



(43) International Publication Date
12 November 2015 (12.11.2015)

- (51) **International Patent Classification:**
B22F 3/20 (2006.01) *C22C 29/02* (2006.01)
B21C 23/14 (2006.01)
- (21) **International Application Number:**
PCT/EP2015/059818
- (22) **International Filing Date:**
5 May 2015 (05.05.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/990,761 9 May 2014 (09.05.2014) US
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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** EXTRUDED MULTI-GRADE CARBIDE ARTICLE

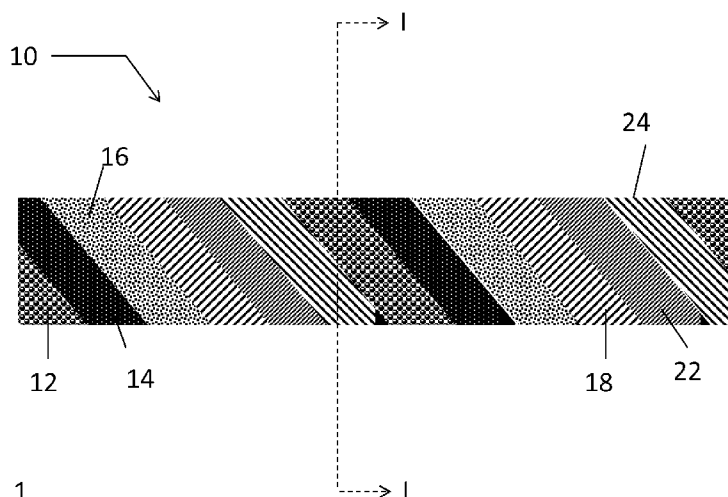


Fig. 1

(57) **Abstract:** A multi-grade composite article of a plurality of cemented carbide composite materials twist extruded together, at least two of the cemented carbide composite materials having a different composition. A method of forming a multi-grade composite article includes the steps of providing a plurality of different cemented carbide composite materials; positioning the plurality of cemented carbide composite materials in an extrusion device; and extruding and twisting the plurality of cemented carbide composite materials to form the multi-grade composite article.



EXTRUDED MULTI-GRADE CARBIDE ARTICLE

TECHNICAL FIELD

[0001] A multi-grade twist extruded composite cemented carbide article for a rotary tool or end milling includes a plurality of different cemented carbide composite materials twist extruded together to form the article.

SUMMARY

[0002] A multi-grade composite article of the present disclosure includes a plurality of cemented carbide composite materials twist extruded together, at least two of the cemented carbide composite materials having a different composition.

[0003] A method of forming a multi-grade composite article according to the present disclosure includes the steps of providing a plurality of different cemented carbide composite materials; positioning the plurality of cemented carbide composite materials in an extrusion device; and extruding and twisting the plurality of cemented carbide composite materials to form the multi-grade composite article, wherein at least two of the cemented carbide composite materials have different compositions.

[0004] The present disclosure also discloses a multi-grade composite tool comprising a plurality of cemented carbide composite materials twist extruded together, at least two of the carbide composite materials having a different composition at pre-determined positions of the tool.

[0005] The foregoing summary, as well as the following detailed description of the embodiments, will be better understood when read in conjunction with the appended drawings. It should be understood that the embodiments depicted are not limited to the precise arrangements and instrumentalities shown.

BACKGROUND

[0006] Drilling/milling composite materials can be difficult as different grades are required for optimized drilling of the different materials in the composite. For example, in the aerospace industry, drilling aluminum/titanium stacks would ideally require different carbide grades for each the two materials.

[0007] Due to the different toughness and wear resistance demands on a rotary tool, such as a drill, it is known to use different grades of cemented carbide in the core and periphery of the tool. Typically, tool blanks of this type are produced by a double pressing method, wherein a core or rod is pressed by powder metallurgical methods and an outer tube is pressed around the outside of the core. Such methods are expensive and time consuming and limit the number of different grades that can be used in a single tool.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a side view of a twist extruded multi-grade composite cemented carbide article.

[0009] Fig. 2 is a cross-section of the multi-grade composite cemented carbide article of Fig. 1, taken along line I-I.

[0010] Fig. 3 is a cross-section of another embodiment of a twist extruded multi-grade cemented carbide article.

[0011] Fig. 4 is a cross-section of the twist extruded multi-grade composite cemented carbide of Fig. 3 in a barrel of a twist extrusion device.

[0012] Fig. 5 is a cross-section of another embodiment of a twist extruded multi-grade composite cemented carbide article in a barrel of a twist extrusion device.

[0013] Fig. 6 is a cross-section of the twist extruded multi-grade composite cemented carbide being extruded in a twist extrusion device.

[0014] Fig. 7 is a cross-section of a twist extrusion device arranged to produce the disclosed twist extruded multi-grade composite cemented carbide articles.

[0015] Fig. 8 is an enlarged view of the internal surface of the nozzle of the twist extrusion device.

[0016] Fig. 9 is a flow diagram of a method of producing a twist extruded multi-grade composite cemented carbide.

