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(71) Applicant: **NV BEKAERT SA** [BE/BE]; Bekaertstraat 2, 8550 Zwevegem (BE).

(72) Inventor: **ROMMEL, Hendrik**; Graaf Pierre de Brieylaan 27, 8200 Sint-Michiels (BE).

(74) Agent: **MESSELY, Marc**; Bekaertstraat 2, 8550 Zwevegem (BE).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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[Continued on next page]

(54) Title: STRANDED WIRE ROPE

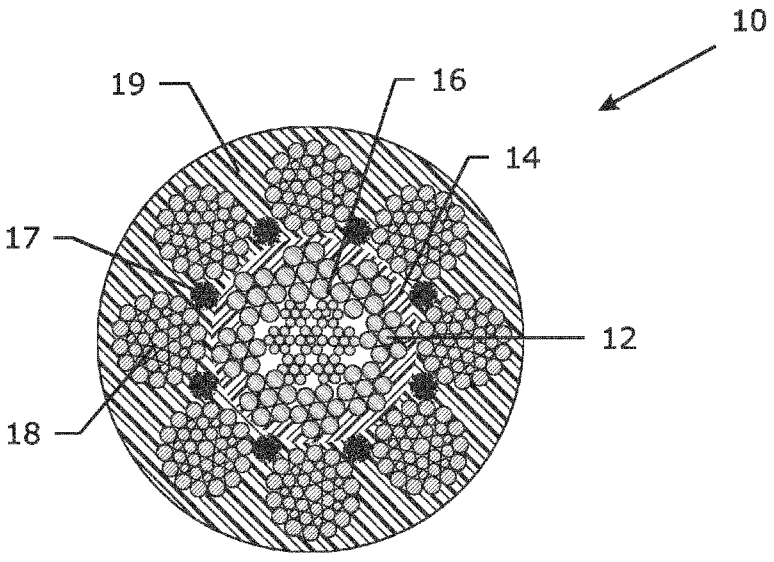

Fig. 1

(57) Abstract: A wire rope (10, 20), comprising: a core (12, 22), a plurality of outer strands (18, 28) and a plurality of separator strands (17, 27) laid on said core (12, 22), and a first plastic jacket (19) around said plurality of outer strands (18, 19) and said plurality of separator strands (17, 27), wherein said plurality of separator strands (17, 27) extend from said core (12, 22) and in-between each pair of said plurality of outer strands (18, 28) so as to produce and maintain gaps between said pair of said plurality of outer strands (18, 28). Plastic impregnation of the wire rope (10, 20) can be ensured due to the separator strands /17, 27).

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Stranded Wire Rope

Description

Technical Field

[0001] The present invention relates to a wire rope, in particular to a high performance stranded wire rope, a method for producing such a wire rope and the applications of such a wire rope.

Background Art

[0002] Plastic impregnated ropes are recommended for severe mining applications where the rope is exposed to high levels of wear and fatigue and particularly where there is a possibility that abrasive dust, dirt or corrosive material might penetrate the rope during normal operation.

[0003] The steel wire rope is impregnated by a special process whereby the individual strand gaps within the rope are filled with a sealing thermoplastic material forming a protective layer between the individual strands and around the core of the rope.

[0004] Plastic impregnation protects the rope from dirt and dust penetration and other corrosive materials, and also from internal wear from friction between the strands. Therefore, the life of the rope is greatly prolonged. In addition, plastic impregnated wire rope has several advantages. It has no stretch qualities because the thermo-plastic sticks the strands together; this is hugely beneficial for rotating ropes too as this process prevents the rope from twisting apart. Another benefit is their bend qualities: the plastic filling reduces wire contact bending stresses and so improving load transfer and sharing between wires and strands. Impregnated plastic results in continued flexibility, much more resistant to shock loading and a great increase in the working life of the rope.

[0005] Plastic impregnated wire rope is useful in more extreme conditions (e.g. dirty, dusty or chemical environments). It is also often used in the coal or

ore industry, piling operations and shovel cranes, as well as applications with very high wear levels.

