Title: ULTRA-HARD CUTTING TOOL COMPONENTS

Abstract: A tool component (10) comprising a cemented carbide substrate (12) and a layer (14) of ultra-hard material bonded to a surface (16) of the substrate through an intermediate layer (18), the layer (14) of ultra-hard material having a thickness of no greater than 0.2 mm and having a working surface (20) which presents a cutting region (22) and the intermediate layer (18) being made of a material softer than the ultra-hard layer. The ultra-hard material is preferably PCD or PCBN.
ULTRA-HARD CUTTING TOOL COMPONENTS

BACKGROUND OF THE INVENTION

This invention relates to ultra-hard cutting tool components.

Ultra-hard abrasive cutting elements or tool components utilizing diamond compacts, also known as PCD, and cubic boron nitride compacts, also known as PCBN, are extensively used in drilling, milling, cutting and other such abrasive applications. The element or tool component will generally comprise a layer of PCD or PCBN bonded to a support, generally a cemented carbide support. The PCD or PCBN layer may present a sharp cutting edge or point or a cutting or abrasive surface.

Diamond abrasive compacts comprise a mass of diamond particles containing a substantial amount of direct diamond-to-diamond bonding. Polycrystalline diamond will typically have a second phase containing a diamond catalyst/solvent such as cobalt, nickel, iron or an alloy containing one or more such metals. cBN compacts will generally also contain a bonding phase which is typically a cBN catalyst or contain such a catalyst. Examples of suitable bonding phases are aluminium, alkali metals, cobalt, nickel, tungsten and the like.

Polycrystalline diamond (PCD) cutting elements are widely used for machining a range of metals and alloys as well as highly abrasive wood composite materials. The automotive, aerospace and woodworking industries in particular use PCD to benefit from the higher levels of productivity, precision and consistency it provides. Aluminium alloys, bi-metals, copper alloys, graphite reinforced plastics and metal matrix composites are typical materials machined with PCD in the metalworking industry. Laminated flooring boards, cement boards, chipboard, particle
board and plywood are examples of wood products in this class. PCD is also used as inserts for drill bodies in the oil drilling industry.

The failure of a tool due to progressive wear is characterised by the development of wear scars on its operating surfaces. Typical areas on a cutting tool insert where the wear scars develop include the rake face, the flank face and the trailing edge, and the wear features include flank wear, crater wear, DOC notch wear, and trailing edge notch wear.

To numerically describe wear occurring on cutting tool surfaces, a number of parameters are used. The flank wear land is the best known tool wear feature. In many cases the flank wear land has a rather uniform width along the middle portion of the straight part of the major cutting edge. The width of the flank wear land (VB_gmax) is a suitable tool wear measure and a predetermined value of VB_gmax is regarded as a good tool life criteria [INTERNATIONAL STANDARD (ISO) 3685, 1993, Tool life testing with single point turning tools]. The cutting forces and temperatures tend to increase as VB_gmax increases. There is also a greater tendency for vibration to occur and there is a reduction in the quality of the surface finish of the workpiece material. In finishing applications where PCD and PCBN cutting tools are normally used the flank wear criteria is: VB_gmax = 0.2 - 0.3 mm. In roughing application, where only carbide is normally used, the flank wear criteria is 0.6 mm and higher.

In order for the wear to be limited to the PCD and PCBN layer, current commercially available PCD and PCBN cutting tools all have sintered PCD/PCBN (hard layers) with thicknesses above 0.2 mm. These thick hard layers, especially in the case of PCD, make them extremely difficult and expensive to process. Typical processes used to fabricate cutting tools are wire electrical discharge machining (w-EDM), electrical discharge grinding (EDG), mechanical grinding, laser cutting, lapping and polishing. Cutting tools comprising PCBN, ceramics, cermets and carbides are normally mechanically ground to the final ISO 1832 specification, while cutting tools comprising PCD are finish produced by EDG or w-EDM.
Where PCD elements are mechanically ground, the cost of the grinding operation can be up to 80% of the element's cost. This is because PCD is much harder and therefore more difficult to grind than carbide. It is also not possible to grind PCD on the same grinding machines that are used for grinding PCBN, carbide, cermet or ceramics containing components. PCD requires much suffer machines and only one corner can be ground at a time as compared to PCBN, ceramic and carbide, where one can grind 4 corners at a time.