DETAILED DESCRIPTION

[0017] According to the present disclosure, two or more composition or grades of cemented carbide composite materials can be combined using a twisting extrusion method to create a multiple grade rotary tool/ end mill, for example, the production of cemented carbide rotary tools used in material removal operations such as drilling, reaming and end milling. Moreover, it is possible to combine more than two grades of cemented carbide composite materials if desired.

[0018] Rather than being limited to a core/rim structure, the position of the different materials can be controlled to a more optimized position. The present twisting extrusion method is also a single operation, which would save both time and cost in production.

[0019] Referring to Figs. 1 and 2, a multi-grade composite cemented carbide article 10 is shown. Article 10 can be a rotary tool, wear part, end milling, or other tool of multiple different cemented carbide composite materials and is not limited to a particular tool or item.

[0020] Cemented carbide composite material normally has a tungsten carbide hard phase and one or more carbides, nitrides or carbonitrides of tungsten, titanium, chromium, vanadium, tantalum, niobium, molybdenum, hafnium and zirconium, i.e., elements belonging to groups IVB through VIB of the periodic table, bonded by a metallic phase binder.

[0021] The binder comprises Co, Ni, Mo or Fe, or mixtures (alloys) of these elements in any proportion. The binder phase may also contain elements such as W, Cr, Ti, Ta, V, Nb, C, etc. up to the solubility limits of these elements in the binder alloy. Additionally, the binder may contain up to 5% by weight of elements such as Cu, Mn, Ag, Al, etc.

[0022] Cemented carbide composite material preferably comprises approximately about 70 to about 97% by weight of one or more of the above

carbides and approximately about 2 to about 40% by weight of the binder alloy. The average grain size of the cemented carbides preferably varies within the range of approximately of about 0.2 to of about 20.0 μm .

[0023] The cemented carbide composite materials can be fabricated by consolidating a metallurgical powder blend of at least one powdered ceramic component and at least one powdered binder. The physical and chemical properties of cemented carbide composite materials depend in part on the individual components of the metallurgical powders used to produce the cemented carbide composite material. The composition of a cemented carbide composite material can be determined by, for example, the chemical composition of the metal carbide, the particle size of the metal carbide, the chemical composition of the binder, and/or the ratio of binder to metal carbide. By varying the components of the metallurgical powder, rotary tools such as drills and end mills can be produced with unique properties matched to specific applications.

[0024] Cemented carbides composite materials exist in different grades. Grade refers herein to cemented carbide as described hereinabove or hereinafter in one of several proportions and with a certain grain size. It should be appreciated that other materials are contemplated by the present disclosure, for example, cermets.

[0025] Generally, there is no restriction, compositionally or micro-structurally (i.e., carbide grain size), to the grades of cemented carbide composite material that may be combined to produce the multiple grade ("multi-grade") article, such as a dual grade article, as defined hereinabove or hereinafter. In general, the grade of the cemented carbide composite material is defined by its composition, i.e., the identity of its constituents and the amounts thereof, as well as its microstructure (grain size). Two cemented carbides composite materials of different grades have different compositions and/or microstructures and, therefore, have different properties.

[0026] In order to produce a rotary tool or article that has different properties at different locations on the tool, different cemented carbide composite materials each having one or more different metal carbide components, binder chemical composition, metal carbide component grain size, and ratio of binder content to

metal carbide content can be located at different regions of the article, so as to select the relative properties of cemented carbide composite material at the different regions. As an example, the hardness and wear resistance of one region of a rotary tool can be enhanced relative to another region by locating particular cemented carbide composite material in a particular region. Thus, the tool or article may be constructed so that the regions of the cutting edge experiencing relatively high cutting speeds will wear and chip at a rate similar to that of regions experiencing lower cutting speeds.

[0027] Although the present disclosure is presented in terms of rotary tools having a particular number of regions of different cemented carbide composite material, it should be understood that any number of regions of cemented carbide composite material, each having selected properties can be provided. Accordingly, the present tool or article has a plurality of different cemented carbide composite materials. It should be appreciated that the number of cemented carbide composite materials is not limited; however, at least two cemented carbide composite materials are provided.

[0028] Referring again to Fig. 1, and described further herein, a multi-grade tool or multi-grade article 10 is formed by a twist extrusion process, such that a plurality of different cemented carbide composite materials 12, 14...24 are twisted about each other (Fig. 3) or a core 20 (Fig. 2). Cemented carbide composite materials 12, 14...24 form an outer region and component of core 20 forms an inner region. As used herein, plurality refers to two or more. A twist extrusion process refers to pushing material through a static grooved nozzle which has a helical geometry thereby forcing the material to twist as it is forced out.