[0006] On the other hand, conventional plastic impregnation of ropes is not a very controlled process since it is difficult to control how the rope is impregnated. Usually, the plastic just fills randomly the voids of the interior of the rope. During this process, it is difficult to avoid situations whereby two or more outer rope strands contact each other or the outer rope strands contact the outer strands of the core when the rope is flexed during use. These contact points become steel-to-steel abrasion points during the operation of the ropes, leading to the eventual failure of the rope.

[0007] Maintaining the strand-to-strand and strand-to-core separation in a plastic impregnated rope is quite difficult. One such method is disclosed in U.S. Patent No. 5,386,683 and U.S. patent 7,389,633 where specially designed plastic or fibrous rods are provided as wormings to prevent contact between the outer strands. However, this system requires a precise operational control and still leaves the possibility of contact between the wires of the outer strands after fretting of the plastic or fibrous rods.

Disclosure of Invention

[0008] It is an object of the present invention to provide a wire rope having a high fatigue life and wear resistance.

[0009] It is an object of the present invention to provide a stable wire rope suitable for severe fretting operations.

[0010] It is yet another object of the present invention to provide a stable wire rope which is feasible to produce by conventional punching and cabling process.

[0011] According to the present invention, there is provided a wire rope comprising a core, a plurality of outer strands and a plurality of separator strands laid on said core, a first plastic jacket around said plurality of outer strands and

said plurality of separator strands, wherein said plurality of separator strands extend from said core and in-between each pair of said plurality of outer strands so as to produce and maintain gaps between said pair of said plurality of outer strands.

[0012] In the content of the present invention, “separator strands” refer to strands used as wormings, spacers or separator means for maintaining a gap between each pair of the outer strands. Separator strands or wormings are distinguished from fillers in the prior art. The location and function of wormings are different from fillers. Separator strands or wormings are sitting in-between each pair of the outer strands while fillers would fill in voids in-between two adjacent layers of strands. Separator strands or wormings are used to remain the gaps between each pair of strands while fillers are usually used to fill in the gaps in the ropes to make the rope more circular. Separator strands or wormings have the same lay length of the layer that they are associated with while fillers have the same lay length of the filaments they touch.

[0013] In the content of the present invention, ‘strands’ can also be interpreted as 'cords'. It is typically made up of several single filaments. ‘Single filament’ in this context is a wire of a single, uninterrupted length. Herein, individual wires having an uninterrupted length need not be the same. Each of the wires maybe of a different type, depending on its needed properties. The filaments or wires are twisted with an intended lay length to form a strand or a cord. Either all filaments receive the same lay of which typical examples are compact cords (wherein all filament diameters are equal), Warrington or Seale strands (wherein filaments fit together in a certain pattern). Alternatively strands can be made in layers wherein a layer of filaments is twisted with a layer lay length around a center filament or precursor strand resulting in a layered cord (for example a 3+9+15 cords wherein a core strand of 3 filaments twisted together is surrounded by a layer of 9 filaments

and finally with a layer of 15 filaments). As another example, the steel strands are so called 7x7 cord which consists of a core strand of 7 filaments around which 6 strands each comprising 7 filaments are twisted with a same lay length.

[0014] The core of the wire rope can also be a wire strand or an independent wire rope. As an example, said core can be synthetic rope, such as made of fibers of polypropylene, nylon, polyester. Yarns of high modulus fibers are preferably used, for example yarns of fibers of liquid crystal polymer (LCP), aramid such as poly(p-phenylene terephthalamide) (known as Kevlar®), high molecular weight polyethylene (HMwPE), ultra-high molecular weight polyethylene (UHMwPE) such as Dyneema® and PBO (poly(p-phenylene-2,6-benzobisoxazole). Preferably, said core is an independent steel wire rope.

