Service Training

Ceramic Brakes in Audi Vehicles

Self-Study Programme 994441AG

The material in this Self Study Program (SSP) may contain technical information or reference vehicle systems and configurations which are not available in the Canadian market.

Please ensure you reference ElsaPro for the most current technical information and repair procedures.

A ceramic disc brake system was offered as optional equipment for the first time in an Audi production car on the Audi A8' 06. By virtue of their material properties, ceramic brake systems have major advantages over conventional brake systems, particularly when used on high-performance and high-mileage vehicles. For this reason, the product range has been extended to include other models. For the first time in an Audi, a ceramic brake is available as standard equipment with the Audi Q7 V12 TDI. This Self-Study Programme will provide you with a working knowledge of this interesting topic.

441_031

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Introduction

Ceramic brakes in Audi production vehicles

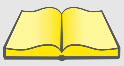
Servicing

The Self-Study Programme teaches the design and function of new vehicle models, new automotive parts or new technologies.

The Self-Study Programme is not a Repair Manual.
All values given are intended as a guideline only and refer to the software version valid at the time of preparation of the SSP.

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

Reference



Note

Fibre composites in brake systems

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

Carbon-based fibre composites (C/C materials*) have been used successfully for many years as brake discs and brake pads in motor racing. 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 *441_001*

***Glossary:**

CRP: Carbon Fibre-reinforced Plastic
C/C: Carbon Fibre-reinforced Carbon
C/SiC: Carbon Fibre-reinforced Silicon Carbide

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, thereby reducing unsprung rotating masses in the vehicle (saving approx. 50 % in weight per wheel)

– The brake discs are highly resistant to wear and last four times longer than conventional brake discs

441_002

– Much higher resistance to rapid changes of temperature (thermal shock resistance), with the result that virtually no geometric deformation of the brake discs occurs under heat stress

– High thermal resistance, with the result that there is less loss of friction between the brake disc and the brake pad at increasing temperatures (fading) *

* on salted roads and in wet conditions, the braking power is equal to that of a conventional brake system. The driver may notice a reduction in braking power, being accustomed to the high braking performance of the ceramic brake system.

The C/SiC ceramic material

The C/SiC ceramic material is a carbon fibre-reinforced silicon carbide.
Silicon carbide has similar properties to diamond, i.e. it is very hard and consequently has a very high resistance to wear, while possessing very good chemical and thermal resistance.

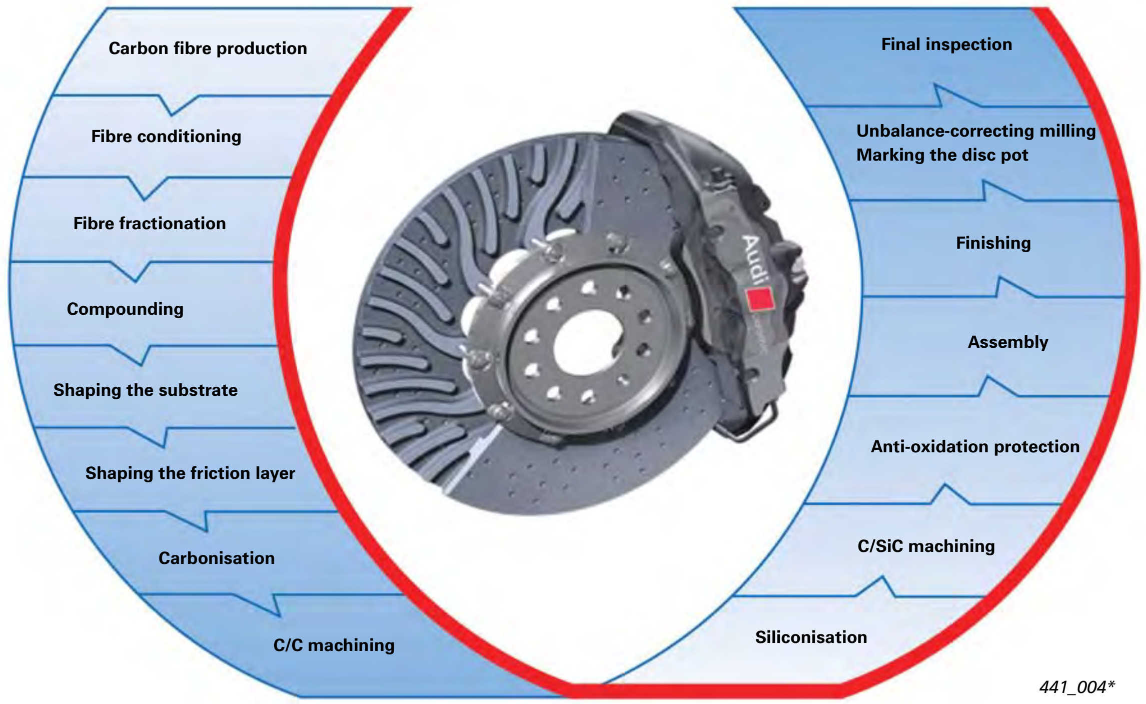
To make use of this brittle material in brake discs, reinforcing carbon fibres are added to the silicon carbide matrix. The resulting material is much tougher and a great deal more resistant to fracture, in addition to having a significantly higher damage tolerance due to its pseudoplastic behaviour.

