

Ceramic Brakes in Audi Vehicles

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Always check Technical Bulletins and the latest electronic repair literature for information that may supersede any information included in this booklet.

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The Self-Study Workbook provides introductory information regarding the design and function of new models, automotive components or technologies.

The Self-Study Workbook is not a Repair Manual!

All values given are intended as a guideline only.

Refer to the software version valid at the time of publication.

For maintenance and repair work, always refer to the current technical literature.

Reference



Note



Introduction

The first Audi to offer an optional ceramic brake system in Europe was the 2006 Audi A8. The 2011 R8 is the first, and currently only vehicle that offers ceramic brakes as an option in the United States market. Because of the material properties, ceramic brake systems have major advantages over conventional brake systems, particularly when used on high-performance and high-mileage vehicles. This Self-Study Program will provide you with a working knowledge of ceramic braking systems.



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Introduction

Fiber Composites in Brake Systems

Fiber-reinforced material applications are being used more frequently in automotive applications. This is because they have special material properties which render them ideally suited to certain applications. These properties include, in particular, high strength at low mass per unit area, high temperature resistance and outstanding wear properties.

Carbon-based fiber composites (C/C materials*) have been used successfully for many years as brake discs and brake pads in racing applications. The material was developed into a C/SiC ceramic* for use of the brake on production vehicles. This material will be described in greater detail in the next chapter.



Use of C/C brake discs on the Audi R10 TDI

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*Glossary:

CRP: Carbon Fiber-reinforced Plastic

C/C: Carbon Fiber-reinforced Carbon

C/SiC: Carbon Fiber-reinforced Silicon Carbide

Introduction

When used as a brake disc material, the C/SiC ceramic has the following significant advantages over conventional metallic brake materials such as cast iron:

- The components are lighter, reducing unsprung rotating masses in the vehicle (saving approx. 50% in weight per wheel)
- The brake discs are highly resistant to wear and they last four times longer than conventional brake discs
- Much higher resistance to rapid changes of temperature (thermal shock resistance), resulting in virtually no geometric deformation of the brake discs under heat stress
- High thermal resistance, resulting in a lower loss of friction between the brake disc and the brake pad at increasing temperatures (fading) *



S441_002

* On salted roads and in wet conditions, the braking power is equal to that of a conventional brake system, causing the driver to feel a reduction in braking power.

Introduction

The C/SiC Ceramic Material

The C/SiC ceramic material is a carbon fiber-reinforced silicon carbide.

Silicon carbide has similar properties to diamond. For example, it is very hard and has a very high resistance to wear, while possessing very good chemical and thermal resistance.

To make use of this brittle material in brake discs, reinforcing carbon fibers are added to the silicon carbide matrix. The resulting material is much tougher and a great deal more resistant to fracture. It also has a significantly higher damage tolerance due to its pseudoplastic behavior.



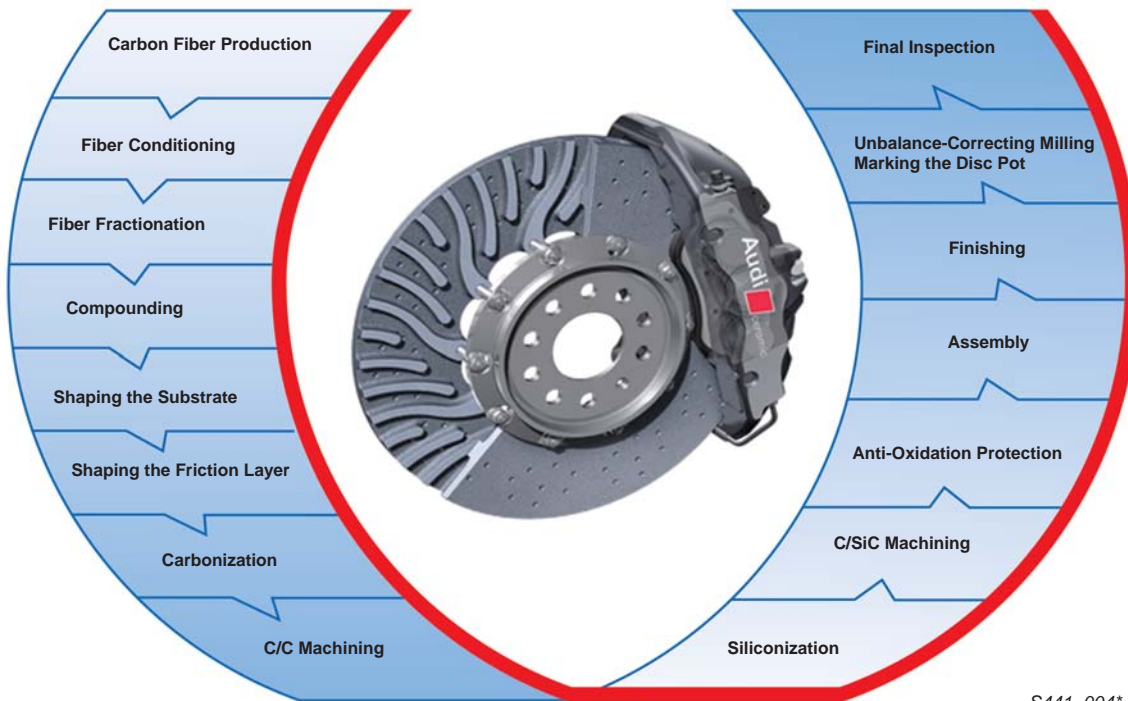
Primary materials: a compound of carbon fibers, phenolic resin and silicon granulate

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The Process of Manufacturing a Ceramic Brake Disc

The manufacturing of a ceramic brake disc is an extremely complex process. Many of the processing steps are still performed manually and are very time-consuming. To meet the high quality standards, the blank brake disc must first undergo several technically complex stages of finishing.

