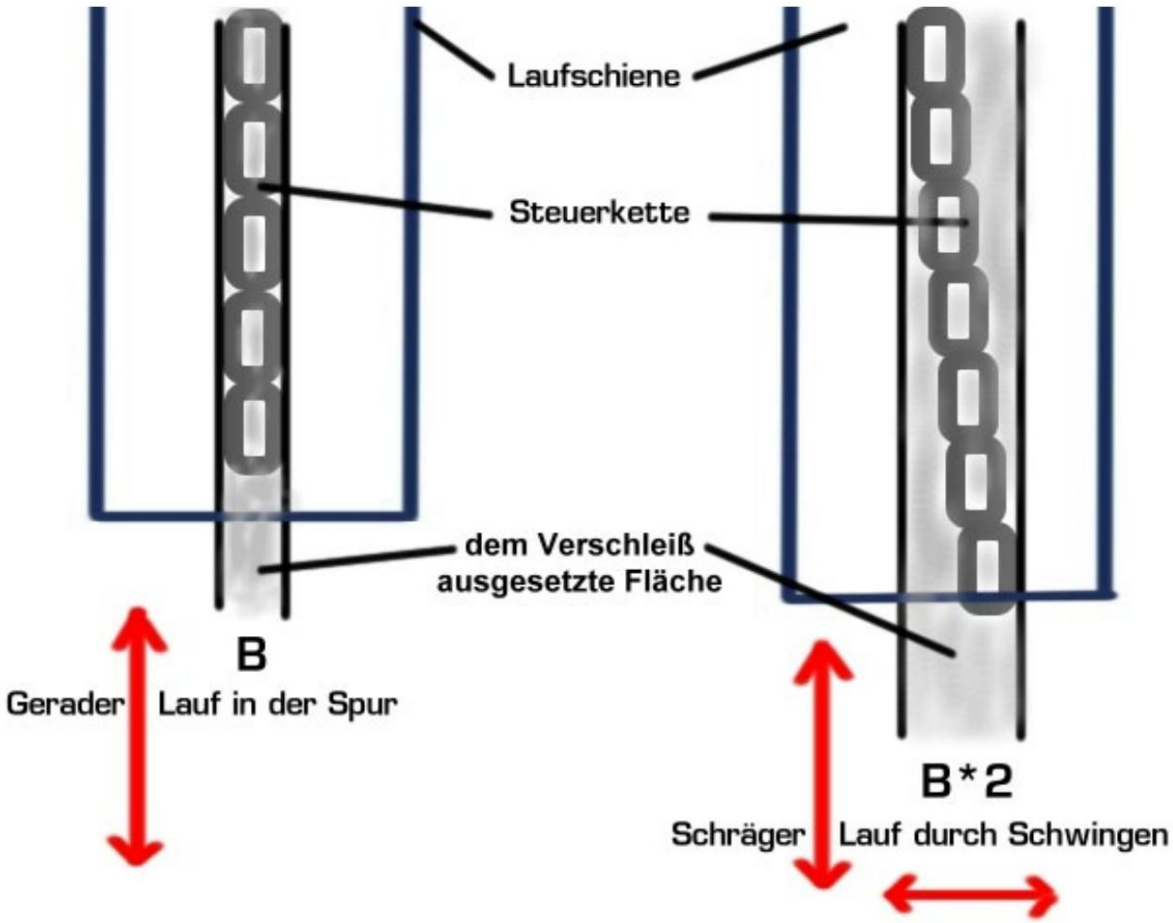


Image 5.4_10 - Sketch: Representation of the tracks of different widths with an intact timing chain and a timing chain with skewing

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5.5 Tips for buying a used car

What should you consider when buying a used car?

The previous points showed some essential characteristics that can prevail in a damage. If you specifically pay attention to this, you can minimize the risk of catching a car with a creeping timing chain elongation.

If you work through the following points when buying a used car, you can classify the ACTUAL condition quite well.

audio sample
Pay attention to rattling, scraping, scratching and clicking noises. Once in the gap between the air filter box and the engine. Clicking noises are more noticeable in the area of the oil cap and the elevation of the cylinder head cover. In the wheel arch on the driver's side you can usually hear scraping and tinny noises.

sight test
The underside of the oil cap must not show any oil slick or oil foam traces. The wall of the chain case must be bare metal and must not show any deposits such as oil sludge or carbon.

smell test
If you open the oil cap and smell the oil filler opening, it should smell like engine oil.
Caution if there is a strong smell of petrol or solvents.

Reading out the error memory and the measured value blocks 208 + 209
No error may be stored with the identifier 17748 or 17755
The values in the measured value blocks 208 + 209 should be between 0° and -2° if possible.
At -3° to -4° you can usually hear noises.
The reading can be done by the VW/Audi workshop or an independent workshop that has the appropriate diagnostic device.

Manual visual inspection
It can only be carried out by a qualified specialist workshop. But offers the greatest security in terms of chain elongation.

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6. The influencing factors

6.1 The oil

The oil is an essential component in achieving the service life of an engine. It is responsible for the lubrication of all components and binds the pollutants that are produced in order to conduct them out of the engine when the oil is changed.
The oil also has the task of absorbing and dissipating the heat from the components.

As already described in Chapter 3.3, there are various key figures for engine oils which, if overstressed, can become a cause of failure in many components in the engine.

The blow-by in the engine uses up the TBN (and thus important additives) and acidic residues remain in the engine. This leads, among other things, to chemical corrosion. The oil is also no longer able to keep the engine completely clean. This then leads to oil sludge and deposits in the engine during operation.

A TBN value that corresponds to approx. 50-60% of the fresh oil can be used as a “wear limit” using a thumb.

Another point that appears critical with LL oils is the dilution by the fuel.
With every cold start, unburned fuel that condenses on the cold cylinder walls gets into the oil. This dilutes the oil and reduces the viscosity. The consequence of this is that an oil loses its high-temperature viscosity over time and a 30-grade oil then quickly becomes a 20-grade oil. The consequence of this is that at a certain point the oil is no longer able to adequately protect a hot engine from wear. If the engine is run at operating temperature for a long period of time, the fuel will boil out of the oil again, but it will never go back to "zero".

Increased wear occurs in particular when an engine is driven short distances over a long period of time and is then exposed to high loads on the motorway. Under certain circumstances, abrasion of the cylinder walls can occur.

The HTHS value is a next critical point. The first 3.2L VR6 in the Golf IV R32 were delivered in 2002 with the so-called LongLife II oil.
These were 0w-30 oils, which according to the standard had to have a lowered HTHS value.
In practice, this was typically 3.0 for almost all LL2 oils. The standard prescribes a value of 2.9 to 3.5.
The reason for the reduction was better consumption values with a low-HTHS oil. In practice, however, you won't get much out of it
have noticed. If at all then on paper with standard consumption. The disadvantage, however, is that you run a higher risk of wear and tear.
Later came the LL3 oil which has a "normal" HTHS value again. The standard requires a value greater than 3.5. The viscosity has also changed to 5w-30.

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These effects are further intensified by the long-life interval of 30,000 km that is common today.
The LL oils, which have a very low TBN anyway, must come with this stock
survive a complete LL interval, while a mobile 1, for example, has almost double the TBN and is changed after half an LL interval.
Since in most vehicles no real oil check is carried out by the electronics and these
so that no one knows objectively when the oil has aged too much, this behavior with an unfavorable combination of influences quickly leads to the engine silting up and thus to increased wear.

6.2 Blowby: what is it and what are the effects?

Blow-by is a complex mixture of oil, exhaust gas, unburned fuel and water that is forced past the piston rings and into the crankcase.

The aggressive hydrocarbons, carbon dioxide and water can form corrosive acids if they are present in sufficiently high concentrations. These acids can now in turn damage the engine and above all seals, hoses and lines in the engine.

When blow-by losses occur between the piston and cylinder barrel, this is known as blow-by losses. These losses also reduce efficiency, which affects the proportion of work that can be effectively used. In order to minimize these losses, the piston is now equipped with an oil scraper ring and two compression rings.

Due to the geometric design and the contact pressure of the piston rings, they ensure a high level of sealing. However, care must be taken not to set the contact pressure too high. Because otherwise friction losses arise due to excessive friction.
Furthermore, one must ensure that the cylinder tube does not deform, which can easily happen under the influence of forces and temperatures.

The blow-by gases then mix with the oil in the crankcase, which in turn results in a dilution of the lubricating oil. Oil consumption can also increase if the blow-by gases are returned via the intake tract of the crankcase ventilation. Even the catalytic converter can be damaged if it comes into contact with too many oil additives.

Normally, at full load, i.e. high engine speeds, around 30 to 50 liters of blow-by gases occur per minute.

In order to prevent the pressure in the crankcase from rising to an unacceptable level and oil being forced out of the engine, the blow-by gases must be discharged. Initially, these gases were simply discharged into the ambient air using a hose. But as early as 1958 it was found that the discharge of blow-by gases into the environment is responsible for around 50% of the hydrocarbon emissions from a motor vehicle.

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The closed crankcase ventilation introduced in the 1960s helped here.
The blow-by gases are fed back into the engine's intake tract via hoses and a control valve, and from there they are returned to the combustion chamber.

Although one of the main sources of hydrocarbon emissions could be eliminated in this way, the problem of damage to elastomer parts such as hoses, seals and O-rings from aggressive media in the engine compartment, especially during continuous operation, was solved due to the higher blow-by proportion strengthened. In particular, lines or reinforced hoses made of epichlorohydrin rubber (ECO), chlorinated polyethylene (CPE) and chloroprene rubber (CR) can swell or be destroyed if they come into constant contact with these gases.

Seals made of chlorine-containing elastomers are also damaged and their sealing effect is reduced. In this way, blow-by gases can escape into the environment in excess of what is legally permissible. This effect will be intensified in the coming years through increased exhaust gas recirculation.

Excerpt from: www.motorlexikon.de

Furthermore, metallic engine parts are attacked. Blowby has a PH value of 1, so it is extremely is acidic and is therefore one of the representatives of the acids. Being an aqueous solution and containing water, it causes an excessive accumulation of water vapor inside the engine.

This can damage high-strength and hardened metal parts, as well as copper and its alloys, by introducing hydrogen into the structure. This is referred to as hydrogen embrittlement.
Affected parts can suddenly break or tear without warning.

Unfavorable routing of the blow-by gases leads to increased condensation.
For example, if the inflowing wind is directed directly onto such parts through faulty ventilation openings in the front. Then the vapors condense faster due to the cold air and much larger amounts of blow-by liquid are formed.

Annex 5.4_1 shows part of the crankcase ventilation radiographically

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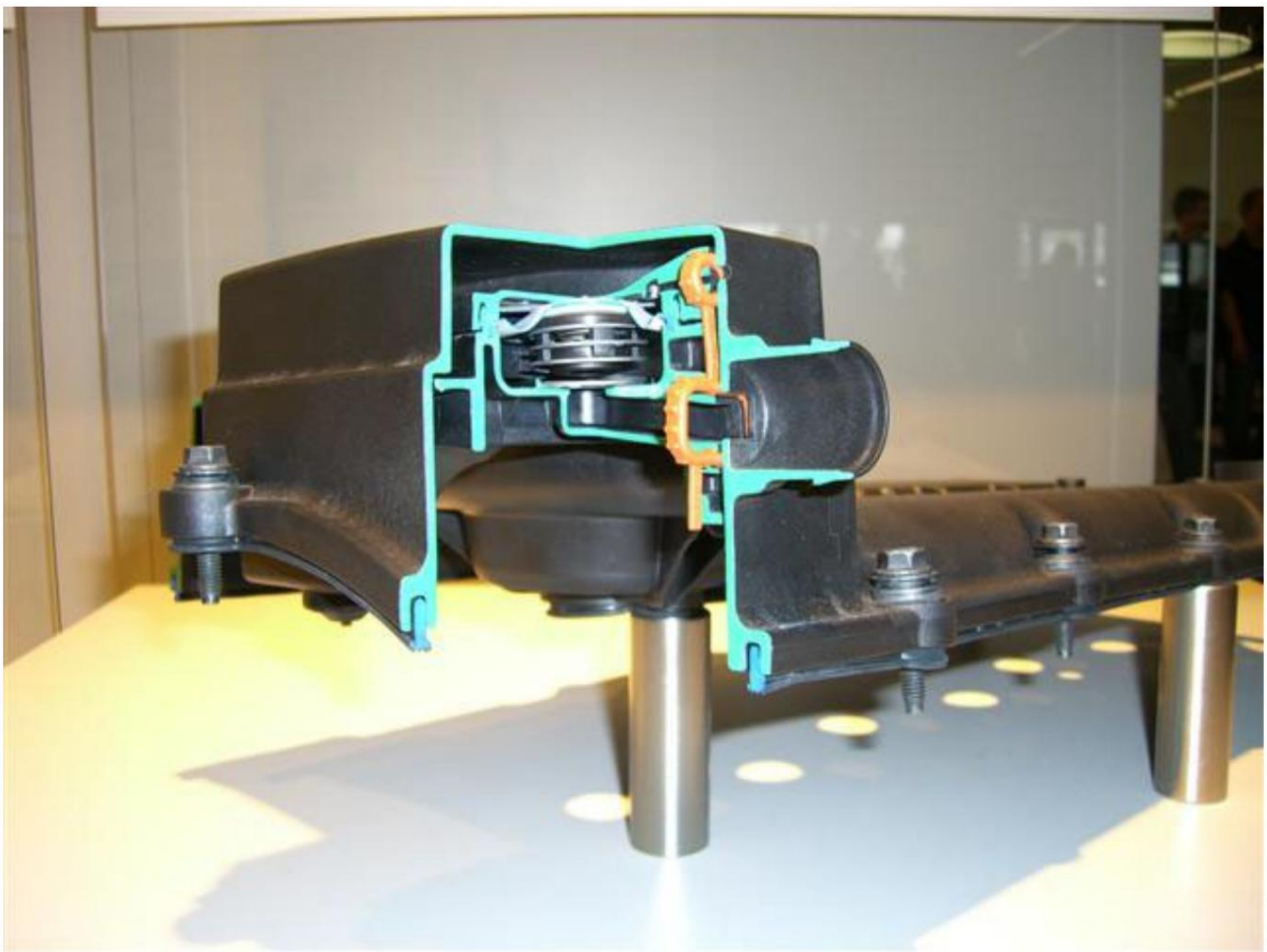


Figure 6.2_1 – Sectional model of the oil mist separator on the VR6 3.2FSI / 3.6FSI

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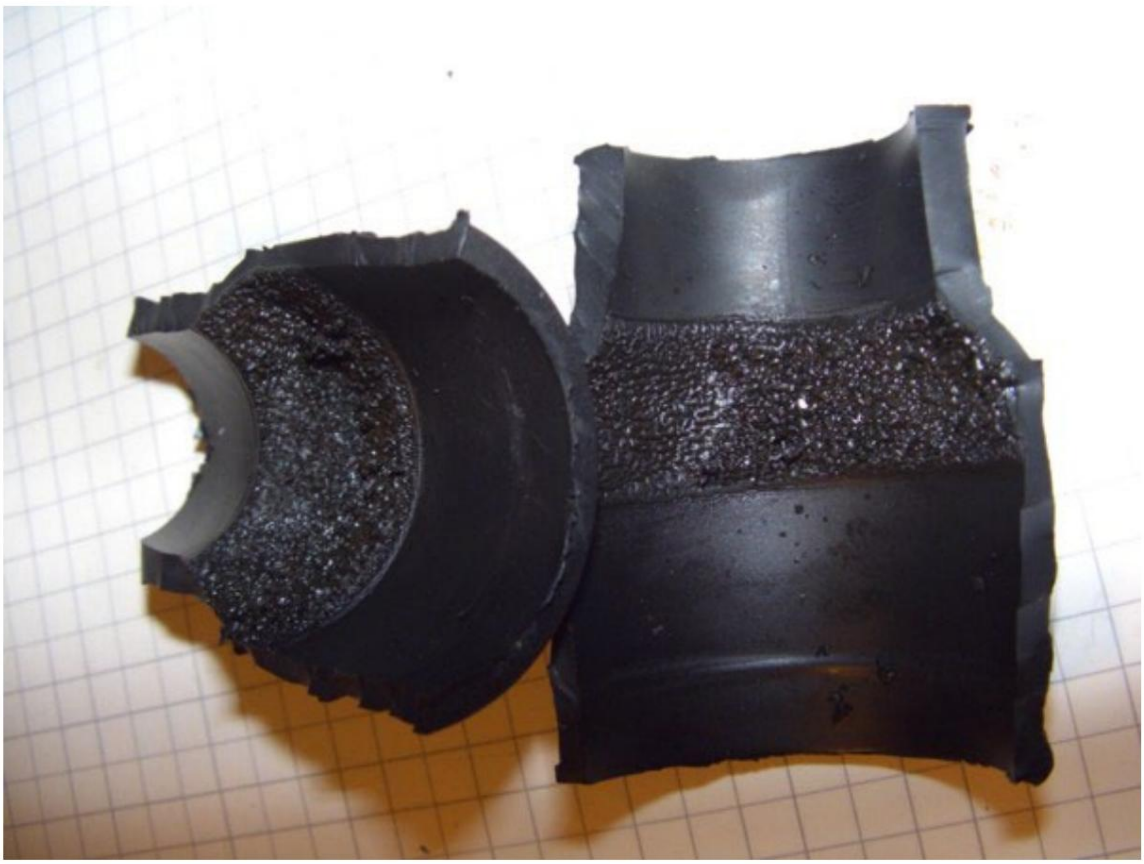


Figure 6.2_2 - Crankcase ventilation connector destroyed by blow-by



Figure 6.2_3 - Crankcase ventilation connector destroyed by blow-by

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6.3 Frequent cold starts, short trips and hot operation

cold operation

Short driving distances with frequent cold starts lead to very low oil temperatures, so that large amounts of fuel can accumulate in the oil. This dilution of the oil reduces its lubricity and makes it more reactive due to the increased aromatic content, so that increased engine wear can occur."

The extent of the fuel entry in vehicles with petrol engines in short-distance operation can be enormous. As part of a fleet test under typical second car conditions, fuel levels well above 10% in the oil could be observed after just a few 1000 km. The fuel content can return to normal values after a stretch of motorway driving. However, you should not drive too hard too early, as the oil is diluted and does not have the full lubricating properties.

There are many effects of such heavily diluted oils on engine wear.
The most common among others:
Suddenly, sharply increasing iron levels in engine oil are a clear indication of wear and tear in the engine. This sudden increase could be observed in all vehicles in the test, albeit with different mileages due to the design. The engine evaluation after 10,000 km of short-distance operation showed that under these operating conditions significant wear occurred on the cylinder liner, piston rings, valve train and bearings

war.

hot operation

High speeds, especially under high loads (as is likely to be typical for passenger cars with a mileage of more than 40,000 km/year), lead to high oil temperatures with the result of nitration, oxidation and an increase in viscosity. The risk that the wear protection of the engine oil can be used up prematurely with long oil change intervals increases. The serious increase in oil viscosity that often occurs under these operating conditions impairs engine function and leads to increased fuel consumption.

Excerpt from: www.motorlexikon.de

Cold start behavior with the VR6 engine

Measurements using OBD while driving showed that the VR6 engine needs a good 20 kilometers to reach the operating oil temperature. This is due to the volume of the engine, as well as the large volumes of coolant and engine oil. It takes time for all of this to warm up. In severe frost this can of course take considerably longer.

With this knowledge in the background, it almost goes without saying why cold starts should be avoided wherever and whenever possible. A quick trip to the local bakery or driving the children to school is poison for this type of engine in the long run.
Too much petrol residue and blow-by are formed, which damage engine components.
In addition, the fuel consumption in this starting phase is relatively high.

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6.4 Topic of the glass fiber reinforced guide rails of the timing chain drive

Here is the topic of the glass fiber reinforced rails.
They wear out a lot because the chain links with the straps literally dig into them.

First something about the component as such.
These rails are usually made of PA66 GF+ or a modification of the PA66 family.
As a rule, they have 35-40% glass fiber content.
The polyamide used is not a standard polyamide as is known from other components.

Plastics can be specially designed. This means that for every application there is a special mixture with individual mechanical and technological properties by adding fillers and additives.

Rails must be stable. At the same time, however, they should have gliding properties.
This is called the self-lubricating effect in tribology. This condition can be achieved by adding graphite, PTFE or silicone oils.
When used in chain drives, special additives are very important so that the new material becomes resistant to oils, petrol and solvents. Since the rails are built into the engine, special materials for heat stabilization are required. If they were exposed to sunlight, you could add UV stabilization particles.

If you wanted to mill the running rails yourself from the solid material that you procured, the project would not go well. Because you don't know which stabilizers are contained in it or are missing.

In the case of metals, material analysis using spectral analysis is very easy. In the past, the component was briefly radioed, and using the resulting pattern of the decomposed spectrum, it was possible to say exactly how many percentages of each alloying element it contained. Tables could be used to read which steel grade it was. Today something like this is done via a special type of X-ray examination.

There are similar processes for plastics, but they are not nearly as simple. Complex and cost-intensive laboratory tests are required here.

For this reason, we can only advise against anyone who wants to rebuild the parts themselves in order to implement lateral supports.

Besides the additives, there is another reason not to do this. The rails are injection molded from the factory. These granules, which have been correctly mixed with additives beforehand, are heated and pressed into the mold under pressure. Then ejected and cooled. Because the molding compound reaches the smooth inner wall of the mold and cools down,
a kind of spray skin is formed. Similar to the skin of a chilled pudding.
she is smooth The contained glass fibers are mainly aligned parallel to the surface below. Very few come across sharply. Due to this alignment, hardly any glass fibers emerge from the plastic, which can wear out the chain links.

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If you now take a block of PA66 and mill out the guide rail, you have open glass fibers everywhere, which would wear out the chain in a very short time.

Another advantage of the injection molding process:
Over time, some of the lubricating additives and stabilizers accumulate in the spray skin.
As a result, there are more sliding parts in the material in the upper layer. Similar to the roller floors at the airport on which the containers are moved.

If you now have long-life oil that has become aggressive due to blow-by, this can trigger the lubricating particles and additives in the outermost layer or partially reduce their effect. The sliding coating is slowly disappearing. Under the increased tensioner pressure caused by the
defective oil pump, the chain links are constantly being pressed more firmly onto the rail. The lubricating effect of the oil also decreases thanks to the blow-by and increased water entry, the splash skin is slowly removed at the contact points.

Once it's damaged, things go very quickly.
The lubricating effect of the modified PA66 decreases rapidly because the component is damaged. The engine oil washes the last lubricants out of the material. The actual engine oil no longer lubricates properly and the chain links dig into the rail in a track.

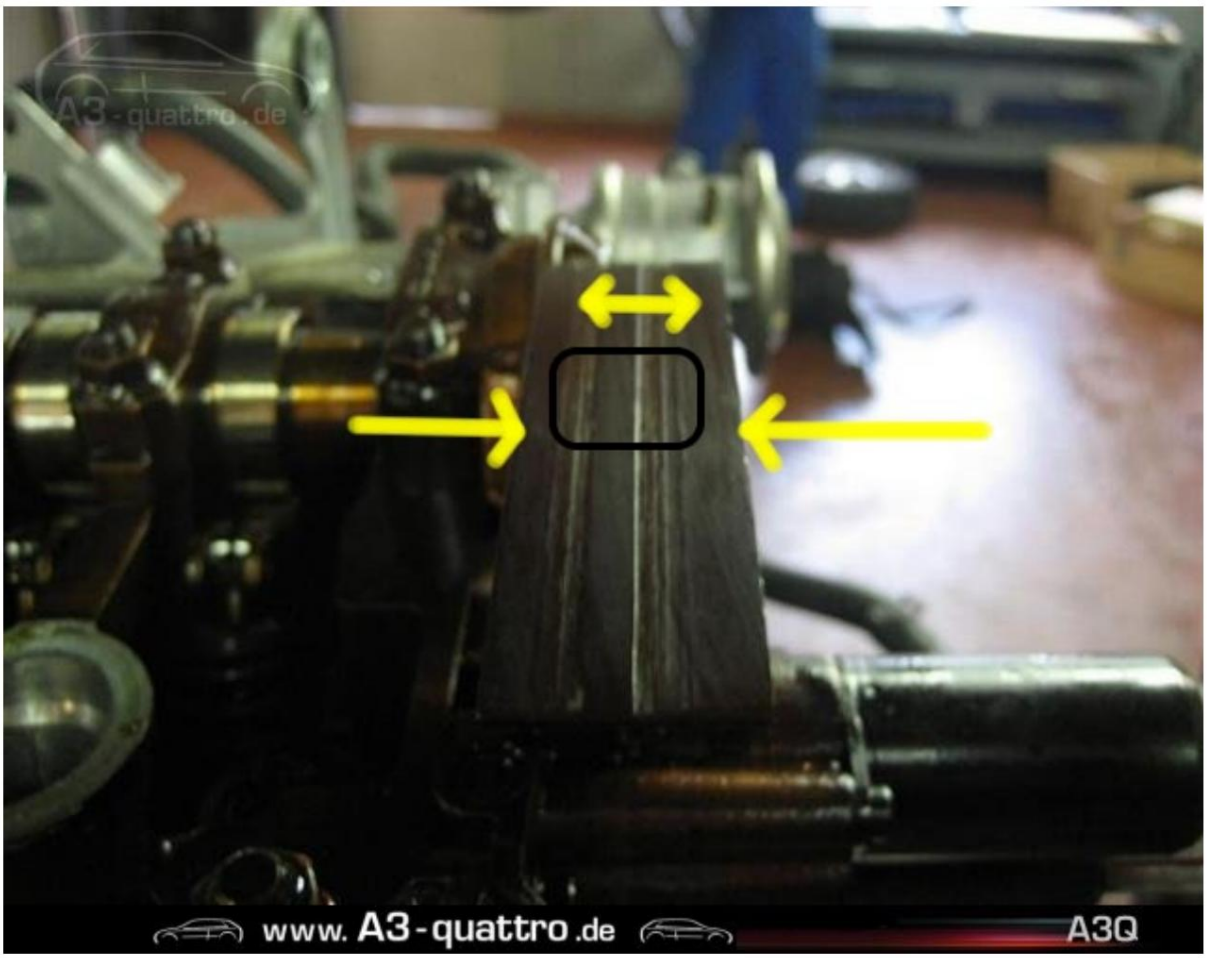


Image 6.4_1 - Dismantled running rail with damage caused by the chain

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There they meet the glass fibers that are erected. Wear the tops of the chain links. Partly only selectively. The chain links wear away the longitudinal glass fibres, they are swept along with the oil and wear out many parts that lead to the oil channel in the constant flow of oil.

The older the oil, the higher the oil pressure and the more the chain digs into the bar. Favored by the fact that there is no lateral guidance for the chain, the chain can hit and slip laterally, stimulated by vibrations and excessive chain tension.
Why a wide area wears out. And a lot of fiberglass gets into the oil.

Mixed with soot, suspended particles and hard oil carbon, the loosened glass fibers do their destructive work in the oil flow. Abrasive wear occurs.

Visually one could imagine the Grand Canyon. Or rather, Niagara Falls.
The underground of the landscape is the rail.
The river water, with the help of sand and small stones, grinds the river bed deeper and pushes the waterfall further and further back. Or. in the Grand Canyon, it washes out the river bed deeper. Something similar happens in the engine with the contaminated long-life oil.
Namely on all components that this contaminated oil meets.
The chain parts are also worn out in this way. The chain gets more play in the longitudinal direction.
In addition, it swings out more to the side.



Figure 6.4_2 - Signs of wear on the link plates

So much for the topic of the running rails and the glass fiber entry into the oil with the resulting effects.

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6.5 Contamination particles in the oil (soot, glass fiber, black sludge, etc.)

soot and solid foreign matter

Solid foreign matter is the sum of all insoluble components contained in used motor oils. They are essentially made up of soot particles from combustion, solid aging products from the engine oil, metallic abrasion and dust (determined as silicon) that got into the oil with the intake air of the engine.
Furthermore, solid lubricants such as graphite and molybdenum disulfide, if added to engine oil, go into the amount of solid foreign matter.

An increased foreign matter content of the engine oil leads to a thickening of the engine oil and to faster oil aging. The content of solid foreign matter is therefore one of the main criteria for changing the oil and determining the oil change intervals. The increase in foreign matter content in engine oil depends on both the engine type and the operating conditions. The foreign matter content in diesel (pre-chamber engines) is higher than in direct injection engines and lowest in petrol engines. Operation in the upper load range increases the foreign matter content due to the increase in soot formation during combustion (diesel engines) and due to increased oil aging. Dispersing additives in the engine oil keep the foreign matter in suspension, prevent them from combining to form larger particles, precipitating out in the oil circuit and causing blockages and deposits. In order to avoid engine damage caused by foreign matter, the aim of selecting and concentrating the dispersants is to keep the size of the foreign matter particles as small as possible.

If necessary, a more in-depth analysis of the foreign substances can provide information about their composition. This can e.g. B. in the engine and engine oil development may be required. An effective reduction of the foreign matter content during engine operation through oil filtering is not possible with either main or partial flow filters, since the particle size is predominantly below that of the filter pore size.

black mud

With the spread of engines with stoichiometric or lean combustion, the formation of black sludge in petrol engines became a new problem, even with oils that had previously had sufficient additives. The cause was the higher content of nitrogen oxides, which enter the crankcase as components of the combustion gases via the piston rings and are converted into nitrogen dioxide during their residence time either in the gas phase or through reactions with engine oil components:

The reactive NO2 then reacts with polar oil components to form organic nitrates, which can lead to undesirable black sludge-like deposits in the crankcase and valve train and premature engine oil breakdown. The content of organic nitrates in used oils is therefore a good indicator of their condition and further usability. It can be determined using infrared spectroscopy in accordance with DIN 51454.