The higher processing cost together with the inability to grind PCD on existing carbide grinding machines, has been one of the major obstacles restricting PCD's penetration into traditional carbide applications. End-users generally specify a minimum tool life criteria (generally one shift) together with a certain cycle time, which is dependant on the overall speed of the production line. Since carbide can only be used at low cutting speeds, tooling for carbide normally consist of multiple inserts. The use of multiple inserts allows the feed per tooth or chip load to stay the same, while increasing the necessary production speed. PCD and PCBN, however, can be used at much higher cutting speeds making it possible to either use fewer inserts in the tool body or to achieve a much longer tool life. Since the cost of carbide tools are only about 10% of that of PCD, the tool life in PCD needs to be 10 times longer than that of carbide in order to justify the use of PCD. This has lead to PCD tooling being used only for very severe and abrasive applications as well as high volume applications where carbide tools are unable to meet the minimum tool life criteria.

In addition to this, the lower chip resistance of PCD compared to carbide has restricted its use even further to only finishing applications. In roughing and severe interrupted applications (high feed rate and depth of cut), where the load on the cutting edge is much higher, PCD can easily fracture causing the tool to fail pre-maturely. Carbide on the other hand wears quicker than PCD, but is more chip resistant. Unlike in finishing operations, dimensional tolerance is not so critical in roughing operation \( \text{VB}_d \text{max} > 0.6 \text{ mm} \) which means that tool wear is not that critical. However, chip
resistance is important in roughing applications and can cause the tool to fail prematurely. Also, in less severe applications, like MDF, low SiAl-alloys, chipboard etc, wear is generally not an issue and carbide is preferred due to economic reasons.

For PCD and PCBN to be considered for typical carbide applications, it has to be easier and cheaper to process and have higher chip resistance, while still outperforming carbide in terms of wear resistance.

Another disadvantage of currently available PCD cutting tools is that they are not designed to machine ferrous materials. When machining cast irons for example, the cutting forces and thus the cutting temperature at the cutting edge are much higher compared to non-ferrous machining. Since PCD starts to graphitise around 700°C, it limits its use to lower cutting speeds when machining ferrous materials, rendering it uneconomical in certain applications compared to carbide tools.

US patent 3,745,623 describes a method of making a tool component comprising a layer of PCD bonded to a cemented carbide substrate. The thickness of the PCD layer can range from 0.75 mm to 0.012 mm. The tool component is intended to provide a less expensive form of diamond cutting tool to be used in the machining of metals, plastics, graphite composite and ceramics where more expensive synthetic or natural diamond is normally used.

US patent no. 5,697,994 describes a cutting tool for woodworking applications comprising a layer of PCD on a cemented carbide substrate. The PCD is generally provided with a corrosion resistant or oxidation resistant adjuvant alloying material in the bonding phase. An example is provided wherein the PCD layer is 0.3mm in thickness.

EP 1 053 984 describes diamond sintered compact cutting tool comprising a diamond sintered compact bonded to a cemented carbide substrate in which the thickness of the diamond layer satisfies a particular relationship
to the carbide substrate. Diamond compact layers varying in thickness from 0.05 mm to 0.45 mm are disclosed. Generally, the carbide substrates are thin, particularly when thin diamond layers are used because the substrate thickness needs to be matched to that of the PCD.

SUMMARY OF THE INVENTION

According to the present invention there is provided a tool component comprising a cemented carbide substrate and a layer of ultra-hard material bonded to a surface of the substrate through an intermediate layer, the layer of ultra-hard material having a thickness of no greater than 0.2 mm and having a working surface which presents a cutting region and the intermediate layer being made of a material softer than the ultra-hard layer.

Essential to the invention is the provision of an intermediate layer (interlayer) between the ultra-hard layer and the cemented carbide substrate and an ultra-hard layer which is ultra thin, i.e. has a thickness of no greater than 0.2 mm. In use, the cutting region of the working face, generally an edge of the working face, effects a cut. Soon thereafter, the intermediate layer and the carbide substrate also act as part of the cutting region of the tool component. The properties and, in particular, the hardness and wear resistance of the intermediate layer can be varied to produce a range of products and one to suit a particular cutting operation. For example, for ultra-hard intermediate layers, the properties can be varied by varying the nature of the abrasive particle, the particle size of the abrasive particle, or varying the composition of the binder phase. Further, the intermediate layer can also be ceramic or a metal or essentially metallic in nature.

The thickness of the intermediate layer can also vary according to the type of tool component desired and the cutting action sought. In many cases, the intermediate layer will also be ultra-thin, i.e. a thickness of no greater than 0.2 mm. In other cases, a thicker intermediate layer may be desired.
The thickness of the ultra-hard layer is preferably from 0.001 to 0.15 mm.