Primary materials: a compound of carbon fibres, phenolic resin and silicon granulate *441_003*

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 itemised in the following description.



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The primary material for the production of a C/SiC ceramic brake disc is a compound of carbon fibres 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 (carbonisation), during which the phenolic resin is converted to carbon, producing a so-called C/C material.

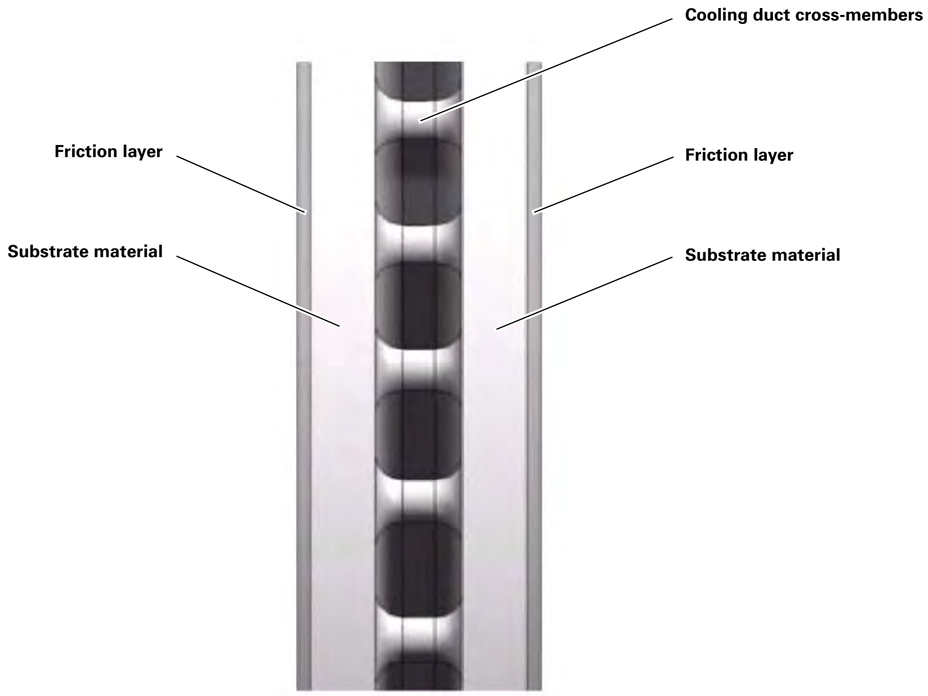
After an intermediate mechanical machining stage, molten silicon is infiltrated into the C/C blank (siliconisation) in vacuum furnaces at temperatures of over 1500 °C. The carbon matrix reacts with the molten silicon to produce silicon carbide while preserving the reinforcing carbon fibres within the 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.*

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 tribological behaviour of the ceramic material in the brake system. These friction faces are made of a slightly different material to the underlying substrate, which has the task of imparting strength to the component and absorbing braking energy.

All ceramic brake discs used on Audi production vehicles are inside ventilated using a special cooling duct designed to maximise brake cooling efficiency.



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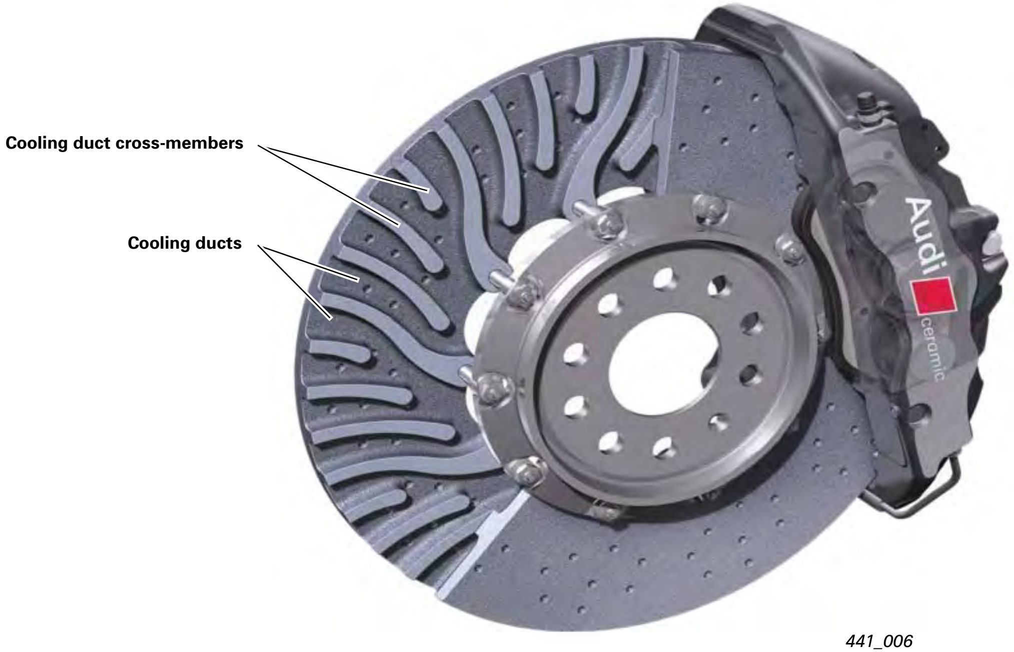