It is beyond the scope of this SSP to explain each individual processing step in detail. All key stages in the production of a ceramic brake disc are itemized in the following description.



S441_004*

The primary material for the production of a C/SiC ceramic brake disc is a compound of carbon fibers of differing length and phenolic resin. This compound is compacted under pressure and temperature and hardened to produce what is known as a Carbon-Reinforced Plastic (CRP) material. The blank is subsequently heat-treated at approx. 900 °C in an oxygen-free environment (carbonization), during which the phenolic resin is converted to carbon, producing a so-called C/C material.

After an intermediate mechanical machining stage, molten silicon is infiltrated into the C/C blank (siliconization) in vacuum furnaces at temperatures of over 1500 °C. The carbon matrix reacts with the molten silicon to produce silicon carbide while preserving the reinforcing carbon fibers within the microstructure. This process produces the so-called C/SiC ceramic friction ring, which is subsequently machined and bolted onto the metallic brake disc pot before being finish-ground.

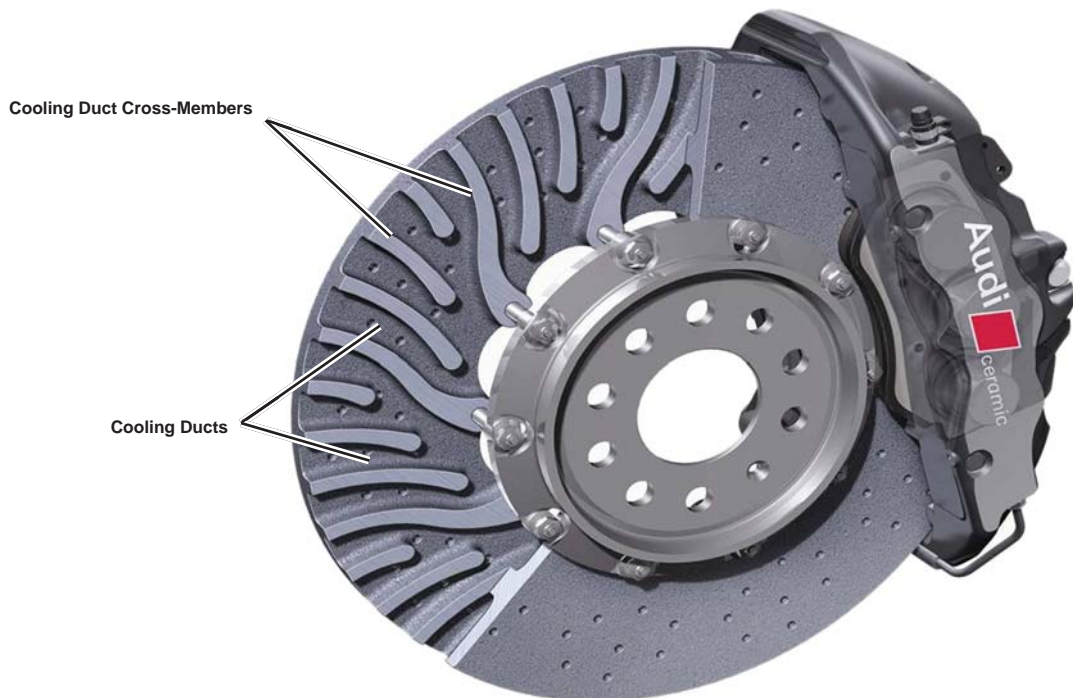
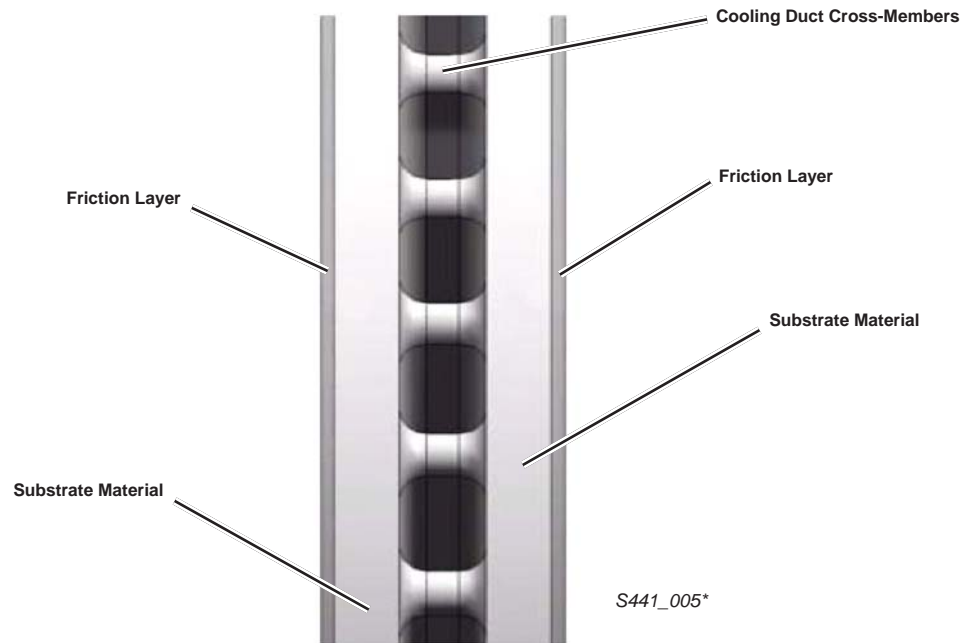
* provided by SGL Group Meitingen.

Introduction

Microstructure of a Ceramic Brake Disc

A ceramic brake disc has a so-called friction face on each side, which is major factor influencing the behavior of the ceramic material in the brake system. These friction faces are made of a slightly different material to the underlying substrate. The underlying substrate is responsible for component strength and absorbing braking energy.