[0029] The position of particular cemented carbide composite material can be controlled such that a specific cemented carbide composite material is positioned at a predetermined position in the multi-grade article/tool, i.e., in the outer region or inner region and in a particular location of the outer region of the multi-grade article. Thus, the multi-grade composite cemented carbide tools can have properties of regions of the tools tailored to suit different applications. For example,

the thickness, geometry, and/or physical properties of the individual cemented carbide composite material regions of a particular composite article may be selected to suit the specific application of the rotary tool fabricated from the article. Thus, for example, the stiffness of one or more cemented carbide composite material regions of the multi-grade rotary tool experiencing significant bending during use may be of a cemented carbide composite material having an enhanced modulus of elasticity; the hardness and/or wear resistance of one or more cemented carbide composite material regions having cutting surfaces and that experience cutting speeds greater than other regions may be increased; and/or the corrosion resistance of regions of cemented carbide composite material subject to chemical contact during use may be enhanced.

[0030] For example, the cemented carbide composite materials can be 89 wt-% WC, 10 wt-% Co and 0.5 wt-% Cr_3C_2 ; or 87wt-% WC; 12wt-% Co and 0.5% Cr_3C_2 . or 90.2 wt-% WC, 09% Co, 0.35% Va and 0.45% Cr_3C_2 ; or 90.85 wt% WC, 8.5% Co and 0.65% Cr_3C_2 , etc.

[0031] Referring to Fig. 4, the multi-grade cemented carbide composite can be either pre- extruded cemented carbide composite materials 12, 14, 20 24 placed in desired positions in an extrusion barrel 30 depending on the desired position of the cemented carbide composite material in the article. Alternatively, as shown in Fig. 5, the cemented carbide composite materials can be in a dough form 32, 34, 36. As referred to herein dough is formed by using ready to press powder to which a solvent premix containing appropriate organic binders are added and mixed to get a homogeneous mixture of different cemented carbide grades that can be placed in the extrusion barrel 30.

[0032] As shown in Figs. 6 -8, extrusion apparatus 40 includes a shear plate 42 communicating with extrusion barrel 30 through which the cemented carbide composite materials 12, 14...24 are introduced as described above. Shear plate 42 has nozzles 45 that give the extruded cemented carbide composite materials the desired twist due to a predetermined nozzle helix angle or shape. The nozzles can have multiple helical grooves or guidelines 43, as shown in Fig. 8, that are product

dependent, for example, about 10° to about 50°, which give the compacted dough the necessary twist. Accordingly, the step of extruding includes twisting the plurality of cemented carbide composite materials about each other. Shear plate 42 can also serve to position and feed a filament wire of plastic or metal which gives the desired shape, position and size for coolant channels and to reduce shear during extrusion.

[0033] A ram 44 movably disposed within extrusion barrel 30 pushes the cemented carbide composite materials through shear plate 42 forming twist extruded multi-grade article 46. As will be described further herein, after passing through shear plate 42, the cemented carbide composite materials are twisted by the nozzle angles to form the twisted multi-grade article 46.

[0034] Referring to Fig. 9, a method 50 of twist extruding a plurality of cemented carbide composite materials is described. A plurality of different cemented carbide composite material compositions are prepared and provided in step 52. The cemented carbide composite materials can be made according to known powder metallurgical methods.

[0035] Each of the cemented carbide composite materials of different grades can be pre-extruded as shown in Figs 1-4 or in dough form as shown in Fig. 5. Next in step 54, each of the different cemented carbide composite materials are introduced into extrusion apparatus 40 shown in Fig. 6.

[0036] In step 56, the cemented carbide composite materials are extruded and twisted to form the multi-grade article 46. Cemented carbide composite material in the form of dough present in the barrel is pushed at a certain ram speed for example, of about 0.01 to about 0.6 mm/sec and pressure of about 200 to about 800 bar that is forced to move forward through the reducer and shear plate 42, where the dough gets compacted and channelized towards the nozzles. As set forth above, the nozzles are designed to have multiple helical grooves or guidelines, which give the compacted dough the necessary twist.

[0037] After multi-grade article 46 is twist-extruded to a desired length(s) in step 58, it is dried, for example, in an oven, at a temperature of from about 80°C to

about 120°C to remove the organic substances, such as monopropylene glycol (MPG).

[0038] Then, in step 60, the dried green state multi-grade cemented carbide article as defined hereinabove or hereinafter is sintered at a high temperature for example, of from about 1350°C to about 1450°C, in a sinter furnace or other apparatus (DMK Ltd.) to obtain solid carbide. During sintering, the properties of each of the different grade twist extruded cemented carbide composite materials remain intact; however, there is a possibility to form a third grade when the multi-grade article is sintered. Boundary conditions at the grades of each of the twisted cemented carbide composite materials may undergo or experience physical and chemical modifications. Similar grain size and cobalt content range should not promote grain growth, but with dissimilar grades there is a probability of cobalt migration and grain growth, e.g. if one grade has grain growth inhibitor and another doesn't, thus forming a third grade.

[0039] After sintering the rods can be machined in step 62. For example, the outer diameter can be ground to a close, specified tolerance. In step 64, the article can be cut to specified lengths. It should be appreciated that the multi-grade article(s) and/or tool(s) can be machined in a variety of different ways and sizes depending on the desired end use.

[0040] The method and multi-grade extruded cemented carbide article of the present disclosure enables different grade cemented carbide composite materials to be held inside the extrusion barrel and positioned strategically as per the application of the end use article demands. Co-extruding with different grades of cemented carbide composite materials overcomes additional operations like joining and brazing.

