Reinforced ceramic cutting tool.

Priority: 09.06.87 SE 8702390

Date of publication of application: 21.12.88 Bulletin 88/51

Publication of the grant of the patent: 21.10.92 Bulletin 92/43

Designated Contracting States: AT CH DE FR GB IT LI SE

References cited:
EP-A-0 194 811
EP-A-0 284 584
US-A-4 218 253
US-A-4 543 345
US-A-4 657 877

Proprietor: SANDVIK AKTIEBOLAG
S-811 81 Sandviken 1(SE)

Inventor: Brandt, Gunnar
Skogsvägen 3
S-171 65 Solna(SE)
Inventor: Theilin, Anders
Smastugvägen 12
S-162 40 Vällingby(SE)

Representative: Östlund, Alf Olof Anders et al
Sandvik AB Patent Department
S-811 81 Sandviken(SE)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).
Description

The present invention relates to a cutting tool material. More specifically, the present invention relates to a cutting tool material exhibiting excellent toughness.

A cutting tool edge is subjected to fluctuating stresses and temperatures of dynamic nature with peak temperatures exceeding 1000 °C and average rake face stresses of up to 150 MPa. There exists also steep temperature and stress gradients in the cutting edge. As a consequence of the dynamic conditions described above several failure mechanisms operate simultaneously. For a given set of cutting data, however, one mechanism usually dominates, leading to tool failure.

One objective of the present invention is to obtain a cutting tool material with better toughness behavior for some applications than heretofore known cutting tool materials.

Known toughening mechanisms in cutting tool materials include transformation toughening, which utilizes a phase transformation of ZrO₂-particles dispersed in a ceramic matrix, this type of material is described in U.S. Patent No 4,218,253; and whisker reinforcement which utilizes the bridging effect of small diameter (typically 0.6μm, high aspect ratio and high strength single crystal whiskers in a ceramic matrix as described in U.S. Patent No. 4,543,345 and the combined effect of ZrO₂ and small diameter SiC-whisker as described in U.S. Patent No. 4,657,877.

Both of these effects have led to substantial improvements of the toughness behavior in certain metal cutting operations. However, the search for further improvements in the properties of cutting tools is continuously ongoing.

Disc-shaped single crystals have also been used to increase toughness and thermal shock resistance of ceramic materials.

SU 298668 discloses a material with discs of beta-Al₂O₃, 70-90 weight-%, in alpha-Al₂O₃ which shows an improved toughness compared to alpha-Al₂O₃. SU 421674 discloses a material with discs of Cr₂O₃ in a ZrO₂-matrix. SU 487863 is similar to SU 421674 using discs of Cr₂O₃ (thickness 2-10μm, diameter 100-500μm) in Al₂O₃. SU 526606 discloses a material with discs of beta-Al₂O₃ in a matrix of alpha-Al₂O₃ and Al₂O₃ showing increased toughness and thermal shock resistance.

It has now surprisingly been found that additions of 5-35 weight-% single crystal discs with an equivalent diameter (hypothetical diameter of a circle with the same area as the disc) of 5-50 μm preferably 5-40 μm and a thickness of 0.5-8 preferably 0.5-6 μm homogeneously dispersed in the matrix significantly can increase the toughness behavior in metal cutting of tools based on alumina or silicon nitride. Even further improvements can be gained with the addition of 3-20 weight-% preferably 5-15 weight-% monoclinic or tetragonal zirconia particles to the alumina based matrix or up to 10 weight-% monoclinic or tetragonal zirconia particles to the silicon nitride based matrix. The alumina based matrix may further comprise chromium in amounts corresponding to a total of 1-20 weight-% as Cr₂O₃. The composite may still further comprise refractory nitrides or carbides to increase hot hardness and thermal conductivity which is advantageous in certain metal cutting applications.

The toughening mechanisms are not identified in detail, but probably include other mechanisms than whisker pull out as commonly observed for high strength small diameter whiskers (U.S. Patent No. 4,543,345). One of the probable mechanisms is crack deflection which will take place if there is a sufficiently weak interface between the disc and the matrix. This mechanism will increase toughness but not strength.