[0015] The plurality of outer strands and the plurality of separator strands can be made from metals or metal alloys, such as copper, aluminum or steel. Preferably, the hardness of said plurality of separator strands is lower than that of said plurality of outer strands of the wire rope. As an example, said core, said plurality of outer strands, and said plurality of separator strands are all made from steels. Preferably, said core and said plurality of outer strands are made from high carbon steel having a carbon content in the range of 0.2 to 1.5 weight percent and said plurality of separator strands are made from low carbon steel having a carbon content in the range of 0.02 to 0.2 weight percent. As an example, a high carbon steel can have a carbon content ranging between 0.2 wt % and 0.8 wt %, a manganese content from 0.3 wt % to 0.80 wt%, a silicon content ranging from 0.10 wt % to 0.50 wt %, a maximum sulphur content of 0.05 wt %, a maximum phosphorus content of 0.05 wt %, the remainder being iron and possible traces of copper, chromium, nickel, vanadium, molybdenum or boron. Alternatively, the wire of outer strands may also have the following composition: a carbon content ranging between 0.8 wt %to 1.0 wt %, a manganese content from 0.5 wt %to 0.8 wt %, a silicon content ranging from 0.1 wt % to 5.0 wt %, a

chromium content from 0.1 wt % to 0.5 wt %, a vanadium content from 0.02 wt % to 0.2 wt %, the remainder being iron and possible traces. As an example, the wires of the outer strand have a composition of 0.84 wt % carbon, 0.67 wt % manganese, 0.23 wt % silicon, 0.24 wt % chromium, 0.075 wt % vanadium, the remainder being iron and possible traces. A low carbon steel composition is a steel composition where – possibly with exception for silicon and manganese – all the elements have a content of less than 0.50 % by weight, e.g. less than 0.20 % by weight, e.g. less than 0.10 % by weight. E.g. silicon is present in amounts of maximum 1.0 % by weight, e.g. maximum 0.50 % by weight, e.g. 0.30 % by weight or 0.15 % by weight. E.g. manganese is present in amount of maximum 2.0 % by weight, e.g. maximum 1.0 % by weight, e.g. 0.50 % weight or 0.30 % by weight. For an example of low carbon separator strands, the carbon content ranges up to 0.20 % by weight, e.g. ranging up to 0.06 % by weight. The minimum carbon content can be about 0.02 % by weight.

[0016] As an alternative solution, said core and said plurality of outer strands are made from steels (either high carbon steel or low carbon steel), and said plurality of separator strands are made from copper. The use of copper as the material for separator strands, or low carbon steel as the material for separator strands while high carbon steel as the material for the outer strands has the advantage that these separator strands can be the “weak” parts when fretting occurs since they are relatively soft. In this way, the outer strands are not suffering of huge fretting due to the metal separator strands.

[0017] According to the present invention, said wire rope comprising a first plastic jacket penetrates in-between said plurality of outer strands and said plurality of separator strands. The separator means between the outer strands of the wire rope are in the form of strands allowing that the plastic goes around the separator strands and so the plastic is not stopped by the separators or wormings. The plastic jacket can penetrate into said plurality of separator strands. This is advantageous over fiber-wormings as there is

no or no sufficient space for fiber wormings with respect to plastic penetration. On the other hand, from production point of view, the separator strand can be easily handled than a single wire with the same diameter during punching and cabling the wire rope since a strand has better flexibility than a single wire.

[0018] The application of separator strands on the one hand provides better fretting resistance over plastic or fibrous rod separators, and on the other hand assures that there is a minimum gap between the outer strands facilitating the plastic to flow and pass the separator strands during jacketing in order to have full plastic penetration. Consequently, the performance of the rope can be significantly improved as a benefit of full penetration of plastic jacket.

[0019] Preferably, said wire rope further comprises a second plastic jacket on said core or the wire rope. The first plastic jacket on said wire rope and the second plastic jacket on said core can be made from polyamide (PA), polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polyurethane (PU), polysulfone (PES), ethylene tetrafluoroethylene (ETFE) and others. The first and second plastic jacket can be made from the same or different material. The plastic jacket is formed to extend over the periphery of the wire rope by a thickness preferably in the range of 0.5 mm to 5 mm, e.g. 2 to 4 mm. When the core is an independent wire rope, the second plastic jacket thereon can result in a more round cross-section and the separator strands can be precisely laid on the plastic jacket and placed in-between the outer strands. In addition, the cushion between the core and the separator strands as well as the outer strands can be avoided.