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Oils that are safe from black sludge can be replaced by non-polar base oils, e.g. B. highly refined mineral oils or synthetic base oils, but also by special additives or by a combination of both measures. Phenolic antioxidants and zinc dithiophosphates act z. B. as NO2 scavengers and thus ensure adequate protection against the formation of organic nitrates and thus the formation of black sludge, as long as these active ingredients are still present in the oil in sufficient concentration and are not used up.

Oils can be tested for black sludge safety in the laboratory by simulating nitration with the simultaneous addition of oxygen and in the presence of reactive fuel components. Ultimately, the test in the ACEA test engine M111 and fleet tests under critical conditions and extended oil change intervals provide information.

Excerpt from: www.motorlexikon.de

fiberglass entry
Glass fibers are detached from glass fiber reinforced plastics, from which most components in the engine area are made today, and carried away with the oil flow.
The cause is usually mechanical wear caused by damage to the component surfaces. More information on this can be found in **Chapter 6.5**
Glass fibers are extremely abrasive.

The oil with the particles listed here thus mutates into a wearing solution, which slowly abrades all the parts in it.
It is therefore essential to prevent such a solution from occurring, and what is far more important: it must not remain in the engine for too long.

The supply of fresh air to the engine compartment, which flows in or is sucked in while driving, should also be viewed critically.
Air flows, especially in engine compartments, are very complex.
If cold fresh air hits critical areas here, it can lead to cooler spots locally.
For example in the area of the chain case. There is a larger gap between the engine and the air filter.
The chain case is exposed almost to the gearbox and is unprotected from cooler air.

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Figure 6.5_1 – Area at risk from cooling air on the VR6 engine

If cold driving air hits it here due to turbulence, this means that the chain case can firstly cool down more and secondly can get local cold spots.

At these cold spots, more blow-by can form on the inside due to condensation. Oil mist vapors can also strike, carrying the finest soot particles. They stick to the chain case. The oil slowly drips off, solid particles collect. Over time, these accumulations grow larger.

Also in the area near the oil filler neck. Here the oil always squirts up through the chain. And this is exactly the area where this hard oil sludge collects.

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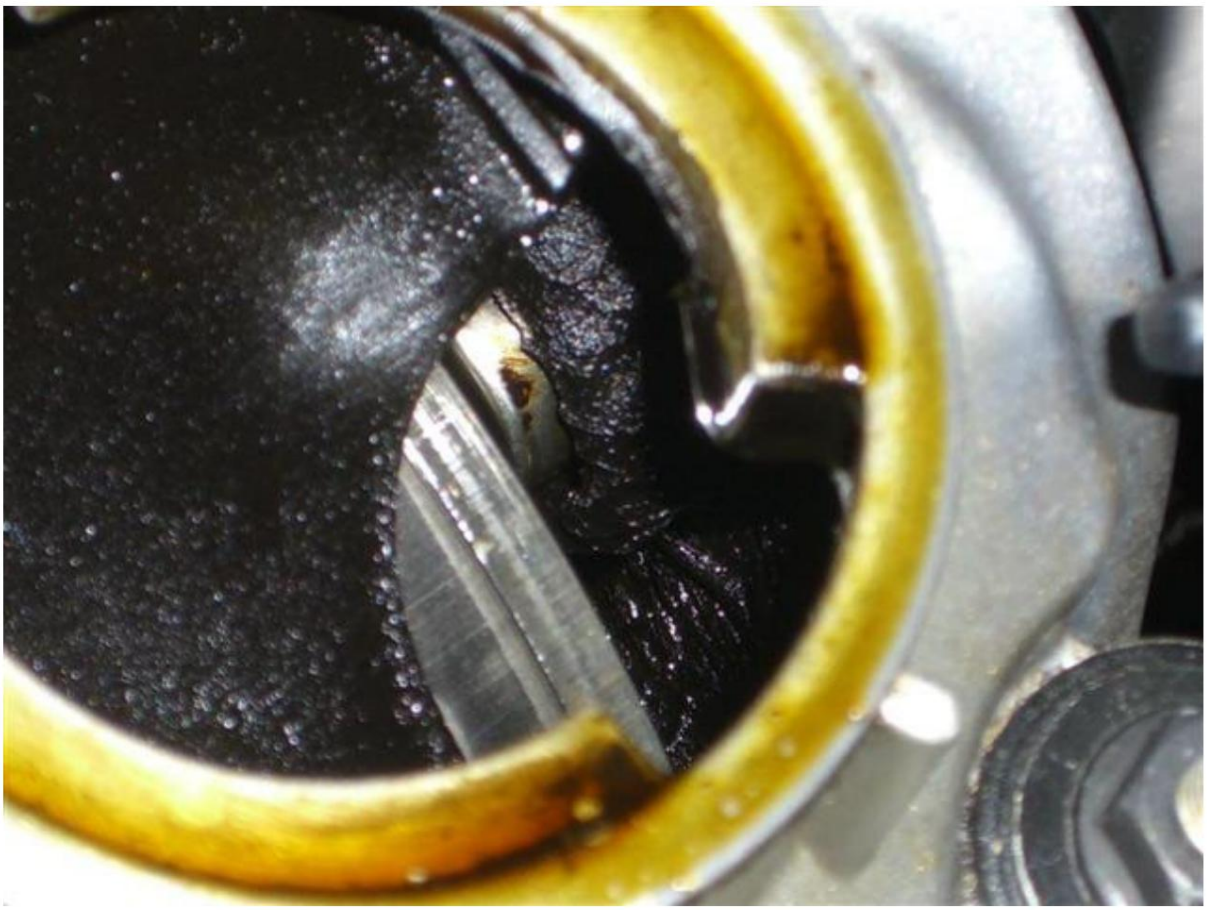


Image 6.5_2 - Oil sludge deposited in the chain case of a VR6 with approx. 60000 kilometers, long-life oil (Casrol SLX II + III) and long-life change interval

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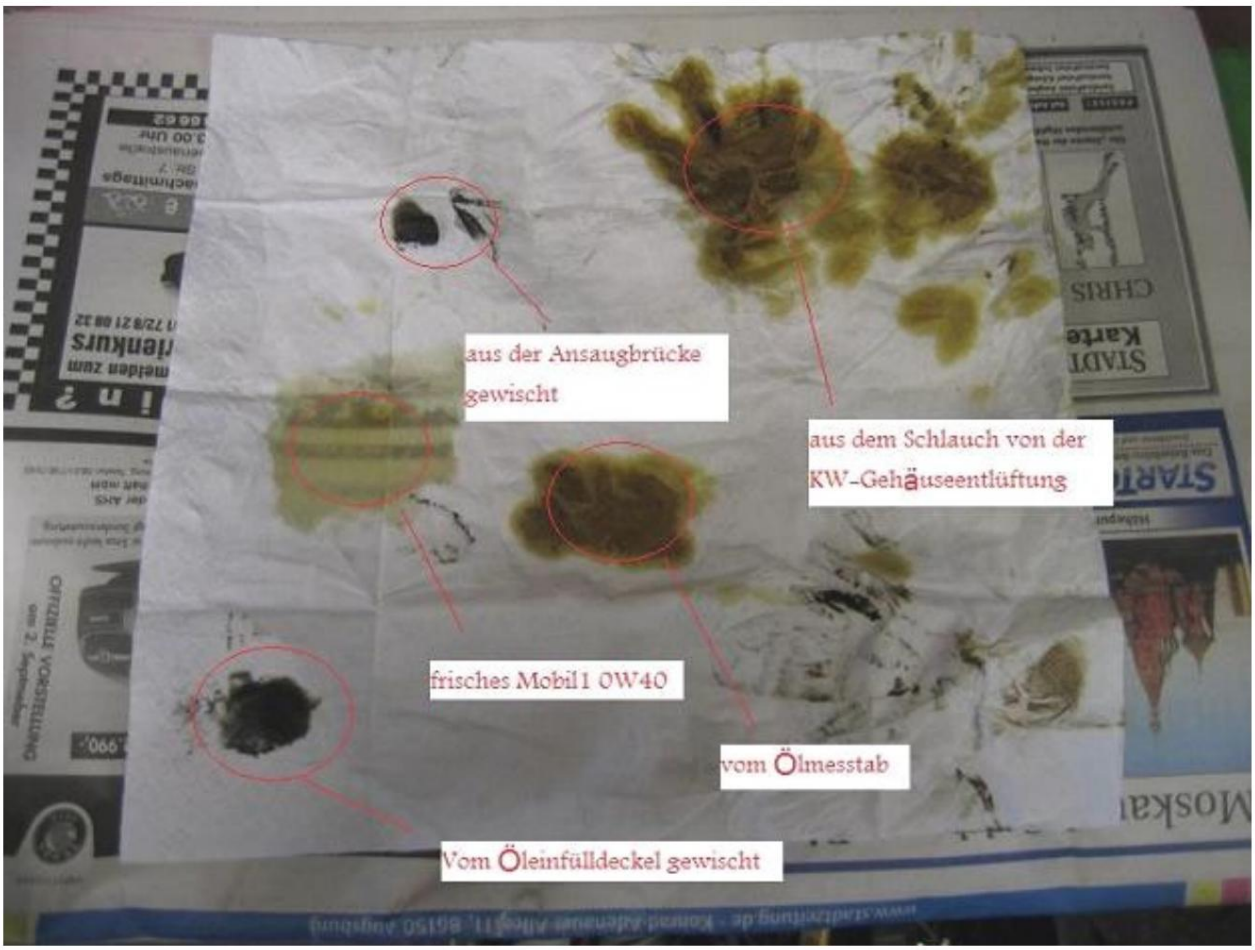


Figure 6.5_3 - Overview of the degree of contamination of various measuring points and areas

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6.6 Water entry in the oil

Used motor oils contain small amounts of water, which gets into the oil from condensed exhaust gas, especially if the vehicle is driven frequently for short distances. Usual water contents are in the range between 0.1 and 1%. In the event of damage to the sealing elements or corrosion of wet cylinder liners, large amounts of water can penetrate the oil.

Water is an undesirable component in motor oil because it promotes acid formation, corrosion and oil aging; at higher concentrations, of course, the lubricating properties are also impaired. The additives used in the oil neutralize the adverse effects of low water concentrations.

Water in oil can be determined using different methods. Simple qualitative
In the case of high water contents, the methods are a visual assessment of emulsion formation, and in the case of low concentrations, the so-called spatter test, in which the oil sample is heated in a test tube and the presence of water is identified by cracking noises. Quantitative methods are a distillation process with the addition of xylene according to DIN ISO 3733, the titration process with methanol according to Karl Fischer according to DIN 51 777 and the so-called

FINA test using calcium hydride as the reactant.

Excerpt from: www.motorlexikon.de

6.7 Resonant vibrations

In a passenger car with an internal combustion engine, a wide variety of resonance vibrations occur in different strengths. Always under the influence of the engine speed and the forces introduced by the chassis.

Under unfavorable conditions, this can cause problems, especially when individual assemblies or add-on parts resonate. Various processes can be disturbed and the acoustic behavior of individual parts can be strongly influenced.

The acoustic behavior is explained under **point 5.4 .** You can also find more details here in Part 2
to the vibration behavior of individual parts of the chain drive.

The vibrations of the stretched and weakened chain are partly responsible for the damage pattern. The more the chain vibrates and has play, the more dangerous, swelling loads form. If they become too strong, they can cause a chain to break.

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Evidence of such a case is shown by the REM analysis **(Annex 2.3_2)** of a broken chain from the Sachs company. The vibrating stripes in the structure can be clearly seen in the pictures.

A cause could also be the influence of a defective oil pressure pump. Similar to a motorcycle, a chain that is too tight hits the ground. This can only be ruled out if the chain tension is optimal.

6.8 Missing lateral guides of the rails

The rails of the VR6 chain drive all have no or hardly sufficient lateral guides. In addition, there is too much leeway because the rails are too short.

They are therefore partly responsible for the chain slipping sideways or swinging up at particular load levels. Stimulated by engine resonance, the chain and tensioner can form an oscillating system. If the chain is stretched and the tensioner is defective, the chain tension drops drastically.

The wear of both components is increased. The risk of the chain skipping a tooth on the wheel increases significantly.

This could be remedied by better lateral guides and supports.

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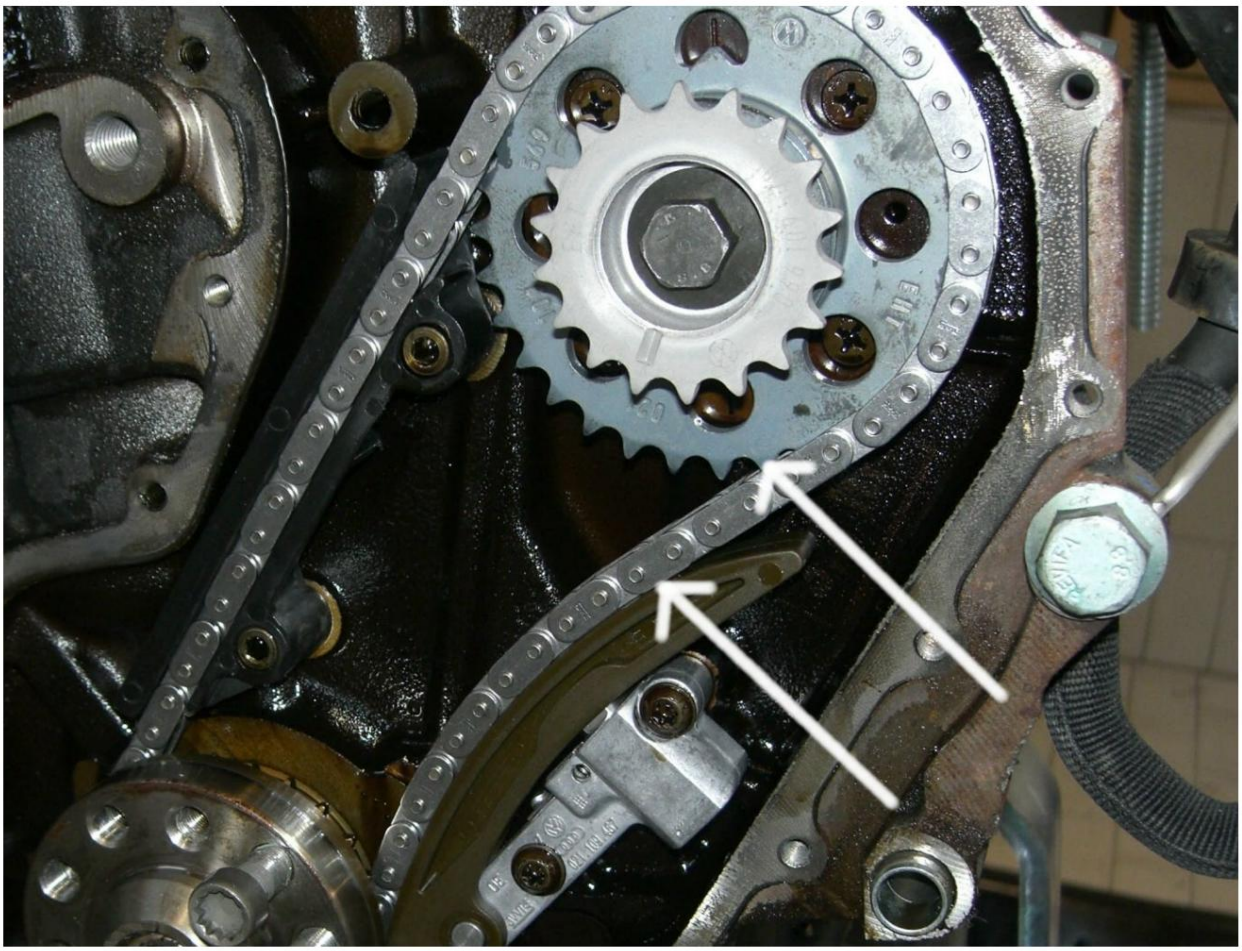


Figure 6.8_1 - too much leeway

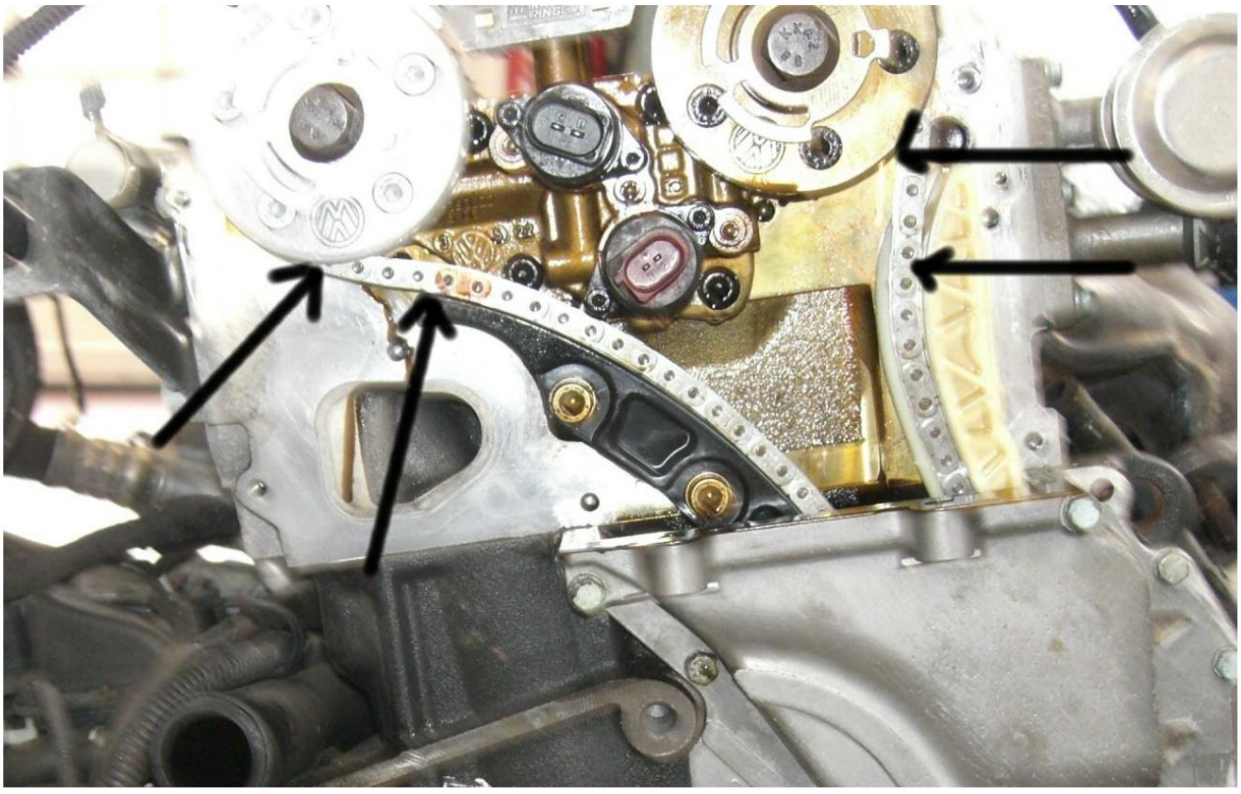


Figure 6.8_2 - too much leeway

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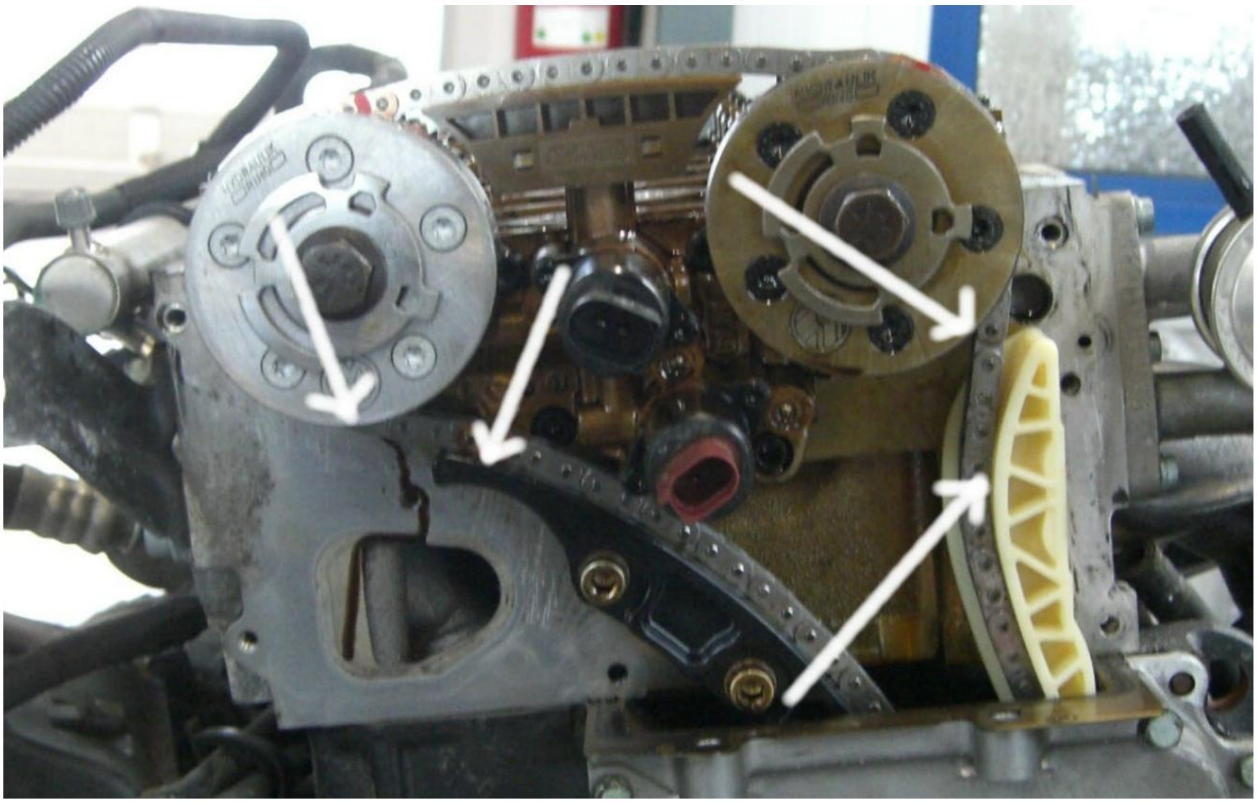


Figure 6.8_2 - too much leeway

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6.9 Vulnerable camshaft position sensors

These sensors are already exposed to a large amount of scatter ex works.
Depending on the pair of sensors used, the true zero point can vary greatly. This means there is no 100% sure value for the position.

The workshops sometimes exchange several crosswise to reach the zero point. For this reason, an error is not always generated. The workshop finds no value in such a case.

Laptop-dependent workshop personnel who only trust the OBD let the customer understand that the engine is OK. Despite the noise. Only manual visual inspection can provide 100% security here.

Unfortunately, there are hardly any workshop personnel who still listen to the good gut feeling and carry out a visual inspection. This is actually required by the factory. Unfortunately, many workshops cannot do anything with it and are mercilessly overwhelmed and helpless with the implementation and diagnosis.

More about the sensors in **chapter 3.9 .**

Chapter 5.3 describes how a manual visual inspection is carried out

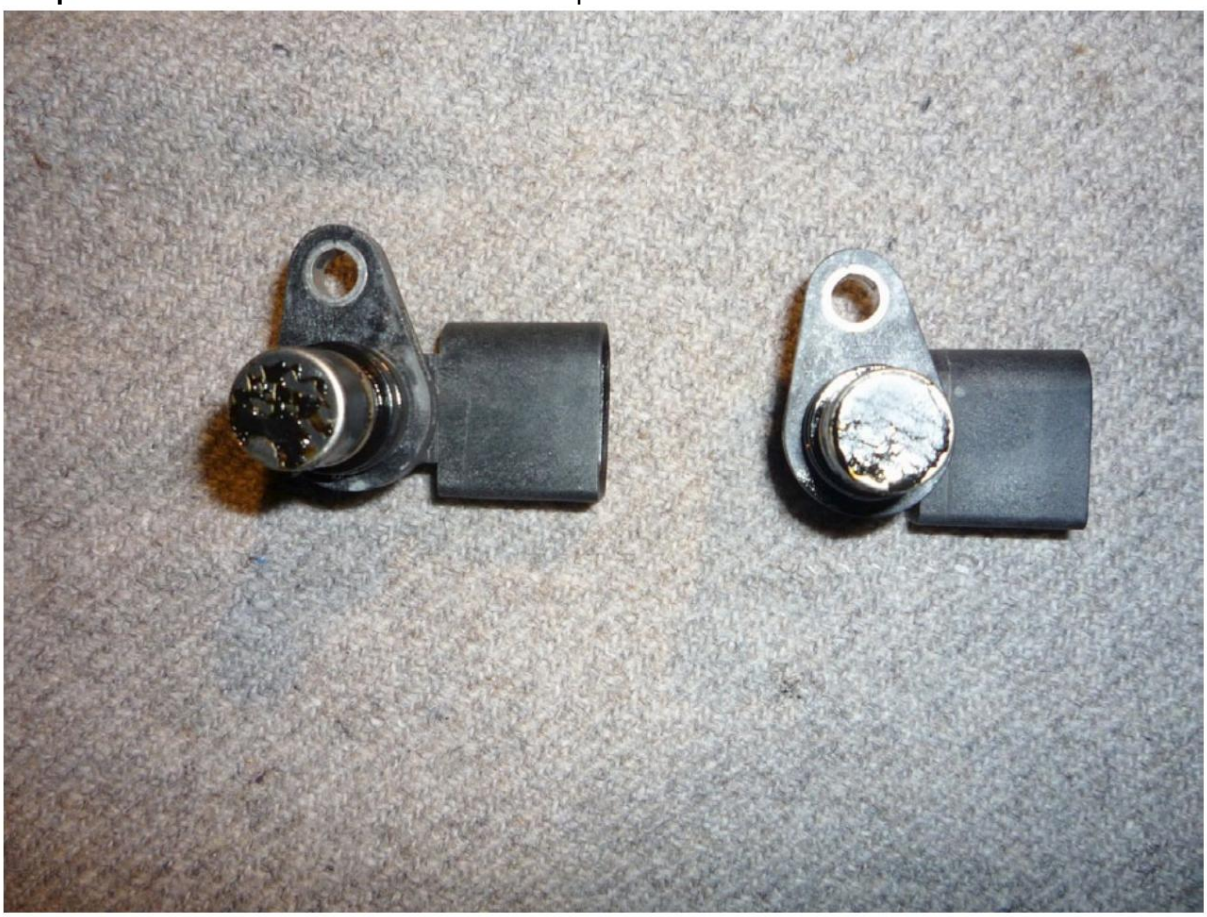


Figure 6.9_2 - Removed camshaft position sensor (Hall sensor)

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6.10 Corrosion-prone chain materials

When designing a component, you always have to walk a certain fine line to ensure the optimal properties and to adapt the materials to the requirements of the system.

In the case of timing chains, these requirements are strength, hardness, durability and wear.

Austenitic steels, which have good corrosion resistance, usually do not meet the load requirements. For this reason, high-carbon steels, which can be hardened and tempered very well, are generally chosen for the main components of a chain. They can be produced with very high strength.

Unfortunately, in this state they are very susceptible to corrosion, especially hydrogen embrittlement. At an advanced level, it causes the chain to suddenly fail.
Usually through a violent breach. Recognizable by its fine-grained structure.

Hydrogen embrittlement is dealt with in **Section 6.11 .**

6.11 Hydrogen embrittlement

In addition to the chain variants weakened by the embossing, hydrogen embrittlement is the second cause of chain breaks.

High-strength and tempered steels are very often used in modern engine construction. These consist of carbon steels, since only such steels can be heat-treated due to the carbon embedded in the structure. Hardening, tempering, stress-relief annealing, etc., are only possible with carbon.

Unfortunately, these steels have the unpleasant property of accumulating atomic hydrogen in the structure, along the grain boundaries. There they usually collect at gaps in the lattice.

If these sensitive steels are also surface-treated, more hydrogen atoms can get into the lattice through pickling processes.

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WEBU-Handel (www.webu-handel.de) describes this as follows:

As is well known, all highly tempered materials eagerly absorb free hydrogen (chemical symbol "H") from the atmosphere.
This leads to the destruction of the molecular structure of the material. When exposed to free hydrogen (H2), chain parts made from tempered, through-hardened material experience what is known as "hydrogen embrittlement".

Free hydrogen is produced with every galvanic treatment (electrolysis process).
In principle, all parts of a chain such as pins, bushes, rollers and link plates can be made from tempered material. In principle, they are all "endangered by hydrogen". In practice, however, the greatest danger lies with the link plates. This particular sensitivity of the link plates is based on the following causes:

- Relatively small wall thickness with a large surface at the same time. This enables intensive and rapid penetration of the free hydrogen.
- When assembled, link plates have a high internal tension (pretension) within the chain due to the press-fit connection with the chain pins or chain bushings.
- In practical use, they experience further high tensile stresses through the transmission of the tensile forces introduced.