All ceramic brake discs used on Audi production vehicles are ventilated from the inside using a special cooling duct. This duct is designed to maximize brake cooling efficiency.



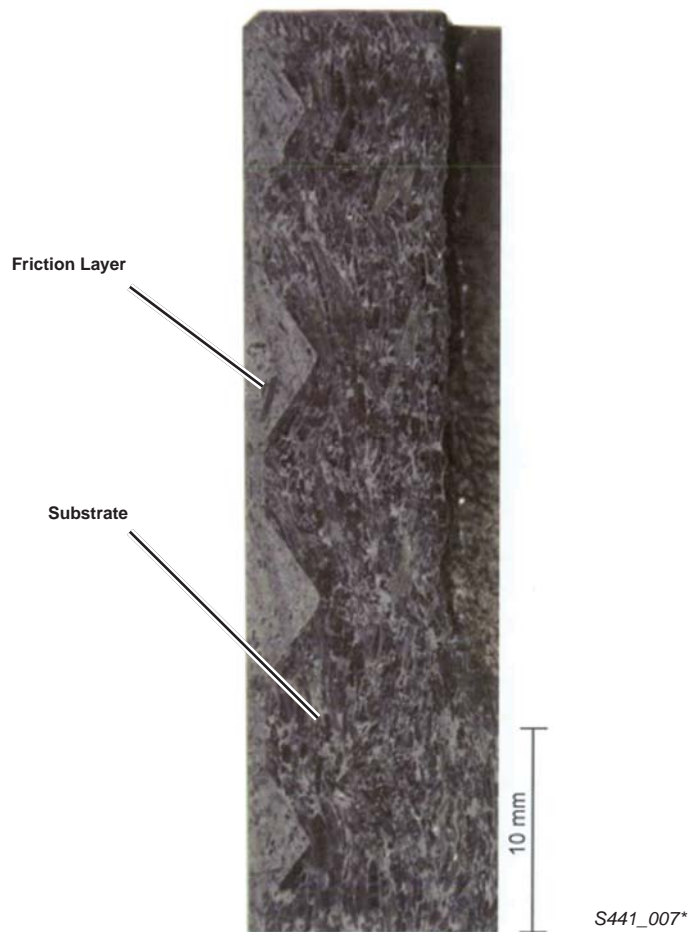
* provided by SGL Group Meitingen.

Introduction

The C/SiC brake disc ring basically consists of three different material components. The matrix is made up of silicon carbide and free silicon reinforced by embedded carbon fibers.

The proportion of silicon carbide ceramic is much higher in the friction layers than in the substrate since surface hardness and wear resistance are key factors.

In the substrate, on the other hand, the proportion of carbon fibers is correspondingly higher in order to guarantee sufficient component strength.



Microstructural image of the friction layer and substrate materials of the ceramic brake disc (cross-sectional image)

Ceramic Brakes in Audi Production Vehicles

Technical Implementation

Fiber composites were first used in racing applications. However, the demands on the C/C components used were very different to those needed on production vehicles.

In racing applications the emphasis is on high braking performance at high temperatures. Criteria such as wear resistance, controllability, comfort and cost are the primary differences between racing applications and production vehicles.

In racing applications, C/C brake discs and pads first have to reach a certain temperature before they can produce sufficient friction to achieve satisfactory braking performance. This behavior would be unacceptable on production vehicles. Audi production vehicles come equipped with C/SiC brake discs, which provide superior stopping power in all operating conditions, even when they are relatively cold.

The ceramic brake system on Audi production vehicles uses conventional organic-bonded brake pads. The brake pad compound contains slightly more non-ferrous metal than the brake pad material used in a conventional brake system in order to create higher operating temperatures.

The service life of the brake pads matches that of conventional brake pads.



Organic brake pads for the ceramic brake

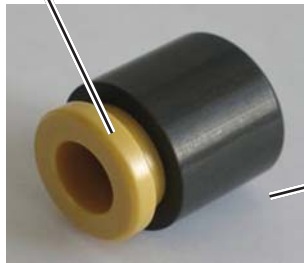
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Ceramic Brakes in Audi Production Vehicles

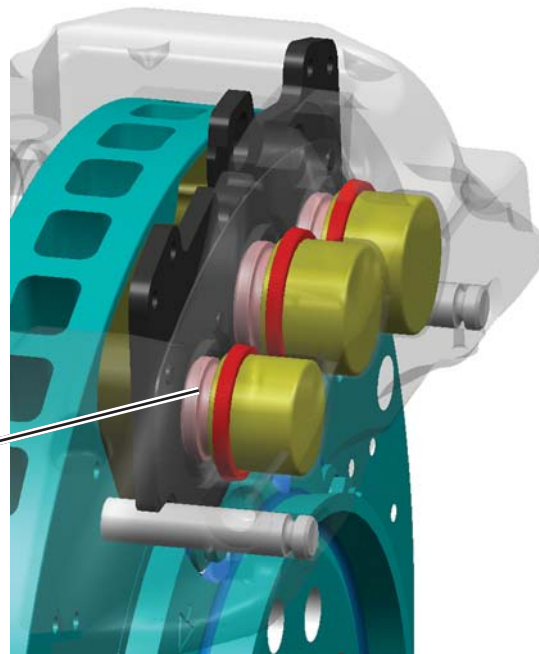
Because the brake disc and brake pad are subjected to higher temperatures than conventional brake systems, special brake calipers are necessary. It is important to prevent the transfer of high temperatures from the brake pad and brake piston to the brake fluid.

Boiling brake fluid would produce vapor bubbles (air) in the brake system. To prevent this, some manufacturers (e.g. Brembo) place zirconium oxide ceramic insulators between the brake piston and the brake pad.