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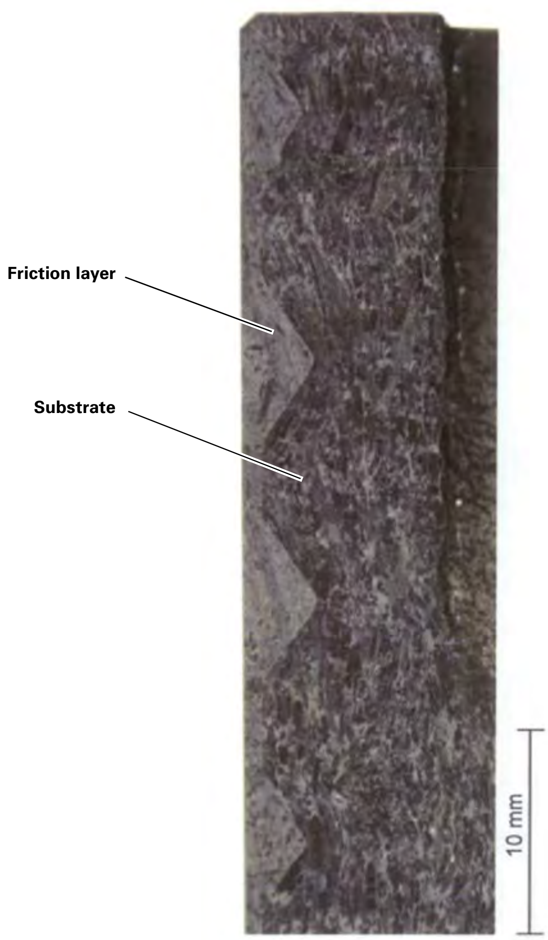
** provided by SGL Group Meitingen.*

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 fibres. 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 fibres is correspondingly higher in order to guarantee sufficient component strength.



*441_007**

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

** provided by SGL Group Meitingen.*

Technical implementation

Fibre composites were used for the first time as brake discs in motor racing. However, the demands on the C/C components used for this application are very different to those for production vehicles. Whereas in motor racing the emphasis is on high braking performance at high temperatures, criteria such as wear resistance, controllability, comfort and cost are also major factors in the case of production vehicles.

In motor racing, 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 behaviour would be unacceptable on production vehicles. Audi production vehicles therefore come equipped with C/SiC brake discs, which provide superior stopping power in all operating conditions.

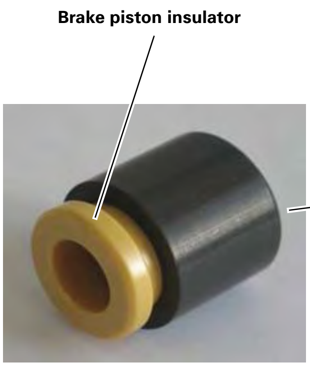
The ceramic brake system on Audi production vehicles uses conventional organic-bonded brake pads. The brake pad compound contains slightly more non-ferrous metal than the brake pad material used in a conventional brake system, in order to realise higher operating temperatures.
The service life of the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

441_008

Organic brake pads for the ceramic brake

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 vapour bubbles, and therefore 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.



