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(54) Title: HIGH SPEED CUTTING TOOL

(57) Abstract

The tool comprises at least one cutting edge formed by a compacted mixture of carbide containing alloy steel and an oxide containing ceramic material, preferably zirconium oxide in an amount 0.01-15 wt.% of the mixture, preferably in the region of 1 to 6 wt.%, advantageously in the region of 3 wt.%. The mixture may additionally comprise particles of a hard or abrasive material, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

HIGH SPEED CUTTING TOOL

The present invention relates to a high speed cutting tool, the material of which it is constructed, and the method of making such a tool. More particularly, the invention relates to materials formed by compaction of powdered materials.

It is known to produce metallic bodies by hot isostatic pressing (hip-ing) of powdered steel. In this procedure, the steel powder is compacted physically within a tube which is then evacuated of gas and sealed. The tube is then placed in a furnace and heated to a temperature in the region of 1050 to 1250°C, usally 1100-1200°C. An inert gas such as argon is supplied to the furnace at a desired pressure which may be in the region of 103MPa. The cycle time may be in the region of 2 to 6 hours, allowing slow cooling. The powder in the tube is thereby compacted to form a unitary steel body which is cohesive, homogenous, and substantially free of potential stress fractures.

It is also known to make high speed and other cutting tools from materials such as carbide containing steel, or from other steels. However, the high speed at which they operate, which may be 20,000rpm, causes a high degree of wear at the cutting edges of the tool. Attempts have been made to extend the life of the tool by coating the edges with titanium nitride, which will lower the coefficient of friction by up to one third. However, this is not entirely satisfactory since the titanium nitride coating quickly wears away to leave an unlubricated steel cutting edge, which becomes blunt even more quickly.

It is an object of the present invention to provide a high speed cutting tool and a material from which it is constructed which enables the cutting tool to give improved performance for a longer period of use.

According to a first aspect of the present invention, there is provided a cutting tool comprising at least one cutting edge formed by a compacted mixture of carbide containing alloy steel and a ceramic material.

Preferably the mixture of at least one cutting edge comprises additionally particles of a hard or abrasive material.

The abrasive material may comprise 0.01 - 15 wt% of the mixture, optionally in the region of 1 to 10 wt%.

The abrasive material may comprise a carbide, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

The ceramic material preferably comprises 0.01-15 wt% of the mixture, optionally in the region of 1 to 6 wt%.

In preferred embodiments, the amount of ceramic material may be 2 to 5 wt%, advantageously in the region of 3 wt%.

The ceramic material may comprise zirconium oxide, optionally stabilised by a minor amount of calcium oxide.

The ceramic material may have a particle size in the region of 1 to 15μm, preferably 1 to 4μm.

The steel may have a particle size of less than or equal to 500μm.

The hardness of the steel body formed from the powder may vary slightly with the powder size but is generally in the region of 270 to 295 Hv20, which is increased after hardening.

Particles of carbide in the steel may have a size in the region of 3 to 5μm.

According to a second aspect of the present invention there is provided a metallic body comprising a steel core zone and a peripheral zone comprising a compacted mixture of carbide containing alloy steel and a ceramic material.

The core zone may comprise a compacted mass of powdered alloy steel.

The core zone may alternatively or additionally comprise a core of mild or other steel.

The peripheral zone may additionally comprise particles of a hard or abrasive material.

The abrasive material may comprise 0.01 - 15 wt% of the mixture, optionally in the region of 1 to 10 wt%.

The abrasive material may comprise a carbide, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

The ceramic material preferably comprises 0.01-15 wt% of the mixture, optionally in the region of 1 to 6 wt%.

In preferred embodiments, the amount of ceramic material may be 2 to 5 wt%, advantageously in the region of 3 wt%.

The ceramic material may comprise zirconium oxide, optionally stabilised by a minor amount of calcium oxide.

The density of zirconium oxide is approximately 6 g/cm3, rendering it compatible for powder metallargy for combination with steel powder having a density in the region of 8 g/cm3.

The ceramic material may have a particle size in the region of 1 to 15μm, preferably 1 to 4μm.

The steel may have a particle size of less than or equal to 500μm.

Particles of carbide in the steel may have a size in the region of 3 to 5μm.

The size of the ceramic powder may be selected to be greater than that of the general size of carbide particles.

According to a third aspect of the present invention there is provided a method of manufacturing a metallic body comprising the steps of providing a core of steel material, locating said body substantially centrally within a tube and filling an annular space between the core and the tube with a powdered mixture of steel and ceramic material, substantially evacuating the tube, sealing the tube, heating the tube at a high temperature, preferably in the region of 1000°C -1300°C, supplying an inert gas external of the tube at a high pressure, preferably in the region of 14000-16000psi, whereby the annular mixture is compacted and bonded to the core to form a unitary body.

The powdered mixture may comprise 0.1 to 15 wt % ceramic material, preferably 1 to 6 wt %, most advantageously in the region of 3 wt %.

The powdered mixture may additionally comprise 0.1 to 15 wt% hard or abrasive material, preferably 1 to 10 wt%.