Brake Piston Insulator



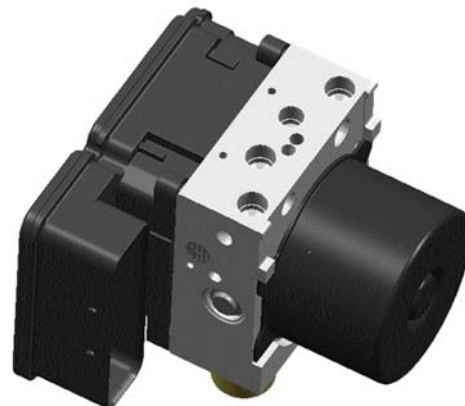
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Ceramic brake discs behave differently than conventional brake discs when they are wet due to the properties of the material.

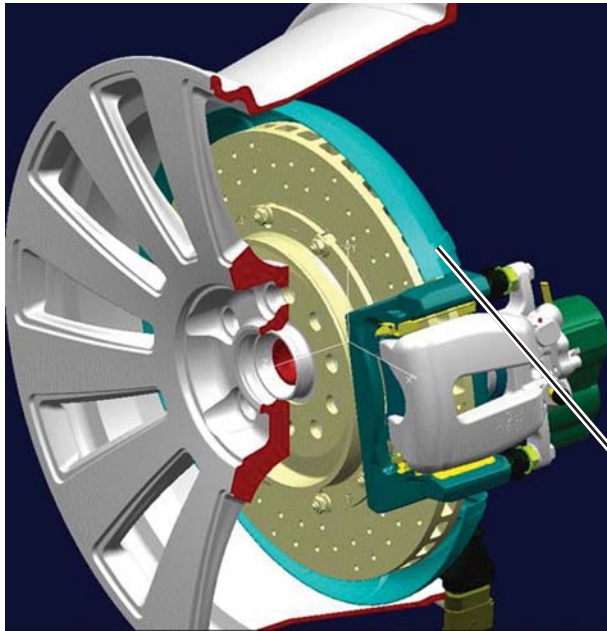
The familiar "Brake Disc Wiper" function is integrated in the ESP system for all Audi vehicles with ceramic brakes. When wet conditions are present, the brake pads are applied cyclically to dry and clean the rotor surface.



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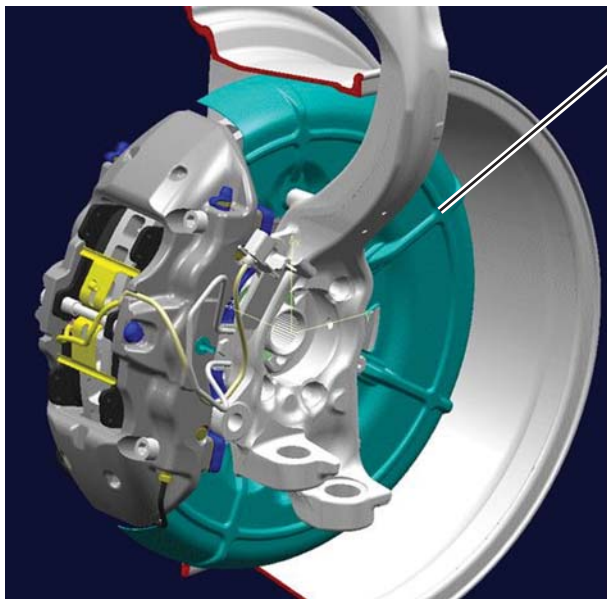
Ceramic Brakes in Audi Production Vehicles