[0041] Itemized list of embodiments

1. A method of forming a multi-grade composite article comprising the steps of:
 - providing at least two cemented carbide composite materials;
 - positioning the cemented carbide composite materials in an extrusion device; and
 - extruding and twisting the cemented carbide composite materials to form the multi-grade composite article, wherein the at least two cemented carbide composite materials have different compositions .
2. The method of item 1, wherein each of the cemented carbide composite materials comprises tungsten-carbide and a binder.
3. The method of items 1 or 2, wherein each of the cemented carbide composite materials comprises a hard phase of tungsten carbide and one or more carbides, nitrides or carbonitrides of tungsten, titanium, chromium, vanadium, tantalum, niobium, molybdenum, hafnium and zirconium or combinations thereof.
4. The method of any of items 1-3, wherein the binder is selected from the group of cobalt, nickel, iron, molybdenum and alloys thereof.
5. The method of any of items 1-4, characterized in that each of the cemented carbide composite materials is of a different grade.
6. The method of any of items 1 -5, further comprising the step of drying the extruded multi-grade composite article.

7. The method of item 6, further comprising the step of sintering the extruded multi-grade composite article.

8. The method of item 7, further comprising the step of machining the extruded multi-grade composite article to form a tool.

9. A multi-grade composite tool comprising at least two cemented carbide composite materials twist extruded together, the at least two cemented carbide composite materials having a different composition at pre-determined positions of the tool, the tool being made according to the method of items 1-9.

[0042] Although the present embodiment(s) has been described in relation to particular aspects thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred therefore, that the present embodiment(s) be limited not by the specific disclosure herein, but only by the appended claims.

WHAT IS CLAIMED IS:

1. A multi-grade composite article comprising a plurality of cemented carbide composite materials twist extruded together, at least two of the cemented carbide composite materials having a different composition.
2. The multi-grade composite article of claim 1, wherein each of the cemented carbide composite materials comprises tungsten-carbide and a binder.
3. The multi-grade composite article of claim 2, wherein each of the cemented carbide composite materials has a hard phase of tungsten carbide and one or more carbides, nitrides or carbonitrides of tungsten, titanium, chromium, vanadium, tantalum, niobium, molybdenum, hafnium and zirconium or combinations thereof.
4. The multi-grade composite article of claim 2, wherein the binder is selected from the group of cobalt, nickel, iron, molybdenum and alloys thereof.
5. The multi-grade composite article of claim 1, wherein each of the cemented carbide composite materials is of a different grade.
6. The multi-grade composite article of claim 1, wherein a plurality of the cemented carbide composite materials form an outer region of the multi-grade article and at least one cemented carbide composite material forms an inner core region.
7. The multi-grade composite article of claim 1, wherein the multi-grade article is selected from a group of a multi-grade rotary tool, blank and end mill.

8. A method of forming a multi-grade composite article comprising the steps of:
- providing a plurality of different cemented carbide composite materials;
 - positioning the plurality of cemented carbide composite materials in an extrusion device; and
 - extruding and twisting the plurality of cemented carbide composite materials to form the multi-grade composite article, wherein at least two of the cemented carbide composite materials have different compositions.
9. The method of claim 8, wherein each of the cemented carbide composite materials comprises tungsten-carbide and a binder.
10. The method of claim 9, wherein each of the cemented carbide composite materials has a hard phase of tungsten carbide and one or more carbides, nitrides or carbonitrides of tungsten, titanium, chromium, vanadium, tantalum, niobium, molybdenum, hafnium and zirconium or combinations thereof.
11. The method of claim 9, wherein the binder is selected from the group of cobalt, nickel, iron, molybdenum and alloys thereof.
12. The method of claim 8, wherein each of the cemented carbide composite materials is of a different grade.
13. The method of claim 8, further comprising the step of drying the extruded multi-grade composite article.

14. The method of claim 13, further comprising the step of sintering the extruded multi-grade composite article.

15. The method of claim 8, further comprising the step of machining the extruded multi-grade composite article to form a tool.

16. A multi-grade composite tool comprising a plurality of cemented carbide composite materials twist extruded together, at least two of the cemented composite materials having a different composition at pre-determined positions of the tool.

17. The multi-grade tool of claim 16, wherein each of the cemented carbide composite materials comprises tungsten-carbide and a binder.

18. The multi-grade tool of claim 17, wherein each of the cemented carbide composite materials has a hard phase of tungsten carbide and one or more carbides, nitrides or carbonitrides of tungsten, titanium, chromium, vanadium, tantalum, niobium, molybdenum, hafnium and zirconium or combinations thereof.

19. The multi-grade tool of claim 17, wherein the binder is selected from the group of cobalt, nickel, iron, molybdenum and alloys thereof.