Brittle fractures in link plates, which are caused by the influence of free hydrogen, do not usually occur in the area of the plate heads, but run lengthwise and transversely through the link plate in any form.
However, they do not only occur during operation due to the stresses mentioned, but also when the device is not installed.
In order to avoid hydrogen embrittlement, special measures - before and after the galvanic process - are required.

The tempering of the link plates has to be reduced to a moderate value and, moreover, the treated parts are subjected to a heat treatment process.
Galvanically treated chains have a breaking strength that is approx. 15-20% lower.
However, within the scope of their permissible load capacity, they have the same operational safety and reliability up.

Chemical surface treatment Chemical
surface treatment is a process we know from the galvanic process. However, the required reduction is carried out here by added reducing agents such as sodium boronate or sodium hypophoshite. There is no danger from free hydrogen atoms here. This process is usually used when the surfaces are to be nickel-plated. There is no reduction in the breaking force here.

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Mechanical surface coating In this process, the chemically pretreated chain parts are treated in a drum that contains fillers in addition to the anti-corrosion material to be plated on. A connection is made between the chain parts and the material to be plated under mechanical pressure. The coating can be produced in any layer thickness. There is no reduction in breaking force here.

Here are two pictures to clarify. The first shows a pearlite structure as it appears in the normal state. Figure 2 shows the storage of individual atomic hydrogen particles (H+) and hydrogen particles that have bonded molecularly (H2).



Image 6.11_1 - Basic structure

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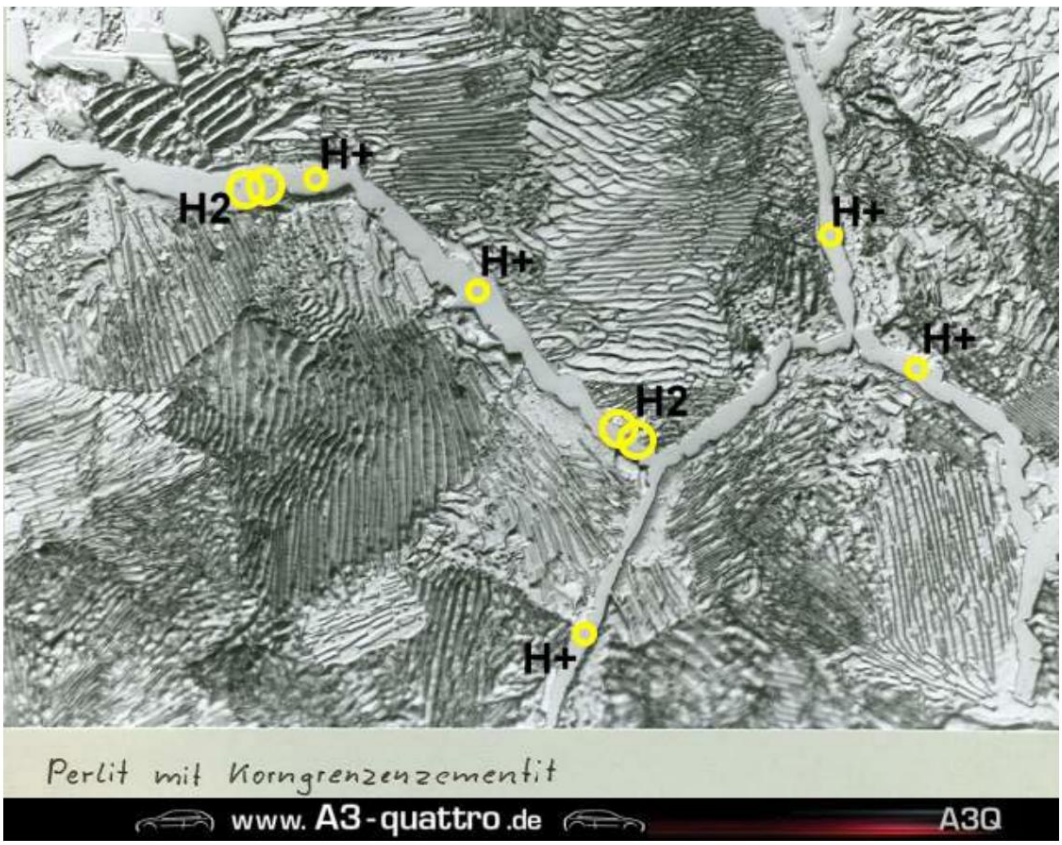


Image 6.11_2 - Basic structure with embedded H+ atoms and embedded H molecules (connection of two H+ atoms)

Molecular hydrogen takes up much more space than atomic hydrogen.
For this reason, extremely high pressures develop inside the structure. In some cases, such parts with a lot of hydrogen input can fail “just like that”.

This is very common with high-strength screws. Suddenly there is a screw with a broken screw head in the box. Too much hydrogen blew off the head here. This happens without external influence.

However, it can also happen that stress peaks cause a part that has been weakened by the introduction of hydrogen to break.

In the case of our chain, the tension peaks could be caused by heavy gas blasts at high revs.

Or suddenly strong acceleration in cold operating conditions. The possibilities are far-reaching.

Further literature on hydrogen embrittlement can be found in **Annex 2.3_3** and **Annex 2.3_4.**

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6.12 The timing chains of the revision levels in series use

In the case of the BDB engine type, the timing chains were intervened three times in series production.

The following changes are known:

March 2004
June 2004
January 2005

The change from the Sachs company to the Iwis company was recognizable. Furthermore, you could external appearance of both chains make differences. The Sachs chain was dark.
It may have been surface treated. The Iwis chain is metallic bright. It can also be surface-treated, but this is not obvious at first glance.



PICTURE 6.12_1 - IWIS chain above (light) / Sachs chain below (dark)

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There is currently no known case of a broken chain on the Audi A3. But very many chains that lengthened.

On the Golf R32, some of the replaced chains broke again and just as quickly or faster than the first chain.
In this case it was improved Sachs chains.

The reason for the first series of cracks was the "Sachs" lettering embossed into the chain link plate.

See the REM analysis of a broken Sachs chain with embossing in **Appendix 2.3_2**

If, after the first complaints, the Sachs company had brought stronger chains into series production via hardening and tempering, this would be fatal. Because the higher the strength of a chain, the more susceptible it is to hydrogen embrittlement, since higher-strength steels store more hydrogen atoms in the structure.

Since only the chain was exchanged, the attack mechanisms (blow-by, long-life oil, long-life interval, etc.) which destroy the chain but were not switched off, renewed damage was/is inevitable.

Nothing is currently known about the measures regarding the newer and newer chains of the Iwis company. You would have to have a chain examined by each revision.
The following values are required to obtain information:

- hardness
- Material
- Compensation
- REM - Examination of the structure
- Abmaße

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6.13 Material, volume, flow and geometry of the engine

The amount of blow-by or condensed water with which the blow-by forms the acidic compound can probably be determined by the shape and mass of the engine.

Condensation and blow-by mainly occur when the engine is cold. So cars that have to do a lot of short trips and frequent cold starts are more at risk.

An aluminum motor cannot retain heat as well as a cast iron block. Therefore, the aluminum blocks cool down faster. Condensation forms on the cool walls and then runs into the oil.

Since the small engines have less mass, they cool down faster and you have a cooler engine than the VR6 with the same downtimes and with the small engine you are closer to a cold start like the VR6. As a result, more blowby whistles into the crankshaft housing due to the design .

Here is a report on engine death in the 1.4L engines, most of it is actually quite good there:

Citation

The light metal, VW spokesman Jens Bobsien admitted for the first time last Friday, is probably the main reason for the ice formation in the oil sump according to the latest findings. Aluminum cools down faster than gray cast iron when the engine is switched off. Condensation water forms more easily in the housing. It collects in the oil pan and freezes in extreme cold.

The origin of the moisture is also clear: in all piston engines, especially during cold starts, fuel gases containing water ("blow-by gases") penetrate along the cylinder walls into the crankcase and condense there. When the engine warms up, this condensate evaporates again immediately and escapes as gas through the housing ventilation.

However, if the car is only driven very short distances, the engine does not get warm enough and the condensation can seep into the oil bath - usually only in unproblematic amounts.

However, aluminum motors are particularly sensitive in this operating state. Because of their out-of-round cylinder bores, they produce more "blow-by gases" and cool down more quickly - which promotes condensation.

In the case of small sizes, the effect is all the more dangerous because even small amounts of condensate reduce the lubricity.

Almost no other manufacturer uses aluminum light-alloy engines in small displacement classes, where the weight advantage is only small anyway. One of the exceptions is Peugeot. However, the small aluminum engines of the French have no problems with ice formation. The Peugeot technicians attribute this, among other things, to good ventilation.

At VW, this was exactly where the central weak point was. The ventilation hose on the Wolfsburg model is positioned so unfavorably that it sometimes freezes completely and no longer releases any moisture at all.

Those: http://www.f-tor.de/freestile/board_free/showthread.php?t=2649

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Another point would be the inflow of cooling air into the engine, which is fed into the engine compartment through the factory inlets in the front while driving.

If this air flow hits a critical point, more condensate can form due to this local cooling.

7. The interaction of all influencing factors

The previous points all explained various influencing factors that affect the complex "timing chain drive" system.
Summarizing all this in order to get an overall picture should be under this point
happen. For a better overview, the most important factors are briefly listed again.

- Longlife-Öl
- Longlife-Intervall
- Frequent short trips
- Blowby formation
- Oil mist separation
- Particulate entry (soot, glass fiber, oil carbon) in the oil
- Water entry into the oil
- Oil sludge formation
- Premature cooling of the engine due to light metals
- Hydrogen embrittlement
- Stamping of the link plate with the manufacturer's name
- Increased oil pressure due to defective oil pumps
- Resonant vibrations
- Running rails without sufficient lateral guidance
- Corrosion-prone chain materials
- MPI or FSI technology with or without turbocharging
- Unfavorable cooling and introduction of airflow into the engine compartment

Due to its properties, long-life oil burns/evaporates in the upper area of the cylinder wall. The resulting very fine soot particles get into the engine with the other blow-by gases and thus also into the oil.

If the oil stays in the engine for 30,000 kilometers or 2 years, more and more soot will appear. Oil carbon and oil sludge are formed. Because the chain is lubricated from below and also gets oil via the intermediate shaft, it takes oil up the chain parts as it runs concentrically, where it sprays off the chain due to the high rotational speed and the centrifugal forces and ends up on the inside of the chain case.

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This is a fairly cool area of the engine. On the one hand because the space is not directly adjacent to the hot cylinders and forms a cavity. On the other hand, because the chain case is an aluminum part with a thin wall. Here the part cools down considerably. When driving, unfavorable flow of cold wind can get into the engine compartment, right into the gap between the engine and the air filter housing and hit the outer wall of the chain case directly. This cools him down.

The oil mist is thus deposited on the wall, slowly drips down the wall as it cools and slowly separates the soot parts.

They stick to the inner wall of the chain case. Over time, more and more particles accumulate on those that are already there. Thick deposits and accumulations occur. Similar to stalactites.

This is the only way to explain pictures like the one below.

It shows a view through the oil filler neck onto the wall of the chain case. The thick oil sludge is clearly visible. The following picture shows the muddy inside of the chain case

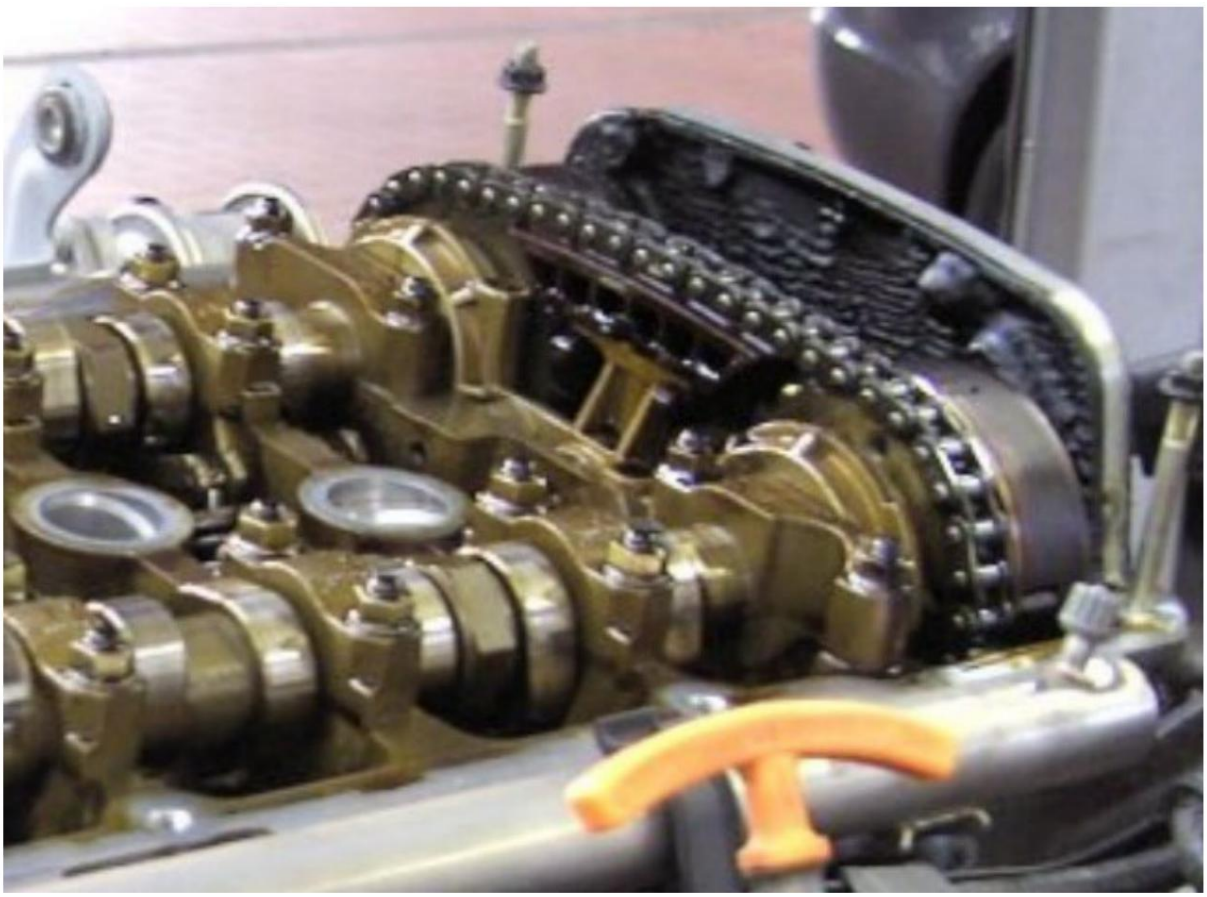


Image 7_1 - muddy inside of the chain case (to the right of the camshaft adjuster)

Machine Translated by Google

Residual combustion gases from the cold start phase condense into the so-called aqueous blow-by liquid, which collects in the oil. The PH value of Blowby is given by institutes as PH1, i.e. extremely acidic. In addition, the oil is damaged by the ingress of water. There are tears in the lubricating film in certain areas of the engine, which will be explained in more detail later. There they contribute to wear and tear.

The so-called oil mist separator is located in the area of the oil cap under an elevation of the cylinder head cover. Its function has already been explained under **point 3.8 .**

If it is not efficient enough and there is no adequately dimensioned ventilation, it can easily lead to an unfavorably large accumulation of blow-by in the engine. Over the course of its long life, it would be exposed to ever increasing concentrations of this harmful substance. If certain areas of the engine were hit unfavorably by the inflowing driving air, larger amounts of blow-by could also occur here.

A corrugated hose leads from the housing of the oil mist separator to an opening in the suction bridge. The junction is electrically heated. See **Appendix 5.4_1.**

Blow-by gases separated from the oil are fed back into the combustion process via the intake tract. If watery blow-by with oil residues gets into the area of the intake valves due to the negative pressure prevailing in the intake manifold, damage from coking and corrosion can occur here.

Whereby FSI engines would be far more at risk than our VR6 MPI engine. This could actually only happen if the oil mist separator were not working properly.

If blow-by gets into the area of the cylinder head with the camshaft bearing, bearing damage could occur here, caused by the entry of hydrogen into the bearing materials, which usually contain copper alloys.

Like tempered steel, copper is very susceptible to the entry of hydrogen and develops a great affinity for atomic hydrogen.
See **Annex 2.3_3** and Annex **2.3_4.**

High-strength and tempered materials such as timing chains are also susceptible to hydrogen entry. Since the chain is constantly immersed in oil and the oil mist separator blow-by-oil mixture can drip onto the chain, it is constantly operated in an environment containing hydrogen. It accumulates with this substance and can be at risk of breaking if the hydrogen is not constantly flushed out of the structure over long distances.

In the first models from 2003 to 2004, the Sachs timing chains are highly susceptible to breakage. The manufacturing company stamped the company name into the link plates.
In many Golf 4 R32, the timing chains tore due to this weak point at the factory. Under a pulsating load, as is the case with chain drives, cracks can spread from the edge of the embossing into the inner structure and trigger breakage. **Annex 2.3_2**

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In addition to the pulsating load, there are operating vibrations in the engine and vehicle. They can cause certain parts to resonate, which can adversely affect the overall system. If the running rails are not designed to prevent the chain from slipping sideways, critical operating conditions can occur under load.

The chain would slip sideways or could hit.

The soot and oil sludge produced by long-life oil in the long-life interval can damage the oil pressure pump to such an extent that the bolt can no longer function properly. The pump therefore generates too much pressure.

This acts on both chain tensioners, which now apply increased force to the chain. It digs into the material of the chain guide rails and releases abrasive, dangerous glass fiber parts, which now flow with the oil flow. See **point 6.5**

In addition, an effect can develop that often occurs with motorcycles. Chains that are too tight tend to open up.

Oil sludge is also caused by the fact that the additives are used up prematurely due to the high proportion of blow-by in the oil and the particles are therefore no longer kept in suspension.
The result is sludge formation, see also **point 4.3.**

So much for a brief repetition of the influencing variables and their effect in detail.

More interesting is the joint behavior of all influences in the system.

The particles in the oil such as carbon, soot and glass fibers slowly wear out the parts of the chain. This makes them a little thinner in all parts and the chain more unstable.
Carbon, soot and oil sludge caused by blow-by and the resulting reduced proportion of additives in the oil damage the bolt in the oil pressure pump, which now generates more pressure and passes it on to the hydraulic chain tensioner.

These press with maximum force on the chain, which has already been weakened by abrasive wear.
It also lengthens as a result, so it becomes wider in overall length and also deforms more laterally.

If vibrations caused by certain driving and operating conditions are passed on to the engine and its parts, various sensitive parts of the chain drive can resonate. This would also result in increased wear.

The stretched chain can slip sideways on the rails, which have insufficient guides, or partially hit. The rails and sprockets can be damaged by this no longer optimal straight run. Running noises arise, which the driver can perceive as scratching, clicking and scraping. Wear leads to increased fiberglass and metal chippings.

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The blow-by dilutes and acidifies the oil, the lubricating film breaks off with locally increased wear.

In winter with prolonged frost, ice can form with serious consequences for the engine. Major engine damage is possible.

Due to the lengthened chain, the control times are adjusted in such a way that the engine runs unevenly, loss of power and increased fuel consumption.
The chain damaged by the introduction of hydrogen can tear in the event of sudden peak loads. This could be a load change at high rpm or an engine start on a cold morning.

In the case of Sachs chains with embossing, the increasing operating load can lead to breaks.

8. The professional repair

A professional repair depends primarily on a good workshop.
If a workshop is not able to diagnose the defect, there is usually no point in fighting for a repair and having it carried out in this workshop.

If you are not able to recognize the error, you will certainly not be able to repair it professionally.

Good workshop personnel can already tell from the sound that something is wrong. A few specialists can even recognize the chain elongation directly from the noise.

You should have the error memory and the measured value blocks 208 + 209 read out.
More on this under **Points 5.1** to **Point 5.2 :**
In addition to the fault memory entries, a manual visual inspection MUST be carried out.
This is the only way to tell if and how far the chain has stretched.
The procedure is described **in point 5.3.**

Important for documentation. You should be on site during the visual inspection and take pictures of both viewing windows to record the position of the control cams.

As a rule, if the result is positive, it should first be clarified who has to pay for the repair costs, which can easily amount to 3500 euros and more.
People who still have a factory warranty or new car warranty are in a good position. The latter usually pays 100% up to 5 years and 100,000 kilometers.
Unfortunately, those who have a used car guarantee or dealer guarantee are in a slightly worse position. In most cases, 100% refunds are not given here.

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Anyone who has neither a guarantee nor insurance is dependent on goodwill from the group.
The goodwill request is usually made by the dealer. It is recommended that you contact customer service again, as experience has shown that there are major differences in the goodwill arrangements. A lot of dealers don't really try. This is shown by cases in which A3 drivers changed dealerships and received better goodwill from the new dealer despite the same vehicle and a defect.

Once the details for the assumption of costs have been clarified, it is a matter of having the car repaired optimally.

Some dealers indicate repair days from 2 to 2.5. You can repair without completely removing the engine. This is entirely doable. But not recommended. Hardly any worker can work precisely under these circumstances.

It is better to take the engine completely out of the vehicle and then repair it.
In this case it usually takes 4-5 days.

Many dealers want to replace just the top chain, or just both chains without a camshaft phaser. There are also cases where no new tensioners and rails were installed. Something like that doesn't make sense. Most of the affected vehicles are built between 2003 and 2005 with old camshaft adjusters. In the internal repair instructions from the factory to the workshops, the dealers are asked to identify the installed parts based on their part number in order to exchange them for newer ones if necessary. These part numbers are listed under **item 3.6**

If newer camshaft adjusters are not installed, in almost 99% of all cases engine jerking and rough running will occur shortly afterwards.

So make sure that all parts are replaced. As of now, this would be:

- Obere Rollenkette
- Lower roller chain
- Both camshaft adjusters
- Both chain tensioners
- All running rails

Other important points that are not covered by the repair specification but are useful because the engine is disassembled:

- Checking the dual mass flywheel for damage or traces of overheating
- Checking the clutch (for manual transmissions)
- The sprockets on the intermediate shaft

You would have to pay for these parts yourself. At least with a mileage of around 80-100,000 kilometers, replacing the clutch makes sense. Material price approx. 400 euros
There is no working time here, as is the case with the dual-mass flywheel, which costs approx. 500 euros.
Installing new sprockets prevents premature chain wear.

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A chain drive can only run optimally if the sprocket and the chain are undamaged. In this way, both “partners” can “run in” together.

Useful additional work:
It is important to inspect all attachments for oil sludge and coking. Especially the parts of the chain case. Here the workshop should be given the order to clean these parts by hand until everything is metallically bright. This prevents it from being flushed into the system. Later removal is no longer cost-effective to carry out. Only the upper chain case could be exchanged when installed. However, labor costs of approx. 700 euros are incurred here.

The cleaning work should be documented by the workshop with before/after photos.

If you find out during the diagnosis that there are heavy traces of silt and mud in the area of the oil filler neck, it is worth having the engine flushed out with the old oil using Liqui Moly Motorclean. This cleans the inside of the engine.

Then you should have good oil such as Mobil 1 0W40 filled in.
The long-life interval should be changed to a fixed interval. And at the latest after 10,000 - 15,000 kilometers or 1 year, whichever comes first, the further oil changes should be carried out.

If everything is properly repaired, you should ask the workshop to read out the measured value blocks 208 + 209. The values now determined are the "true" zero points of the camshaft position sensors. This is the only way to later get a clue as to how the chain lengthens.
To be on the safe side, I would have these values read out every 3 months.

Pictures of a repair can be viewed in **Appendix 7_1 .**

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8.1 Workshops and timing chain damage

The SWR car magazine Rasthaus reported on October 4th, 2008 about drivers with Audi A3 3.2 quattro vehicles and their experiences with workshops and the goodwill handling.

9. Quoting SWR

Defective timing chain: Car buyers on workshop odyssey

A timing chain should actually last the entire life of the car. If not, the manufacturer will fix it - thought a rest house viewer. Little did he know that he was in for a lot of trouble.

Martin Hertweck bought his dream car six months ago. The used Audi A3 Quattro was worth just under 20,000 euros to him – quite a bit for an average salary. After only two weeks the motor rattled. The performance decreased, the consumption increased. Concerned, Hertweck informed himself on the Internet. Everything pointed to a defect in the timing chain. That drives the valves. Hertweck asked his Audi workshop. She was at a loss, there was nothing about it in the internal product information.

The timing chain usually lasts the lifetime of the car. So it's all just imagination? With TÜV expert Eberhard Lang we do the listening test on Hertweck's Audi. Small clicking noises over and over again, that's not what a V6 engine should sound like. If it really is the timing chain, Hertweck must take action. If damage occurs to the valve train and ultimately even the timing chain tears, this can lead to major engine damage with high repair costs. A clear case for Hertweck. Audi should fix it. He still has no idea what might be in store for him. Another Audi driver already knows: Michael went from one Audi dealership to the next with his rattling engine and had to listen to it: Not a defect, but "state of the art". Ten months passed before the truth finally came to light: it was indeed a defect in the timing chain. Audi apologized, speaking of a "regrettable isolated case". But there are enough victims of Audi timing chains, the manufacturer knows the problem: We have documents that show that Audi has intervened in production several times because of this. The VR6 engine is affected, installed in the A3, TT and also in the Golf, among others.

Audi declines an interview. We were informed in writing: "We have become aware of a few cases of complaints (...) for vehicles built before mid-2004." But now the problem is solved.

But disgruntled customers driving 2003 and 2004 A3s won't benefit. Some have had similar experiences with the workshops as Michael.
Expertise looks different. Audi writes to us: "The information" from the car dealerships "has only really been made clear since May 2008."

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The workshops only find out about it years after the production error. Customers pay for it. You must now hope for goodwill from Audi. But nobody can rely on that.
That's why Martin Hertweck has taken out a used car guarantee. Of course, they only pay if there is damage. But that's a matter of opinion, as long as the engine rattles, it's a defect, but not damage. This would only happen if, for example, the chain snaps, the tensioners are damaged or, in the worst case, the engine completely gives up the ghost. The insurance is not forced to bear material defects, so Hertweck could be left with the costs completely. And that for a defect ex works that the customer cannot do anything about.
No wonder that some Audi fans want to get rid of their A3 quickly before things get tricky.

Those: http://www.swr.de/startklar/
Video: http://www.youtube.com/watch?v=8KvDz2TGJv0
Editor: Mr. Thomas Kurella, c/o Exemplar, www.vorbild.tv

Unfortunately, the above report reflects the reality as it is currently experienced by many customers whose car has a defective chain drive.

Many workshops are overwhelmed with a diagnosis. When the repair is then carried out, many are not able to repair it professionally according to the instructions.

Sometimes only 1 chain or 2 chains are replaced. Tensioners, rails and camshaft adjusters not at all. The goodwill regulations are also totally opaque.

Drivers of almost identical vehicles in terms of age and mileage get totally different percentage shares.

Note: Since
March 2009, the former TV magazine Rasthaus has been on TV under the name *"Startklar"* .

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10. Prevention of damage

So far, only the current state of the art has been listed, which influencing factors cause the damage and how the damage occurs.

Based on this information, certain measures can be taken in the current state of affairs to prevent damage or mitigate an already weak one.

It is essential to prevent the oil from becoming so polluted by the ingress of particles that it wears out the chain and thus causes chain elongation. Also, there must be no excessive formation of blowby, which acidifies the oil and corrosively attacks high-strength and tempered components and copper-based elements.

Without structural intervention, the normal driver does not have many options.
But they are effective enough to prevent damage.

- do not use oil in the long-life change interval
- do not use oil according to the long-life specification
- no cold starts and short trips under 20km

The oil must not be long-life oil (see **point 6.1 for explanation).** Many drivers are very happy using Mobil 1 0W40. However, there are other very good oils (see **Appendix 8_1)** that are recommended.

The oil should not be left in the engine for too long and the service interval should be changed from long-life to fixed intervals. It proved useful to use the intervals from previous models. Maximum 10,000 to 15,000 kilometers or 1 year, whichever comes first.
In this way, solids dissolved in the oil and blow-by do not remain in the oil circuit for too long.

In order not to produce excessive particles and blow-by in the first place, you should drive more consciously. Cold starts and short trips should be avoided wherever and whenever possible.
According to measurements, the VR6 engine needs up to 20 kilometers to reach operating temperature due to its mass and large liquid volume. The pure cooling water temperature, which has been improved to 90°C, is no indication of the oil temperature, and certainly not of the operating temperature of the entire engine.

For this reason, you should drive long distances more often and also drive the car well on the freeway. This is the only way for the water in the sump to evaporate.

But: Don't step on the gas immediately shortly after the motorway entrance. The engine must first be well warmed up, otherwise there would be excessive wear. The reason for this is the temporary break in the lubricating film. Lubrication cannot take place where there is water. Material rubs
on material. Therefore carefully increase the load.

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If you have bought the car new or used, you should check certain points regularly so that you are always informed about the current status.

It is actually enough to unscrew the oil cap every month and look into the oil filler neck. If black mud or soot forms here, then something is wrong and you should react as quickly as possible. The same applies if there is a sharp smell of petrol/solvent from the oil filler neck. This is an indication of too much fuel and blow-by in the oil, as occurs when driving short distances.

You can also have the measured value blocks 208 + 209 read out when you buy them in order to have an approximate "zero point". This is the only way to see changes.