[0020] As an example, each of said plurality of separator strands may be covered with a third plastic jacket as to reduce the cushion between the separator strands and the outer strands. Preferably, the plastic coating is the same material of the first and second plastic jackets.

[0021] The first, the second and/or the third plastic jacket can be made by any suitable method, preferably by extrusion.

[0022] The plurality of outer strands and the plurality of separator strands may both have a near circular cross-section. Preferably, the plurality of outer strands have a same size and the plurality of the separator strands are also the same. The ratio of the diameter of said plurality of outer strands to the diameter of said plurality of separator strands is in the range of 3 to 10, e.g. 6 to 10. This ratio plays the role to control the magnitude of the gaps between the outer strands and the filling ratio of metals in the wire rope.

[0023] As an example, the diameter of said plurality of outer strands is in the range of 2 to 40 mm, e.g. in the range of 10 to 30 mm or in the range of 15 to 25 mm. The diameter of said wire rope is in the range of 5 to 200 mm, e.g. in the range of 10 to 100 mm or in the range of 30 to 50 mm. The metal or metal reinforced separator strands can be especially used for big diameter ropes where the gap between the separator strands and the ropes are rather big (e.g. about 1 mm, about 2 mm or even bigger) and therefore allow the plastic going easily around the separators. For medium-small diameter ropes, this will be very important when jacketing with full penetration is needed. Minimum gaps are required for the good flow of plastics during jacketing. If the gaps are too small, very high pressure is required. By using separator strands, the gaps between the outer strands are maintained and still plastic can pass by. This is an important advantage even for ropes with a coated core strand.

Brief Description of Figures in the Drawings

[0024] The invention will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompanying drawings, in which:

[0025] Figure 1 schematically shows an example of the wire rope according to the present invention.

[0026] Figure 2 schematically shows another example of the wire rope according to the present invention.

Mode(s) for Carrying Out the Invention

[0027] A construction of the wire rope of the present invention is illustrated in Fig. 1. The wire rope has a diameter of 44 or 71 mm and a configuration of EP8xK36WS+IWRC (1+6-8-8+8). Herewith, EP refers to the wire rope covered with a polymer. The wire rope has 8 compacted outer strands having 36 wires in combined parallel lay, indicated by 8xK36WS. The core is an independent wire rope (IWRC). The entire rope has a Warrington construction (1+6-8-8+8), i.e. it is a parallel lay strand construction having an outer layer of wires containing alternately large cords and small cords, the number of cords in the outer layer being twice that in the underlying layer of cords.

[0028] As shown in Fig. 1, the wire rope 10 has an independent wire rope core (IWRC) 12 which is provided with a plastic jacket 14. Preferably, the plastic jacket 14 is made of a hard plastic material, such as polyamide. The independent wire rope 12 can be synthetic rope. The independent wire rope 12 is preferably a steel wire rope and more preferably the interior of the wire rope 12 is lubricated, e.g. with a conventional asphaltic lubricant 16 which is entrapped within the core 12 by the plastic jacket 14.

[0029] On the periphery of the plastic jacket 14, there are placed 8 separator strands 17 and 8 compacted outer 18, which are made from metal or alloys. Preferably, the separator strands 17 and the outer strands 18 are made from steel. More preferably, the steel for the outer strands 18 has higher carbon content than that of the separator strands 17. The separator strands

17 are provided in-between the compacted outer strands 18 so as to create a gap between each pair of compacted outer strands 18 laid on top of the plastic jacket 14.

[0030] The wire rope 10 is enclosed with a plastic jacket 19. Preferably, the plastic jacket 19 is made of polypropylene and more preferably produced by extrusion. The plastic jacket 19 is extruded to extend over the periphery of the wire rope by a thickness in the range of 1 mm to 2 mm, i.e. 1.50 mm.

[0031] Such a wire rope provides a considerable improvement in GAP uniform distribution among 5% to 10%.