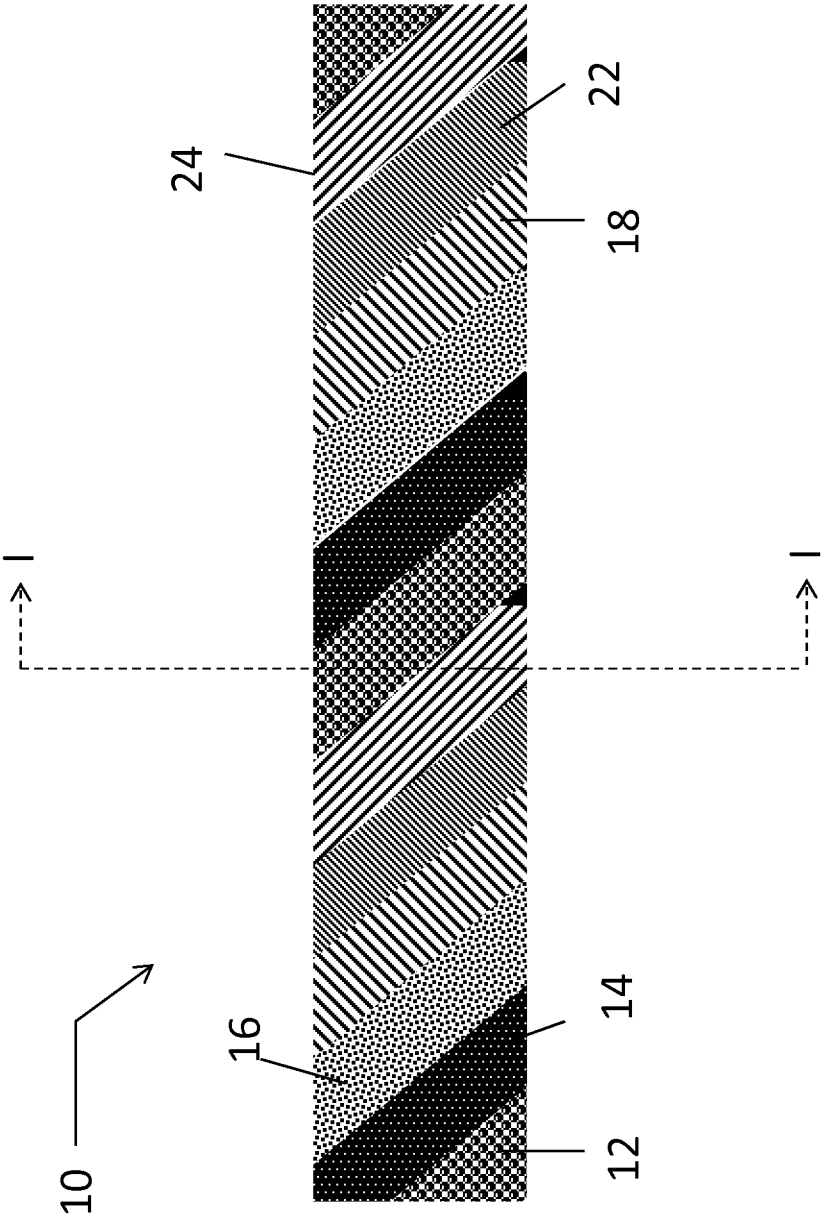


Fig. 1

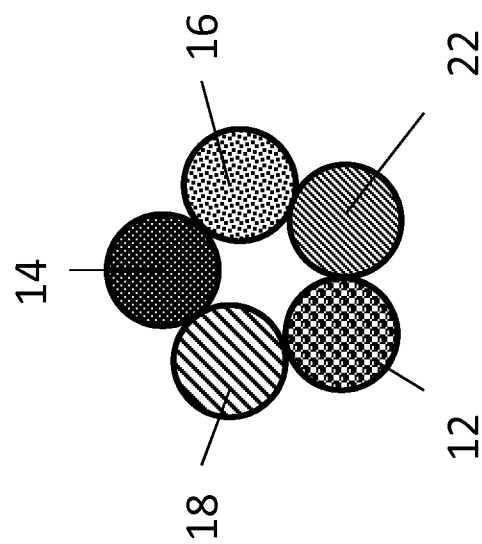


Fig. 2