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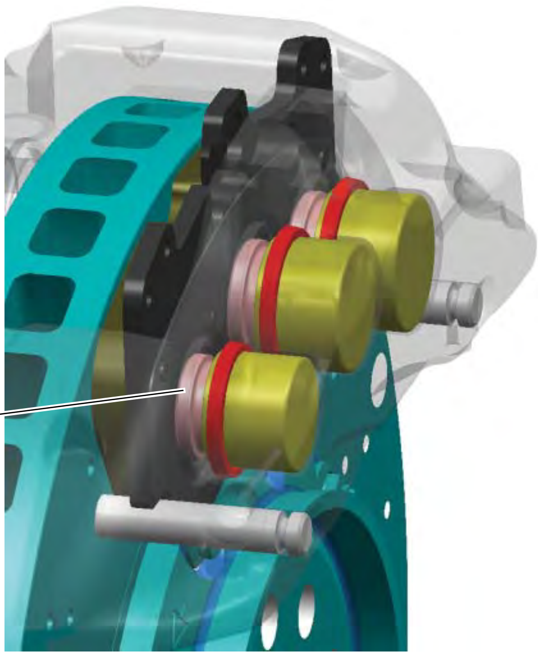

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Ceramic brake discs behave differently to conventional brake discs in the wet on account of their material properties. The familiar "Brake Disc Wiper" function is integrated in the ESP system for all Audi vehicles with ceramic brakes. When the brake pads are applied in the wet, the brake disc surface is cyclically dried and cleaned.

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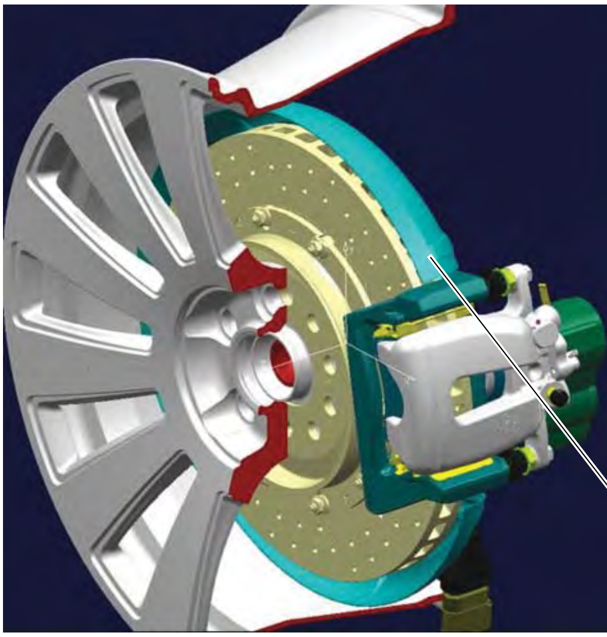
Technical implementation



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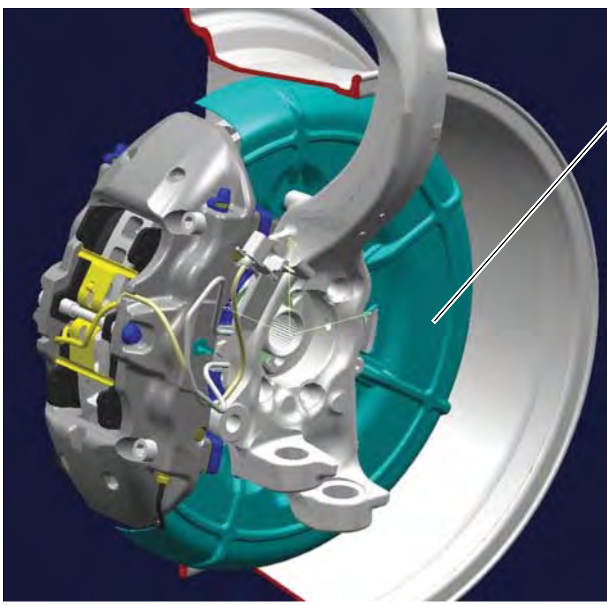

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In addition, larger heat shields are used on vehicles equipped with ceramic brake systems.

Overview of models

According to the current product range as at December ’08, ceramic brake systems are only available for the Audi models listed in the following table.

Model	Equipment	Axle position
A8 W12	Optional standard equipment	on front and rear axles
S8	Optional standard equipment	on front and rear axles
A8 V8 (TDI and FSI)	Optional standard equipment, retrofittable	on front and rear axles
RS4 (Avant, saloon, Cabriolet)	Optional standard equipment	front axle only
RS6 (Avant, saloon)	Optional standard equipment	on front and rear axles
Q7 V12 TDI	Standard equipment	on front and rear axles
Q7 V8	Optional standard equipment	on front and rear axles
R8	Optional standard equipment	on front and rear axles