Example 1

Cutting tool materials are prepared from the following starting materials:
A. Alumina with a grain size ≤ 1 μm.
B. ZrO₂ with a grain size ≤ 2 μm.
C. SiC-single crystal discs with an average equivalent diameter of 20 μm and average thickness of 1 μm.
D. SiC-single crystal discs with an average equivalent diameter of 60 μm and average thickness of 9 μm.

The composition variants are shown in Table 1.
Example 2

The materials from Example 1 are tested as inserts SNGN 120412 in cast iron SS 0125 in an interrupted facing operation with high toughness demands. Both mechanical strength and thermal shock resistance are simultaneously tested to a varying degree depending on the cutting conditions used. The following tool life ranking is obtained for different cutting conditions (Table 2).

<table>
<thead>
<tr>
<th>Variant</th>
<th>Composition Weight Percent</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Total ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bal</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>prior art</td>
</tr>
<tr>
<td>2</td>
<td>bal</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>invention</td>
</tr>
<tr>
<td>3</td>
<td>bal</td>
<td>10</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>invention</td>
</tr>
<tr>
<td>4</td>
<td>bal</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>outside invention</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Cutting speed m min⁻¹</th>
<th>Feed rate mm rev⁻¹</th>
<th>400</th>
<th>0.3</th>
<th>400</th>
<th>0.5</th>
<th>700</th>
<th>0.3</th>
<th>700</th>
<th>0.5</th>
<th>Total ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown from Table 2 large discs outside the preferred embodiment of the invention show an insufficient toughness behaviour at high feed rates.

Claims

1. A single crystal disc reinforced ceramic cutting tool material characterized by increased toughness behaviour in metal cutting applications comprising composite defined by a matrix based on silicon nitride or alumina with 5-35 weight-% single crystal discs homogeneously dispersed herein, said discs having a diameter of 5-50 μm and a thickness of 0.5-8 μm.

2. A single crystal disc reinforced ceramic cutting tool material according to claim 1 characterized in that the matrix is based on alumina and further comprises 3-20 weight-% zirconia in a monoclinic and/or a tetragonal phase and, optionally, chromium in amounts corresponding to a total of 1-20 weight-% as Cr₂O₃.

3. A single crystal disc reinforced ceramic cutting tool material according to claim 1 characterized in that the matrix is based on silicon nitride and further comprises <10 weight-% zirconia in a monoclinic and/or a tetragonal phase.

Patentansprüche

1. Mit Einkristallscheiben verstärktes keramisches Schneidwerkzeugmaterial, gekennzeichnet durch gesteigertes Zähigkeitsverhalten bei Metallschneidanwendungen mit einem Verbundmaterial, das durch eine Matrix auf Siliciumnitrid- oder Aluminiumoxidbasis mit 5 bis 35 Gew.-% homogen darin dispergierten Einkristallscheiben definiert ist, wobei diese Scheiben einen Durchmesser von 5 bis 50 μm und eine Dicke von 0.5 bis 8 μm haben.
2. Mit Einkristallscheiben verstärktes keramisches Schneidwerkzeugmaterial nach Anspruch 1, dadurch gekennzeichnet, daß die Matrix auf Aluminiumoxid basiert und weiterhin 3 bis 20 Gew.-% Zirkonoxid in einer monoklinen und/oder einer tetragonalen Phase und gegebenenfalls Chrom in Mengen entsprechend einer Gesamtheit von 1 bis 20 Gew.-% als Cr₂O₃ umfaßt.


Revendications

1. Un matériau pour outils de coupe en céramique renforcée par des disques de monocristaux, caractérisé par un comportement de ténacité accru dans la coupe de métaux, qui comprend un composite défini par une matrice à base de nitrure de silicium ou d'alumine avec de 5 à 35 % en poids des disques de monocristaux en dispersion homogène, disques qui ont un diamètre de 5 à 50 μm et une épaisseur de 0,5 à 8 μm.

2. Un matériau pour outils de coupe selon la revendication 1, caractérisé en ce que la matrice est à base d'alumine et comprend en outre de 3 à 20 % en poids de zircone en phase monoclinique et/ou quadratique, et le cas échéant aussi du chrome dans des proportions correspondant à un total de 1 à 20 % en poids en Cr₂O₃.

3. Un matériau pour outils de coupe selon la revendication 1, caractérisé en ce que la matrice est à base de nitrure de silicium et comprend en outre moins de 10 % en poids de zircone en phase monoclinique et/ou quadratique.