

Ceramic material

The invention relates to a ceramic material which is particularly suitable for dynamic stresses.

Ceramic materials offer a wide range of possible applications. Their composition can be adapted to their intended use by the targeted addition of specific elements and/or compounds thereof. Aluminium oxide and zirconium oxide, for example, are ceramic materials which, individually or in combination with one another, can be processed into cutting tools, catalyst supports or prostheses.

Ceramic materials are brittle and therefore not generally suitable for dynamic stresses, in particular caused by vibrations and impacts.

Embodiments of the invention seek to provide a ceramic material which may be suitable for dynamic stresses.

According to a first aspect of the present invention, there is provided a use of a ceramic material for the production of components with the ability to absorb energy under dynamic stress, characterised in that the ceramic material contains 72 to 82 wt.% Al_2O_3 , 18 to 28 wt.% ZrO_2 , 0 to 1 wt.% Cr_2O_3 , 0 to 6 wt.% Y_2O_3 (relative to ZrO_2), 0 to 2 wt.% SrO , 0 to 0.5 wt.% TiO_2 and 0 to 0.5 wt.% MgO .

According to a second aspect of the present invention, there is provided a use of a ceramic material for the production of armour platings, particularly body armour, characterised in that the ceramic material contains 72 to 82 wt.% Al_2O_3 , 18 to 28 wt.% ZrO_2 , 0 to 1 wt.% Cr_2O_3 , 0 to 6 wt.% Y_2O_3 (relative to ZrO_2), 0 to 2 wt.% SrO , 0 to 0.5 wt.% TiO_2 and 0 to 0.5 wt.% MgO .

Surprisingly, it has been shown that an aluminium oxide material of the composition listed in the following table in a sintered compact is suitable as a material having the ability to absorb energy under dynamic stress. This material is

therefore particularly suitable for use as an armour ceramic, i.e. for the production of components in which energy absorption is necessary, such as e.g. in armour platings and particularly in body armour.

Material	wt. %	wt. %
ZrO ₂	18	28
Cr ₂ O ₃	0	1
Y ₂ O ₃ (relative to ZrO ₂)	0	6
SrO	0	2
TiO ₂	0	0.5
MgO	0	0.5

Aluminium oxide to make up to 100 wt. %

The dominant structural component of a material combination of this type is aluminium oxide. The property-determining features, such as hardness, modulus of elasticity and thermal conductivity, are therefore very close to the properties of pure aluminium oxide. The components zirconium oxide and strontium aluminate
5 are embedded in the aluminium oxide matrix. The raw materials are preferably used in high purity. As a result of the high purity of the raw materials, grain-boundary phases are only formed to an extremely small extent. The strontium aluminate forms characteristic plate-like crystallites, platelets, which make a significant contribution to the increase in strength.

10 The components zirconium oxide and strontium aluminate contribute to the increase in fracture toughness, which is about 60% higher than is the case with pure aluminium oxide. These reinforcing components result in an increase in strength by a factor of almost 2, and at the same time the damage tolerance, i.e. the property of the component to retain high residual strength even with possible
15 damage, also increases.

When a sintered compact made of the material is under high mechanical stress, mechanisms are surprisingly activated which, for example, inhibit or stop crack propagation. The most important mechanism here is the stress-induced conversion of the zirconium oxide from the tetragonal to the monoclinic phase.

20 The volume expansion of the zirconium oxide associated with the conversion causes the formation of local compressive stresses, which counteracts the external tensile load and thus prevents crack growth.

Surprisingly, the crack path is deflected by the embedded platelets, and so additional energy is absorbed during crack propagation.

25 It may be regarded as a special feature of the material according to the invention that the two mechanisms mutually reinforce one another so that the effective increase in fracture toughness is even greater than would be expected from the simple addition of the individual mechanisms.

A preferred material composition is listed below with its properties:

Batch, PL specs	ZrO ₂	Y ₂ O ₃	Cr ₂ O ₃	SrO	ED 2000	4-point strength	Min. break strength	Weibull modulus	HV10	mono	K _{IC}	Grain size
	wt. %	wt. %	wt. %	wt. %	g/cm ³	MPa	MPa	-	-	%	MPa m ^{0.5}	µm
min	24.0	0.50	0.26	0.70	4.360	1000	700	7	1740	10	5.5	medium
max	25.5	0.65	0.35	0.85	≥	≥		≥	≥	≤	≥	0.58

The Al₂O₃ content of 72.65 wt.% to 74.54 wt.% makes up the balance. Impurities due to the raw materials (< 0.05 wt.%) are possible, but are not listed separately owing to their small proportion.