Technical Implementation

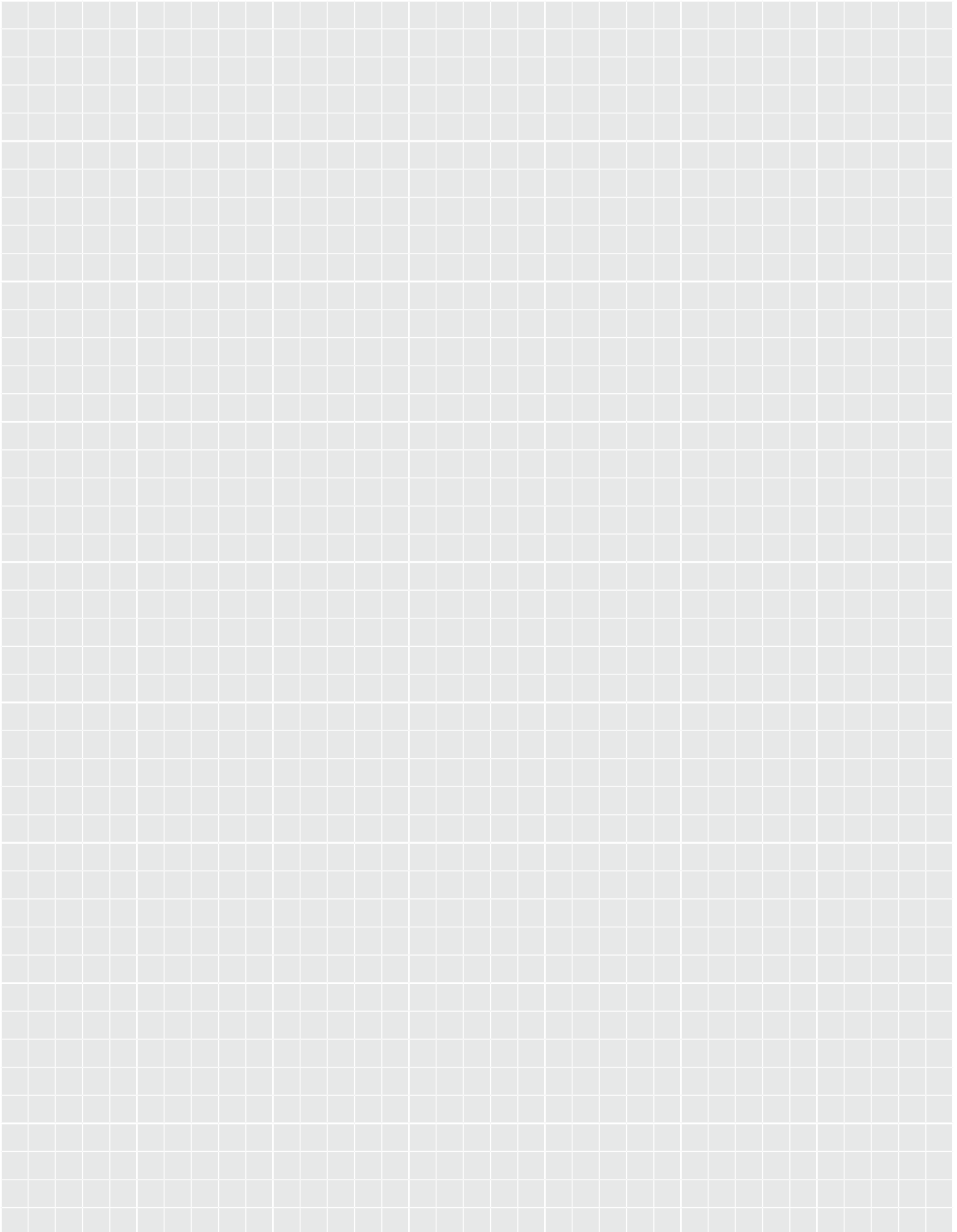


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Larger heat shields are used on vehicles equipped with ceramic brake systems.



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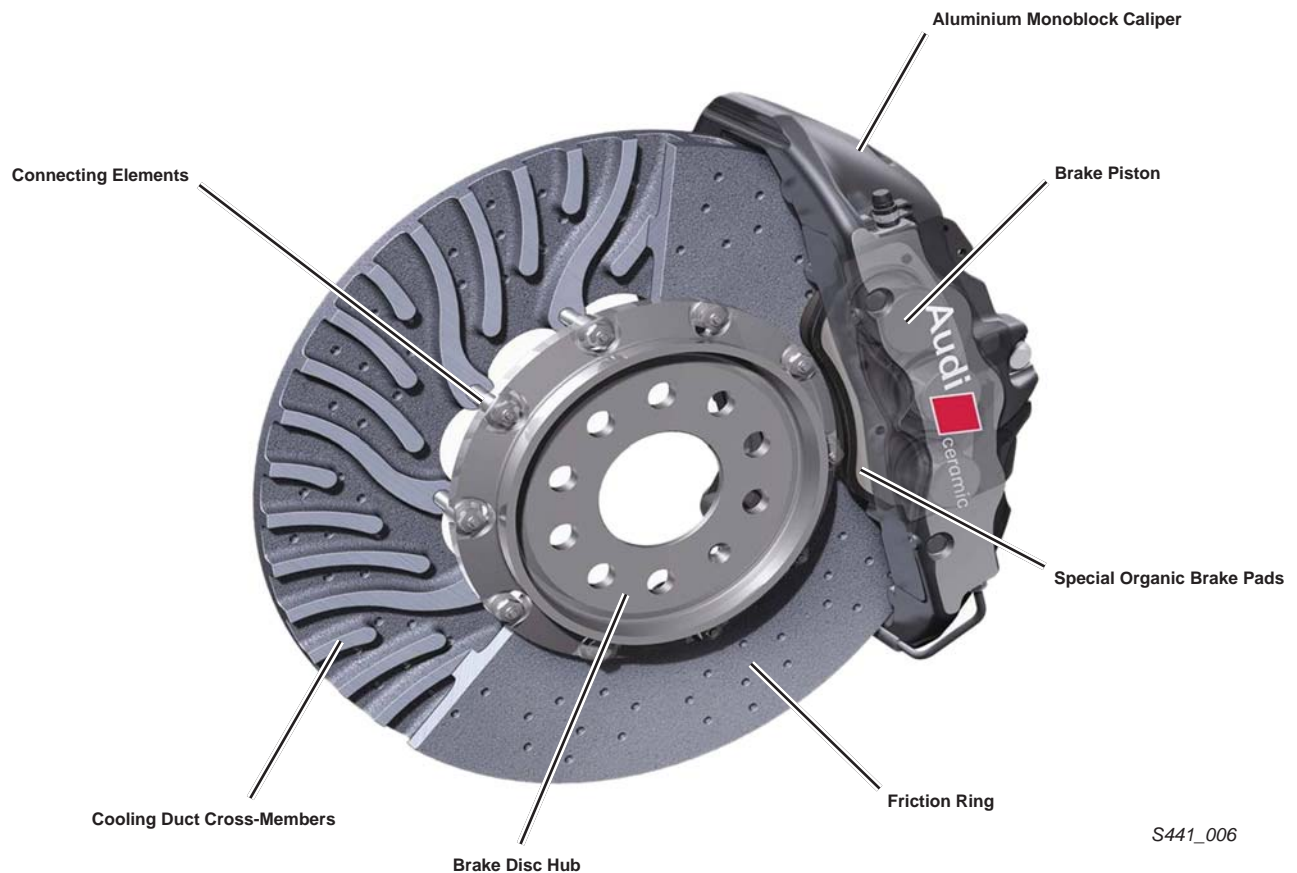


Ceramic Brakes in Audi Production Vehicles

Design and Identification of Ceramic Brake Discs

The ceramic friction ring is permanently connected to the metallic brake disc hub by metallic connecting elements. The brake disc hub and connecting elements are made of a corrosion-resistant metal alloy. On some models, the brake disc hub has a special coating. Perforation holes and cooling ports are integrated in the friction ring.