[0032] Figure 2 illustrates another example of the wire rope according to the present invention. The wire rope 20 has a 7x7+7x19W construction. Steel cords 27 are inserted as separators extending from the core 22 and in-between each pair of plurality of outer strands 28 so as to produce and maintain gaps between each pair of plurality of outer strands 28.

Claims

1. A wire rope, comprising:

   a core,

   a plurality of outer strands and a plurality of separator strands laid on said core, and

   a first plastic jacket around said plurality of outer strands and said plurality of separator strands,

   wherein said plurality of separator strands extend from said core and in-between each pair of said plurality of outer strands so as to produce and maintain gaps between said pair of said plurality of outer strands.
2. A wire rope according to claim 1, wherein said core, said plurality of outer strands and said plurality of separator strands are made from metals or metal alloys.
3. A wire rope according to claim 1 or 2, wherein the hardness of said plurality of separator strands is lower than that of said plurality of outer strands.
4. A wire rope according to any one of the preceding claims, wherein said first plastic jacket penetrates in-between said plurality of outer strands and said plurality of separator strands.
5. A wire rope according to any one of the preceding claims, wherein said first plastic jacket penetrates into said plurality of separator strands.
6. A wire rope according to any one of the preceding claims, wherein said core, said plurality of outer strands, and said plurality of separator strands are made from steels.
7. A wire rope according to claim 6, wherein said core and said plurality of outer strands are made from high carbon steel having a carbon content in the range of 0.2 to 1.5 weight percent and said plurality of separator strands are made from low carbon steel having a carbon content in the range of 0.02 to 0.2 weight percent.

8. A wire rope according to any one of the preceding claims, wherein said core is a wire strand.
9. A wire rope according to any one of the preceding claims, wherein said wire rope further comprises a second plastic jacket on said core.
10. A wire rope according to any one of the preceding claims, wherein each of said plurality of separator strands is covered with a third plastic jacket.
11. A wire rope according to any one of the preceding claims, wherein at least one of said first, said second and said third plastic jacket is made from polyamide (PA), polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polyurethane (PU), polysulfone (PES) or ethylene tetrafluoroethylene (ETFE).
12. A wire rope according to any one of the preceding claims, wherein at least one of said first, said second and said third plastic jacket is made by extrusion.
13. A wire rope according to any one of the preceding claims, wherein the ratio of the diameter of said plurality of outer strands to the diameter of said plurality of separator strands is in the range of 3 to 10.
14. A wire rope according to any one of the preceding claims, wherein the diameter of said plurality of outer strands is in the range of 2 to 40 mm.
15. A wire rope according to any one of the preceding claims, wherein the diameter of said wire rope is in the range of 5 to 200 mm.