The measured value blocks could be read out approximately every 3 months. Drifting away can be recognized very early on and you can counteract chain elongation in a targeted manner.

In any case, you should always carry out the noise test. Examples of undamaged, defective and repaired engines can be found as a video on the DVD or in the noise database in the forum at www.A3quattro-Forum.de .

Further measures that are useful but not absolutely necessary are discussed under **point 10.1 .** This tends to affect do-it-yourselfers or people who know workshop staff who can carry out these conversion measures.

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10.1 Workshop for better monitoring / remedy

There are 2 important factors in this issue. The oil pressure and the blow-by discharge rate.

Both important tools for detecting and avoiding defects.
As already mentioned in point 5.6, damage to the oil pressure pump and the resulting increased oil pressure in the system play a not entirely subordinate role.

Unfortunately, there is no way of reading the oil pressure in the current Audi A3. Be it via the display in the FIS or via OBD. There are no oil pressure sensors installed whose values could be used. An above-average pressure would be quickly recognized. Appropriate countermeasures could be taken.

Measuring the oil pressure manually is very difficult because a suitable connection is very hidden on the engine. Audi states this point, but unfortunately the air conditioning compressor has to be removed for this. It is time-consuming and costly and you would only ever have a momentary value. One continuous monitoring is not feasible in this way.

For this reason you could use the blind plug over the oil filter housing. An oil pressure sensor could be screwed in here, a cable routed up into the fuse box and fitted with a connector. Now all you have to do is connect a corresponding pressure indicator with a mating connector, and you can constantly monitor and log the current pressure.

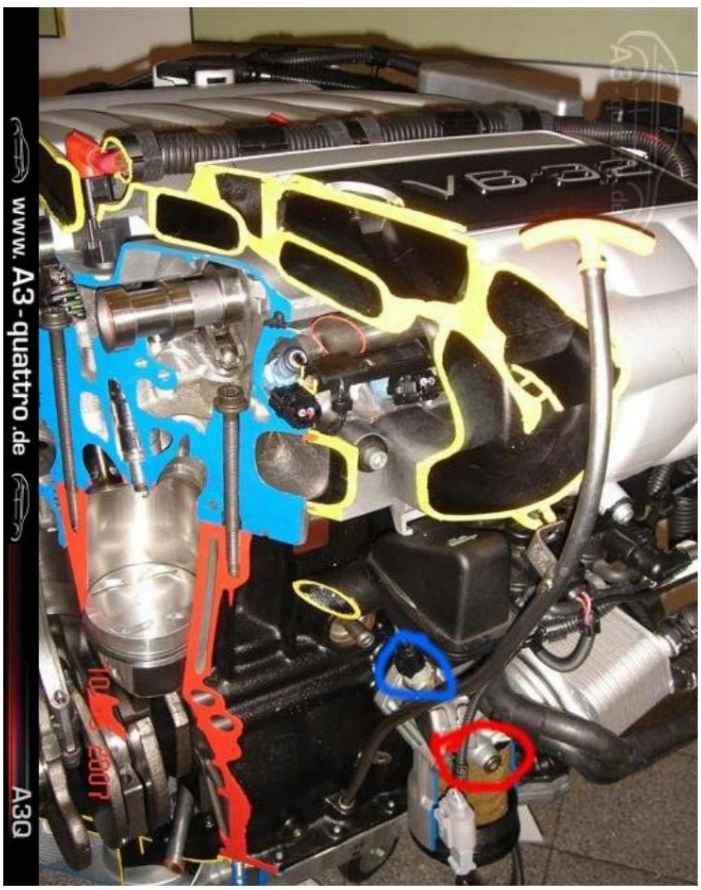


Figure 10.1_1 – Location of the connections (marked in blue in the figure,
the access dictates the Audi. Red is the alternative access for the oil pressure sensor.)

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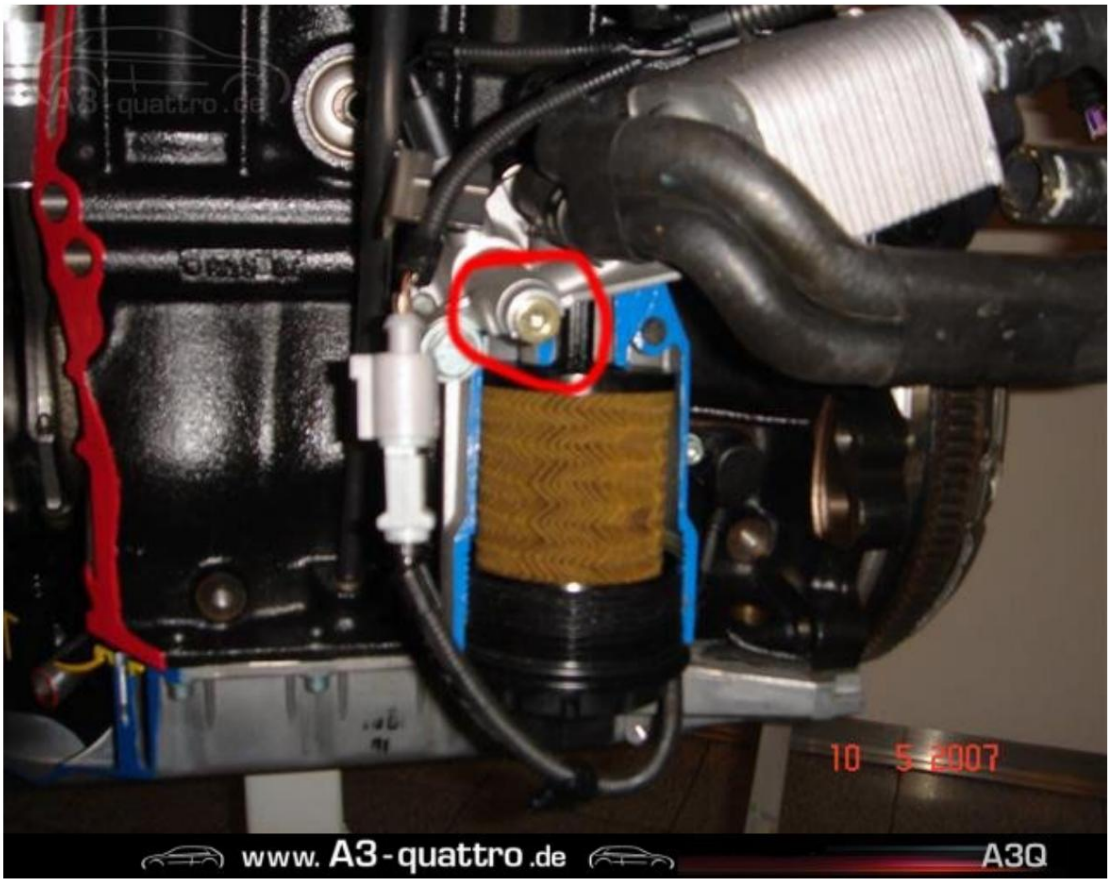


Figure 10.1_2 – Location of alternative connection



Image 10.1_3 - MFA XP in the Golf R32

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A connection to the CANBUS would be optimal, as is possible with the Golf R32 using MFA XP.

Unfortunately, this does not work with the Audi A3 CANBUS variant.

This point can be read here in the forum.
http://www.a3quattro.de/include.php?path=forum/showthread.php&threadid=5420

Another way of containing the damage would be to use structural measures to expel as much blow-by as possible to the outside or to collect it in a targeted manner and then dispose of it.

External and more efficient oil separators could be installed and connected to the series separator using a bypass.

The less blowby in the system, the better for everything.

Reconstruction measures are dealt with in the following thread in the forum.
http://www.a3quattro.de/include.php?path=forum/showthread.php&threadid=5484



Figure 10.1_4 - Oil accumulation in the socket area of the oil mist separator

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Image: 10.1_5 - Oil accumulation in the connection area of the hose from the oil mist separator to the suction bridge

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11. Summary and discussion of the results

Of all the damage with timing chain elongation and timing chain breaks that we are aware of, the drivers stated that they operated their cars with oil according to the long-life specification in the long-life change interval, as specified by the manufacturer ex works.

In detail, this means that the cars can only be driven after approx. 30,000 kilometers or 2 years of operation, whichever comes first, go to the workshop for service.
The oil used was oil according to the Longlife II or Longlife III standard.

Drivers without damage mainly drive very long distances or only a few total kilometers, but this again increasingly in the long-distance profile using the solid oil change interval. On average, they had an oil change every 10-15,000 kilometers.

The consequences and causes of long-life operation have been explained in detail in the previous points and the relationships described.

Finally, a short summary.

Cause:
In the long-life interval, long-life oil forms an excessive amount of particles in the oil circuit with predominantly frequent cold starts and short-distance use.

In addition, frequent short-distance trips generate an excessive amount of blow-by, which mixes with the oil.

This aqueous and PH-1 acidic blow-by contributes to the embrittlement of the link plates due to hydrogen entering the metal structure.

The chain is corrosively damaged and weakened. In addition, particles in the oil such as soot, oil carbon and glass fibers wear out the chain parts. It lengthens and also gets more play on the sides. The chain is also stimulated by the oscillations and vibrations that are introduced depending on the driving condition and by certain engine speeds. It slips on the rails which have insufficient or no lateral guidance. Sometimes the chain can open. This creates dangerous continuous vibrations, which particularly damage the Sachs chain with its deeply embossed logo. The chains, like the chain described in **Appendix 2.3_2 ,** can get their starting point of the later break at it. The particles in the oil also damage parts in the oil pressure pump, as a result of which they pressurize the chain tensioner above the permissible pressure. The chain experiences additional mechanical stress. Furthermore, the chain is pressed more strongly onto the guide rails by the high pressure, whereby more glass fibers are loosened and washed into the oil.

Water entry through blow-by causes lubricating film breakage and increased wear of the parts in places.

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The chain, weakened in this way, is now susceptible to tension peaks such as those that can occur during a cold start or during load changes. She breaks. The fine-grained fracture with its distinctive signs of hydrogen embrittlement is typical. The break comes from within. Not from the outside in like in normal violent fractures.

For the first chains manufactured by the Sachs company, the embossed lettering was mainly responsible for the breaks due to their notch effect (see REM analysis in the **Appendix 2.3_2).**

Remedy:

The damage can only be avoided by turning off the attack parameters as much as possible. These would be first of all oil and oil change interval. The longer the dirty oil stays in the engine, the more it can destroy.

You should use good oil such as Mobil 1 0W40 at fixed intervals. Alternative, other good oils are listed in **Appendix 8_1 .** Never more than 10 to 15000 kilometers or 12 months, whichever comes first.

You should also avoid cold starts and drive as few short trips as possible.
Thanks to these measures, the oil is not acidified too much by blow-by and, thanks to the short change, does not remain in the engine for too long in order to damage the parts excessively through corrosive mechanisms. Wear due to particle entry is also kept to a minimum here.

If you also always warm up the engine gently and often complete long motorway journeys, you reduce wear in the cold start phase and let a lot of blow-by out of the engine over long distances. Due to the longer heating time on long distances, part of the hydrogen that is dissolved in the chain material escapes from the structure again. New hydrogen can hardly penetrate because the concentration in the oil is very low.

In the case of an old Sachs chain with a sharply embossed logo, there is unfortunately nothing you can do as a precautionary measure, since these are vibration fractures and you cannot have any direct influence on the origin of these vibrations.

Outlook:

The knowledge gained with the VR6 3.2 MPI engine can actually be transferred to various other units that are operated with long-life oil in long-live intervals and short-distance operation. Also at other companies.

Engines with parts made of aluminium/light metal alloys would have to be viewed critically as they significantly accelerate the condensation of blow-by gases due to the faster heat dissipation and are therefore responsible for higher amounts of aqueous blow-by solution in the oil.
The small oil filling quantities and turbocharging would also be disadvantageous. As a result, the oil acidifies more quickly, and the pressure of the turbo ensures that it cannot be bled sufficiently. Due to their design, engines with FSI technology are more susceptible than MPI engines.

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Understanding:

The problem of lengthened and torn timing chains on the VR6 3.2 MPI unit from the VW/Audi group is not an engine-specific problem, but a chain of unfortunate factors.
The damage to the chains is only the result of various harmful influences that can also prevail in other engines, sometimes even more than in the VR6 engine.

Table 1.1 in **Appendix 1_1** clearly shows that not only VR6 engines are affected.
In terms of mileage to damage, the VR6 engines even last longer than the 1.6 and 1.4 engines.

If you look at **Diagram 1.1_1** in **Appendix 1_1 ,** you will notice the large number of damages in the production month of March 2004. Something must have gone wrong somewhere in the production process. Be it the chain manufacturer Sachs or the engine builders at Audi.
There is no other way to explain such a high number of damages.

If you stick to the knowledge you have gained, you will definitely have a lot of fun with this great car for a long time. This is shown most impressively by the videos by A3Q moderator Klaschi on the report DVD (title: Night Edition, Summer Edition and Winter Edition)... A3Q wishes you a lot of fun !!!

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12. Conclusion

The authors of this elaboration would like to thank all the people and institutions mentioned under point 13 for their active support, without whose help it would hardly have been possible to obtain and write down this extensive knowledge of such a complex system.

This elaboration is intended to illustrate the complicated interaction of various influencing factors, as well as to help drivers of affected models to avoid damage.

Used car buyers can get a better picture of the condition of a vehicle before buying it. You can avoid an expensive repair, which is usually estimated at 3000 to 4000 euros.

Buyers of new cars will be able to enjoy driving for a long time without major damage if the findings are followed. However, only up to week 22 in 2009, since Audi will stop producing the Audi A3
with the VR6 engine.





Christian Schlenger *Michael Lorch*

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13. Literature- Image and source credits

literature

Frontispiece of the VR6 engine
Offprint of MTZ/ATZ extra, The new Audi A3, page 92, Vieweg Verlag, April 2003
courtesy of Dipl.-Ing. Michael Reichenbach (ATZ_MTZ/Springer Automotive Media from February 27, 2009)

2 and 2.1 Details of the VR6 engine
Offprint of MTZ/ATZ extra, The new Audi A3, pages 92-98, Vieweg Verlag, April 2003
Author: Dipl.-Ing. Uwe Kirsch (VW), Dipl.-Ing. Frank Reschke (VW), Dr.-Ing. Bern Ebel (VW), Dipl.-Ing. Stefan Lieske (VW)
Excerpt with the kind permission of Mr. Dipl.-Ing. Michael Reichenbach (ATZ_MTZ/Springer Automotive Media from February 27, 2009)

Appendix 2_1 Data sheet Audi A3 3.2 quattro customer
service Audi AG Ingolstadt,

3.8 Fig. 3.8_2 Oil mist separator
Cutaway model of the company Mann & Hummel from the booth at the IAA Frankfurt 2007

Attachment 2.3_3
Dr. Peter Sommer (www.instrumentetechnik.com) , excerpt from the trade journal, title: On the trail of hydrogen, part: 1, with kind permission for use by Dr. Peter Sommer from 20.2.2009

Attachment 2.3_4
Dr.-Ing. Simone Schwarz (www.materialtechnik.com) , excerpt from the trade journal, title: On the trail of hydrogen Part:2
with kind permission for use by Dr. Peter Sommer from 20.2.2009

Attachment 4.1_1 to 4.1_3 Performance test bench protocols created by Oettinger Performance GmbH Friedrichsdorf

6.11 Background to hydrogen embrittlement Excerpt from
WEBU trade (www.webu-handel.de)

6.2 What is blow-by?
Excerpt on the subject of blow-by (www.motorlexikon.de)

6.5 Entry of dirt particles in the oil
Excerpt on the subject (www.motorlexikon.de)

6.6 Water entry in the oil
Excerpt on the subject (www.motorlexikon.de)

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Pictures

Matthias E.: *Figure 3.1_1*

Markus Hofer:
Image 3.1_2 / 3.2_2 / 3.2_3 / 3.4_4 / 3.5_2 / 3.8_1 / 10.1_1 to 10.1_2 / Appendix 5.4.1_1 /

Martin Raith:
Image 3.2_1 / 3.5_4 / 5.4_2 / 5.4_4 / 5.4_6 / 5.4_7 / 6.4_1 / Appendix 7.1_5 /

Michael Lorch
picture: 3.3_1 / 3.3_2 / 3.3_3 / 3.4_1 / 3.4_2 / 3.4_3 / 3.5_3 / 3.6_2 / 3.8_2 / 5.3_1 to 5.3_4 / 5.4_1 / 5.4_3 / 5.4_5 / 5.4_8 to 5.4_10 / 6.2_1 / 6.4_2 / 6.5_1 / 6.11_1 to 6.11_2 / 6.12_1 / 7_1 / 14_1 / Annex 2.3.1_1 to 2.3.1_3 / Annex 2.3.5_1 / Annex 2.4.1_1 to 2.4.1_8 / Annex 2.5.1_2 to 2.5.1_4 / Annex 2.6.1_ to 2.6.1_8 / Appendix 5.4.1_3 to 5.4.1_12 / Appendix 7.1_1 to 7.1_4 / Table 1.1 / Diagram 1.1_1 to 1.1._3

Christian Schlenger: *Image:*
3.3_4 / 3.3_5 / 3.3_6 / 3.7_1 / 3.7_2 / 3.7_3 / 3.9_1 to 3.9_2 / 4.3_1 / 5.3_11 / 6.9_1 / 10.1_3 /

Andreas Hirsch (Leo67):
Image 3.6_1 / 6.8_1 / 6.8_2 / 6.8_3 / Annex 2.5.1_1 / Annex 7.1_6 to 7.1_9 /

Oliver Baneux:
Image 5.2_1 / 5.2_2 / Attachment 4.2.1_1 /

Daniel Bochtler:
Image 5.3_5 to 5.3_10 / 6.5_2 / 6.5_3 / 10.1_4 /

Tom300:
Image 6.2_2 to 6.2_3 / Appendix 5.4.1_2 / 10.1_5 /

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The authors would like to thank the following people/institutions for their help and support in compiling this elaboration and the topic in general.

Mr Markus Hofer Mr	University of Graz, engine construction
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Frau Sabine S.	REM
Mr. Martin Meng	University of Kaiserslautern
Mann & Hummel	press department
Mr. Dipl.-Ing. Reichenbach Audi Center Maintal	MTZ / ATZ
Dr. Peter Sommer Tom300	Materials Technology Institute, 47661 Issum-Sevelen
Mr. Thomas Kurella Audi	Fotomaterial
customer service	SWR editorial team car magazine Rasthaus

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14. The DVD accompanying the report



Picture 14_1 – The DVD for the report

The authors recommend the DVD for the report.

There are many comparison videos on it, which help the layman with the diagnosis:
Beautifully prepared in direct comparison with the same position of the camera. This gives you a good impression of the damage pattern compared to a repaired engine.
The positions are: from the front, from above, from the side and in the wheel housing

Other damage is also documented.

A used car purchase is also shown, where you should definitely take an intact car with the VR6 engine. This is the only way to tell whether the used car has a defect in the chain drive or not. A few driving videos also show how much fun an Audi A3 can be if the engine is in order.

The DVD is available in the A3Q download area in the form of an .iso file. You can convert it to a DVD with any DVD burning program.

URL: http://www.a3quattro.de/include.php?path=content/download.php
or in the A3Q shop: http://www.shop-014.de/shop-A3quattro.html

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15. Appendix

Appendix 1_1 List of affected vehicles in the forum

Detected A3Q vehicles from March 2008 to February 2009

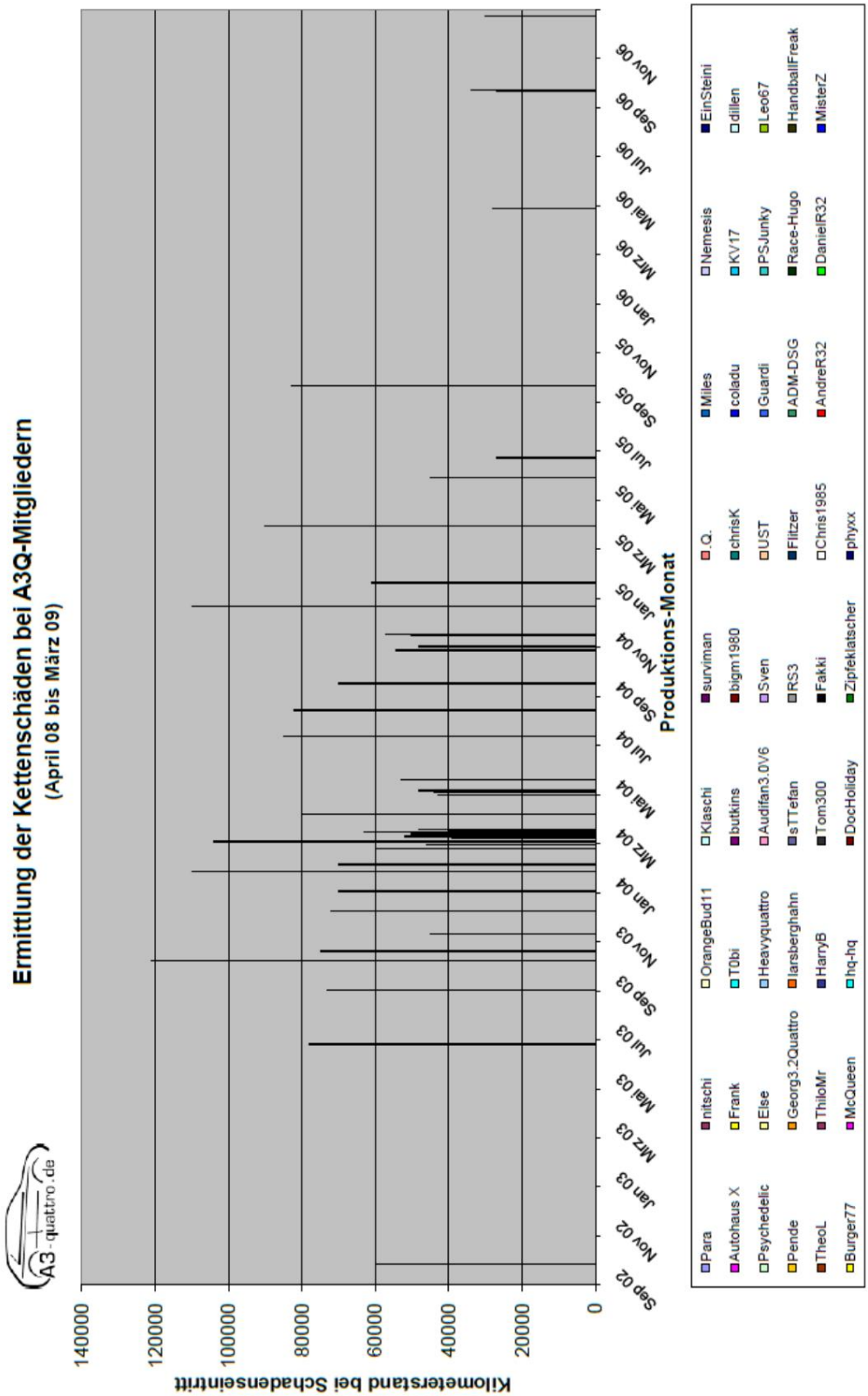
Nickname	Mileage in the event of damage	Year of manufacture of the vehicle
Motor BDB 1 Para 2	73233	2003-09 A3 3.2
nitschi 3	48000	11-2004 A3 3.2
OrangeBud11 4	70000	01-2004 A3 3.2
Klaschi 5 surviman	104000	03-2004 A3 3.2
6 .Q.	86000	03-2004 A3 3.2
	44000	05-2004 A3 3.2
7 Miles	70000	02-2004 A3 3.2
8 Nemesis	48000	05-2004 A3 3.2
9 EinSteini	43000	02-2004 A3 3.2
10 RenaultFreakFFM	80000	04-2004 A3 3.2
11 Frank 12 T0bi 13	121000	2003-10 A3 3.2
Butkins 14 Bigm1980	39000	03-2004 A3 3.2
15 ChrisK 16 Coladu	72000	2003-12 A3 3.2
17 KV17 18 Dillen 19	37000	04-2004 A3 3.2
Psychedelic 20 Else	52000	03-2004 A3 3.2
21 Heavyquattro 22	45000	2003-11 A3 3.2
Audifan3.0V6 23 Sven	46000	04-2004 A3 3.2
24 MisterZ 25 Uqkkih	44000	04-2004 A3 3.2
BurgerST 30	85000	07-2004 A3 3.2
DocHoliday 31 Zipper	36000	03-2004 A3 3.2
32 Guardi 33 PSJunky	50000	03-2004 A3 3.2
34 Leo67 35 Pende	41000	03-2004 A3 3.2
36 George3.2quattro	82000	08-2004 A3 3.2
37 Larsberghahn 38	110000	01-2004 A3 3.2
Phyxx 39 sTTefan 40	54500	10-2004 A3 3.2
RS3	63000	03-2004 A3 3.2
	28000	04-2006 A3 3.2
	60000	02-2004 A3 3.2
	45000	2005-05 A3 3.2
	46000	02-2004 A3 3.2
	90000	03-2005 A3 3.2
	50000	11-2004 A3 3.2
	39208	03-2004 A3 3.2
	70000	09-2004 A3 3.2
	57000	2003-11 A3 3.2
	40000	03-2004 A3 3.2
	48000	03-2004 A3 3.2
	42800	04-2004 TT 3.2
	53000	05-2004 TT 3.2
	75000	2003-10 A3 3.2

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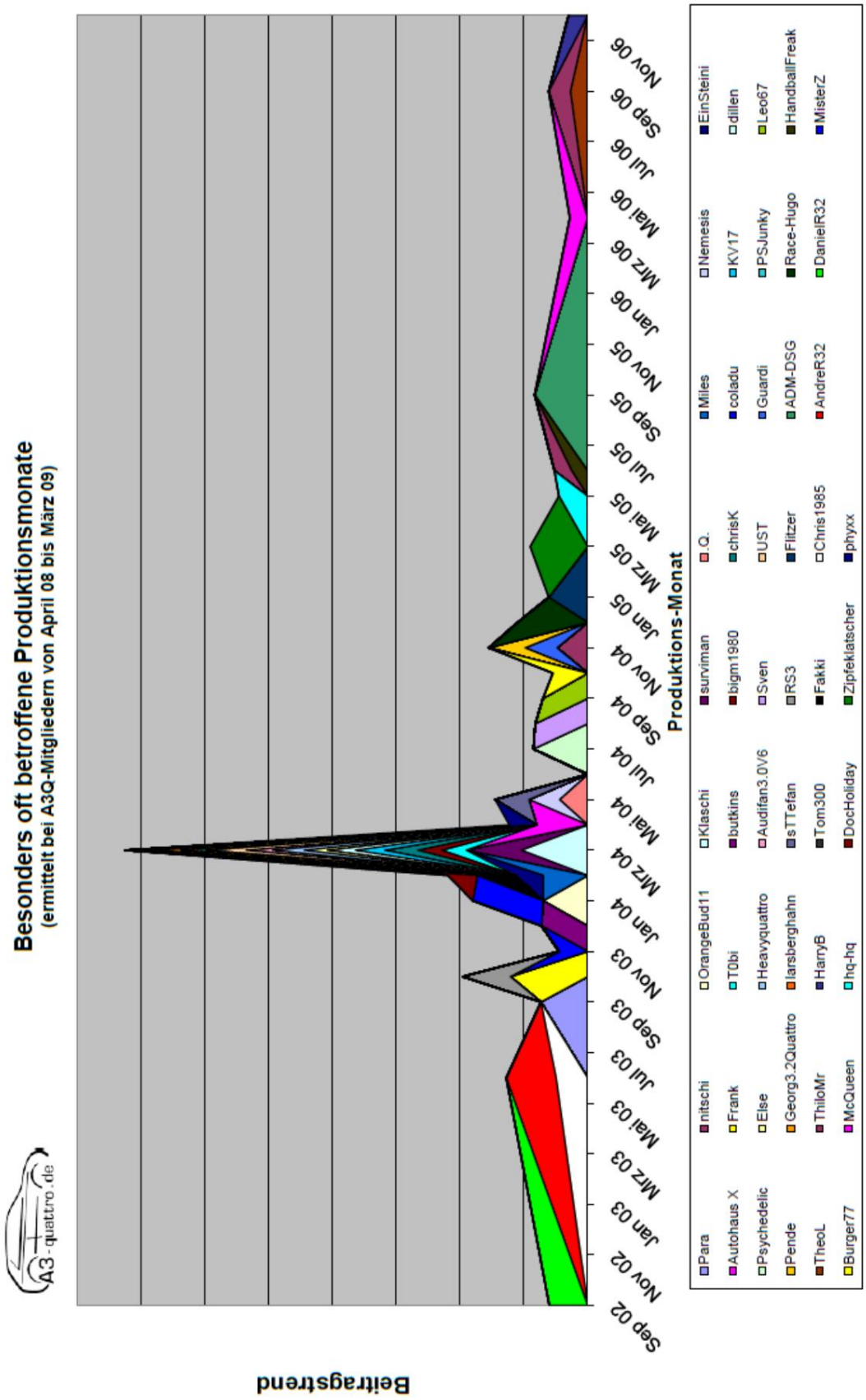
	Nickname	Mileage in the event of damage	Year of manufacture of the vehicle
Motor			
BMJ	41 ADM-DSG	83000	09-2005 A3 3.2
	42 speedsters	61000	01-2005 A3 3.2
	43 Race-Hugo	110000	2004-12 A3 3.2
Engine BUB	44 TheoL	27000	09-2006 A3 3.2
Motor BLF	45 HandballFreak	25000	06-2005 A3 1.6 FSI
Engine BFH	46 Chris1985	49500	06-2003 Golf 4 R32
	47 AndreR32	78000	06-2003 Golf 4 R32
	48 DanielR32	60000	09-2002 Golf 4 R32
Motor BLG	49 ThiloMR	27000	Golf 1,4
	50 HarryB	34000	Golf 1,4