The thickness of the substrate material is preferably from 1.0 mm to 40 mm.

The ultra-hard material is preferably PCD or PCBN, optionally containing a second phase comprising a metal or metal compound selected from the group comprising aluminium, cobalt, iron, nickel, platinum, titanium, chromium, tantalum, copper, tungsten or an alloy or mixture thereof.

In one preferred form of the invention, the ultra-hard layer is PCD and the material of the intermediate layer is a softer grade PCD.

In another preferred form of the invention, the ultra-hard layer is PCBN and the material of the intermediate layer is a softer grade PCBN.

In yet a further preferred form of the invention, the ultra-hard layer is PCD and the intermediate layer is PCBN.

The cemented carbide substrate will generally present a major surface to which the ultra-hard material layer will be bonded through the intermediate layer.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

**Figure 1** is a partial perspective view of an embodiment of a cutting tool component of the invention:
Figure 2 is a schematic side view of a cutting tool component of the invention in use, illustrating the "self-sharpening" effect thereof;

Figure 3 is a graph illustrating the effect of hard layer thickness on wear of a cutting tool component; and

Figure 4 is a graph illustrating the wear resistance on silica-based composites showing the effect of a softer PCD and PCBN intermediate layers.

DESCRIPTION OF PREFERRED EMBODIMENTS

An object of the present invention is to provide an engineered PCD and/or PCBN cutting tool with properties between cemented carbide and PCD as well as between cemented carbide and PCBN.

An embodiment of the invention will now be described with reference to Figure 1. Referring to this Figure, a cutting tool component 10 which comprises a cemented carbide substrate 12 having an ultra-thin layer 14 of ultra-hard material bonded to a surface 16 of the carbide substrate through an intermediate layer 18. The surface 16 will generally be a major surface of the substrate. The top surface 20 of the ultra-thin layer 14 is the working surface of the tool component and presents a cutting edge 22.

The thickness of the ultra-thin layer 14 is no greater than and generally less than 0.2 mm, preferably between 0.001 - 0.15 mm and wherein the substrate typically has a thickness from 1.0 - 40 mm. Further, the ultra-thin layer 14 is bonded to the surface 16 of the carbide substrate through an intermediate layer 18 which itself will generally be ultra-thin and of the same or similar thickness to that of the ultra-hard material layer 14. Such a cutting tool component is produced by high temperature high pressure synthesis. The thickness of the ultra-thin hard layer 14 at the cutting edge
22 is an important parameter determining the properties of the material and allows for cutting with the top hard layer 14 (PCD or PCBN), the intermediate layer 18 and the carbide substrate 12. Wear resistance, chip resistance, cutting forces, grindability, EDM ability and thermal stability are all properties affected by the thickness of the hard layer. Various methods for producing PCD and PCBN cutting tools with cemented carbide substrates exist and are well known in the industry.

The ultra-thin hard layer together with the softer intermediate layer and substrate results in a "self-sharpening" behaviour during cutting, which in turn reduces the forces and temperatures at the cutting edge. The hard layer can be described as an integrally-bonded structure that is composed of a mass of polycrystalline abrasive particles, such as diamond or cubic boron nitride, and a second phase, which is usually a metal such as cobalt, iron, nickel, platinum, titanium, chromium, tantalum, copper or an alloy or mixture thereof, as described in US 4,063,909 and US 4,601,423. The thickness of the ultra-hard layer preferably varies between 0.001-0.15 mm, depending on the required properties for specific applications.

The substrate material can be selected from tungsten carbides, ultra-fine grain tungsten carbides, titanium carbides, tantalum carbides and niobium carbides and generally has a thickness between 1.0 to 40 mm. Methods for producing cemented carbides are well known in the industry. Because cutting is done with both the hard layer and the carbide, the selection of the substrate is another variable which can be changed in order to alter the properties of the cutting element to suit different applications.

In some applications, it may be preferable to provide a substrate having a profiled or shaped surface, which results in an interface with a complimentary shape or profile.

From a processability perspective an important feature of the invention is the ultra-thin hard layer which will reduce the processing cost of PCD and PCBN cutting tools.
In terms of performance, an important feature of the invention is to adjust the hard layer thickness so that the desired properties can be achieved and also to ensure that a "self-sharpening" effect takes place during cutting. By suitable choice of intermediate layer this "self-sharpening" effect can be enhanced. When the wear progresses through the hard layer at some stage during the cutting process, the cutting will be done by the hard layer, the intermediate layer and the substrate. Conventional tools all have a hard layer thickness above 0.2 mm, and hence the substrate never comes in contact with the workpiece (since tool life criteria is $V_{B2}\text{max} = 0.2 - 0.3$ mm) and the properties and behaviour of the tool is that of the hard layer only.