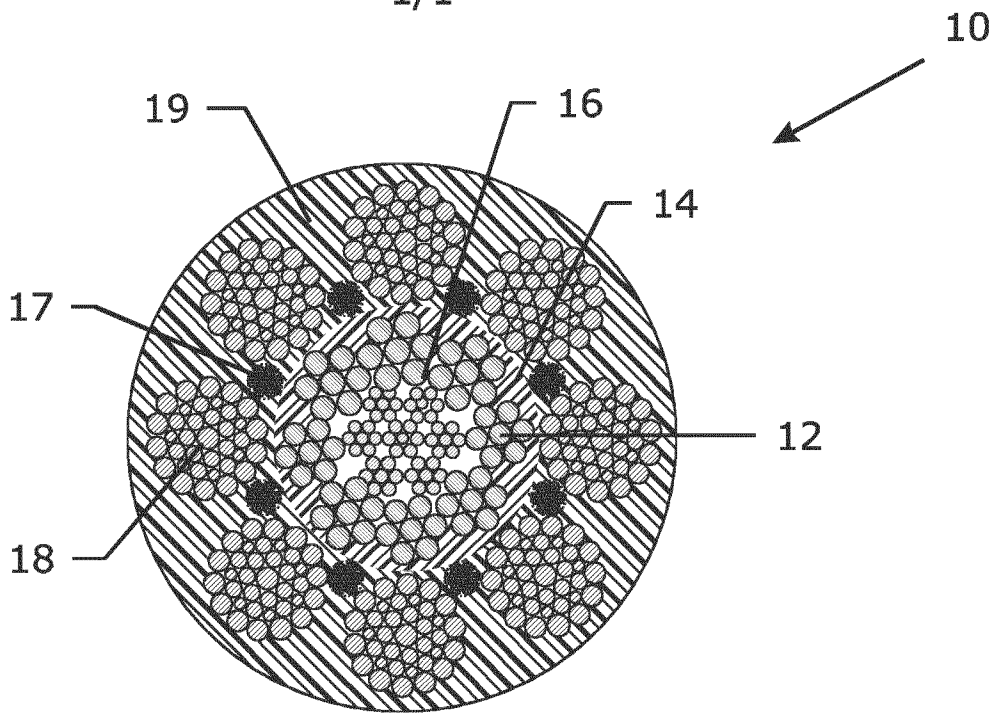

Fig. 1

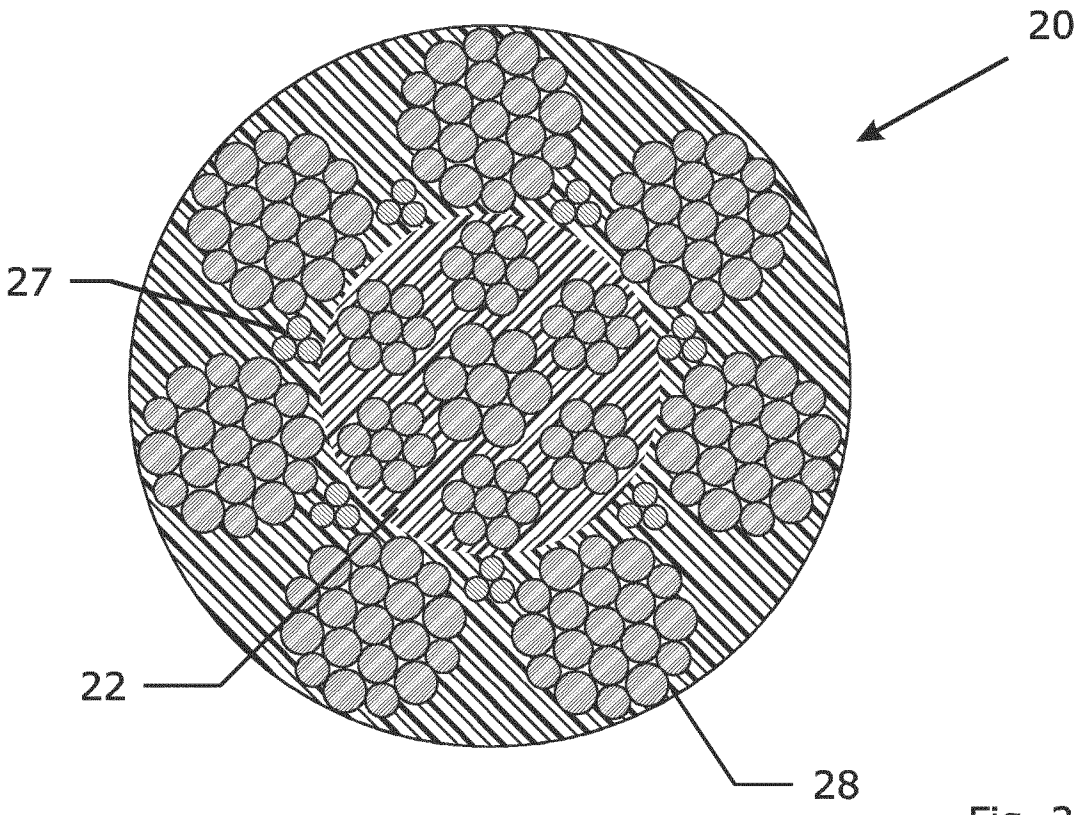

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/051506

A. CLASSIFICATION OF SUBJECT MATTER
INV. D07B1/16 D07B1/06
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)
D07B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 April 2016	12/04/2016

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, Fax: (+31-70) 340-3016	Uhlig, Robert

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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