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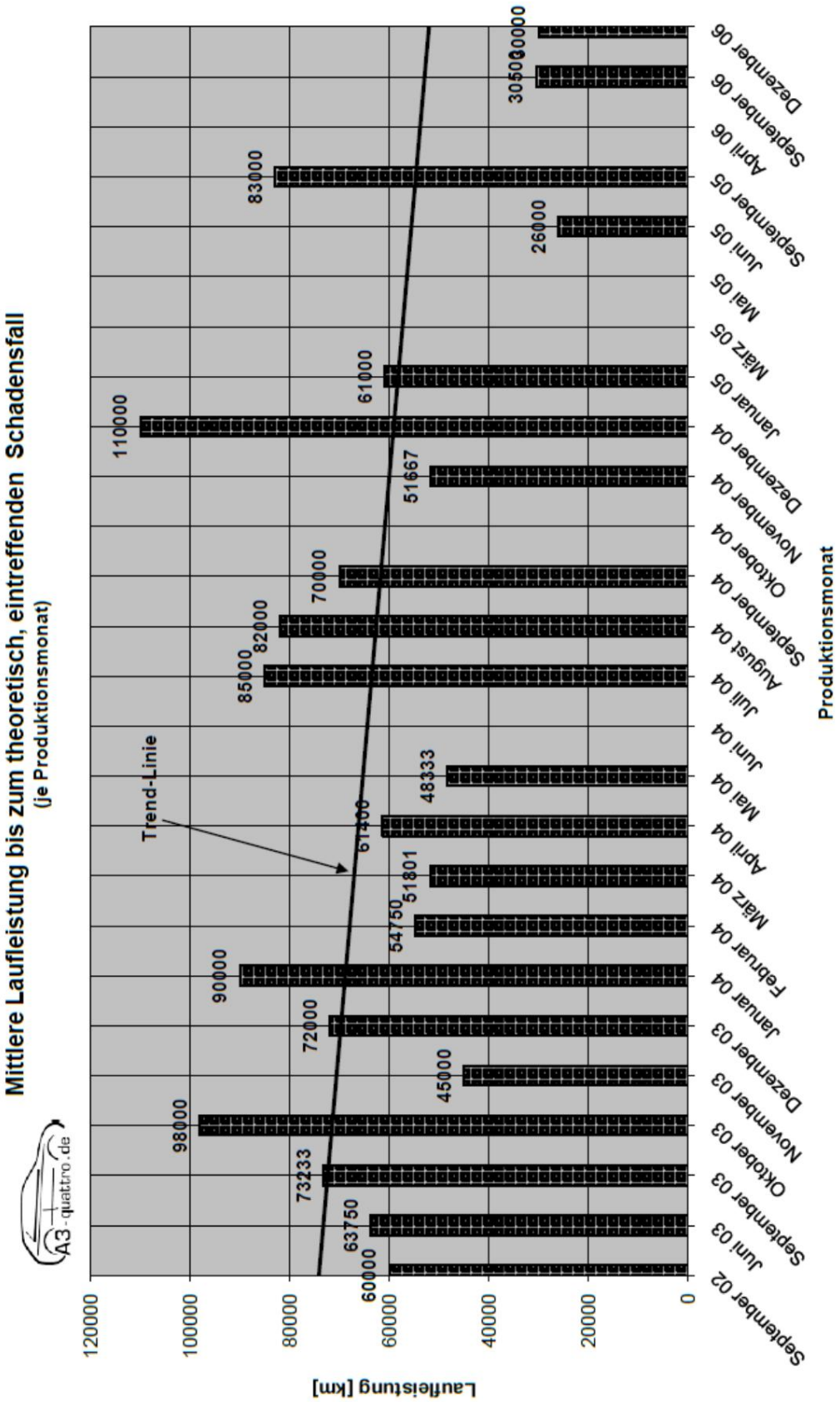
Table 1_1 - Overview of A3Q members with chain damage



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3.3_1 Pictures of the lateral play of the chain, as well as the elongation in the longitudinal direction

Comparison: old Sachs chain (dark) / new Iwis chain (bright metallic)

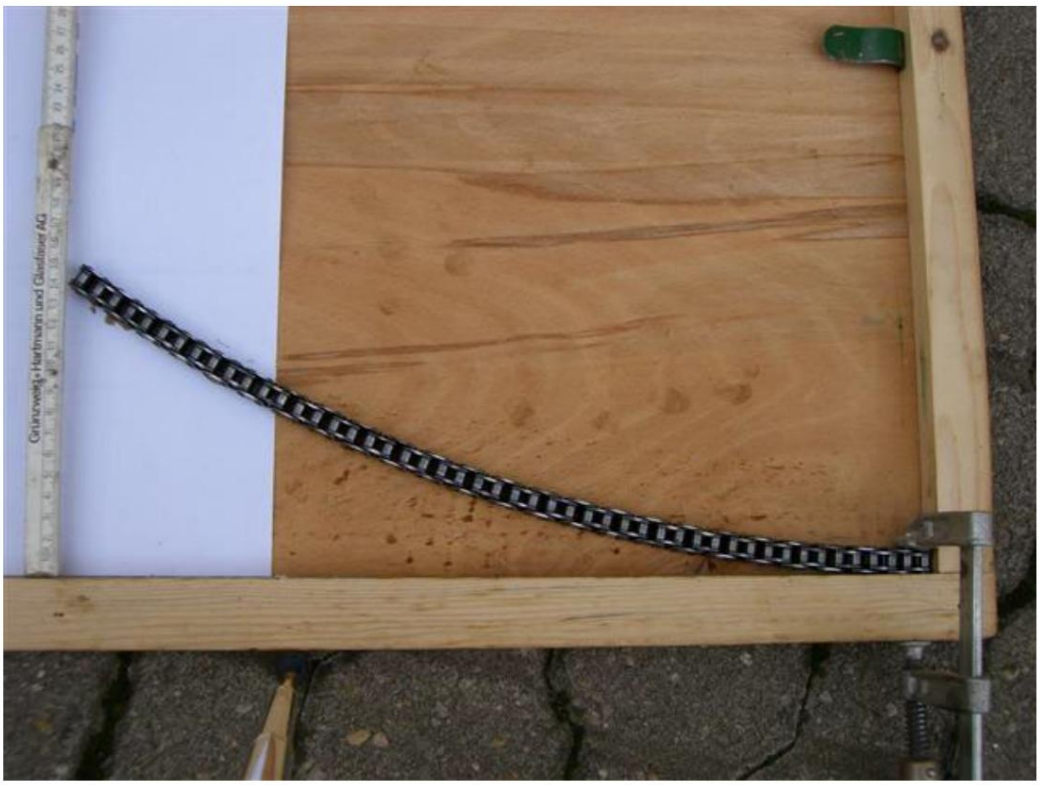


Image: Attachment 2.3.1_1 - lateral elongation of the Sachs chain (approx. 142mm)

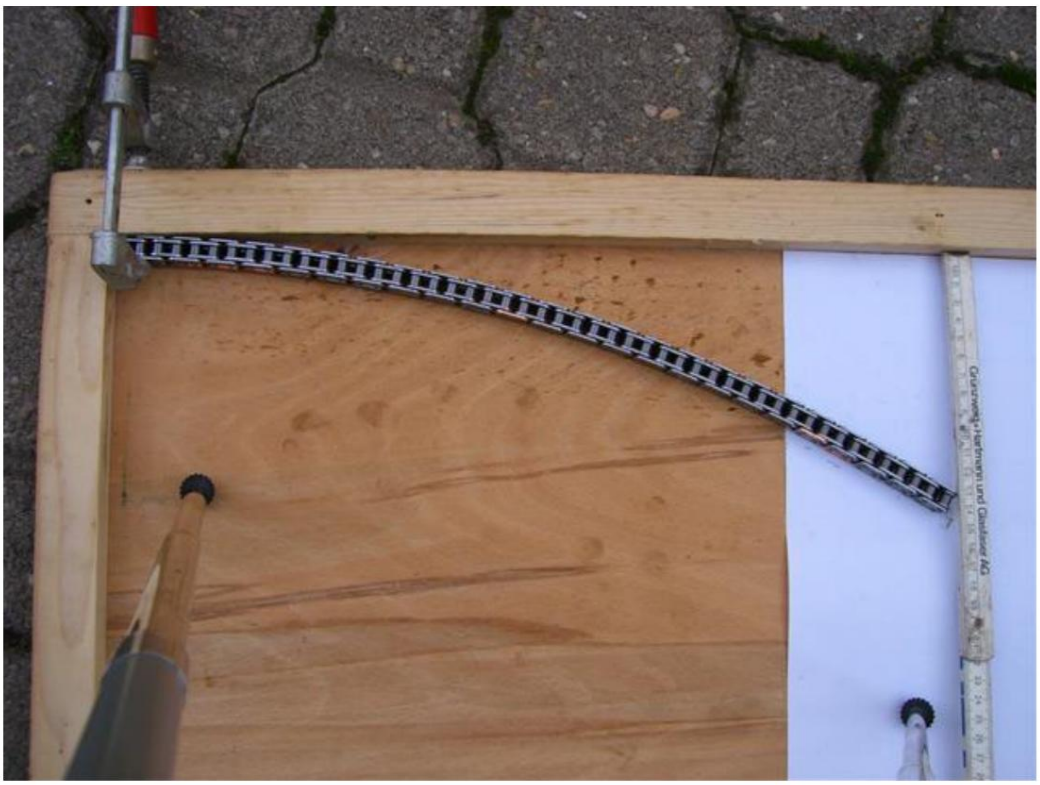


Image: Attachment 2.3.1_2 - lateral elongation of the Iwis chain (approx. 129mm)

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Image: Attachment 2.3.1_3 - Elongation of the Sachs chain and Iwis chain

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Steuerkette der Firma SACHS

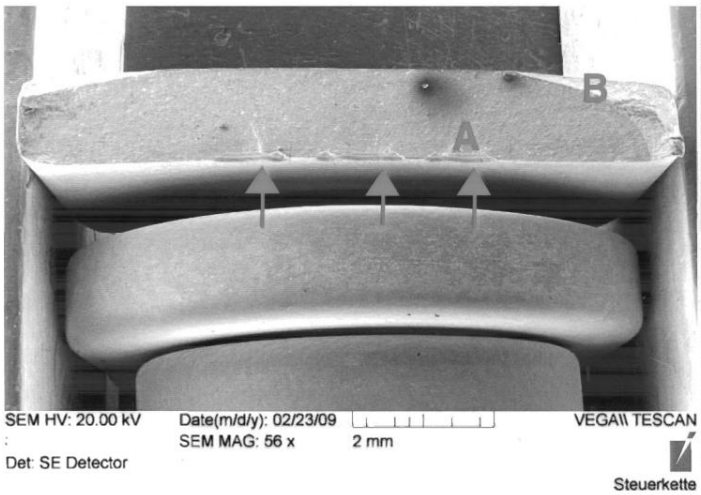


Bild 1: REM-Aufnahme der Bruchfläche

Bruchausgang an eingestempelten Buchstaben (Pfeile)

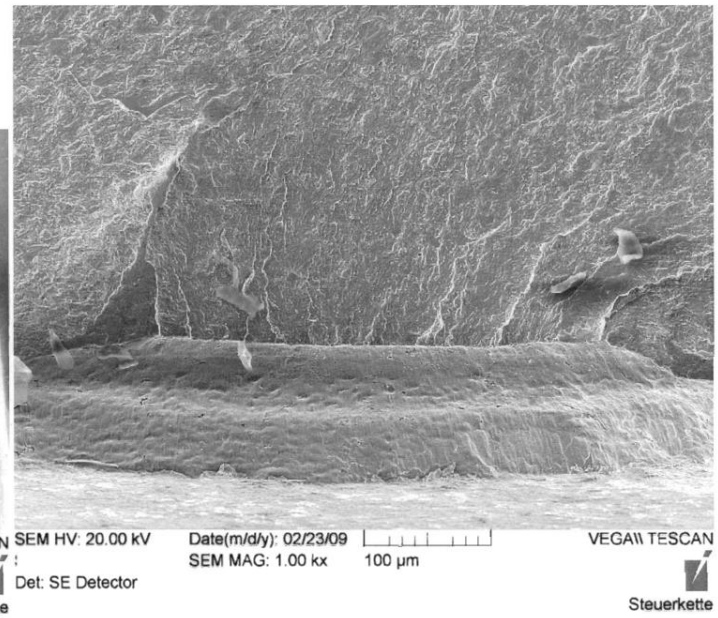


Bild 2: Bereich A bei höherer Vergrößerung

Bruchausgang im Bereich der Stempelung

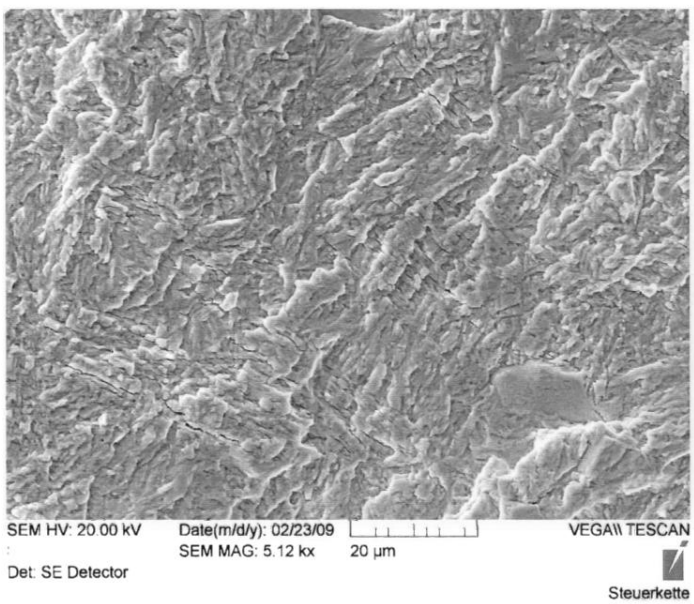


Bild 3: Bruchfläche bei höherer Vergrößerung

Transkristalline, verformungsarme Bruchfläche mit Schwingstreifen und parallelen Rissen

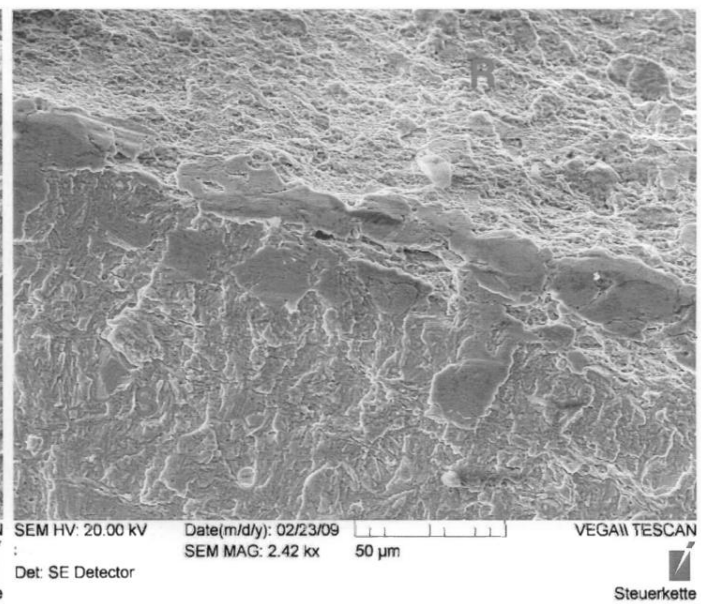


Bild 4: Bereich B bei höherer Vergrößerung

Übergang Schwingbruchfläche (S) / duktiler Restgewaltbruch (R)

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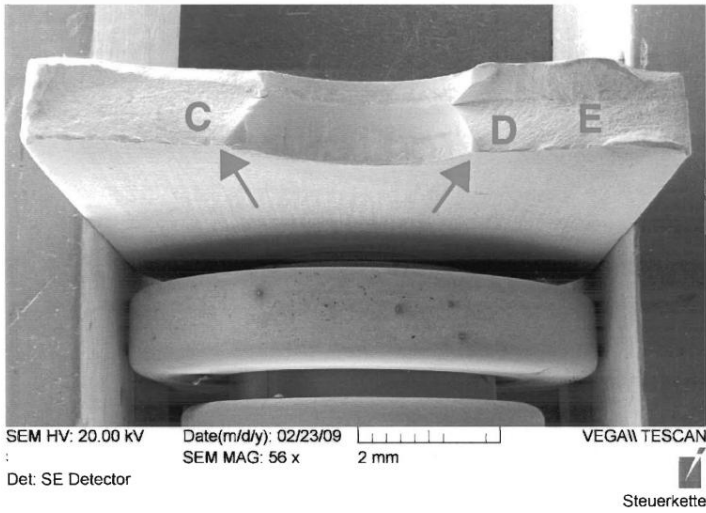


Bild 5: Parallele Bruchfläche

Bruchverlauf in Pfeilrichtung

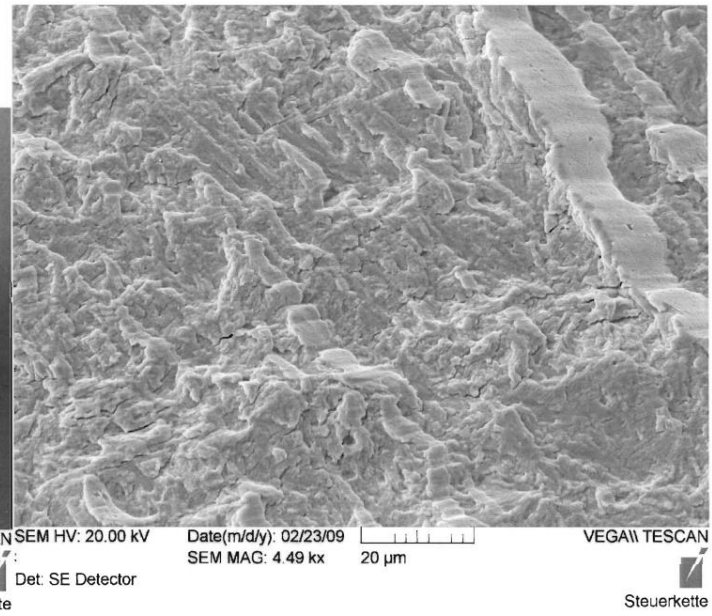


Bild 6: Bereich C bei höherer Vergrößerung

Transkristalline, verformungsarme Bruchfläche mit Schwingstreifen und parallelen Nebenrissen

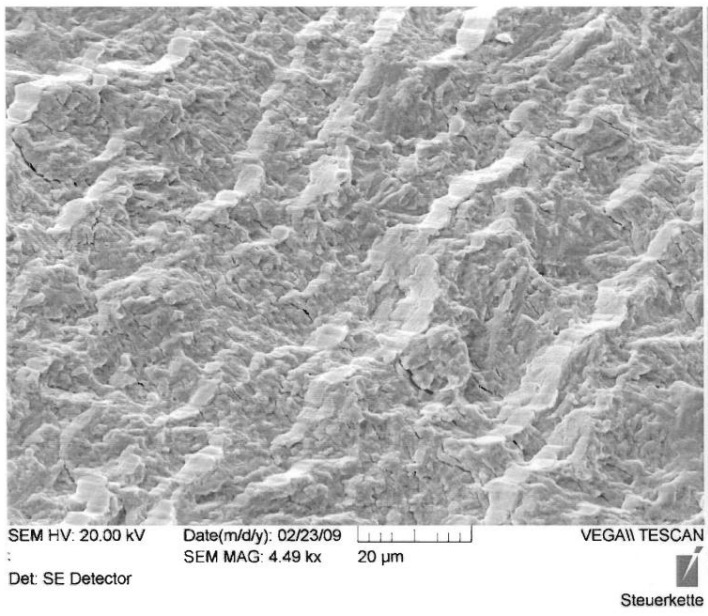


Bild 7: Bereich D bei höherer Vergrößerung

Transkristalline, verformungsarme Bruchfläche mit Schwingstreifen und parallelen Nebenrissen

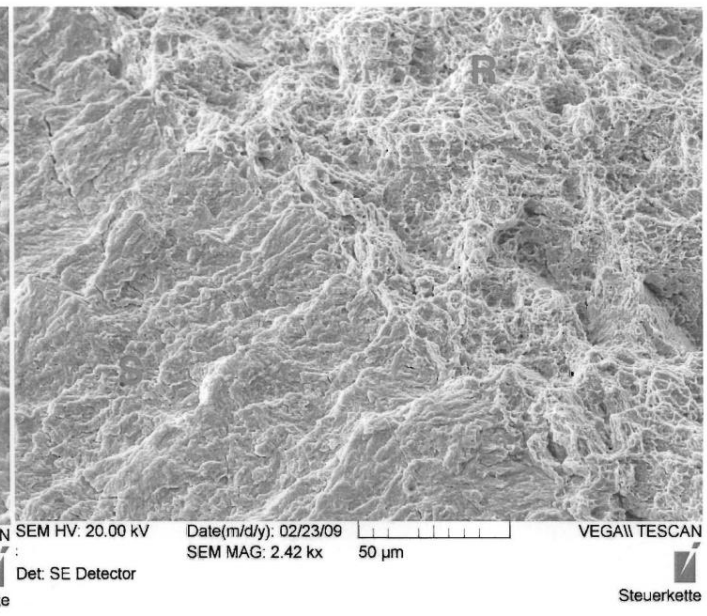


Bild 8: Bereich E bei höherer Vergrößerung

Übergang Schwingbruchfläche (S) / duktiler Restgwaltbruch (R)

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The hydrogen on the track

Part 1 - Introduction

Dr. Peter Sommer



Hydrogen tops the periodic table of the elements, which means that it Of the is the smallest atom of our matter. In 1766, this basic chemical element by the English tutor Henry Cavendish discovered. In the great outdoors our earth is hydrogen only in very encountered to a small extent. Only about 5x10-5 % by volume Hydrogen, which is usually present in the molecular form H2 , is in the lower encountered in the atmosphere. The hydrogen concentration only increases in higher layers of the atmosphere.

A single proton and an electron are the basic configuration of this chemical element. So a very manageable structure.

But this is precisely the reason why the Encountering hydrogen in materials almost always has unpleasant consequences. hydrogen can cause damage to materials and components in a wide variety of ways.

The forms of damage:

ÿ flocculation

ÿ In Beizblas

ÿ Hydrogen-induced brittle fracture

are the most well-known negative effects of this element in steels.

In this issue we launch a series of reports on the interactions between hydrogen and the material steel. It the most diverse points of view and measures are presented and discussed. We want the trace of the hydrogen from steel production to the point of use track a specific component. Like all Technical reports in the heat treatment market This series of reports is also aimed at the User. The sometimes quite complicated ones Basic connections are therefore only in quoted and explained to the extent that is absolutely necessary.

The trail of hydrogen becomes an abundance lead of individual information and the readers interested in this topic can all Arrange report sequences and use them as Use the reference work in your daily practice.

Hydrogen has high mobility in steel

Due to the very small mass and size of the hydrogen atom suggests that this element has a very high mobility in the crystal lattice of iron.

Following the trail of hydrogen

Part 1 - introduction

Dr. Peter Sommer

elements, which means that it is the smal lest Hydrogen is the periodic 1766 in this basic chemical element was discovered by the English private scholar Henry Cavendish. Hydro gen is found only in very small quantities in the open air on our planet. Just about 5 · 10-5 vol. % hydrogen, usually in the molecular form H2, is found in the lower atmospheric layer. The con centration of hydrogen increases only in the higher atmospheric layers.

A single proton and one electron form the basis of this chemical element. That means it has a very clear construction, but that is the very reason why the presence of hydrogen in materials almost always has unpleasant conse quences. Hydrogen can lead to the most diver se forms of damage in materials and compo nents.

The forms of damage:

ÿ flake formation

ÿ pickling blistering

ÿ hydrogen-induced embrittlement

are the best-known negative effects of this element in steel.

In this issue we are starting a series of reports on the interaction between the che mical element hydrogen and the material steel. The most diverse aspects and handlings are to be presented and discussed. We want to trace hydrogen from the production of steel to the place of use of a specific component. As all spe cialist reports in the heat treatment market, this series of reports is geared to the user. For that reason, the basic relationships, which are sometimes fairly complicated, will only be men tioned and explained to the degree to which it is absolutely essential.

Tracing hydrogen will lead to an abundan ce of individual items of information and the reader who is interested in this theme can put all these reports together into one handy refe rence for his daily work.

Hydrogen is highly mobile in steel

The very slight density and size of the hydrogen atom suggests the likelihood of this element being very mobile in the crystal iron lattice. Table 1 lists details on the diffusion coef ficient as a measurement of mobility.

The absolute figures here are sometimes difficult to interpret as we do not encounter such orders of magnitude in our daily experi ence. The rate of diffusion of carbon can be

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Element Element	Atomradius atomic radius [nm]	Diffusion coefficient in pure ÿ-iron at 800°C [cm2 /s] ÿ-iron at 1100° [cm2 /s] Diffusion coefficient in pure ÿ-iron at 800°C [cm2 /s] ÿ-iron at 1100°C [cm2 /s]
hydrogen		
Hydrogen	0,046	2,7 · 10-4 1,9 · 10-4
oxygen		
Oxygen	0,060	- 1,0 · 10-9
nitrogen		
Nitrogen	0,071	7,3 · 10-7 3,8 · 10-7
carbon		
Carbon	0,077	1,7 · 10-6 6,7 · 10-7
There is		
Boron	0,097	- 6,1 · 10-7
iron (short)		
Iron (bcc)	0,128	3,0 · 10-12 -
iron		
Iron (fcc)	0,126	- 9, 0 · 10-12
Diffusion coefficient of hydrogen in unalloyed steels at 25°C ÿ 10-6 Diffusion coefficient of hydrogen in plain carbon steels at 25°Cÿ 10-6		
Diffusion coefficient of hydrogen in alloyed steels at 25°C ÿ 10-7 Diffusion coefficient of hydrogen in alloyed steels at 25°C ÿ 10-7		
Diffusion coefficient of hydrogen in austenitic steels at 25°C ÿ 10-12 Diffusion coefficient of hydrogen in austenitic steels at 25°C ÿ 10-12		

Tab. 1: Diffusion coefficients of some elements in iron or steel (cornerstone)

Tab. 1: Diffusion coefficients of some elements in iron or steel (Eckstein)

Table 1 contains information on the diffusion coefficient as a measure of mobility
listed.

Sometimes the absolute numbers are there difficult to interpret, since such orders of magnitude are not part of everyday experience. The rate of diffusion of the
But carbon can be assessed quite well by all heat treatment experts
will. It is known that relatively high temperatures are required for the carbon to diffuse through the iron grid. Accordingly, it can be deduced from the figures that the

Hydrogen has approximately the same diffusion rate in the bcc iron lattice at room temperature as carbon at a

temperature of 1100°C. From this comparison can be deduced that atomic hydrogen indeed a very great mobility in the Eisengitter has.

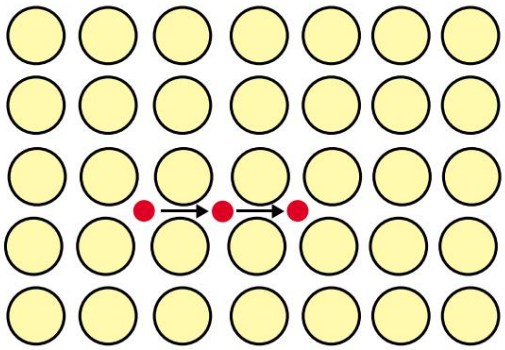
The mechanism in the iron lattice that is important for hydrogen diffusion
is shown in Figure 1. The hydrogen can diffuse to a large extent via the interstitial diffusion mechanism due to its small extent. It is evident that this diffusion process

small atomic radii easier and therefore runs faster than with large atomic radii.

If atomic hydrogen is offered on a barrier layer-free component surface,
it therefore also occurs at room temperature an intense recording. For those still closed descriptive manufacturing stages are therefore far more influencing factors of importance than with other desired and undesired accompanying elements of the steel.

assessed quite well by all heat treatment experts. It is known that relatively high tempe ratures are necessary for the carbon to diffu se in the iron lattice. It can therefore be deri ved from the figures that the hydrogen has
about the same rate of diffusion in the bcc-iron lattice at room temperature as carbon at a tem perature of 1100 °C. This comparison enables us to derive that atomic hydrogen is indeed very mobile in the iron lattice.

The important diffusion mechanism for hydrogen diffusion in the iron lattice is shown in fig. 1. On account of its slight expansion, hydrogen can diffuse to a high degree with the aid of the interstitial diffusion mechanism. It is obvious that this diffusion process is simpler and therefore quicker when the atomic radii are small than when they are large.