As illustrated in Figure 2, as long as cutting is done by the hard layer 14, the wear rate will be that of the hard layer. As soon as the wear extends into the intermediate layer 18 and carbide substrate 12 and the cutting is done by the hard layer, the intermediate layer and the carbide, the wear rate will increase to include both that of the substrate and of the hard layer. Thus, the thicker the hard layer, the longer the wear rate is controlled by the wear resistance of the hard layer and the longer the tool life. This is illustrated graphically in Figure 3. Although the data for Figure 3 was generated by a tool component comprising a PCD layer bonded directly to a surface of a cemented carbide substrate, similar results will be obtained when an intermediate soft layer of the invention is provided. Having an ultra-thin hard layer where the cutting is done by both the hard layer, intermediate layer and carbide gives a wear resistance between that of carbide and the hard layer. By varying the thickness of the hard layer (between 0.001 - 0.15 mm) and nature and thickness of the intermediate layer, it allows one to change the properties and the tool life of the material to what is required for a specific application. This allows one to provide signature products for specific applications. The thinner the hard layer, the closer the cutting tool properties will be to that of the intermediate layer and substrate. However, due to the "self-sharpening" effect of the engineered
cutting tool, the cutting process and wear rate are dominated by the hard layer.

A major benefit of cutting with both the ultra-thin hard layer 14, the intermediate layer 18 and the substrate 12 is the "self-sharpening" effect it has on the tool. As illustrated in Figure 2, it can be seen that because the material of the intermediate layer 18 and substrate 12 is much softer than the top hard layer 14, it wears away quicker than the hard layer 14, forming a "lip" 24 between the hard layer 14 and the intermediate layer and substrate at the edge. This allows the tool to cut predominantly with the top hard layer 14, minimising the contact area with the workpiece which ultimately results in lower forces and temperatures at the cutting edge 22. It also means that when the tool wears it keeps a clearance angle (α) allowing it to cut more efficiently. This wear behaviour is ideal for roughing applications and wood composite machining, especially in saw blade applications, where dimensional tolerances are not so critical. It is also beneficial in oil drilling applications where a sharp cutter results in a lower "weight on bit" and higher penetration rates. It will also be beneficial in the machining of ferrous materials with PCD where forces should be kept to a minimum to prevent graphitisation. Ultra-thin diamond layers can also be used for finish machining of softer materials, like copper where the wear never extends into the carbide. Depending on the nature and hardness of the intermediate layer, a lip can also form between the intermediate layer 18 and the carbide substrate 12.

Another benefit of ultra-thin hard layers is the improved chip resistance it gives to the tool. Thicker layers have higher residual stresses and are more susceptible to chipping and fracture. Also, if chipping does occur, the carbide substrate will arrest the crack and stop it from getting bigger than the thickness of the top hard layer. A thin PCD layer will also possess higher percentages of cobalt due to the back in-filtration process from the substrate during synthesis increasing its fracture toughness.
Effect on Processability

All processing (EDM, EDG, grinding) is easier and faster as the top hard layer becomes thinner. Having ultra-thin hard layers will shorten processing times and allow materials like PCD to be ground on conventional carbide grinding equipment. This opens the door for new applications for PCD in woodworking and metalworking. In conventional PCD cutting tools 80% of the insert cost can be attributed to grinding, while with the engineered material of the invention this cost is reduced to about 5 - 10% of the total cost making the engineered product a much more feasible cutting tool.

As explained earlier conventional PCD and PCBN compacts are manufactured with diamond layer thicknesses > 0.2 mm in order for the cutting to be done by the hard layer only. However, during the synthesis of such thick layers, the compact often bows because of the thermal expansion differences between that of PCD or PCBN and the carbide substrate. This results in additional processing (mechanical grinding, EDG or lapping) to get the compact back to flatness. With ultra-thin hard layers, bending of the disc is minimised and additional processing is not required. This allows for the production of near-net shape PCD or PCBN compacts.

The tool components of the invention can be made using methods and techniques known in the art for producing PCD and PCBN. More particularly, in order to produce sintered polycrystalline diamond abrasive tool components and/or polycrystalline cubic boron nitride abrasive tool components according to the invention typically 500Og powder admixtures were produced. These admixtures were produced using appropriate techniques according to methods already known in the art for PCD and PCBN respectively.