The core of steel material may be formed from a powdered steel which is compacted concurrently with the mixture of steel and ceramic and optionally abrasive material in the peripheral zone.

Preferably said core may comprise powdered alloy steel.

Alternatively said core may comprise an iron containing body, which may optionally be surrounded by an intermediate zone comprising powdered alloy steel.

The powdered steel/ceramic mixture, and where appropriate, the powdered steel may comprise particles preferably of diameter no more than 500μm.

Advantageously, the powdered alloy steel when compacted, contains carbide particles of size within the range of 3-5μm.

The ceramic material provided in the mixture may comprise zirconium oxide optionally stabilised with calcium oxide.

Preferably, such zirconium oxide has a particle size greater than that of the carbide particles, preferably within the range 1 to 4μm.

The abrasive material may comprise 0.01 - 15 wt% of the mixture, optionally in the region of 1 to 10 wt%.

The abrasive material may comprise a carbide, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

According to a fourth aspect of the present invention, there is provided a method of manufacturing a cutting tool, comprising the steps of forming a unitary body as described in the third aspect above, compacting the body, rough forming an exterior surface of the body to have at least one cutting zone, annealing and heat treating said body to cause hardening, and forming said at least one cutting zone to have a cutting edge.

Where the cutting tool is a gear cutting hob, the thickness of the peripheral steel/ceramic zone may be in the region of 1 to 2 inches (2.5 to 5.1cm), some of which is removed to leave outstanding cutting edges comprising the steel/ceramic mixture, or the steel/ceramic/abrasive mixture.

Embodiments of the present invention will now be more particularly described by way of example.

Steel used as the basis in this example comprises the following; by wt%:

C	1.27	1.2	1.3	2.3
Mn	0.27	0.3	0.3	0.4
Cr	4.04	4.0	4.2	4.0
Mo	4.52	4.8	5.2	7.0
V	2.03	2.9	3.2	6.5
Co	8.14	<0.1	8.6	10.4
W	6.04	6.2	6.4	6.5
Si	0.27	0.3	0.55	0.5
S	0.03	<0.1	<0.1	<0.1
P	0.02	<0.1	<0.1	<0.1
Ni	0.09	<0.1	<0.1	<0.1
Cu	0.04	<0.1	<0.1	<0.1
Nb	0.01	<0.1	<0.1	<0.1
Ti	0.005	<0.1	<0.1	<0.1

In all cases remainder Fe and unavoidable impurities

Steels according to each of the above constitutions were powdered to a size of no more than 500μm. The resulting powder was sieved to remove any oversized particles. The material was found to contain carbide particles, mostly, but not exclusively cobalt or tungsten carbide, which had a particle size of 3 to 5μm.

The above powdered steel was then filled into a tube, located centrally within an outer tube. The annular space remaining was then filled with a mixture containing the same steel powder with the addition of 3 wt% zirconium oxide (stabilised by calcium oxide). This ceramic material had a particle size in a range of 1 to 4μm.

The intermediate tube was then removed and the external tube and the contents thereof subjected to hot isostatic pressing (hip-ing). Gas from the tube is evacuated and the tube sealed. It is then placed in the furnace at a high temperature such as 1050 to 1250°C and the furnace is subjected to a high pressure, such as 15,000psi, by introduction of argon or some other inert gas. The powders are thereby compacted into a homogeneous unitary structure having a steel composition at its core and a steel/ceramic composition at its periphery.

In other Examples, the mixture contained additionally particles of a hard abrasive material such as silicon or aluminium carbide.

In some cases, it may be desirable to insert a central core of mild steel or other less expensive steel which may bond directly with the mixture of steel and ceramic, or may bond with an intermediate zone of compacted steel powder. Such a central core may be machined out if so required.

The material thus formed may then be converted into a high speed cutting tool, such as a gear cutting hob, a broach, a drill, a tap, a reamer, a shaper or any other similar cutting tool. One or more cutting edges may be formed roughly thereon, after which the material is annealed and hardened before final grinding is carried out to produce one or more cutting edges on the tool.

It has been found that tools embodying the present invention have a longer life, and it is thought that this may be due, in part, at least, to the heat absorbing properties of the ceramic material which enable the cutting edge to function at a lower temperature and thereby have a better edge retention. Given the high speed nature of the use of such tools (which may be as high as 20,000rpm), the cooling effect should reduce or delay any tendency of the cutting edges to bluntness caused by frictional heating of the cutting edge.

Use of the invention also enables cutting tools to be manufactured from steels of lower hardness than is presently the case, for example from steel to British Standard M42, although it is equally applicable to harder steels such as those to BS T4.

CLAIMS

1. A cutting tool characterised in that it comprises at least one cutting edge formed by a compacted mixture of carbide-containing alloy steel and an oxide-containing ceramic material.

2. A cutting tool as claimed in claim 1, characterised in that the mixture forming at least one cutting edge comprises additionally particles of a hard or abrasive material.

3. A cutting tool as claimed in claim 2, characterised in that the abrasive material comprises 0.01 - 15 wt% of the mixture, optionally in the region of 1 to 10 wt%.