Picture. 1: Diffusion of the hydrogen over the interstitial mechanism in the iron grate

Fig. 1: Diffusion of hydrogen by means of the interstitial mechanism in the iron lattice

If atomic hydrogen is presented at a com ponent surface which is free of barrier layers, intensive sorption occurs even at room tem perature. This means that much more influen cing factors are of significance for the pro duction stages yet to be described than is the
case with other desirable and undesirable com panion elements in steel.

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Appendix 2.3_4

The hydrogen on the track

Part 2 - Hydrogen uptake from Steels from gases and liquids

Dr.-Ing. Simone Schwarz



Hydrogen can be used in various manufacturers position or production processes penetrate into the steel, e.g. B. at Melting, pickling, annealing and also in component use due to corrosion. Once penetrated into the material, the Hydrogen has high mobility (WB market 3/99) and can lead to a dramatic change in mechanical properties, especially toughness. Next to the

Diffusion of atomic hydrogen via interstitial sites in the metal lattice is an important aspect that atomic hydrogen is always in tensile stress areas of the

Metal enriched.

The hydrogen uptake from the gas phase takes place via the dissociation of the molecular hydrogen. This molecular hydrogen is adsorbed on the metal surface and can get into the metal lattice according to the surface activity of the metal by absorption of the atomic hydrogen.

The absorption of hydrogen from liquids takes place in several steps:

1. First, those present in the surrounding solution or liquid move H+ - ions to the metal surface. This is called called upstream transport reaction.

2. On the metal surface, the am next attached hydrogen ions through the metal electrons moving freely in the metal lattice to adsorbed atomic hydrogen. This discharge is called the passage or Volmer reaction. The decisive factor in this reaction is the transfer of electrical charges through the phase boundary

metal/solution.

3. Then diffuses a part of the so absorbed hydrogen in the metal lattice, analogous to the hydrogen absorption from the Gasphase.

4. Parallel to this, the Tafel reaction take place, which describes a recombination of the adsorbed atomic hydrogen to molecular hydrogen.

hydrogen induced Material separations - hydrogen embrittlement

In the last few years, four different mechanisms of hydrogen-induced material separation have gained acceptance in the understanding of the effect of hydrogen.
These are :

Following the trail of hydrogen

Part 2 - Hydrogen absorption of steel through gases and liquids

Dr.-Ing. Simone Schwarz

During various manufacturing and pro duction processes steel hydrogen can penetrate steel, e. g. during melting, etching, annealing likewise through corrosi on when using steel. Once the material is penetrated, hydrogen is highly mobile (WB Markt 3/99) which can lead to dramatic chan ges of the mechanical properties, in particu lar to toughness. Apart from the diffusion of nuclear hydrogen via intermediate lattice sites in the metal lattice it is important to consider that nuclear hydrogen builds up in those areas of the metal which are subject to tensile stress.

The hydrogen absorption during the gas phase is based on the dissociation of the molecular hydrogen. The molecular hydro gen is adsorbed on the metal surface and, corresponding to the surface activity, can enter the metal lattice through the absorp tion of nuclear hydrogen.

The adsorption of hydrogen from liquids is effected via several individual steps:

1. The H-ions in the surrounding solution or liquid move to the metal surface. This is referred to as premature transport reaction.

2. On the metal surface the closely depo sited hydrogen ions are turned into adsor bed nuclear hydrogen by means of the metal electrons moving freely in the metal lattice. This discharge is referred to as transfer or Volmer reaction. The transfer of electric char ge through the phase boundary metal / solu tion represents a decisive factor with this reaction.

3. Subsequently, a part of the absorbed hydrogen diffuses into the metal lattice, ana logue to the absorption of hydrogen from the gas phase.

Simultaneously, the table reaction can take place which describes a recombination of the adsorbed nuclear hydrogen to the molecular hydrogen.

Hydrogen-induced material separations – hydrogen embrittlement

As for the comprehension of the effect of hydrogen, four different mechanisms of the hydrogen-induced material separations have gained acceptance during the last few years. These include:

the voids model (formerly known as pres sure theory);

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the cavity model (formerly pressure theory),

the decohesion model,

the hydrogen-induced phase transition and the Help (hydrogen enhanced local plasticity) mechanism.

Due to their extraordinary importance for the resulting damage pattern Mechanisms 1, 2 and 4 explained in more detail will.

hydrogen induced cavitation (pressure theory)

The cavity model is a model for Presentation of the property change through Hydrogen. According to this model is like this assumed that the atomic hydrogen accumulates in the steel in the already existing cavities such as pores, cavities and void accumulations. through the Approach of two hydrogen atoms it comes to molecule formation and thus Build-up of an internal gas pressure. This can be outside of the thermodynamic equilibrium state considerably above the ambient pressure. This will be around This becomes clearer when one realizes that the molecule volume is ideally approx. 26 times the atomic volume of gas amounts to. This high internal hydrogen pressure is superimposed on the ones in the material existing residual stresses and the externally applied stresses. This voltage superimposition can at even low external loads premature cracking or to lead to crack growth.

The damage pattern resulting from this model presentation is often referred to as Floc formation or so-called fish eyes called conditions. For example shiny metallic on a fracture surface circular areas observed in an otherwise relatively dull surface. This Areas are brittle fracture areas (quasi-cleavage fractures) caused by an increased hydrogen internal pressure were initiated, Picture 2.

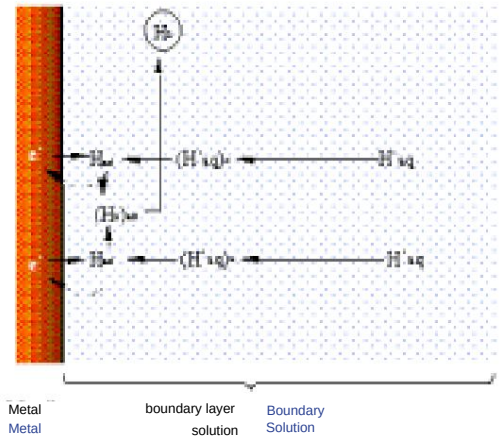


Figure 1: Hydrogen uptake from liquids (schematic)

Figure 1: Absorption of hydrogen from liquids (sche matically)

the decohesion model;

the hydrogen-induced phase transformati on and

the help (hydrogen enhanced local plastici ty) mechanism.

Owing to the extraordinary meaning for the damage analysis the mechanisms 1, 2, and 4 shall be explained in detail.

Hydrogen-induced voids formation (pressure theory)

The voids model is a model to show the change of properties by means of hydrogen. According to this model, it is assumed that the nuclear hydrogen contained in the steel accu mulates in the existing microvoids such as pores, shrink holes, and vacancy accumulati ons. Owing to the approach of two hydrogen atoms, molecules form and internal pressure builds. Outside the thermo-dynamic balance condition, this pressure can considerably exceed the ambient pressure. This becomes extremely clear when you imagine that the molecular volume is ideally approx. 26 times the nuclear gas volume. This high internal hydrogen pressure overlaps with the individu al tensions in the material and the tensions applied from the outside. This superposition of tensions can lead to a premature formation of cracks and / or growth of cracks even under the influence of low external loads.

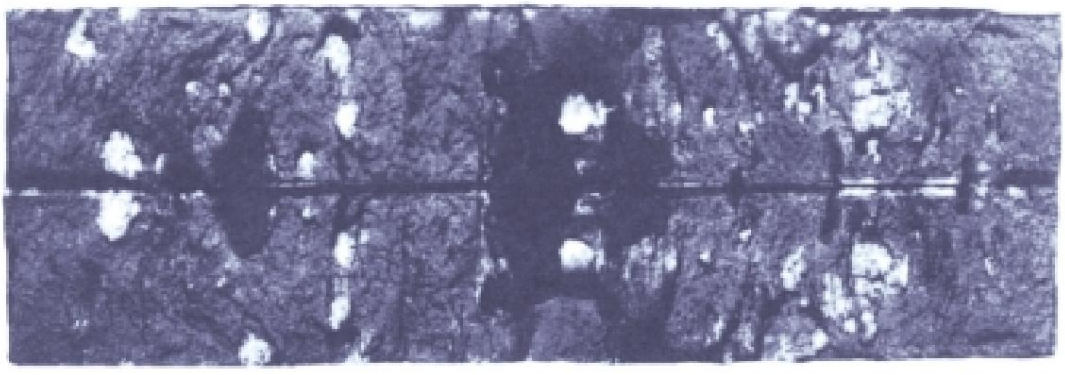


Image 2: Blue fracture sample from Steel 42MnV7 with flakes (from: Schumann, Metallografie, 1990)

Figure 2: Blue fracture speci men of steel 42MnV7 with flakes (from: Schumann, Metallographie, 1990)

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decohesion model

The decohesion model is one of the oldest models for imagining the property changes caused by atomic hydrogen. It was first described in 1941 by Zapf Fe and Sims, Figure 3.

It is based on the increased solubility of the hydrogen in a tensile stress field, for example at a crack tip or in the Tensile residual stress areas or in the stress field of a step dislocation. Through the increased solubility of hydrogen in it comes to these areas of tension Reduction of the atomic binding forces of the metal lattice. Comes under stress the reduction in binding forces leads to premature brittle material failure along grain boundaries

(intergranular cleavage) or lattice planes (transgranular cleavage).

The type of cleavage fracture that occurs depends on unalloyed and low-alloyed According to Haumann, steel depends on their tensile strength. So become transcrystalline Stress cracks due to hydrogen observed at tensile strengths <900 N/mm2 (ÿ280HV) and intergranular stress cracks observed at tensile strengths > 900 N/mm2 , Figure 4.

Other authors name limit values of the Tensile strength at 390 HV (Rm > 1250 N/mm2) for intergranular cleavage fracture of low-alloy steels.

Report continued in the next January 2000 edition.

Figure 4: Intergranular Fracture surface of a hydrogen-induced brittle fracture

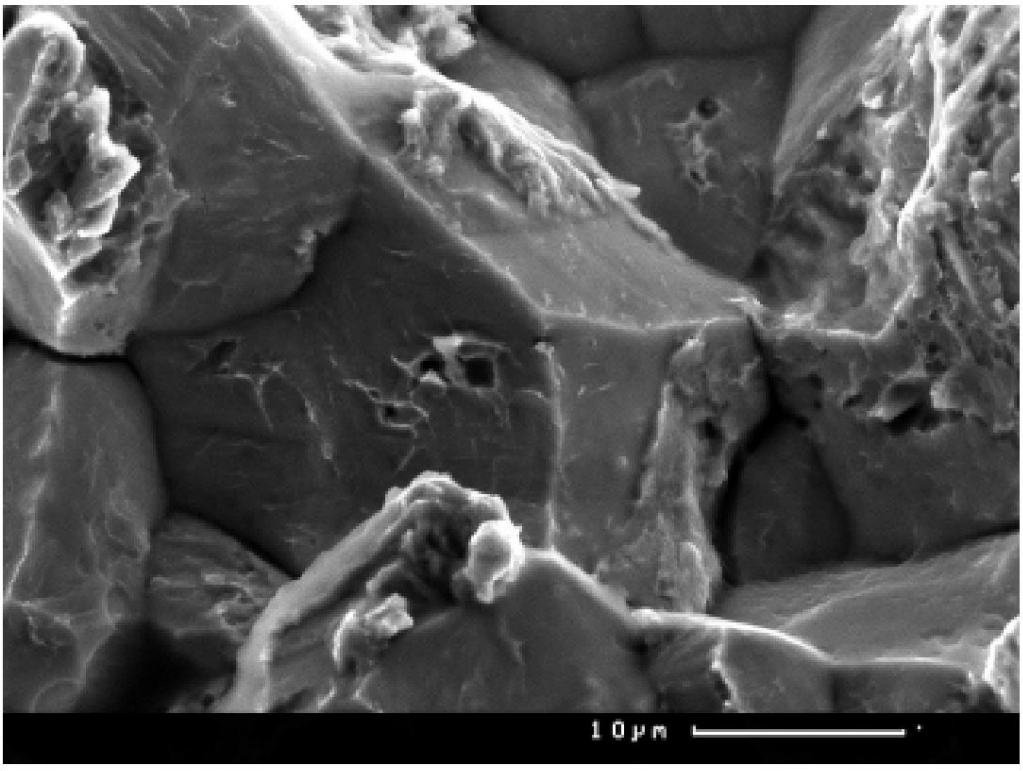


Figure 4: Intergranualar fracture surface of a hydrogen-induced brittle fracture

The damage analysis resulting from this model representation is frequently referred to as flake formation or fisheyes. For instance, metallic glittering, round areas with an other wise relatively matt surface are observed on a crack surface. These areas are referred to as brittle fracture areas (quasi cleavage) which were initiated by means of increased hydrogen internal pressure.

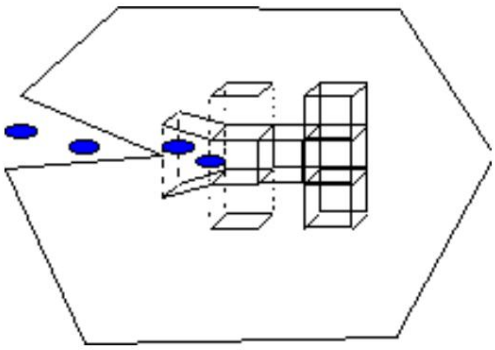


Figure 3: schematic decohesion model

Figure 3: schematic decohesion model

Decohesion Model

The decohesion model is one of the oldest models used to represent the change of pro perties as a result of atomar hydrogen. It was described first in 1941 by Zapffe and Sims. It is based on the increased solubility of hydrogen in a tensile strength field, for instance on the tip of a crack or in areas with internal tensile strength or in the tension field of edge dislo cations. The increased solubility of hydrogen in this tension field results in a decrease in the atomar binding forces of the metal lattice. The influence of stress results in a premature britt le-material fracture along the grain boundaries (intergranular cleavage) or network levels (transgra nular cleavage) owing to the decrease of the bin ding forces.

According to Haumann the type of the cleavage of non-alloyed and low-alloy ed steels depends on their tensile strength. Transgra nular stress-induced cracks caused by of hydro gen with tensile strengths of <900 N/mm2 (ÿ 280 HV) and intergranular stress induced cracks with tensi le strengths of > 900 N/mm2 were observed. Other authors name the limiting value of the tensi le strengths with 390 HV (Rm > 1250 N/mm2) for the intergranular cleavage of low-alloyed steels.

The report will be con tinued in the next issue January 2000.

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2.3.5 Results of measuring the Sachs and Iwis chain

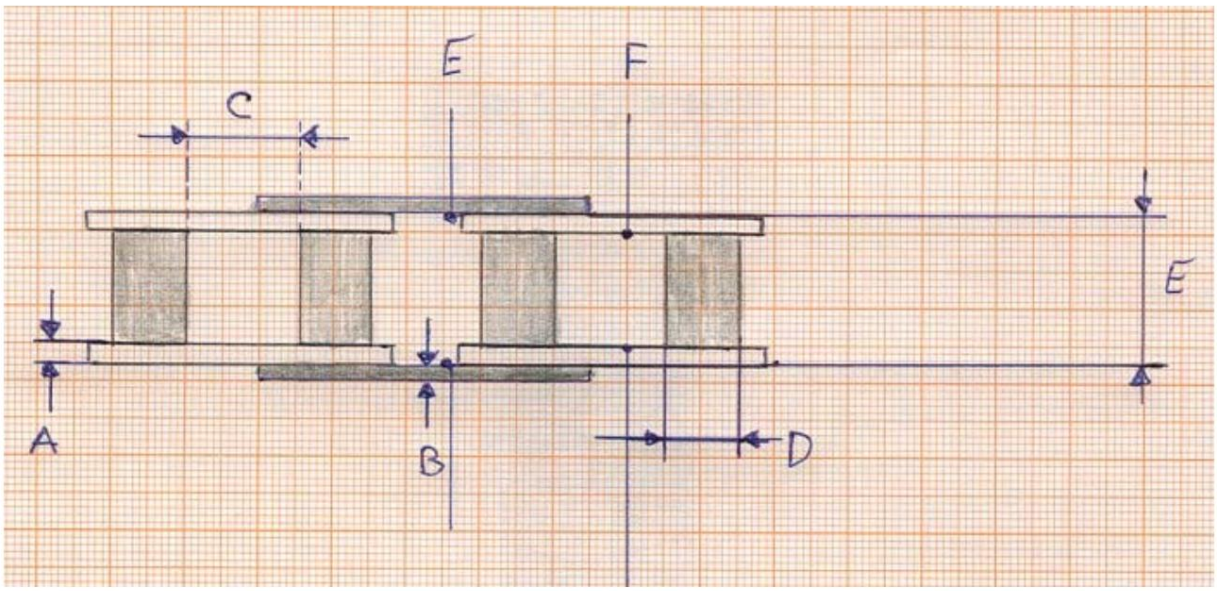


Image: Annex 2.3.5_1 - Position of the measuring points on the chain

	New Chain (IWIS)		Old Chain (Sachs)		setpoint	
Position	Min	Max	Min	Max		
A	1,45	1,5	1,48	1,53	1,3	
B	1,17	1,118	1,15	1,18	1,2	
C	3,27	3,28	3,26	3,33	unknown	
D	6,29	6,33	6,26	6,29	6,35	
AND	9,78	9,82	9,77	9,96	unknown	
F	5,72	5,74	5,8	5,91	5,72	

Result of the spectral analysis of the individual parts:

Tab: Ck45
Not: 39CrMoV139
Sleeve: Ck15
Rolle: 50CrV4

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2.4_1 Radiographic examination of the chain tensioners



Image: Appendix 2.4.1_1 - lower chain tensioner



Image: Appendix 2.4.1_2 - lower chain tensioner

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Image: Annex 2.4.1_3 - lower chain tensioner

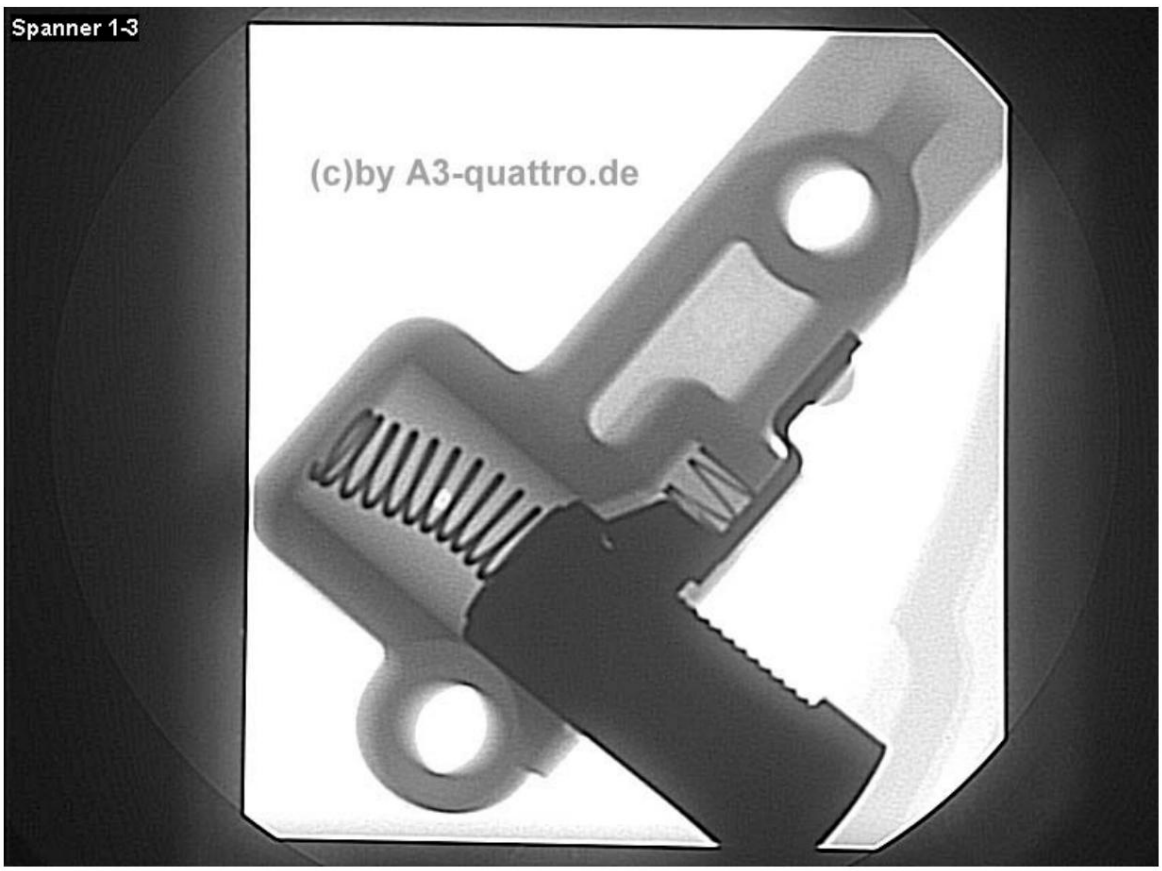


Image: Annex 2.4.1_4 - lower chain tensioner

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Image: Appendix 2.4.1_5 - upper chain tensioner

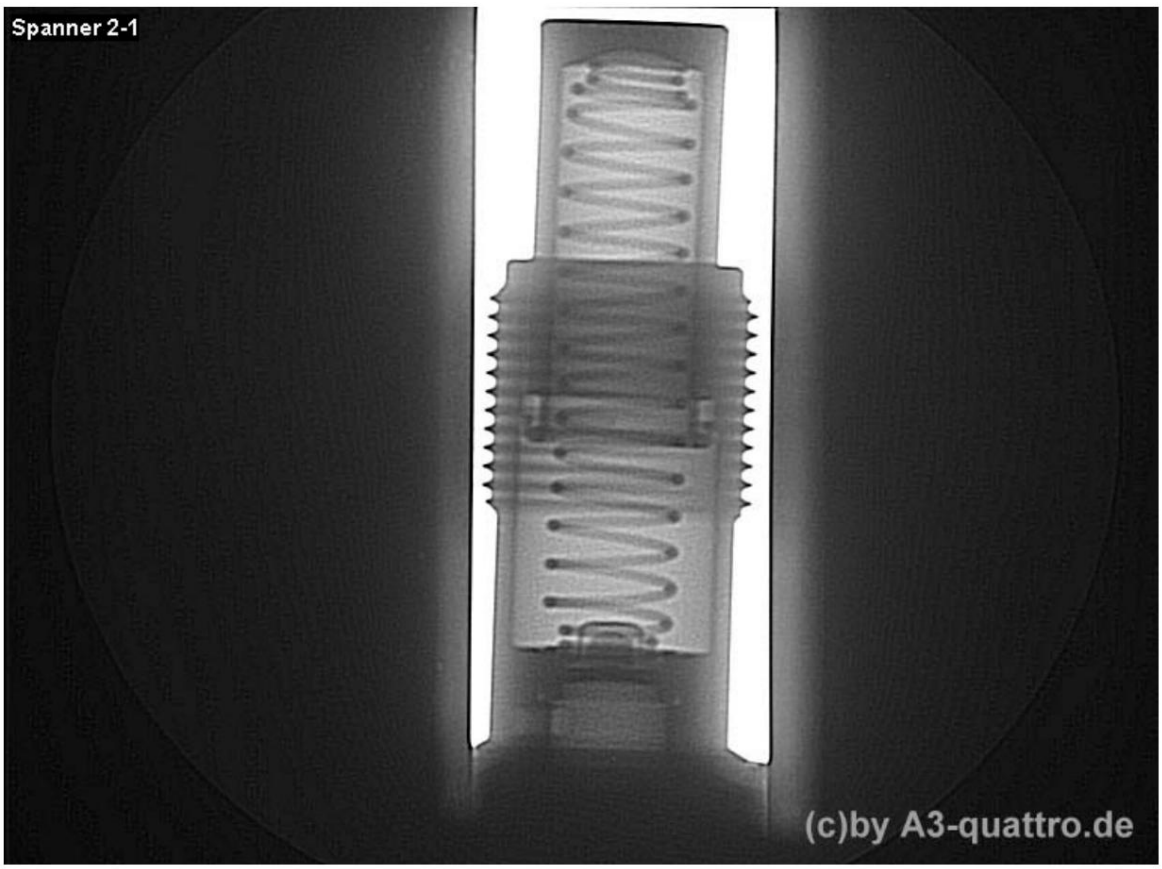


Image: Annex 2.4.1_6 - upper chain tensioner

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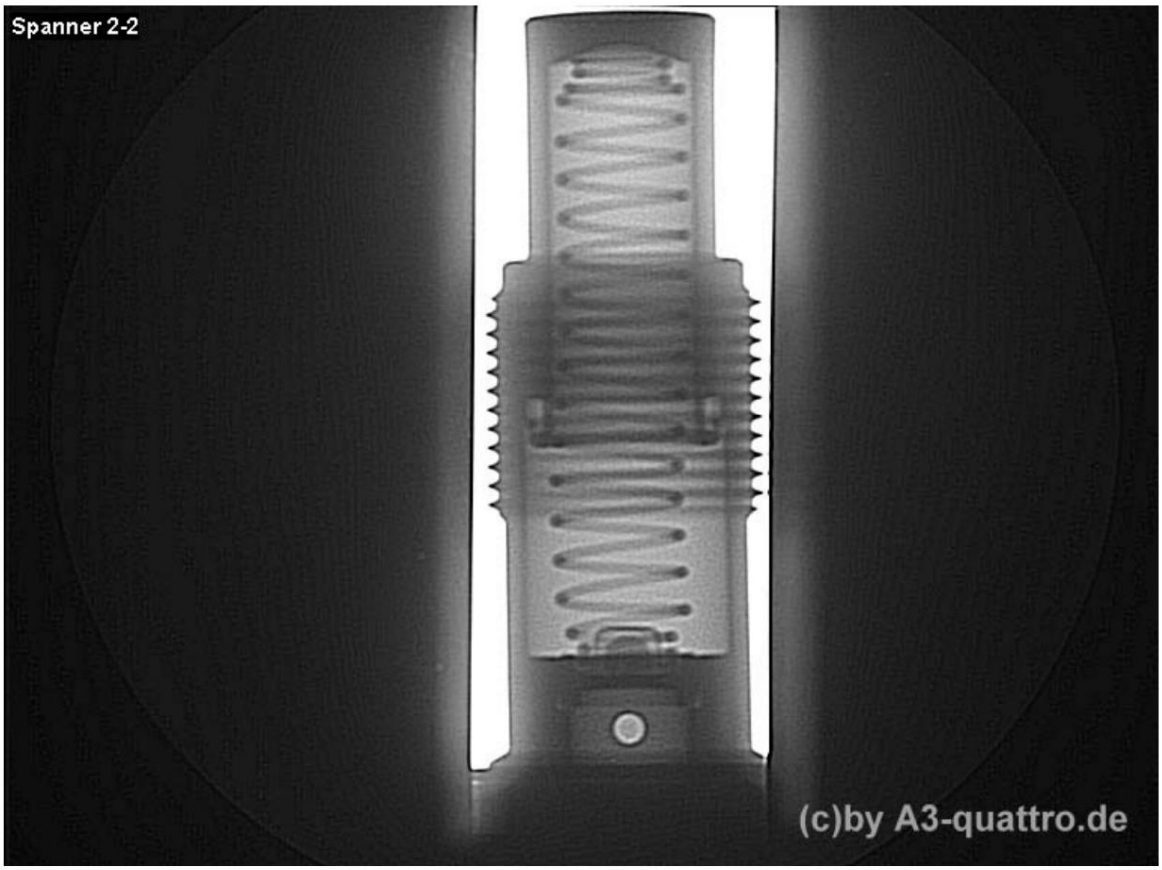


Image: Appendix 2.4.1_7 - upper chain tensioner

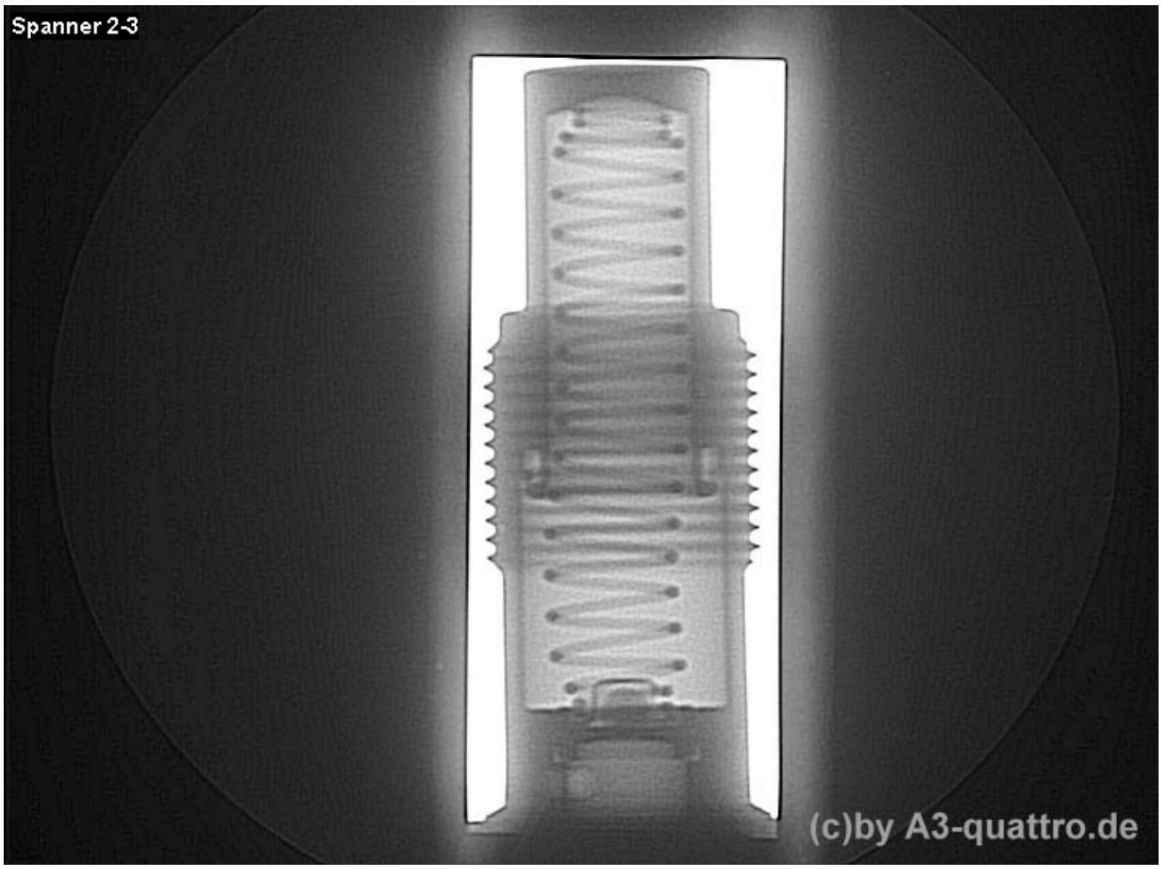


Image: Annex 2.4.1_8 - upper chain tensioner

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2.5_1 Pictures of the VR6 guide rails 3.2 chain drive Pictures of some guide rails of the VR6