Proper cooling is only possible if the brake discs are fitted in the designated position on the vehicle. For this reason, the brake discs are direction specific, i.e. there are different brake discs for the left- and right-hand sides of the vehicle.

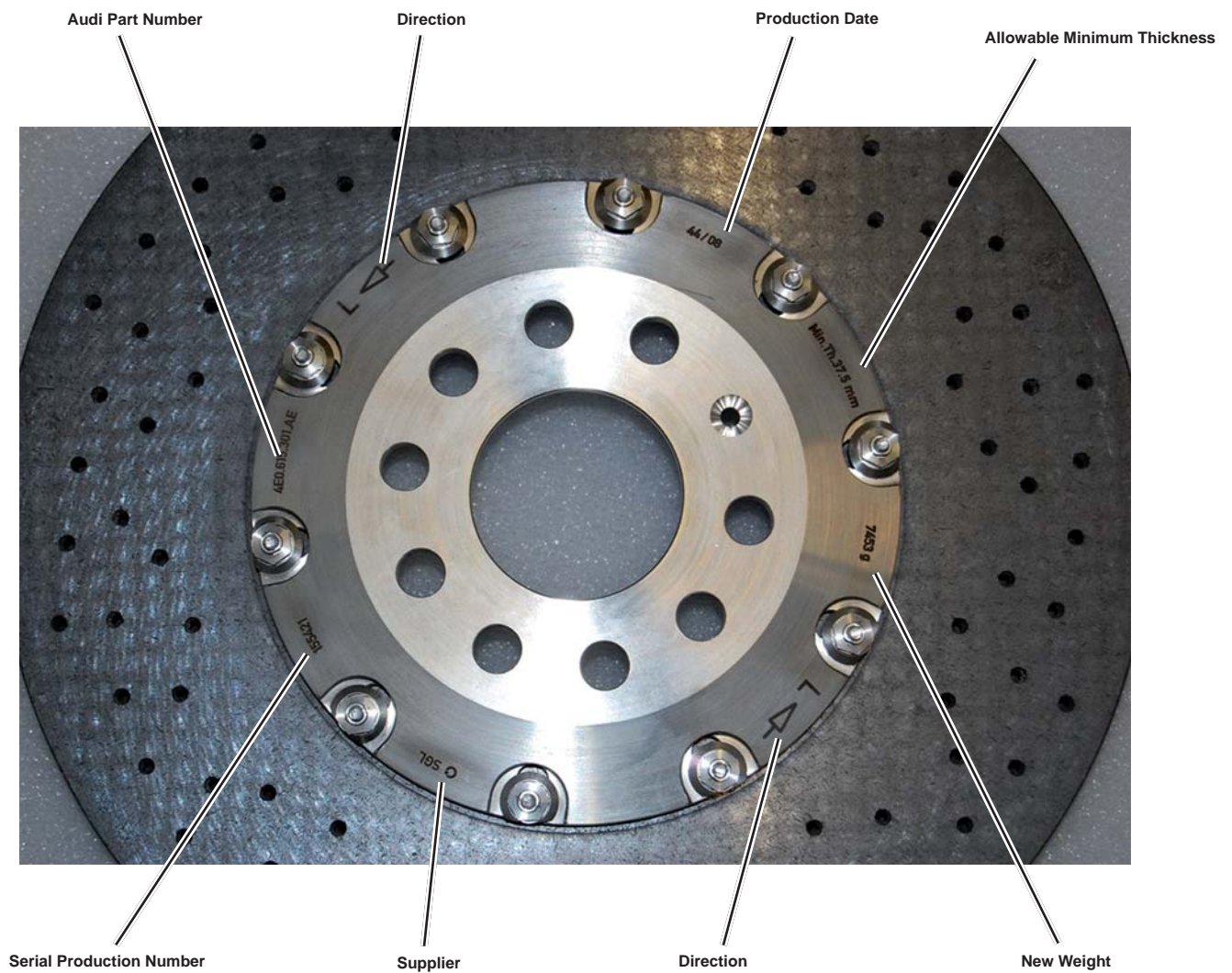


Note

Don't loosen the connecting elements!
If any of the connecting elements are ever loosened, the entire brake disc assembly can no longer be used.

Ceramic Brakes in Audi Production Vehicles

All key product data is engraved on the ceramic brake disc hub:



Servicing

General Servicing of Ceramic Brake Discs

Please note the following when handling ceramic brake discs:

- Avoid subjecting the brake disc to mechanical impacts (e.g do not use a hammer to remove the brake disc from the wheel hub)
- Do not clean the ceramic surface using mechanical means. Stubborn dirt can be removed from the perforation holes by carefully pushing a suitable tool through the holes
- The brake discs can be cleaned using conventional brake cleaning agents, with steam jet cleaning equipment or compressed air

Procedure for Changing a Wheel

The tool kit includes a drift that guides the wheel away from the brake disc. This prevents collision of the wheel with the brake disc upon wheel removal.



Assembly drifts in the tool kit

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Screwed-in assembly drifts

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Note

For detailed instructions, refer to the Owner's Manual and the Workshop Manual. When using compressed air for cleaning purposes, the respiratory protection regulations must be observed.