4. A cutting tool as claimed in either claim 2 or claim 3, characterised in that the abrasive material comprises a carbide, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

5. A cutting tool as claimed in any one of the preceding claims, characterised in that the oxide-containing ceramic material comprises 0.01-15 wt% of the mixture, preferably in the region of 1 to 6 wt%, advantageously in the region of 3 wt%.

6. A cutting tool as claimed in any one of the preceding claims, characterised in that the the ceramic material comprises zirconium oxide, optionally stabilised by a minor amount of calcium oxide.

7. A cutting tool as claimed in any one of the proceeding claims, characterised in that the ceramic material has a particle size in the region of 1 to 15μm, preferably 1 to 4μm.

8. A cutting tool as claimed in any one of the preceeding claims, characterised in that the alloy steel has a particle size of less than or equal to 500μm.

9. A metallic body characterised in that it comprises a steel core zone and a peripheral zone comprising a compacted mixture of carbide-containing alloy steel and an oxide-containing ceramic material.

10. A metallic body as claimed in claim 9, characterised in that said core zone comprises a compacted mass of powdered alloy steel.

11. A metallic body as claimed in claim 9, characterised in that the core zone comprises a core of mild or other steel.

12. A metallic body as claimed in any one of claims 9 to 11, characterised in that the peripheral zone additionally comprises particles of a hard or abrasive material.

13. A metallic body as claimed in claim 12, characterised in that the abrasive material comprises 0.01 - 15 wt% of the mixture, optionally in the region of 1 to 10 wt%, and preferably comprises a carbide, such as silicon carbide or aluminium carbide or a boride/carbide such as aluminium titanium diboride-titanium carbide.

14. A metallic body as claimed in any one of claims 9 to 13, characterised in that the ceramic material comprises 0.01-15 wt% of the mixture, preferably in the region of 1 to 6 wt%, advantageously in the region of 3 wt%.

15. A metallic body as claimed in any one of claims 9 to 14, characterised in that the ceramic material comprises zirconium oxide, optionally stabilised by a minor amount of calcium oxide, and may have a particle size in the region of 1 to 15μm, preferably 1 to 4μm.

16. A method of manufacturing a metallic body comprising the steps of providing a core of steel material, locating said body substantially centrally within a tube and filling an annular space between the core and the tube with a powdered mixture of steel and ceramic material, substantially evacuating the tube, sealing the tube, heating the tube at a high temperature, preferably in the region of 1000°C -1300°C, supplying an inert gas external of the tube at a high pressure, preferably in the region of 14000-16000psi, whereby the annular mixture is compacted and bonded to the core to form a unitary body.

17. A method as claimed in claim 16, characterised in that the powdered mixture comprises 0.1 to 15 wt % ceramic material, preferably 1 to 6 wt %, most advantageously in the region of 3 wt %.

18. A method as claimed in either claim 15 or claim 16, characterised in that the powdered mixture additionally comprises 0.1 to 15 wt% hard or abrasive material, preferably 1 to 10 wt%.

19. A method as claimed in claim 18, characterised in that the core of steel material is formed from a powdered steel which is compacted concurrently with the mixture of steel and ceramic and optionally abrasive material in the peripheral zone.

20. A method as claimed in any one of claim 15 to 19, characterised in that the method includes an initial step of selecting particles of powdered steel/ceramic mixture in which the powdered steel has a diameter of no more than 500μm.

21. A method as claimed in any one of claims 15 to 20, characterised in that the ceramic material provided in the mixture comprises zirconium oxide optionally stabilised with calcium oxide, and having a particle size within the range 1 to 4μm.

22. A method of manufacturing a cutting tool, comprising the steps of forming a unitary body as claimed in any one of claims 15 to 21, characterised in that it comprises the steps of compacting the body, rough forming an exterior surface of the body to have at least one cutting zone, annealing and heat treating said body to cause hardening, and forming said at least one cutting zone to have a cutting edge.

23. A method as claimed in claim 22, in which the cutting tool is a gear cutting hob, characterised in that the thickness of the peripheral steel/ceramic zone is in the region of 1 to 2 inches (2.5 to 5.1cm), some of which is removed to leave outstanding cutting edges comprising the steel/ceramic mixture, or the steel/ceramic/abrasive mixture.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/00200

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C22C32/00 B22F7/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C22C B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,1 826 457 (G.J.COMSTOCK ET AL) 6 October 1931 see column 1, line 46 - column 2, line 98 ---	1-8
A	DATABASE WPI Section Ch, Week 9432 Derwent Publications Ltd., London, GB; Class L02, AN 94-260891 & JP,A,06 192 784 (TOSHIBA KK) , 12 July 1994 see abstract --- -/--	1-8

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 1995	01. 09. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schruers, H

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/GB 95/00200

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO,A,91 19583 (ASEA BROWN BOVERI) 26 December 1991 see page 7, line 1 - line 22; claims 1,6 ---	16-23
Y	DE,A,27 22 271 (THYSSEN EDELSTAHLWERKE AG) 23 November 1978 see page 6, line 13 - page 7, line 5; claims 1-3 -----	16-23

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Interna : Application No
PCT/GB 95/00200

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