The admixtures were then combined with a binder and cast as papers using techniques well known in the art. For the intermediate layer, the
paper was cast at an appropriate thickness and density to produce the targeted post-synthesis thickness required in the ultimate machining application. For the ultrahard abrasive layer, the paper was cast at an appropriate thickness and density to produce a post-synthesis thickness greater than that required in the ultimate machining application.

Discs were then cut from the papers produced as described above. One paper disc of the ultrahard layer was placed into a refractory metal canister (consisting of tantalum). One paper disc of the intermediate layer was then placed on top of the ultrahard layer paper disc. A sintered hardmetal substrate (consisting of tungsten carbide and cobalt) was then placed on top of the intermediate layer paper disc to produce a pre-composite.

The binder was then removed from the pre-composite using techniques well known in the art. The pre-composite was then sintered at conditions of elevated temperature and pressure necessary to produce the polycrystalline diamond or cubic boron nitride layer from a mass of diamond or cubic boron nitride particles. Typically, these conditions are pressures in the range 4 to 8 GPa and temperatures in the range 1300 to 1700°C, for PCD.

The sintered compact was then processed using standard methods to produce a disc with the desired overall height to enable cutting tools to be extracted from the disc. In particular, the refractory metal canister was removed from the ultrahard layer, along with excess ultrahard material in order to achieve the desired thickness of the ultrahard layer required to achieve the desired behaviour in application.

The following example illustrates tool components of the invention in a machining test.

**Example : Machining Composites**
In order to evaluate the effect of an interlayer on performance, the following two examples were manufactured and evaluated:

- A fine grain PCD (1-2 µm grain size) with a softer 2 µm grain PCD as an interlayer between the carbide and the FGPCD layer (FGPCD/Softer PCD). Both the PCD and interlayers had a thickness of 0.15 mm.
- A fine grain PCD (1-2 µm grain size) with a softer PCBN interlayer between the carbide and the FGPCD layer (FGPCD/Softer PCBN). Both the PCD and PCBN layers had a thickness of 0.15 mm.
- Included in the test were two other carbide backed PCD products. The first one was a fine grade PCD (1-2 micron grain size) having a PCD layer thickness of 0.5 mm (FGPCD 05). The second one was a medium grade PCD (10 micron grain size) having a PCD layer thickness of 0.1 mm (MGPCD 01)

The test conditions were:
Workpiece Material: Silica Flour-filled Epoxy resin
Cutting Speed: 400 m/min
Feedrate: 0.1 mm/rev
Doc: 0.5 mm

The FGPCD 05 gave the best wear performance followed by the FGPCD/softer PCD 03 and then the FGPCD/PCBN 03 and then the FGPCD 01 layer (figure 4). Although the 05 gave the best wear performance, the 03 layer gave the best chip resistance, followed by the 01 layer. Again the point in the graph where the wear extends into the softer PCD or PCBN can be noticed by a sudden increase in the wear rate.

Thus, this example demonstrates that the wear performance can be engineered by using different PCD layer thicknesses and/or different hardness interlayers.
CLAIMS

1. A tool component comprising a cemented carbide substrate and a layer of ultra-hard material bonded to a surface of the substrate through an intermediate layer, the layer of ultra-hard material having a thickness of no greater than 0.2 mm and having a working surface which presents a cutting region and the intermediate layer being made of a material softer than the ultra-hard layer.

2. A tool component according to claim 1 wherein the thickness of the ultra-hard layer is 0.001 to 0.15 mm.

3. A tool component according to claim 1 wherein the intermediate layer has a thickness of no greater than 0.2 mm.

4. A tool component according to any one of the preceding claims wherein the intermediate layer is ceramic, metal, ultra-hard material or a combination thereof.

5. A tool component according to any one of the preceding claims wherein the material of the intermediate layer has a hardness between the hardness of the ultra-hard layer and the hardness of the cemented carbide substrate.

6. A tool component according to any one of the preceding claims wherein the ultra-hard material is selected from PCD and PCBN.

7. A tool component according to any one of the preceding claims wherein the ultra-hard layer is a PCD layer and the material of the intermediate layer is a softer grade PCD.

8. A tool component according to any one of claims 1 to 6 wherein the ultra-layer is a PCD layer and the material of the intermediate layer is PCBN.
9. A tool component according to any one of claims 1 to 6 wherein the ultra-hard layer is a PCBN layer and the material of the intermediate layer is a softer grade of PCBN.