The production of sintered mouldings from the material according to the invention takes place by conventional ceramics technology. The essential process steps are:

- Adding the powder mixture to water in the specified composition, using liquefiers to avoid sedimentation.
- Homogenising in a high-speed mixer.
- Grinding in an attrition mill, thus increasing the specific surface area of the powder mixture (= comminution).
- Adding organic binders.
- Spray-drying, resulting in free-flowing granules with defined properties.
- Moistening the granules with water.
- Pressing axially or isostatically.
- Green machining, largely forming the final contours taking into account the shrinkage on sintering.
- Pre-firing, during which shrinkage to approx. 98% of the theoretical density occurs. Any remaining residual pores are closed to the outside.
- Hot isostatic pressing at high temperature and under high gas pressure, resulting in almost complete final compression.
- So-called white firing, resulting in equalisation of the imbalance of the oxygen ions in the ceramic produced during hot isostatic pressing.
- Hard machining by grinding and polishing.
- Annealing.

The properties of the sintered moulding made of the material according to the invention can be further reinforced by means of inclusions. Thus, it is possible to mix whiskers and/or fibres into the material before shaping a sintered compact, or

to incorporate net-like structures or woven fabrics into the material in the green state. The whiskers, fibres or nets or woven fabrics must be made of a material which does not interact with the ceramic material in a way that would lead to an impairment of its properties. Furthermore, the material must not become modified
5 during sintering in a way that would damage the material.

Sintered mouldings produced from the material according to the invention surprisingly combine the best properties of each of the intrinsically competing ceramic materials aluminium oxide and zirconium oxide, particularly for use as an armour ceramic: hardness, ageing resistance, wetting behaviour with respect to
10 water and high thermal conductivity are properties known from sintered mouldings of aluminium oxide, and high strength and high fracture toughness, i.e. damage tolerance, are properties known from sintered mouldings of zirconium oxide.

Claims

1. Use of a ceramic material for the production of components with the ability to absorb energy under dynamic stress, characterised in that the ceramic material contains 72 to 82 wt.% Al_2O_3 , 18 to 28 wt.% ZrO_2 , 0 to 1 wt.% Cr_2O_3 , 0 to 6 wt.% Y_2O_3 (relative to ZrO_2), 0 to 2 wt.% SrO , 0 to 0.5 wt.% TiO_2 and 0 to 0.5 wt.% MgO .
2. Use of a ceramic material for the production of armour platings, particularly body armour, characterised in that the ceramic material contains 72 to 82 wt.% Al_2O_3 , 18 to 28 wt.% ZrO_2 , 0 to 1 wt.% Cr_2O_3 , 0 to 6 wt.% Y_2O_3 (relative to ZrO_2), 0 to 2 wt.% SrO , 0 to 0.5 wt.% TiO_2 and 0 to 0.5 wt.% MgO .
3. Use of a ceramic material according to Claim 1 or 2, characterised in that the ceramic material contains 24.0 to 25.5 wt.% ZrO_2 , 0.26 to 0.35 wt.% Cr_2O_3 , 0.50 to 0.6 wt.% Y_2O_3 , 0.70 to 0.85 wt.% SrO and Al_2O_3 to make up to 100 wt.%.
4. Use of a ceramic material according to Claim 1 to 3, characterised in that the 4-point flexural strength of the ceramic material is ≥ 1000 MPa.
5. Use of a ceramic material according to Claim 1 to 4, characterised in that the fracture toughness K_{Ic} of the ceramic material is $\geq 5.5 \text{ MPam}^{0.5}$.
6. Use of a ceramic material according to one of Claims 1 to 5, characterised in that the Weibull modulus of the ceramic material is ≥ 7 .
7. Use of a ceramic material according to one of Claims 1 to 6, characterised in that the hardness HV10 of the ceramic material is ≥ 1740 .
8. Use of a ceramic material according to one of Claims 1 to 7, characterised in that the density ED2000 of the ceramic material is $\geq 4.360 \text{ g/cm}^3$.
9. Use of a ceramic material according to one of Claims 1 to 8, characterised in that the ceramic material is additionally interspersed with whiskers and/or fibres or net-like structures or woven fabrics.
10. Use of a ceramic material according to one of Claims 1 to 9, characterised in that components zirconium oxide and strontium aluminate are embedded in an aluminium-oxide matrix of the ceramic material.

11. Use of a ceramic material according to Claim 10, characterised in that the strontium aluminate of the ceramic material is present in the form of plate-like crystallites, platelets.

Abstract

Ceramic materials are brittle and therefore not generally suitable for dynamic stresses, in particular caused by vibrations and impacts. The invention therefore proposes a material composed of a large fraction of aluminium oxide together with zirconium oxide and strontium aluminate.