Image: Appendix 2.5.1_1 - upper chain drive with rails



Image: Appendix 2.5.1_2 - upper chain drive / rail in detail

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Image: Appendix 2.5.1_3 - running rail



Image: Annex 2.5.1_4 - running rail

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2.6_1 Radiographic images of the camshaft adjusters



Image: Annex 2.6.1_1 - camshaft adjuster

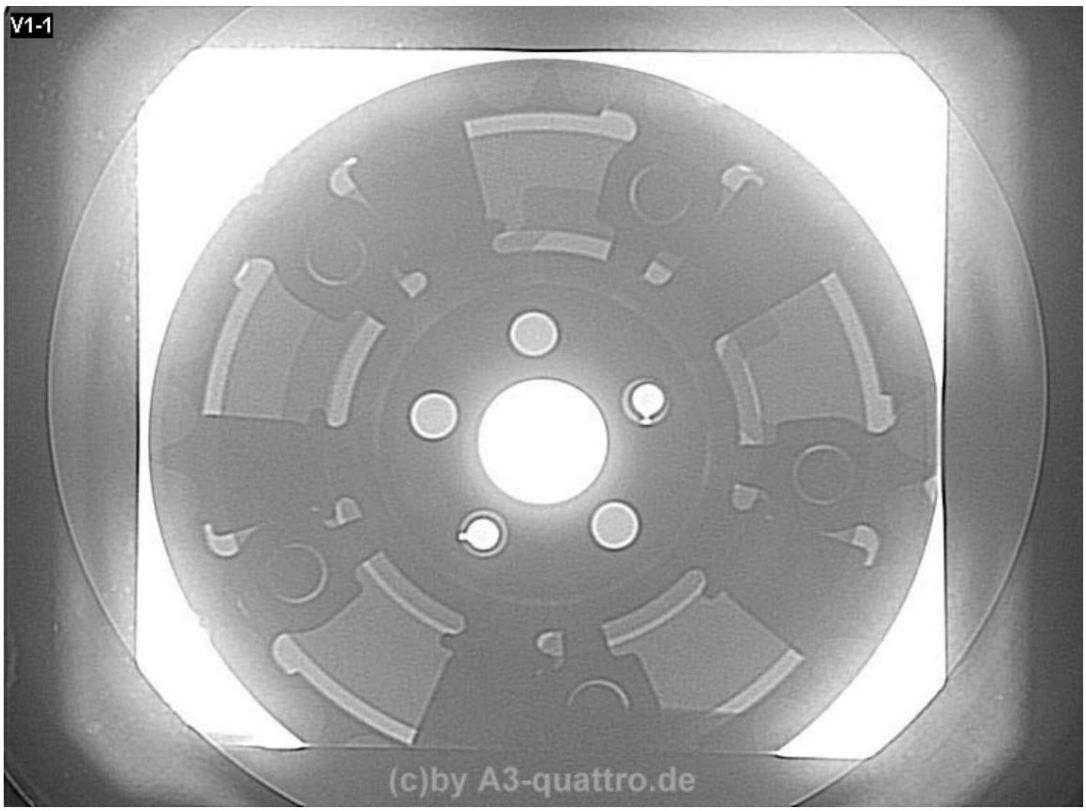


Image: Annex 2.6.1_2 - camshaft adjuster

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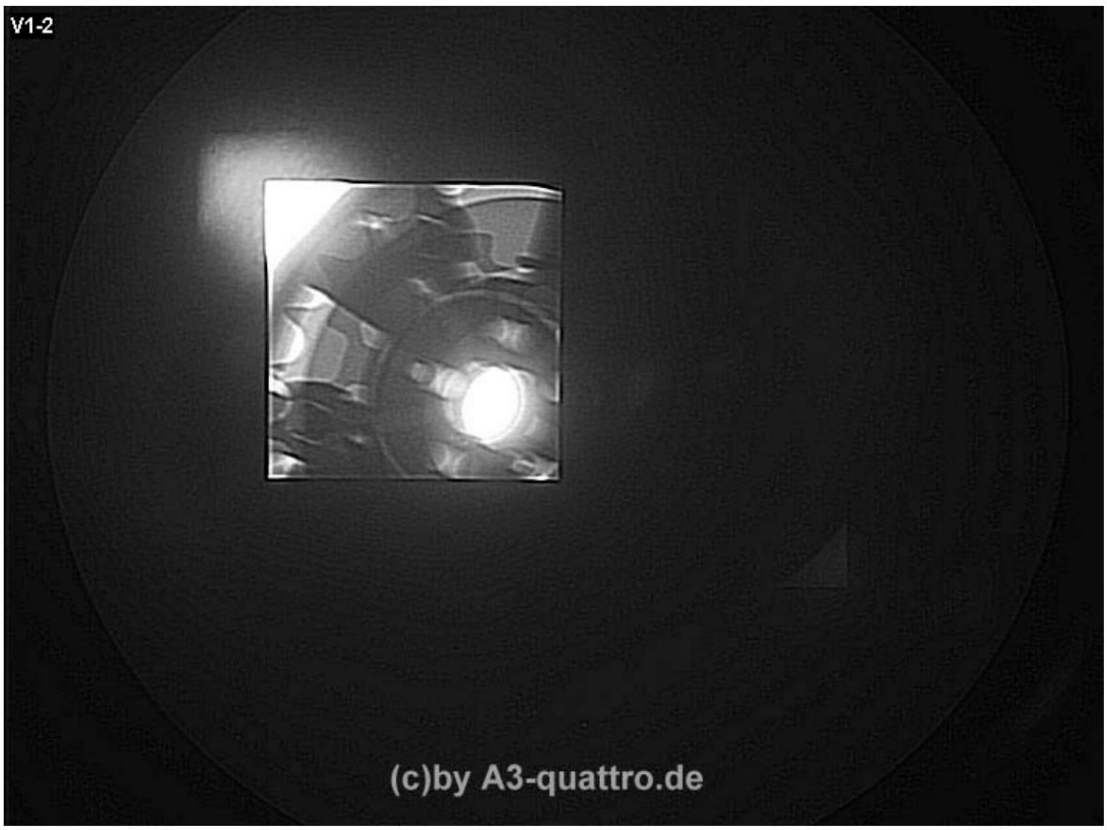


Image: Annex 2.6.1_3 - camshaft adjuster



Image: Annex 2.6.1_4 - camshaft adjuster

Machine Translated by Google

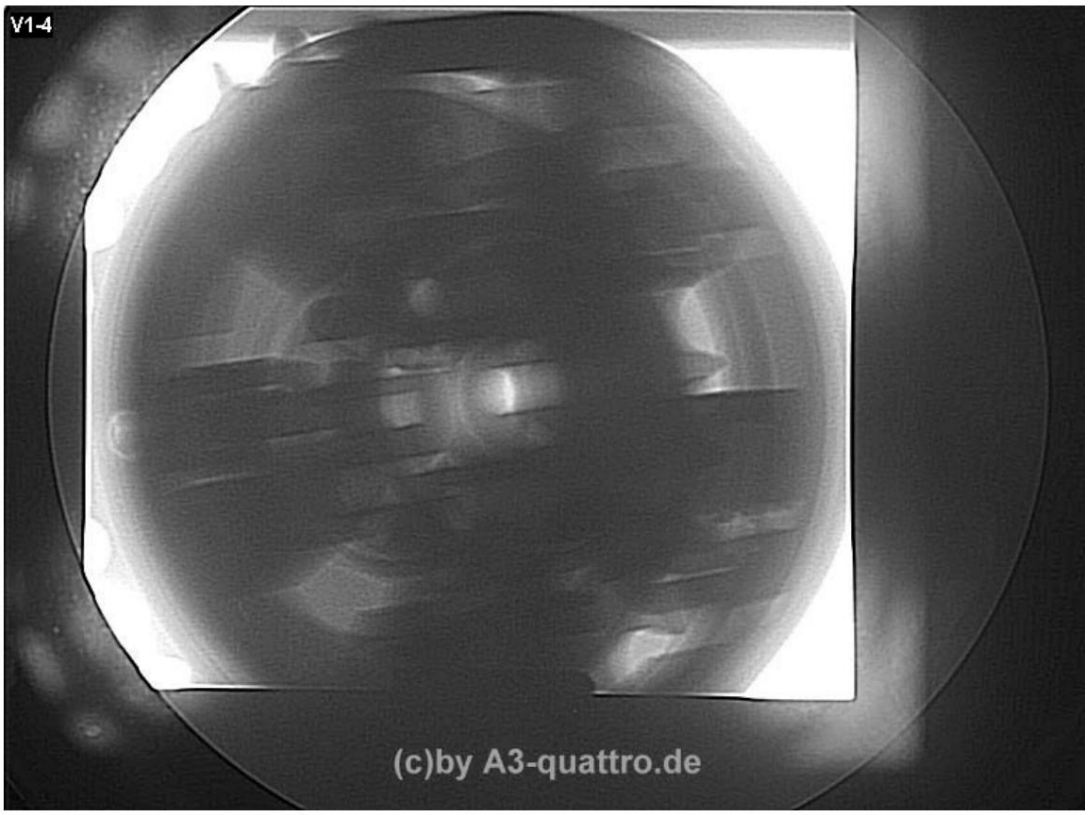


Image: Annex 2.6.1_5 - camshaft adjuster

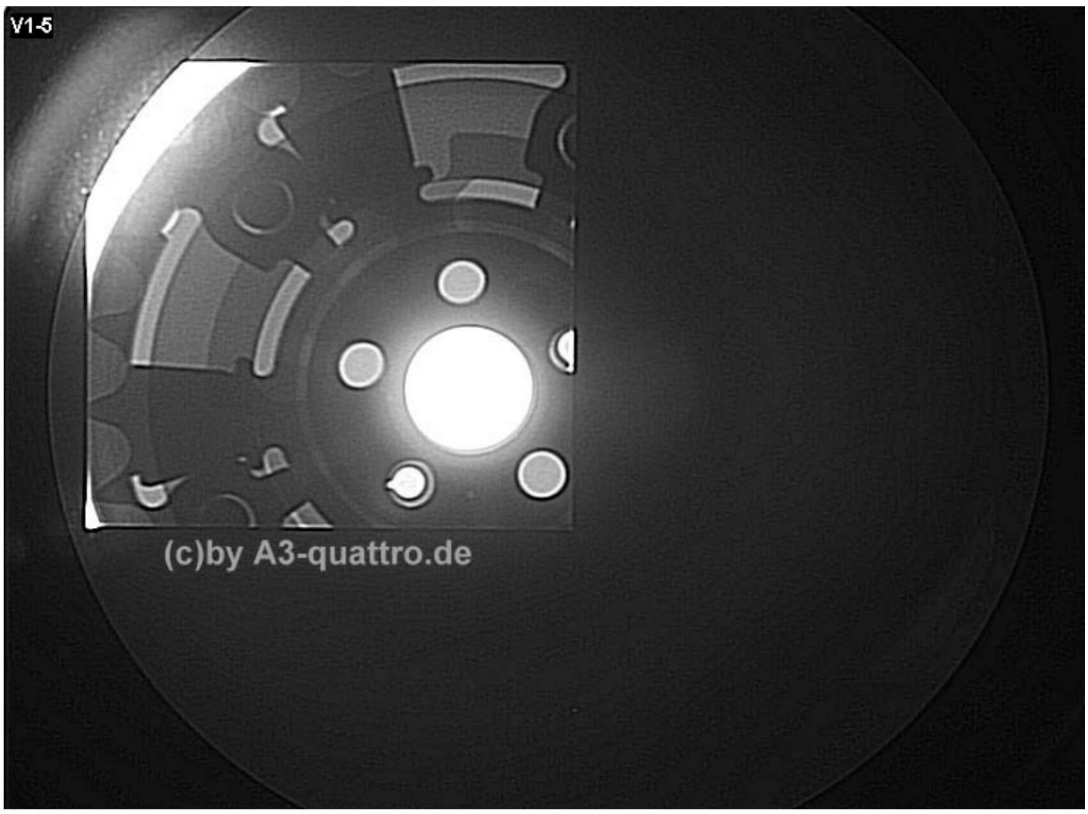


Image: Annex 2.6.1_6 - camshaft adjuster

Machine Translated by Google

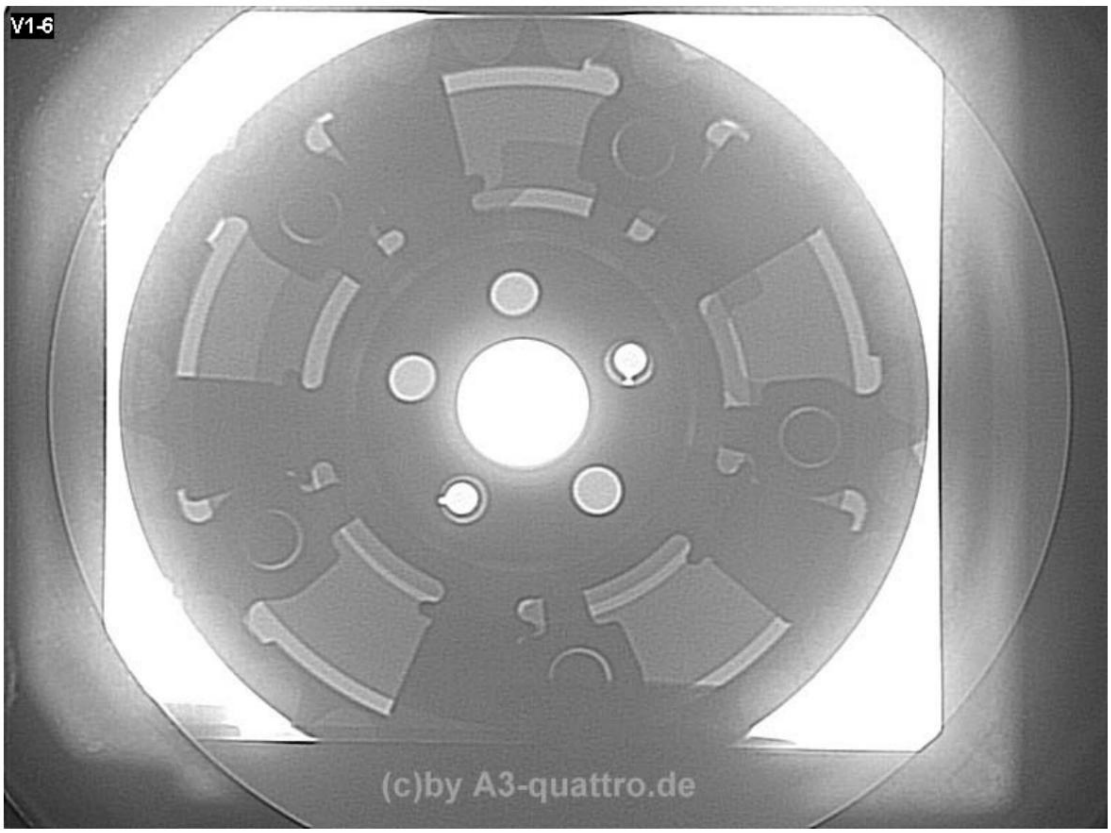


Image: Annex 2.6.1_7 - camshaft adjuster

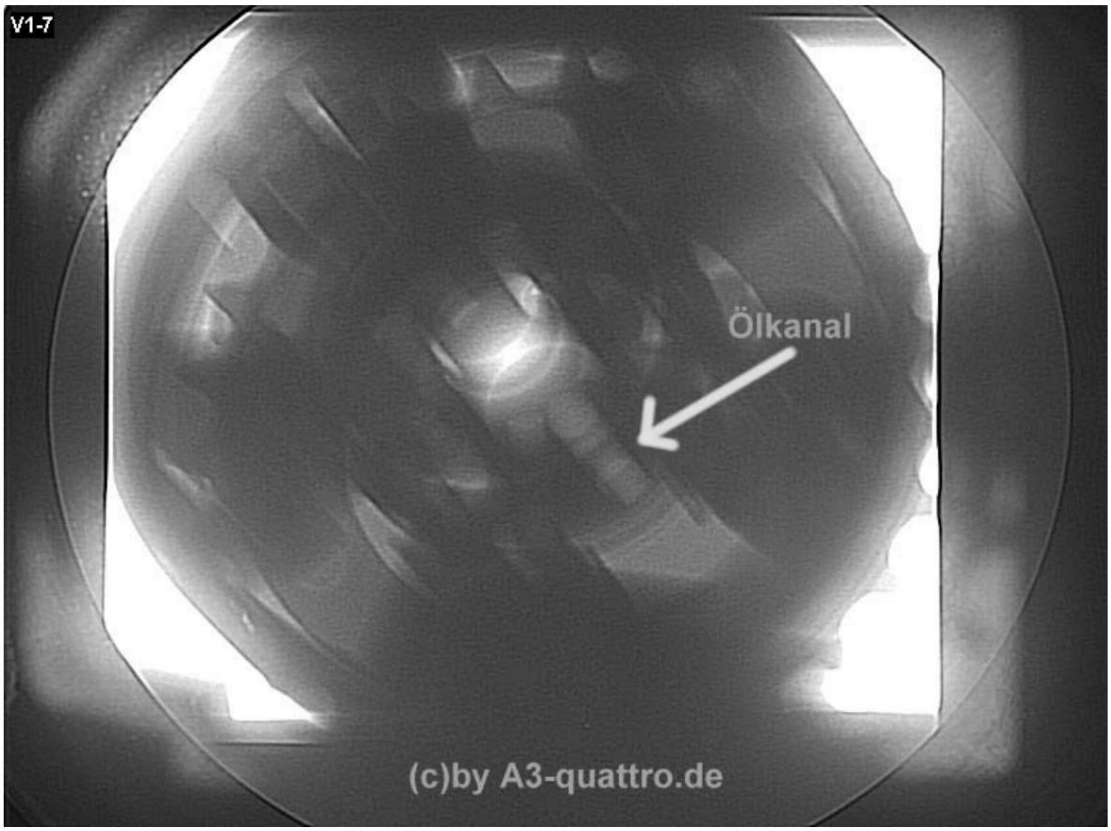


Image: Annex 2.6.1_8 - camshaft adjuster

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Technische Daten Audi A3 3.2 quattro (184 kW)

Angebot in Deutschland - **Stand: März 2004**

Modell	Audi A3 3.2 quattro	
Motor / Elektrik		
Motorbauart	Sechszylinder-Ottomotor, DOHC	
Ventilsteuerung / Anzahl Ventile pro Zylinder	Rollenschlepphebel / 4	
Hubraum in ccm / Bohrung x Hub in mm / Verdichtung	3189 / 84,0 x 95,9 / 11,3	
max. Leistung in kW (PS) / bei 1/min	184 (250) / 6300	
max. Drehmoment in Nm / bei 1/min	320 / 2.500 - 3.000	
Motormanagement	Motronic ME 7.1.1: vollelektronische sequentielle Einspritzung, Schubabschaltung, adaptive Lambdaregelung; Kennfeldzündung mit ruhender Hochspannungsverteilung; zylinderselektive adaptive Klopfregelung; Luftmassenmessung, koordinierte Motormomentsteuerung; Nockenwellenverstellung ein- und auslassseitig; Sekundärlufteinblasung	
Abgasreinigungssystem	4 Lambdasonden (2 beheizt), Aktivkohlefilter, 3-Wege-Katalysator	
Emissionsklasse	EU 4	
Generator in A / Batterie in A/Ah	140 / 380/80	
Antrieb / Kraftübertragung		
Antriebsart	permanenter Allradantrieb quattro mit elektronisch geregelter Lamellenkupplung, elektronische Differenzialsperre EDS	
Kupplung	hydr. betätigte Einscheiben-Trockenkupplung mit asbestfreien Belägen	zwei elektrohydraulisch betätigte Lamellenkupplungen im Ölbad
Getriebebauart	6-Gang-Schaltgetriebe, vollsynchronisiert	6-Gang-Direktschaltgetriebe DSG mit elektrohydraulischer Betätigung
Getriebeübersetzung im 1. Gang / 2. Gang	3,357 / 2,087	2,933 / 1,792
Getriebeübersetzung im 3. Gang / 4. Gang	1,469 / 1,088	1,267 / 0,975
Getriebeübersetzung im 5. Gang / 6.Gang	1,108 / 0,912	1,030 / 0,825
Getriebeübersetzung im R. Gang	3,990	3,35
Achsübersetzung 1.- 4. -Gang / 5.- 6.-Gang	4,235 / 3,273	4,8 / 3,6
Fahrwerk / Lenkung / Bremse		
Bauart Vorderachse	McPherson-Federbeinachse mit unteren Dreiecksquerlenkern, Aluminium-Hilfsrahmen, Rohrstabilisator, Lenkrollradius spurstabilisierend	
Bauart Hinterachse	Vierlenker-Hinterachse mit getrennter Feder-Dämpfer-Anordnung, Aluminium-Hilfsrahmen, Rohrstabilisator	
Bauart Lenkung / Lenkübersetzung / Wendekreis in m (D102)	Elektromechanische Lenkung mit geschwindigkeitsabhängiger Servounterstützung, / 16,2 / ca. 10,7	
Bauart Bremssystem vorn/hinten	Zweikreisbremsanlage mit diagonaler Aufteilung. ESP mit elektronischer Bremskraftverteilung EBV, ABS; hydraulischer Bremsassistent; Bremskraftverstärker mit Dual-Rate Funktion, elektronische Differenzialsperre EDS, vorn und hinten: innenbelüftete Scheiben;	
Räder / Reifen	7,5 J x 17 Aluminium-Gussräder im 5-Arm-Design / 225/45 R 17	
Fahrleistung / Verbrauch / Akustik		
Höchstgeschwindigkeit in km/h	250 (abgeregelt)	
Beschleunigung 0-100 km/h in s	6,5	6,4
Kraftstoffart	Super Plus bleifrei, 98 (ersatzweise bleifrei Super, 95 ROZ, mit geringer Leistungsminderung)	
Verbrauch städtisch/außerstädtisch/insgesamt, l/100km	14,8 / 8,2 / 10,6	13,8 / 7,5 / 9,8
CO2-Massenmission, g/km	254	235
Außengeräuschpegel im Stand/Vorbeifahrt in dB (A)	82 / 74	79 / 72
Wartung / Gewährleistung Deutschland		
Ölwechsel nach km / Inspektion nach km	nach Serviceanzeige bis 30.000 (maximal 2 Jahre) [1]	
Gewährleistung Fahrzeug/Lack/Karosseriedurchrostung	2 Jahre ohne km-Begrenzung / 3 Jahre / 12Jahre	
Versicherungseinstufung: VK / TK / KH	23 / 23 / 17	
Gewichte / Belastbarkeit		
Leergewicht (ohne Fahrer) in kg / Zul. Gesamtgewicht in kg	1495 / 2055	1525 / 2085
Zul. Achslast vorn/hinten in kg	1120 / 1095	1150 / 1090
Zul. Anhängelast ungebremst, kg	750	
Zul. Anhängelast bei 8% / 12 % Steigung gebremst, kg	1800 / 1600	
Zul. Dachlast in kg / Zul. Stützlast in kg	75 / 75	
Füllmengen		
Kühlsysteminhalt (inkl. Heizung) in l	12,3	
Motorölinhalt (inkl. Filter) in l	5,5	
Tankinhalt in l, ca.	60	
Karosserie / Abmessungen		
Art der Karosserie	Selbsttragend, Stahl	
Anzahl der Türen / Sitzplätze	3 Türen mit zusätzlichem Flankenschutz / 5 Sitzplätze	
Luftwiderstandsbeiwert cw / Stirnfläche A in qm	0,32 / 2,13	
Länge (L103) / Breite o. Spiegel (W103) / Höhe (H100), mm	4203 / 1765 / 1421	
Radstand (L101) /Spurweite vorn/hinten (W101/W102) in mm	2578 / 1536 / 1517	
Höhe Ladekante in mm (H195)	655	
Gepäckraumvolumen nach VDA-Quader in l (V211)	281 / 1031	

[1]) abhängig von Fahrweise und Einsatzbedingungen

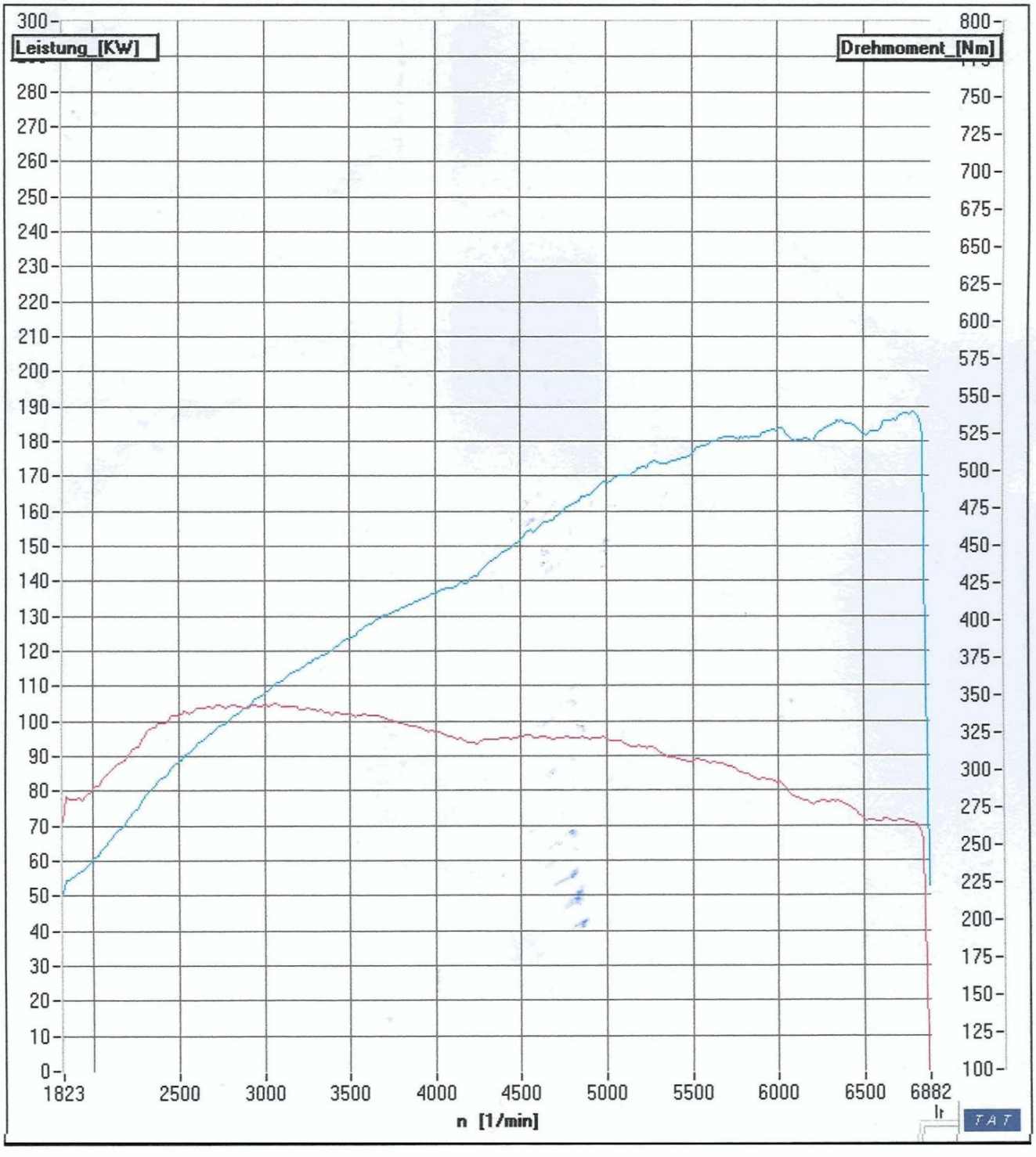
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Anlage 4.1_1