441_014

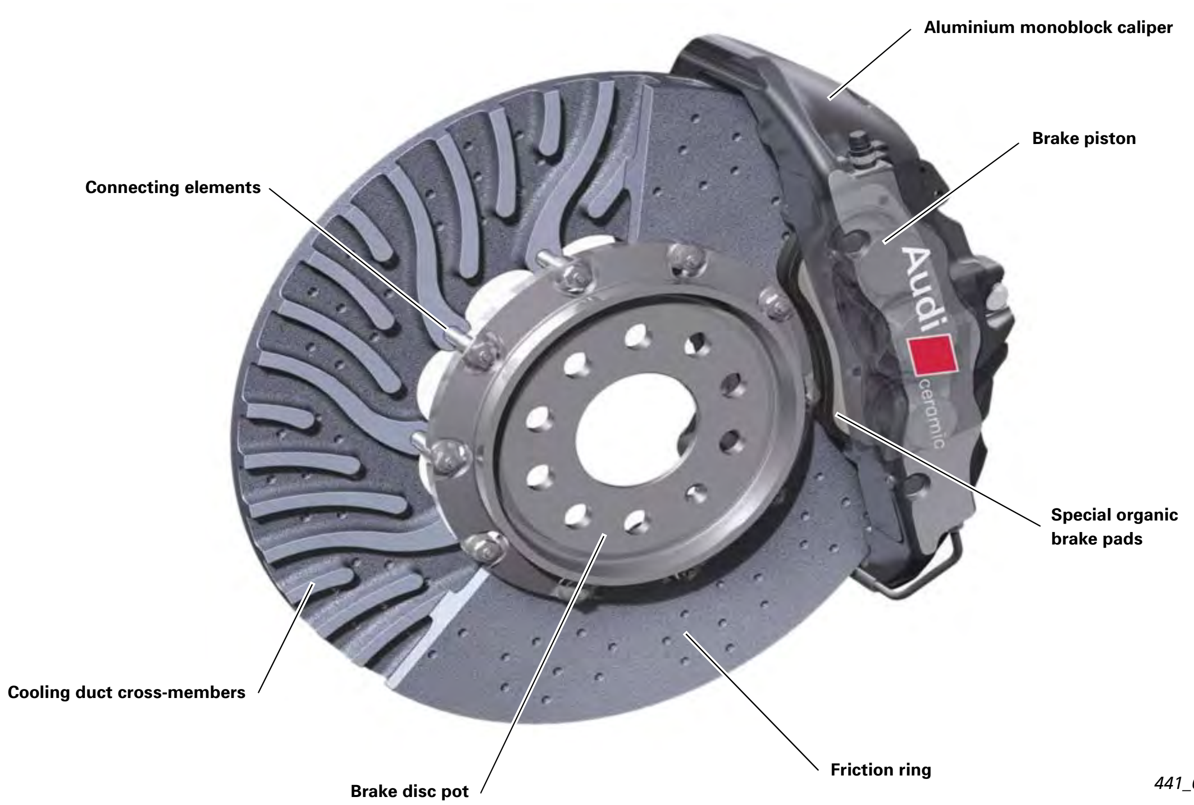
Design and identification of ceramic brake discs

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

Proper cooling is assured only 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

It is not permissible to detach the friction ring from the brake disc pot during servicing.