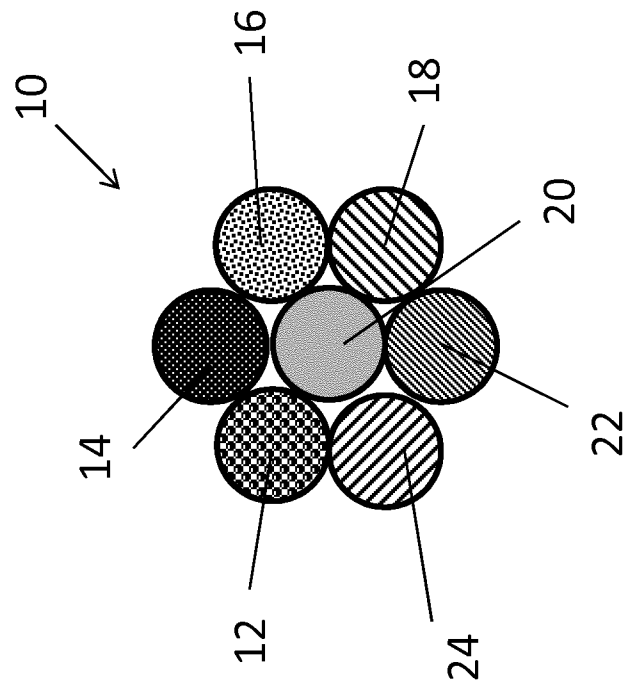


Fig. 3

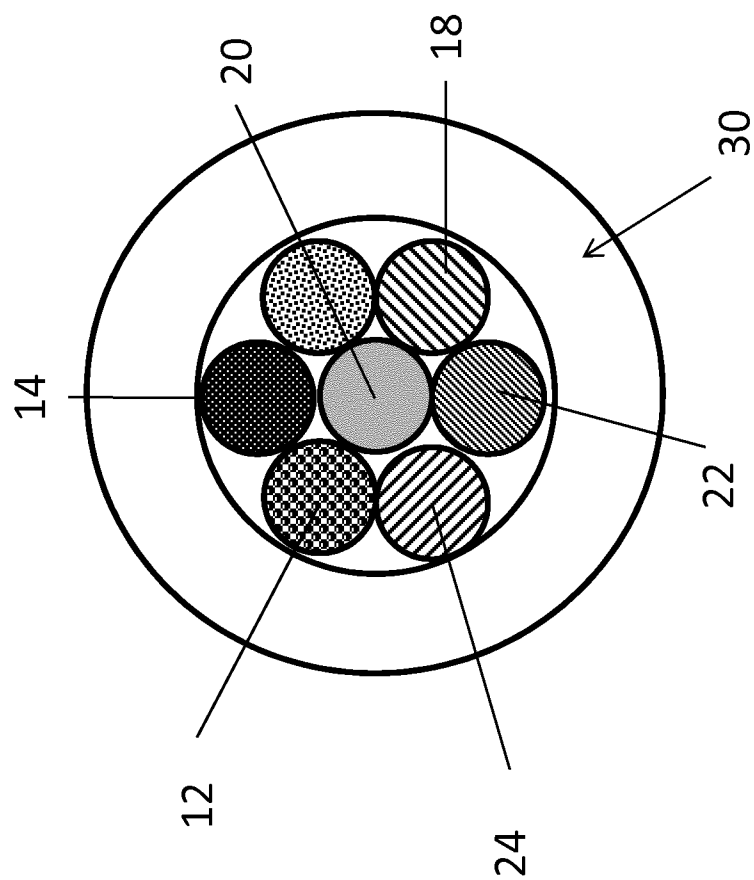


Fig. 4

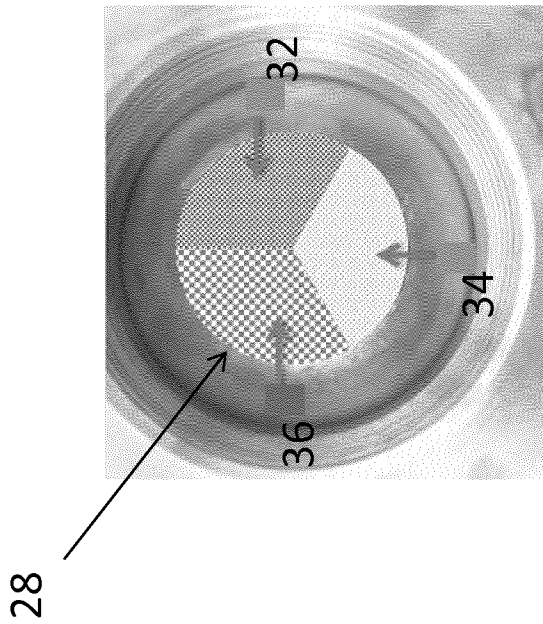