Ceramic Brake Disc Inspection

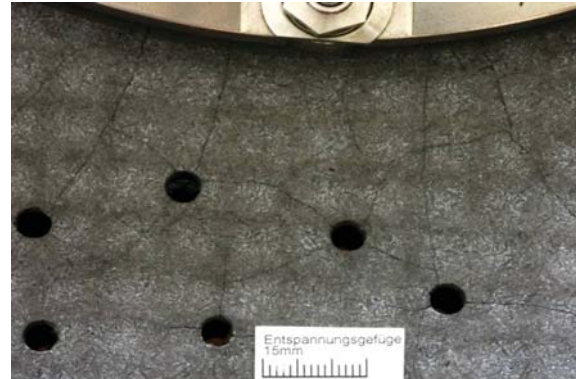
To determine whether a brake disc needs replacing, an objective assessment must be made regarding the extent of wear and damage.

To be able to assess this, it is important to be familiar with the appearance of the brake disc in the as new condition. The principal characteristics are described below.

1. Expansion crack microstructure on the friction faces

New condition the friction faces are covered with a complex and varied expansion crack microstructure. Individual thermal expansion cracks run partially along the perforation holes. This crack microstructure is pronounced in places and can differ considerably from inside to outside rotor surfaces. The thermal expansion crack microstructure occurs during the production process and is not an indication of a problem.

The surfaces of the ceramic friction ring are very different to those of a conventional brake disc. If a conventional brake disc had these cracks it would have to be replaced. Ceramic brake discs in this condition are absolutely acceptable.

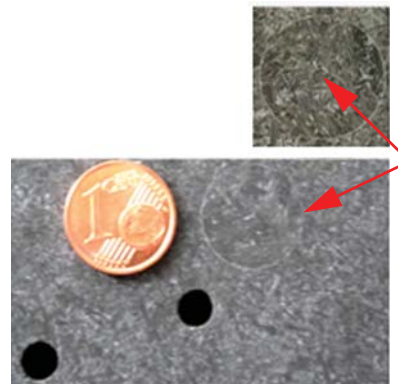


Typical thermal expansion crack microstructure and lattice structure of a ceramic brake disc in the as-new condition

S441_018

2. Wear indicators on the friction faces

Three circular wear indicators offset at an angle of 120° are integrated in each friction face. They can be used to determine the extent of wear after a defined, high mileage and/or after heavy use of the ceramic brake discs. Wear indicator evaluation is covered later in this SSP.

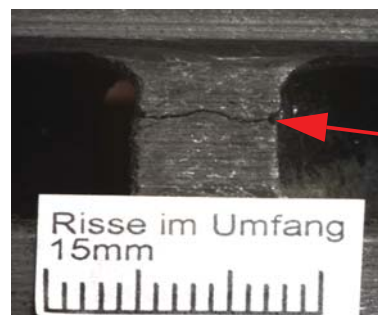


Wear indicator of a ceramic brake disc in the as-new condition

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3. Superficial cracks in the cooling duct cross-members

Superficial cracks in the cooling duct cross-members are manufacturing-related, and do not represent a defect.



Crack in the cooling duct cross-member of a ceramic brake disc

S441_020

Servicing

Wear Criteria

Generally, two types of wear can occur in ceramic brake discs:

1. Loss of thickness

The thickness of the brake disc decreases due to mechanical friction between the brake pad and friction ring. Due to the hardness of the friction face, the loss of thickness is considerably less than in conventional brake discs.

2. Loss of weight due to oxidation

The ceramic brake disc is subject to thermo-mechanical and oxidative wear. When the brake disc reaches temperatures of above 400 °C, the carbon fibers oxidize by reaction with atmospheric oxygen. Consequently, at sustained operating temperatures of above 400 °C, the brake disc continuously loses weight and the material microstructure changes superficially due to material burnout and resultant porosity.



S441_021



Brake disc surface in an as-new condition

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Brake disc surface exhibiting burnout

S441_022b

Determination of Wear

The ceramic brake disc operating conditions dictate wear criteria.

1. Measuring loss of thickness

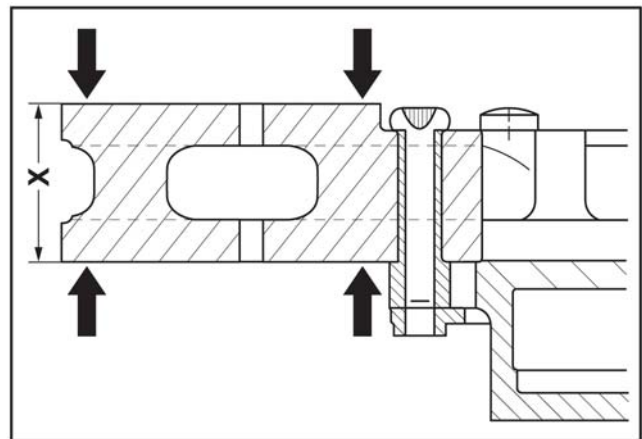
The permissible minimum friction ring thickness min. Th. (= "minimum thickness") is engraved on the ceramic brake disc.



S441_023

Brake disc thickness "X" is measured by applying a suitable micrometer gauge or brake disc gauge to the inner or outer friction face (as indicated by the arrows in the diagram). Brake disc thickness must always be measured when replacing the brake pad and documented in an appropriate fashion.

If $X = \text{minimum thickness} + 0.2 \text{ mm}$, the ceramic brake disc also has to be weighed. See Procedure 2.



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Note

Once the minimum thickness has been reached, the brake discs can no longer be used.