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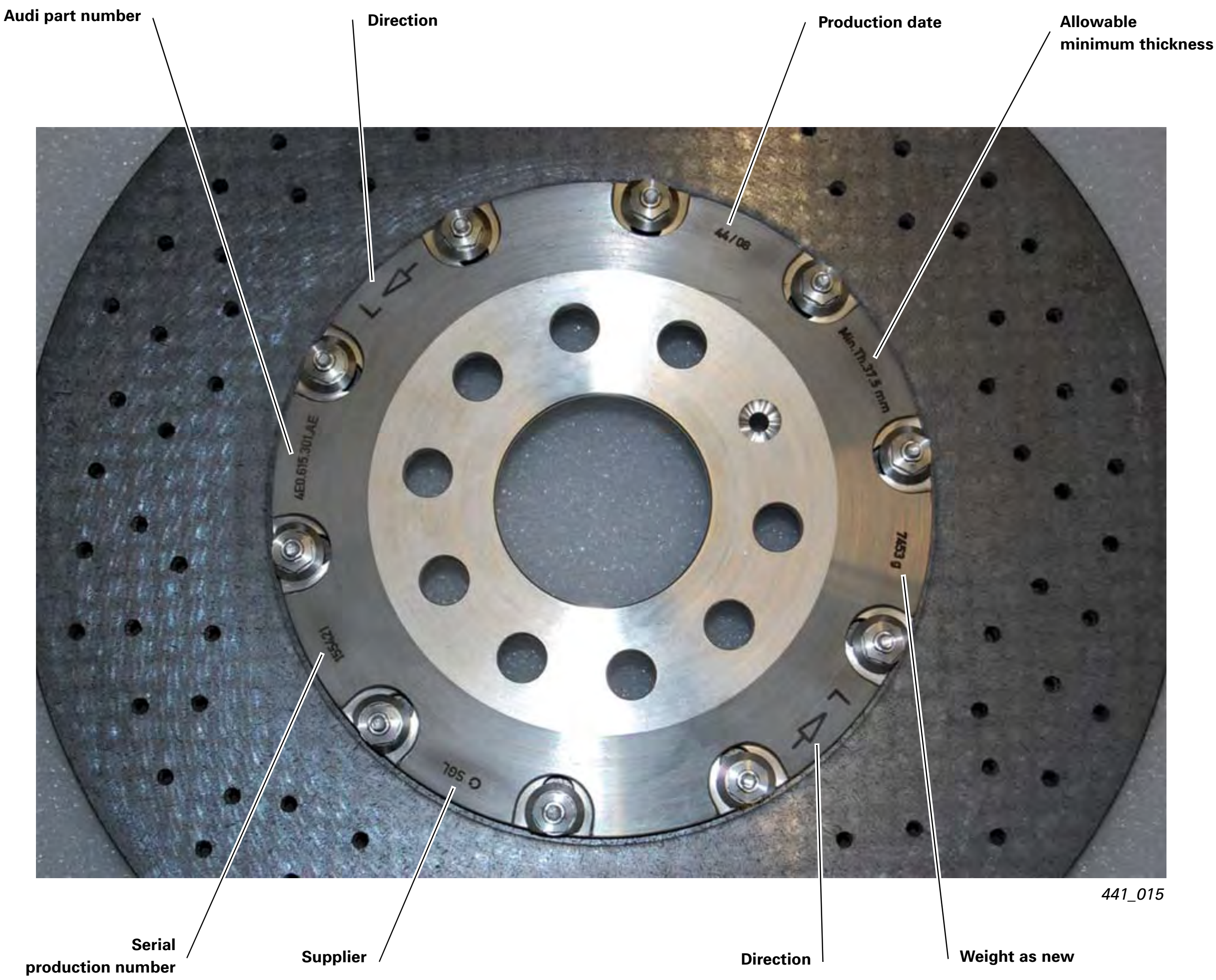
All key product data is engraved on the ceramic brake disc pot:



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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 in brake discs 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. Faulty or worn brake discs must be returned to Audi AG.

Note

When using compressed air for cleaning purposes, the respiratory protection regulations must be observed.

Assembly drifts in the tool kit *441_016*

Procedure for changing a wheel

The tool kit includes an additional assembly aid that is designed to prevent the rim from bumping into the ceramic brake disc when taking the wheel off the vehicle. It consists of a drift which guides the wheel away from the brake disc when it is removed in such a way that the wheel cannot collide with the brake disc.

Screwed-in assembly drifts *441_017*

Note

For detailed instructions, refer to the Owner's Manual and the Workshop Manual.

Visible characteristics of the ceramic brake discs in the as-new condition

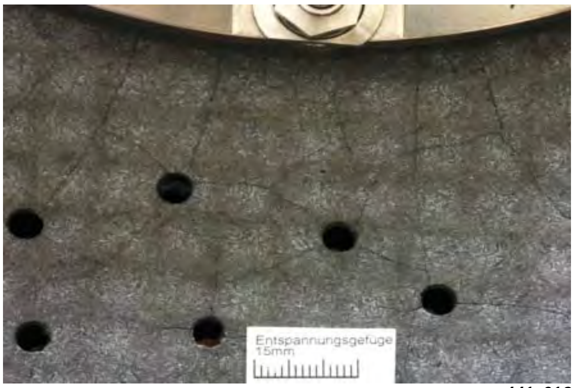
To determine whether a brake disc needs replacing or not, an objective assessment must be made as to the extent of wear and damage.

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

In the as-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 that on the opposite side on the brake disc pot. The thermal expansion crack microstructure occurs during the production process and is not a defect characteristic.

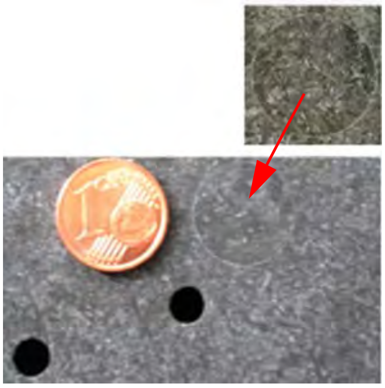
The surfaces of the ceramic friction ring are, therefore, very different to those of a conventional brake disc. Whereas a conventional brake disc with this appearance would have to be replaced, ceramic brake discs in this condition are absolutely acceptable. The profiled structure of the interface between the friction layer and the substrate is, in places, easily recognisable by its superficial lattice structure.