Fig. 5

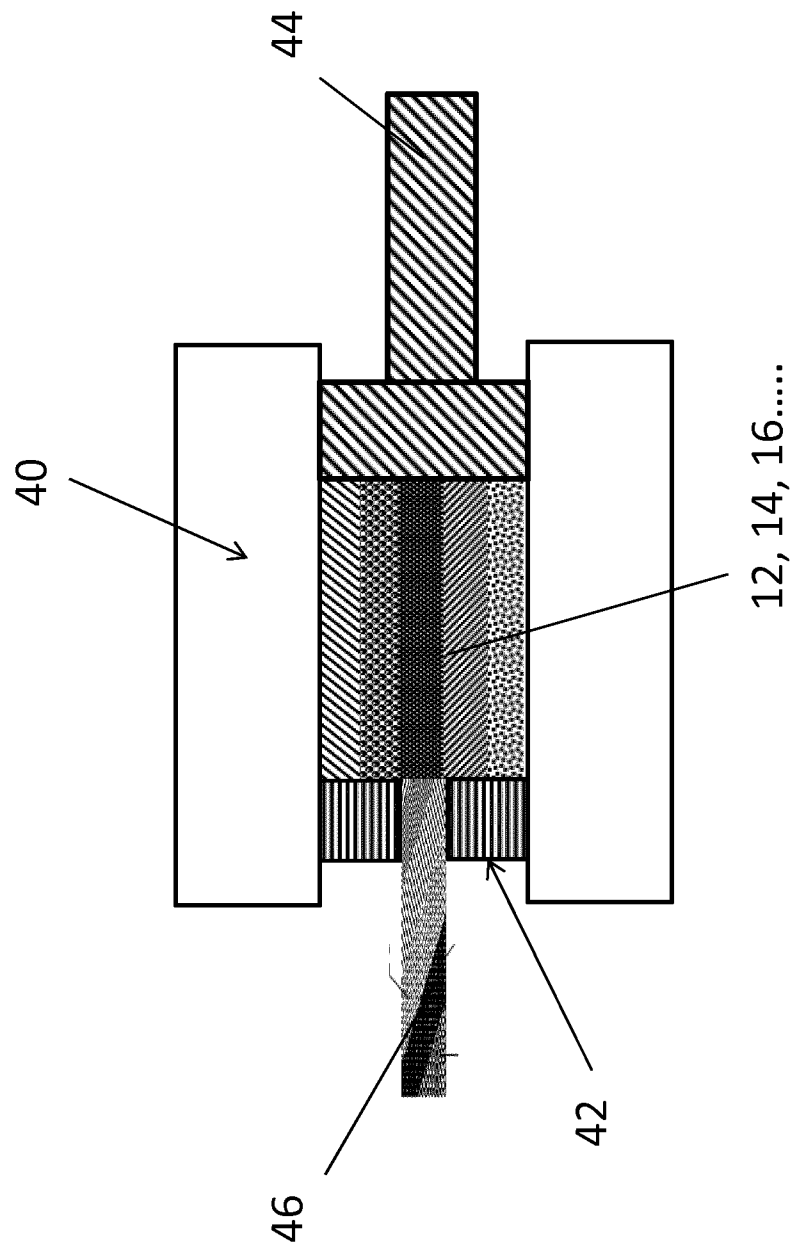
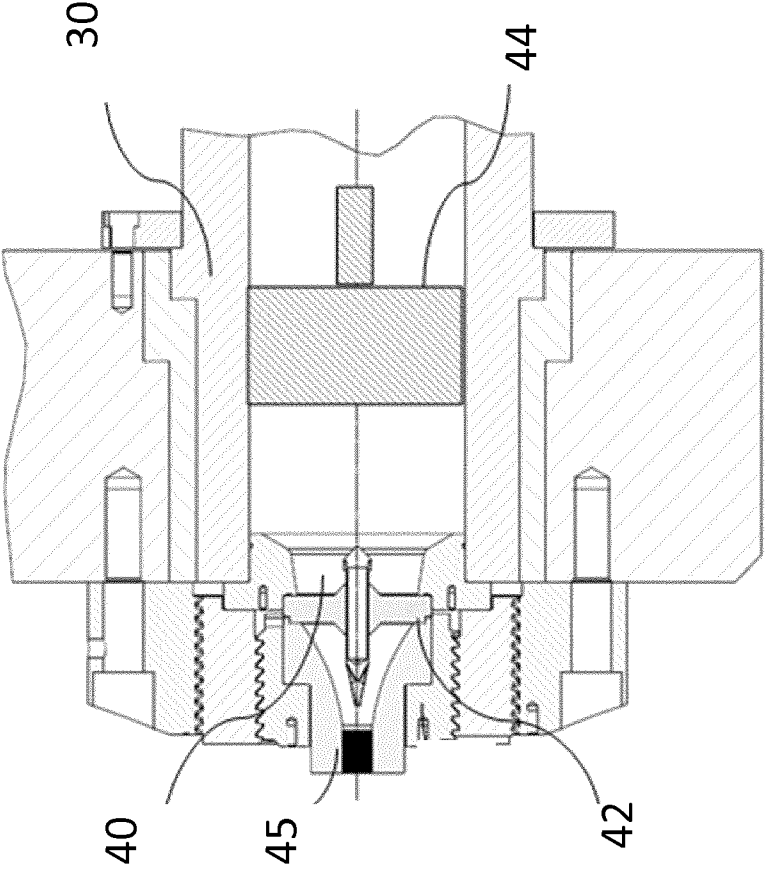