OETTINGER Performance GmbH
D-61381 Friedrichsdorf
Tel. 06172 / 953310

Leistungsmessung

DATEI: 02050954.tmp
Maxima (korr.): 189 KW (256 PS) / 6788 U/min und 345 Nm / 3064 U/min
)***_Kommentar_Ende



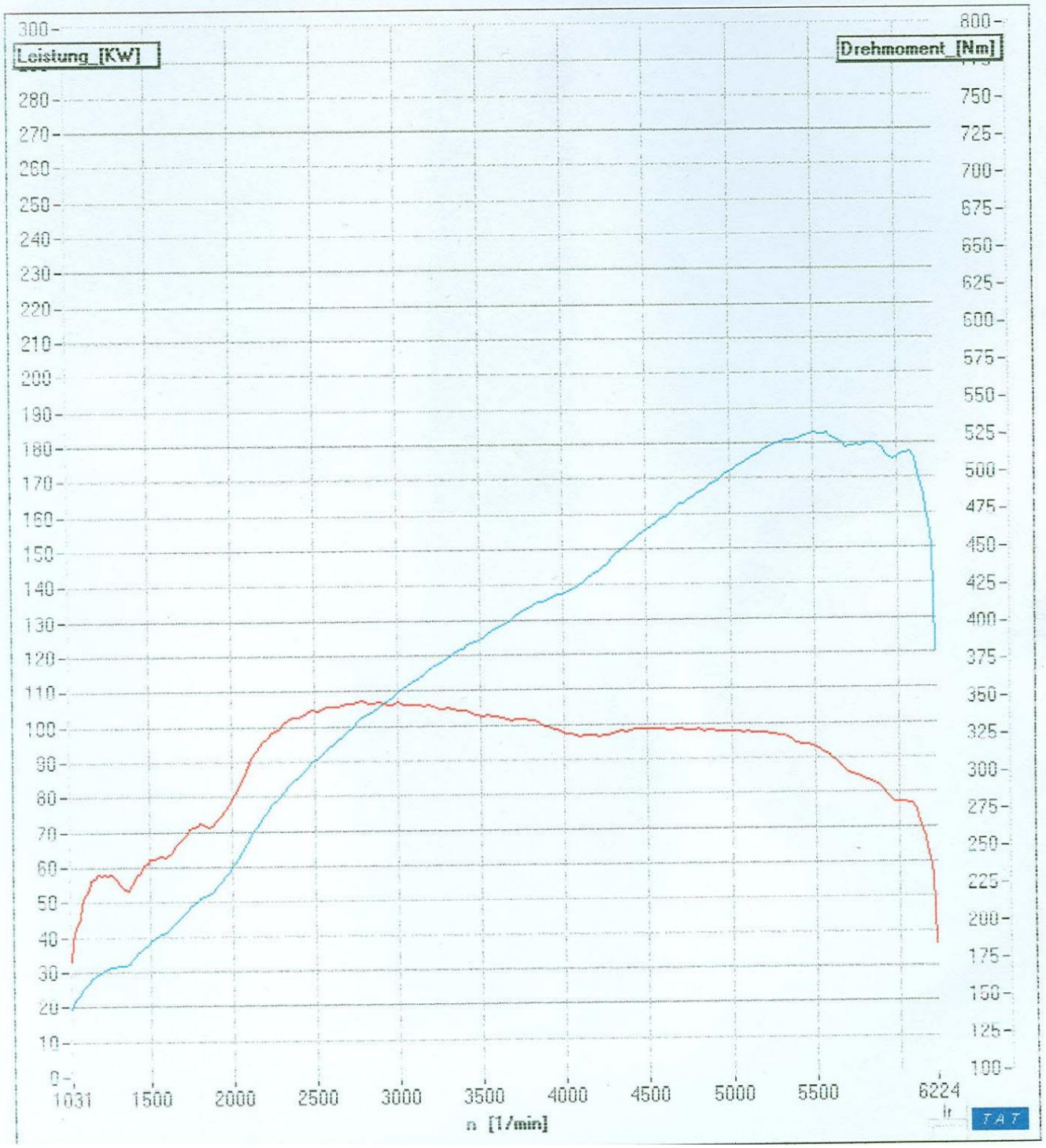
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Anlage 4.1_2 - Leistungsmessung_neuer Kettentrieb

OETTINGER Technik GmbH
D-61381 Friedrichsdorf
Tel. 06172 / 953310

Leistungsmessung

DATEI: 28121020.tmp
Maxima (korr.): 183 KW (249 PS) / 5589 U/min und 350 Nm / 2788 U/min
LU SX 25 A3 3,2 ltr 6.Gag chr _Kommentar_Ende



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FLA - 206 Software Version 4.3 G

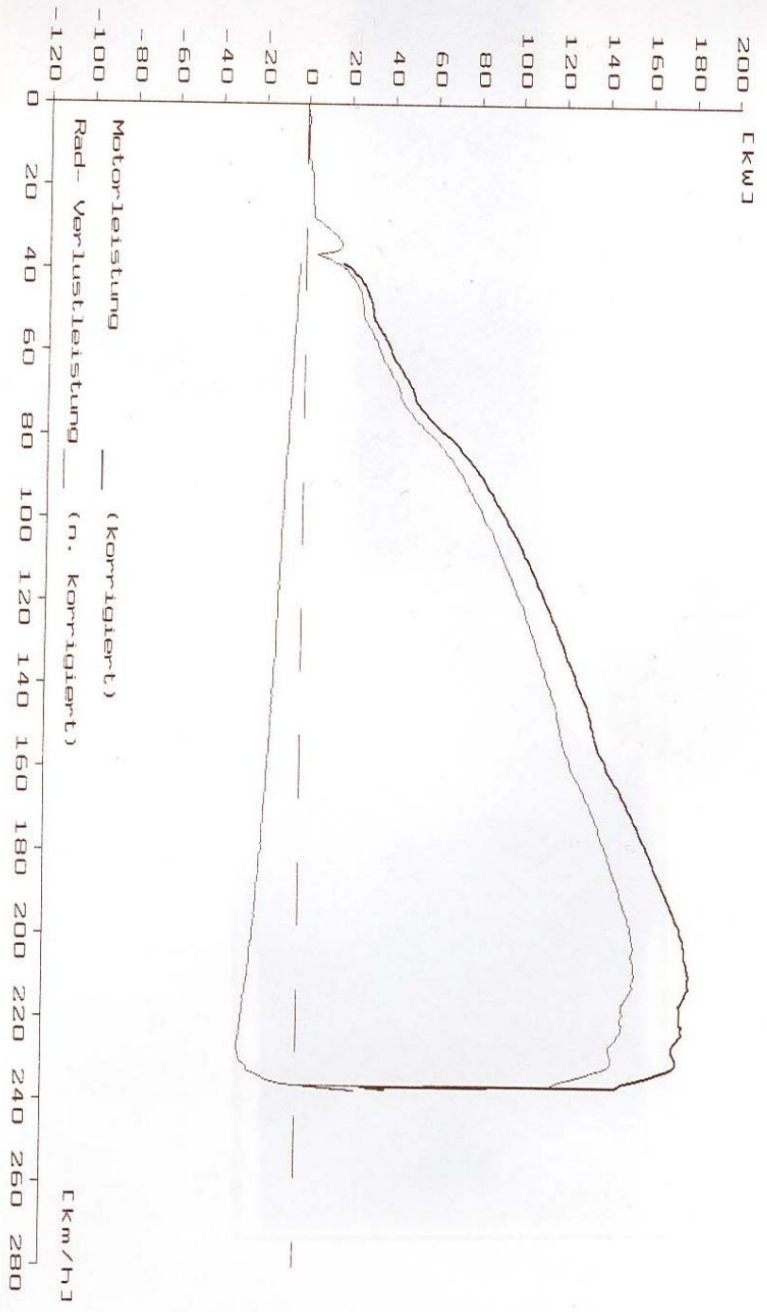
3.01.1980
oettinger Technik GmbH
Marx-Planck-Stasse 36
61381 Friedrichsdorf

Motorleistung

Pnenn = 184 kW nnenn = 6500 1/min vmax = 250 km/h

Pmax = 182.9 kW bei v = 208.5 km/h n = *** 1/min
Ptol = -0.6 % Prad = 157.7 kW Pverl = 22.9 kW

Temp. = 10 C Druck = 983 hPa k = 1.013 (DIN)
PKW Schaltgetriebe 2 Wheel Drive
RUV Einzelfunke



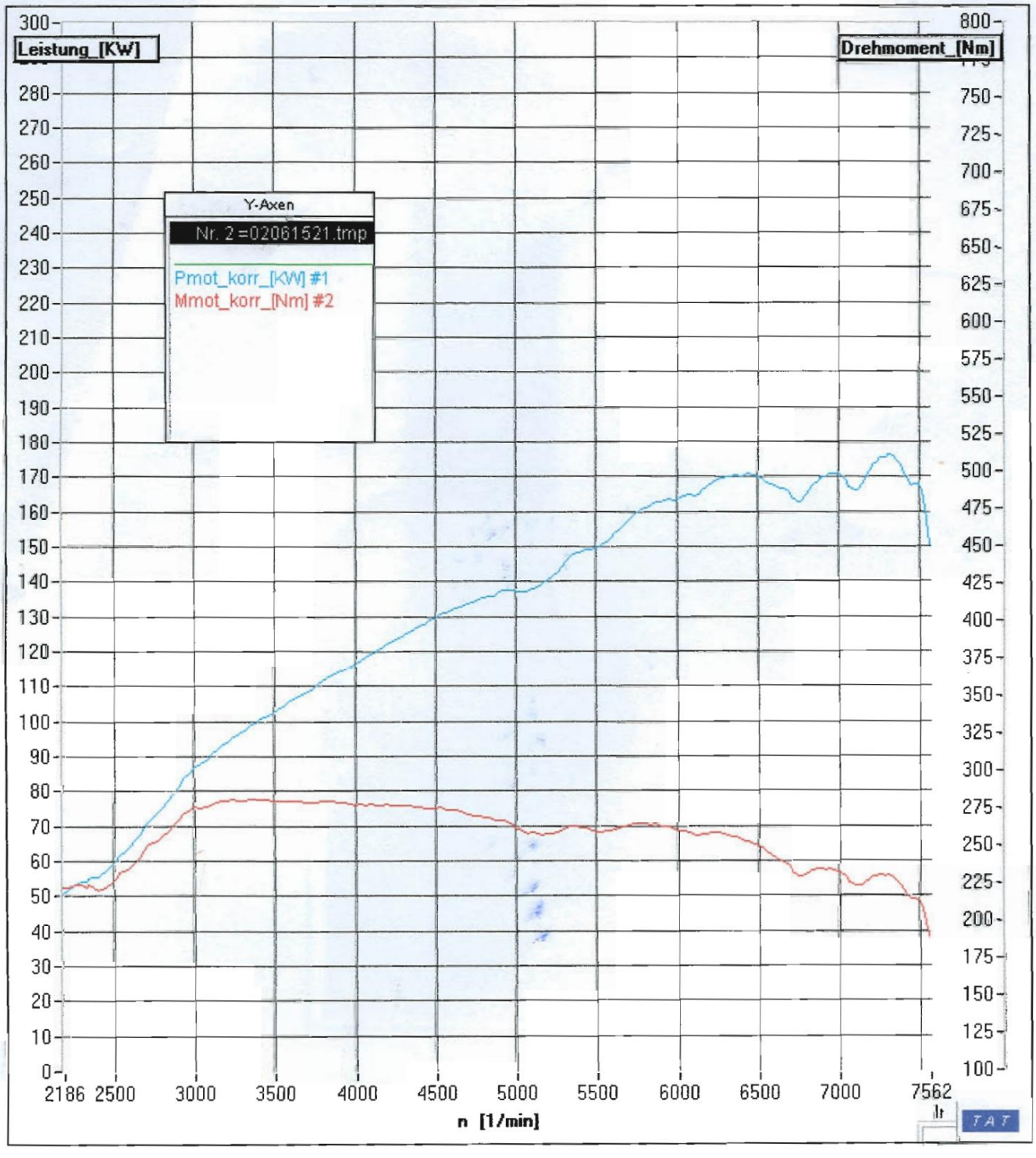
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Anlage 4.1_3

OETTINGER Performance GmbH
D-61381 Friedrichsdorf
Tel. 06172 / 953310

Leistungsmessung

DATEI: 02061521.tmp
Maxima (korr.): 177 KW (240 PS) / 7307 U/min und 281 Nm / 3414 U/min
)***_Kommentar_Ende



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4.2_1 Measurement protocol from the diagnostic device (read MWB 208 + 209)

011 - Messwerte

Anzeigegruppe 209

Messwerte

600	/min
82	
-8.0	°KW
00100100	

Anzeigegruppe 208

Messwerte

640	/min
124	
-3.0	°KW
00100100	



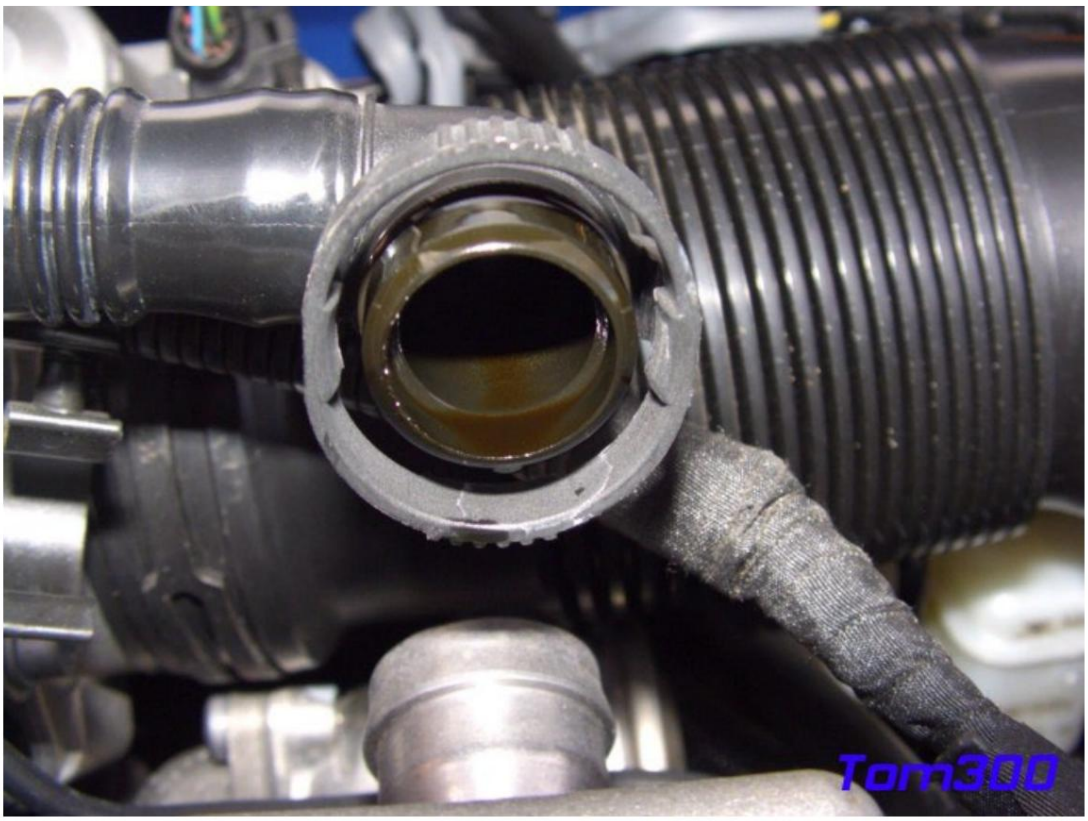
Image Appendix 4.2.1_1 - Diagnostic device on the Audi A3

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5.4_1 Connecting hose crankcase / intake manifold with integrated heater



Image 5.4.1_1 - Intake manifold with mounted hose



Picture 5.4.1_2 - Oil accumulations in the hose

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Picture 5.4.1_3 - Top



Image 5.4.1_4 - Bottom

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Picture 5.4.1_5 – integrated heating element



Image 5.4.1_6 – Radiographic image

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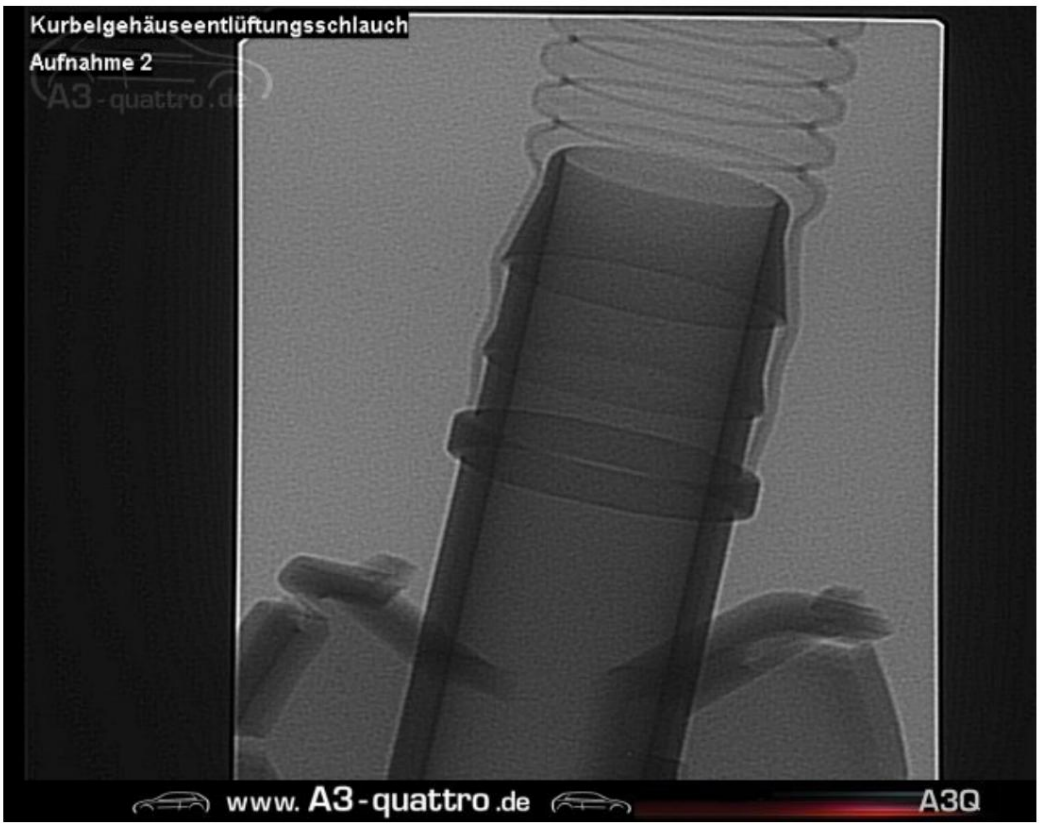


Image 5.4.1_7 – Radiographic image



Picture 5.4.1_8 – Radiographic picture of the heating element

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Picture 5.4.1_9 – Radiographic picture of the heating element

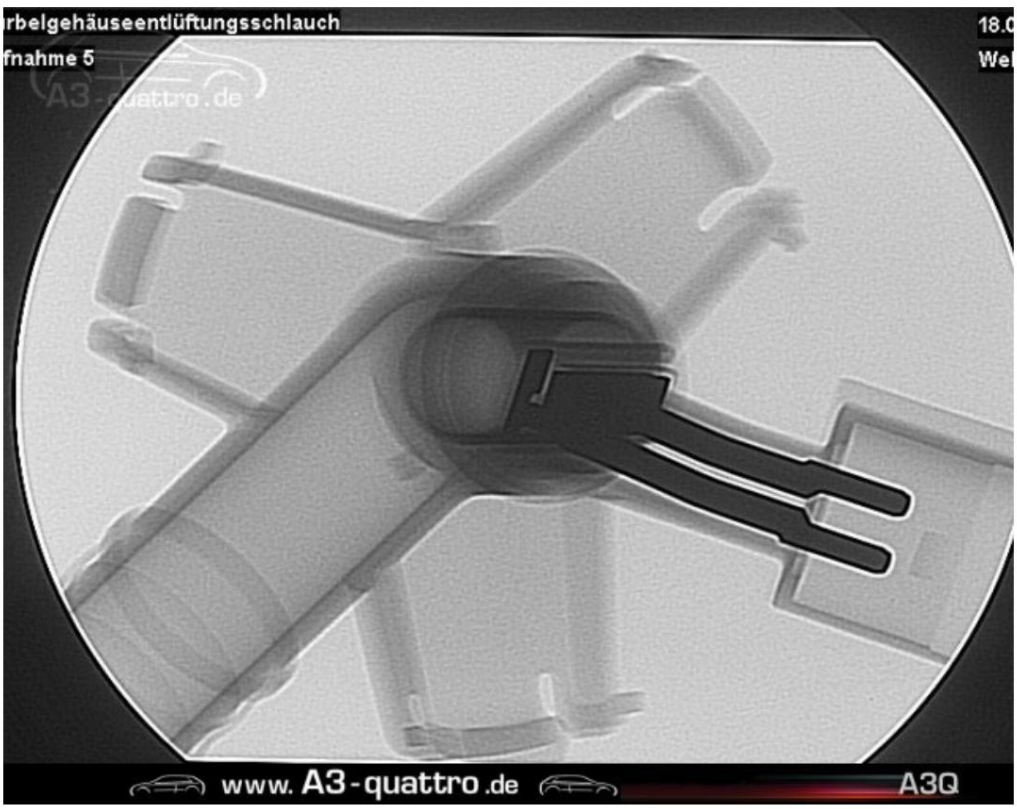


Image 5.4.1_10 – Radiographic image of the heating element

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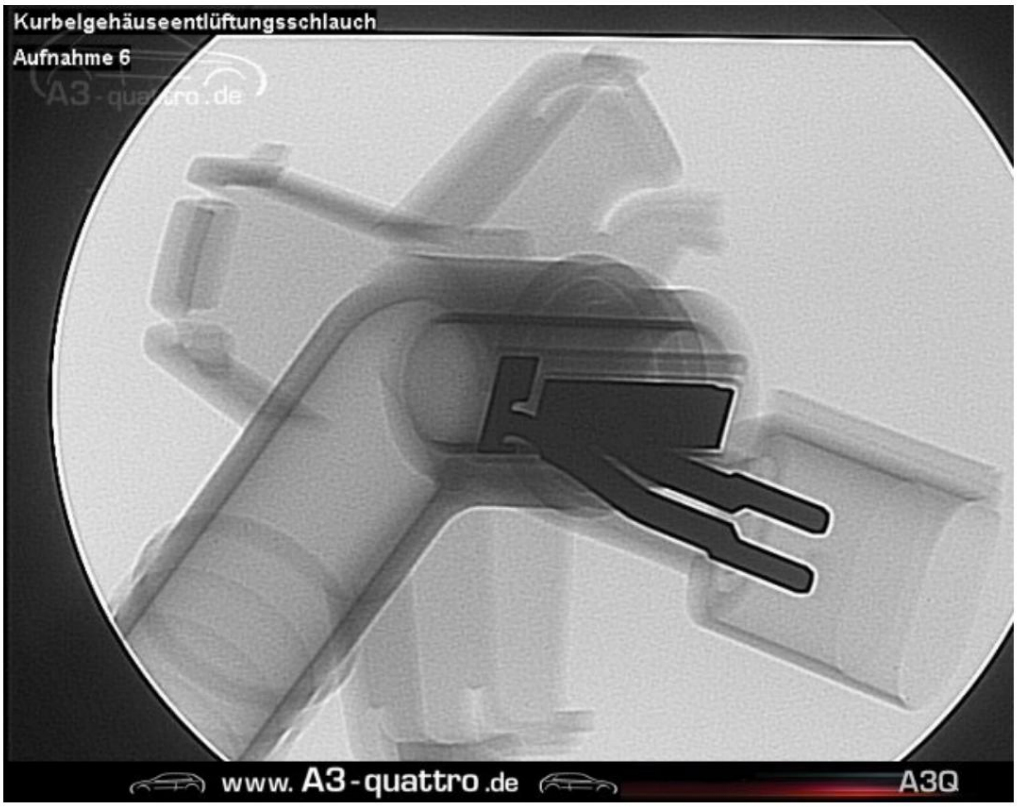


Image 5.4.1_11 – Radiographic image of the heating element



Image 5.4.1_12 – Radiographic recording

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7_1 Pictures of a repair



Image 7.1_1 – The professional repair



Image 7.1_2 – The professional repair

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Image 7.1_3 – The professional repair



Image 7.1_4 – The professional repair

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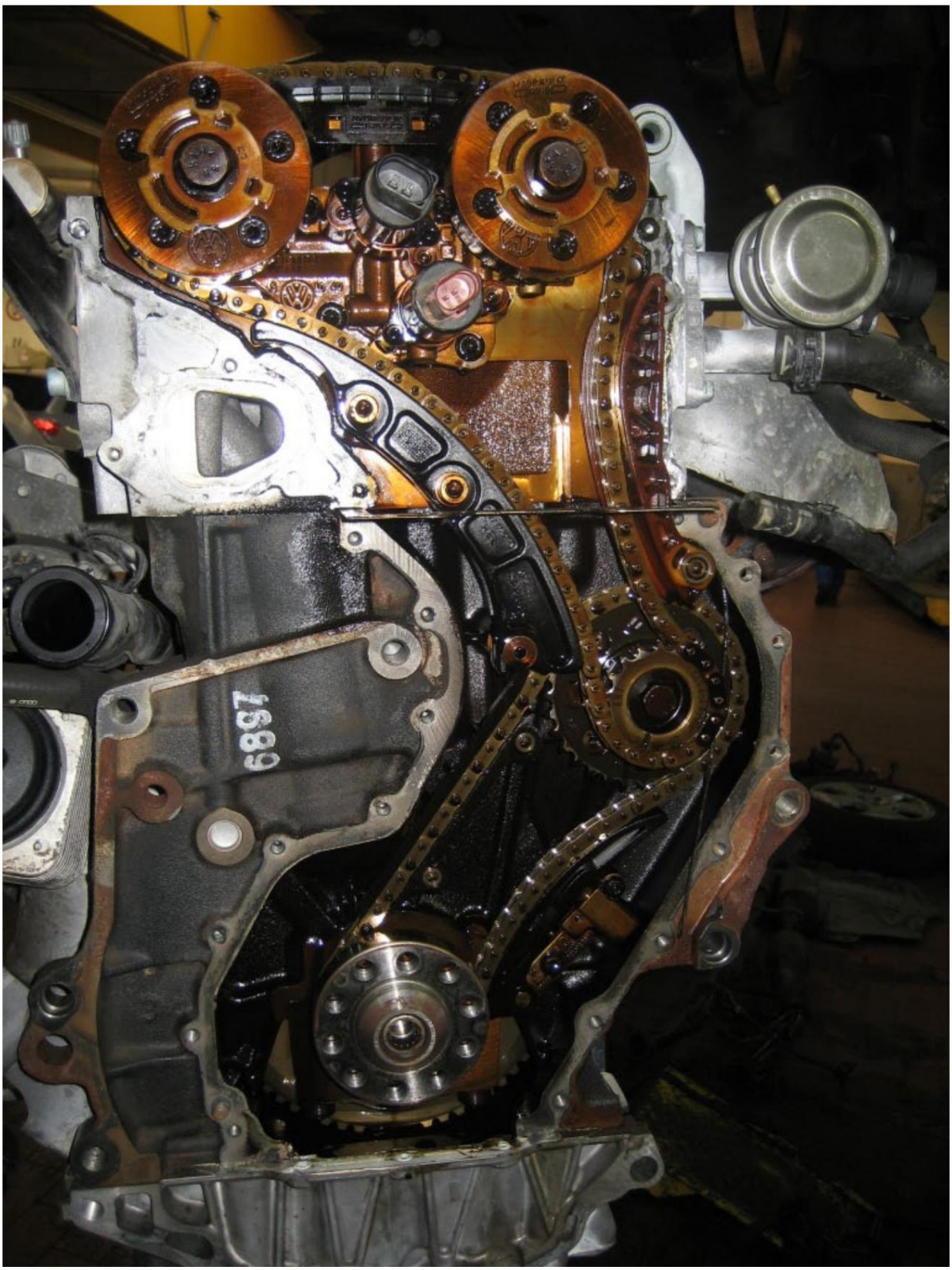


Image 7.1_5 - The professional repair

Machine Translated by Google



Image 7.1_6 - The professional repair



Image 7.1_7 - The professional repair

Machine Translated by Google



Image 7.1_8 - The professional repair



Image 7.1_9 - The professional repair

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Appendix 8_1

The statements made in the report regarding the Mobil 1 0w-40 relate exclusively to the Mobil 1 Supersyn.
Mobil now only offers this oil in the “NewLife” variant.
Since there is not enough information about this oil at the time of publication, the findings cannot be applied to this oil without prior examination.

Alternative good to very good oils are listed in the table below.

1. Mobil 1 5W-50 supersyn
2. Mobil 1 0W-40 supersyn
3. Meguin megol Super Leichtlauf fully synthetic 5W-40 4.
Meguin megol Super Leichtlauf Driver 0W-40 (4894)
5. Shell Helix Ultra 0W-40
6. Addinol Ultra Light MV046 0W-40
7. Addinol Super visco MV 0556 5W-50
8. AVIA AVIASYNTH LS 0W-40

For all of the oils mentioned, BEFORE use, the manufacturer's approvals must be observed, as these can vary in the different engines.