Typical thermal expansion crack microstructure and lattice structure of a ceramic brake disc in the as-new condition *441_018*

2. Wear indicators on the friction faces

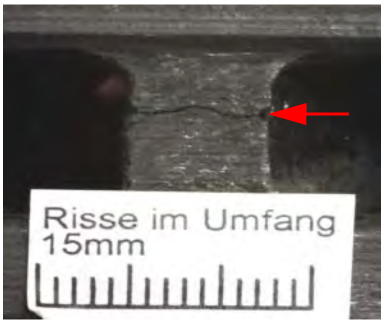
Three circular wear indicators offset at an angle of 120° are integrated in each friction face. They can be used to determine the extent of wear after a defined, high mileage and/or after heavy use of the ceramic brake discs. The next chapter explains how to evaluate the wear indicators.



Wear indicator of a ceramic brake disc in the as-new condition *441_019*

3. Superficial cracks in the cooling duct cross-members

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



Crack in the cooling duct cross-member of a ceramic brake disc *441_020*

Wear criteria

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

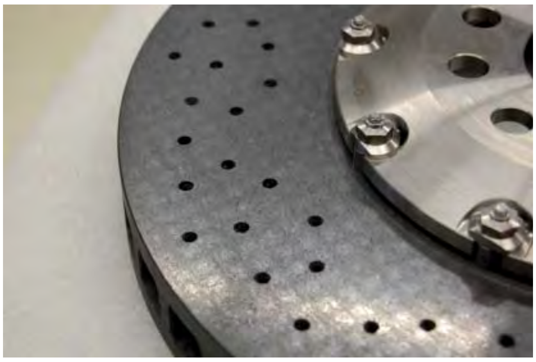
1. Loss of thickness

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, however, is considerably less than in conventional brake discs.

441_021

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 fibres oxidise 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.



Brake disc surface in an as-new condition *441_022a*

Brake disc surface exhibiting burnout *441_022b*

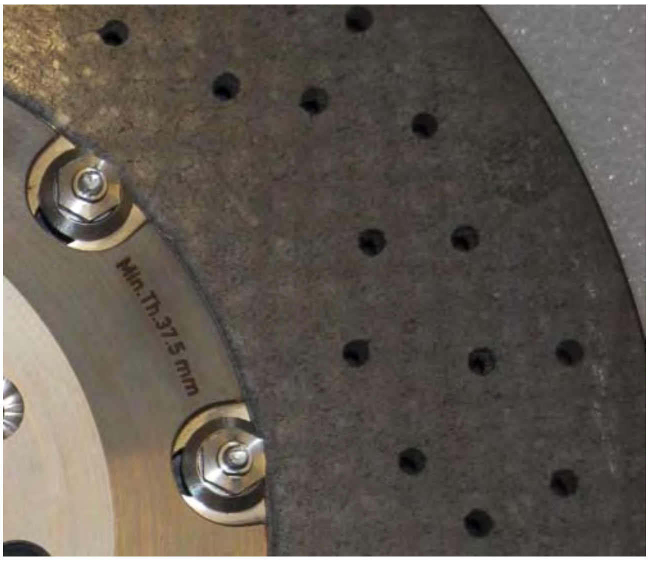
Determination of wear

The conditions under which the ceramic brake disc is used essentially dictate which criterion is met first.

1. Measuring loss of thickness

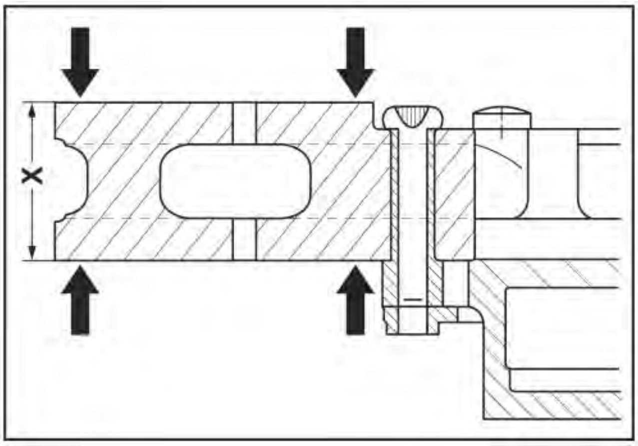
The permissible minimum friction ring thickness

min. Th. (= "minimum Thickness") is engraved on the ceramic brake disc.



441_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 after replacing the brake pad and documented in an appropriate fashion.
If X = min. Th. + 0.2 mm, the ceramic brake disc also has to be weighed (procedure: see 3.).



441_024

Note

Once the minimum thickness has been reached, further use of the ceramic brake disc is not permissible. The brake discs must be removed immediately and returned to Audi AG.

Determination of wear

2. Determination of wear by weighing

Due to oxidation of the carbon, the ceramic brake disc is subject to continuous loss of weight under correspondingly high load. A further possible way of determining wear, therefore, is to weigh the brake disc. However, this method can only be employed if a balance having the required accuracy (tolerance: +/- 1g) is available.