10. A tool component according to any one of claims 1 to 4 wherein the material of the intermediate layer is softer than the cemented carbide substrate.

11. A tool component according to any one of the preceding claims wherein the cemented carbide substrate has a major surface to which the ultra-hard layer is bonded through the intermediate layer.

12. A tool component according to any one of the preceding claims wherein the cemented carbide substrate has a thickness of 1.0 to 40 mm.

13. A tool component according to claim 1 substantially as herein described with reference to any one of Figures 1 to 4 of the accompanying drawings.
Through 0.1 mm hard layer

Wear rate = f(wear resistance of hard layer)

"Break-in" stage

Through 0.3 mm hard layer

Wear rate = f(wear resistance of hard layer + wear resistance of substrate)

Fig. 3

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Wear resistance on silica-based composites showing the effect of a softer PCD and PCBN interlayer

Fig. 4
INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/003564

A. CLASSIFICATION OF SUBJECT MATTER

INV. B23B27/14 C23C30/00 E21B10/573

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)
B23B B23C C23C E21B

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate of the relevant passages</th>
<th>Relevant to claim No</th>
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<td>X</td>
<td>US 4 694 918 A (HALL DAVID R [US]) 22 September 1987 (1987-09-22) column 4, line 23 - column 6, line 35 column 19, line 35 - column 20, line 39 column 7, line 26 - column 8, line 42 column 1, line 60 - column 2, line 8 figures 1-5, 8</td>
<td>1-7, 11, 12</td>
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<td>X</td>
<td>EP 0 272 913 A2 (DE BEERS IND DIAMOND [ZA]) 29 June 1988 (1988-06-29) page 2, lines 35-52 page 3, lines 12, 13 figure 1</td>
<td>1-6, 8, 11, 12</td>
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Further documents are listed in the continuation of Box C

See patent family 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

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another document

“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

“X” document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone or in combination with one or more of the other documents cited

“V” 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

“N” document member of the same patent family

Date of the actual completion of the international search 4 April 2007

Date of mailing of the international search report 18/04/2007

Name and mailing address of the ISA/
European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel (+31-70) 345-2034 Tx 31 651 epo nl, Fax (+31-70) 340-3016

Authorized officer

Lorence, Xavier
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<td>X</td>
<td>EP 0 520 403 A2 (SUMITOMO ELECTRIC INDUSTRIES [JP]) 30 December 1992 (1992-12-30) page 3, line 36 - page 4, line 16 figures 1-3</td>
<td>1,2,4-6, 9,11,12</td>
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<td>X</td>
<td>EP 0 560 287 A (SUMITOMO ELECTRIC INDUSTRIES [JP]) 15 September 1993 (1993-09-15) column 4, line 33 - column 5, line 1 column 7, line 1 - column 8, line 1 figure 1</td>
<td>1-4,6, 10,12</td>
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<td>A</td>
<td>EP 0 411 831 A1 (REED TOOL CO [GB] CAMCO DRILLING GROUP LTD [GB]) 6 February 1991 (1991-02-06) column 7, lines 7-55 figures 3-5</td>
<td>1,5,10</td>
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<td>A</td>
<td>GB 2 345 710 A (BAKER HUGHES INC [US]) 19 July 2000 (2000-07-19) page 2, line 14 - page 3, line 13 figure 1</td>
<td>1,12</td>
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INTERNATIONAL SEARCH REPORT

Box II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos. because they relate to subject matter not required to be searched by this Authority, namely:

   - [X] Claims Nos. because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
     
     see FURTHER INFORMATION sheet PCT/ISA/210

2. [X] Claims Nos. because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos. because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 64(a).

Box III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.

4. [ ] No required additional search fees were timely paid by the applicant. Consequently this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.
Continuation of Box II.2

Claims Nos.: 13

Claim 13 is not clear and therefore does not meet the requirements of Article 6 PCT. According to Rule 6.2(a) PCT, the claims shall not, except where absolutely necessary, rely, in respect of the technical features of the invention, on references to the description or drawings. In the present case, it appears that the subject-matter for which protection is sought can be defined in terms of its physical characteristics rather than by references to the description and/or drawings. It is therefore apparent that it is not "absolutely necessary" for the subject-matter, for which protection is sought to be defined in this manner. The claim 13 is therefore unclear in their present format as it does not meet the requirements of Rule 6.2(a) PCT.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.
<table>
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<tr>
<th>Patent document cited in search report</th>
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