Fig. 6

Fig. 7



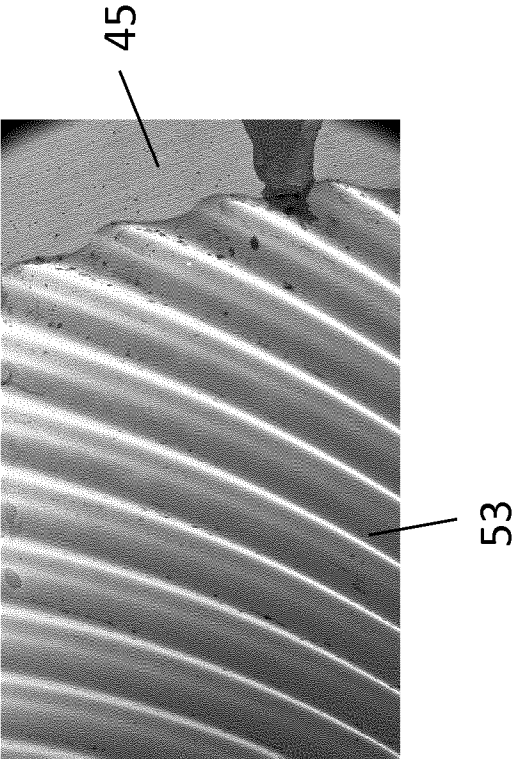


Fig. 8

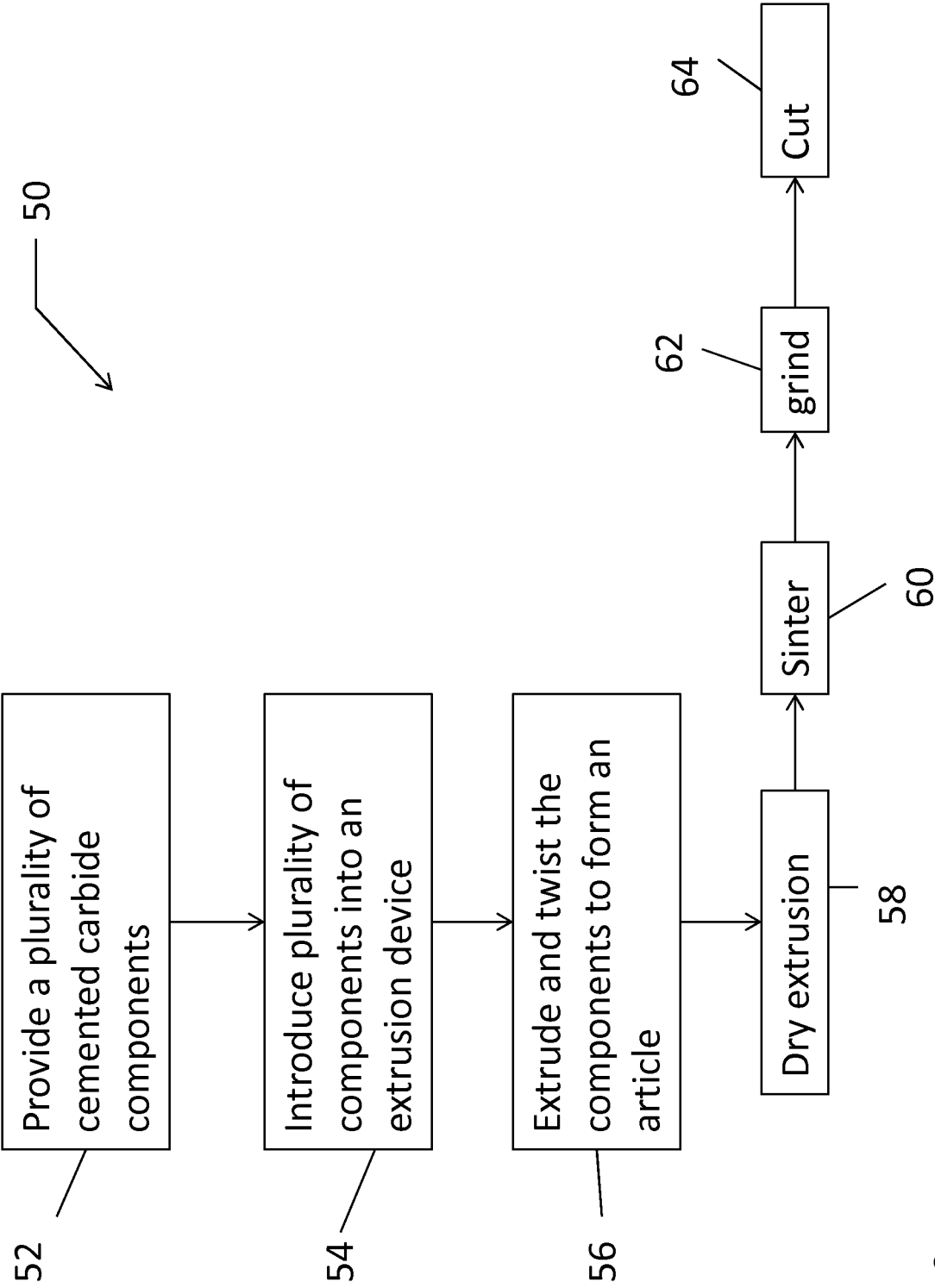


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/059818

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F3/20 B21C23/14 C22C29/02
ADD.

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)
B22F B21C C22C

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 practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 601 857 A (FRIEDRICHS ARNO [DE]) 11 February 1997 (1997-02-11) column 2, line 3 - line 46 -----	1-19
A	US 4 909 720 A (LOMBERG ALFONS [DE]) 20 March 1990 (1990-03-20) the whole document -----	1-19
A	US 4 881 431 A (BIENECK JUERGEN [DE]) 21 November 1989 (1989-11-21) the whole document -----	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 August 2015

Date of mailing of the international search report

24/08/2015

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/059818

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