The initial weight of the as-new brake disc is engraved on the brake-disc pot.
The measurement range of the balance should be 0-12 kg.

441_027

Allowable weight loss limits are given in the relevant Workshop Manual.

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. Further use of the brake discs is not permissible. The replaced brake discs must be returned to Audi AG.

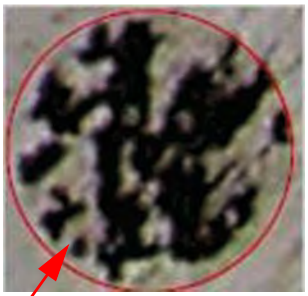
Determination of wear

3. Evaluating the wear indicators

The indicators can be distinguished visually from the surrounding friction face by their slightly different colour. The indicators have a different colour because they have a higher carbon content and, consequently, are subject to greater wear than the other regions of the friction face.

Wear of the indicators manifests itself as material burnout, which can be recognised by dark-coloured recesses. If prominent wear is in evidence, then the thickness of the brake disc must be measured (procedure: see 1.).
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



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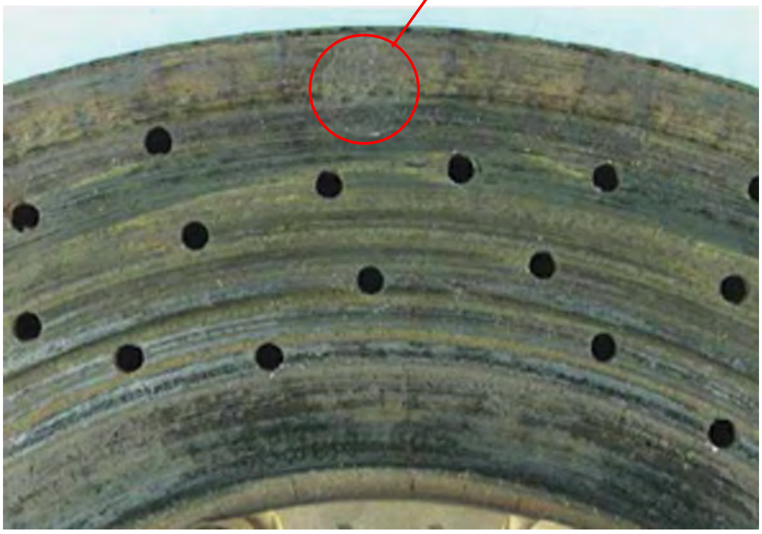

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Damage

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 pot, 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 pot) to the friction faces must always be replaced.

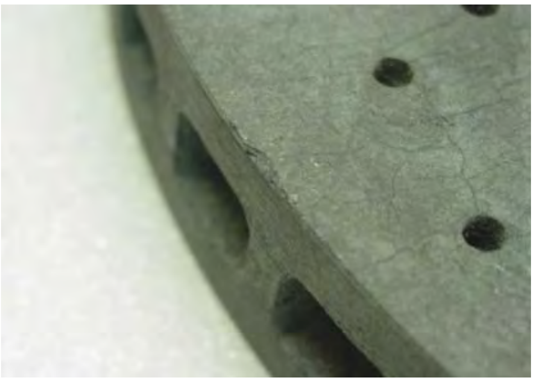
Critical interfacial crack propagation characteristic *441_028*

2. Edge chipping

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

The following are acceptable:
– max. permissible width / depth = 2 mm
– max. permissible length = 10 mm
– max. 3 edge damages per brake disc

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



Edge chipping *441_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 cm^2

must always be replaced.

Chipping of the friction layer *441_030*

Note

Brake discs must be replaced axle wise 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 brake pads must likewise be replaced axle wise.
Replaced ceramic brake discs must always be returned to Audi AG.

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

Bedding instructions

After replacing ceramic brake discs and/or brake pads, the following bedding instructions must be follows:

Pad new, brake disc new

10 braking operations from approx. 80 kph to approx. 30 kph at a low rate of deceleration (corresponds to a cautious, anticipatory style of driving, characterised by early braking, no apparent dive motion of the vehicle under braking, no locking of the seat belt)

20 braking operations from 100 kph to approx. 50 kph 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. 30 minutes

Pad new, brake disc used

5 braking operations from approx. 80 kph to approx. 30 kph at a low rate of deceleration (corresponds to a cautious, anticipatory style of driving, characterised by early braking, no apparent dive motion of the vehicle under braking, no locking of the seat belt)

10 braking operations from 100 kph to approx. 50 kph 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

Knowledge Assessment

In order to receive credit for this self study program, you are required to complete the online Knowledge Assessment
(994441AGB)

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This assessment is also accessible from the Certification Resource Centre.

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