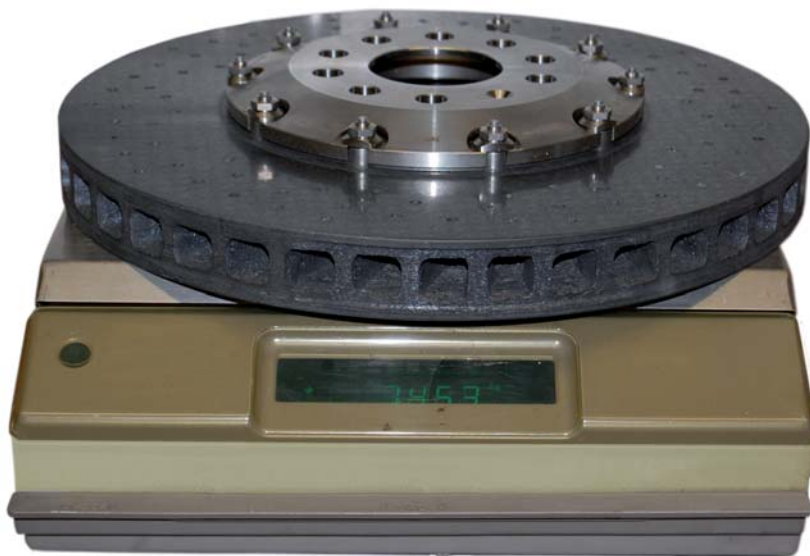
Servicing

Determination of Wear

2. Determination of wear by weighing

Under high load, oxidation of the carbon causes the ceramic brake disc to continually lose weight. Because of this, weighing the brake disc is also an accurate way to determine wear. However, this method can only be used if a scale with an accuracy of $\pm 1\text{g}$ is available. The measurement range of the scale should be 0-12 kg.

The initial weight of a new brake disc is engraved on the brake-disc hub.



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Allowable weight loss limits are given in the Service Information.



Note

The brake disc must be clean and dry prior to weighing, since heavily soiled and wet brake discs will falsify the measurement result. If the friction faces are heavily coated with brake-pad material, the brakes should be applied a few times in order to clean off the friction faces.

When the limits for loss of weight are reached, the brake discs must be replaced.

Determination of Wear

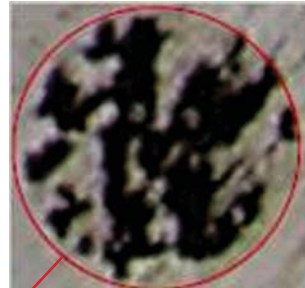
3. Evaluating the wear indicators

The indicators can be visually located on the friction face by their slightly different color. The indicators have a different color because they have a higher carbon content and are subject to greater wear than the other regions of the friction face.

Wear of the indicators appears as material burnout, which can be recognized by dark-colored recesses. If these indicators show heavy wear, the thickness of the brake disc must be measured.

This measurement must be taken as soon as one of the six indicators begins to exhibit these symptoms of wear.

Example of an indicator surface exhibiting more than 50 % wear



S441_025



S441_026

Servicing

Damage

A visual check for damage must always be made during routine inspection work and in the event of complaints. The visual inspection also includes the connecting elements of the friction ring and brake disc hub, screws, nuts and thrust washers. If parts are missing or loose, then the brake discs must be replaced. It is strictly prohibited to "retighten" connecting elements.

1. Interfacial cracks

Ceramic brake discs exhibiting cracks extending from the interfacial region (bolted connection between disc and hub) to the friction faces must always be replaced.



Critical interfacial crack propagation characteristic

S441_028

2. Edge chipping

Edge chipping is caused by mechanical damage to the edge zone.

The following edge chipping is acceptable:

- Maximum permissible width / depth = 2 mm
- Maximum permissible length = 10 mm
- Maximum three edge damages per brake disc

If any of the above-mentioned criteria is exceeded, then the brake disc must be replaced.



Edge chipping

S441_029

3. Chipping of the friction faces

Brake discs exhibiting chipped material on the friction faces over a contiguous **surface area of greater than 1 cm²** must always be replaced.



Chipping of the friction layer

S441_030



Note

Brake discs must be replaced for the entire axle if:

- The brake discs are in need of replacement due to wear
- The replacement brake disc has been modified technically (indicated by a change of part number)

The ceramic brake discs have wear resistant friction faces. After new brake discs have been installed, the discs and pads must be "run in". Depending on the loading conditions, this process can take longer than with conventional brake systems. If the brakes are not broken-in as specified, comfort may be impaired (brake shudder, noise) as well as increased wear can occur.

Break-in instructions

After replacing ceramic brake discs and/or brake pads, the following break-in instructions must be performed:

Pad new, brake disc new

- 10** braking applications from approx. 50 mph to approx. 20 mph at a low rate of deceleration (corresponds to a cautious, anticipatory style of driving, characterized by early braking, no apparent dive motion of the vehicle under braking, no locking of the seat belt)
- 20** braking operations from 60 mph to approx. 30 mph at a medium rate of deceleration (gentle dive motion of the vehicle is noticeable)

Follow-up braking must be avoided.

Allow the brakes to cool down between individual braking operations.

Trip time: approx. 30 minutes

Pad new, brake disc used

- 5** braking applications from approx. 50 mph to approx. 20 mph at a low rate of deceleration (corresponds to a cautious, anticipatory style of driving, characterized by early braking, no apparent dive motion of the vehicle under braking, no locking of the seat belt)
- 10** braking operations from 60 mph to approx. 30 mph at a medium rate of deceleration (gentle dive motion of the vehicle is noticeable)

Follow-up braking must be avoided.

Allow the brake to cool down between individual braking operations.

Trip time: approx. 20 minutes



Note

Always refer to the latest service information for the most current service and repair procedures.

Notes



Knowledge Assessment

An online Knowledge Assessment (exam) is available for this Self-Study Workbook.

The Knowledge Assessment is required for Certification.

You can find this Knowledge Assessment at:

www.accessaudi.com

From the [accessaudi.com](http://www.accessaudi.com) Homepage:

- Click on the “ACADEMY” tab
- Click on the “Academy Site” link
- Click on the “CRC/Certification” link
- Click on Course Catalog and select “960113 - Ceramic Brakes in Audi Vehicles”

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Thank you for reading this Self-Study Workbook and taking the assessment.

