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(71) Applicant(s)
**Compagnie Generale Des Etablissements Michelin**

(72) Inventor(s)
**CHEVALLEY, Marianna;LAURENT, Stéphane;CLEMENT, Emmanuel;GIANETTI, Alexandre;PINAUT, Rémi**

(74) Agent / Attorney
**Griffith Hack, Level 15 376-390 Collins St, MELBOURNE, VIC, 3000, AU**

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(71) **Déposant : COMPAGNIE GENERALE DES ETABLISSEMENTS MICHELIN** [FR/FR] ; 23, place des Carmes-Déchaux, 63000 CLERMONT-FERRAND (FR).

(72) **Inventeurs : CHEVALLEY, Marianna** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, DGD/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND CEDEX 9 (FR). **LAURENT, Stéphane** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, DGD/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND CEDEX 9 (FR). **CLEMENT, Emmanuel** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, DGD/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND CEDEX 9 (FR). **GIANETTI, Alexandre** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, DGD/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND CEDEX 9 (FR). **PINAUT, Rémi** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, DGD/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND CEDEX 9 (FR).

(74) **Mandataire : DESBORDES, Guillaume** ; MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, 23, place des Carmes-Déchaux, CBS/CORP/J/PI - F35 - Ladoux, 63040 CLERMONT-FERRAND Cedex 9 (FR).

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(54) **Titre :** CÂBLE MULTI-TORONS À DEUX COUCHES À PÉNÉTRABILITÉ AMÉLIORÉE

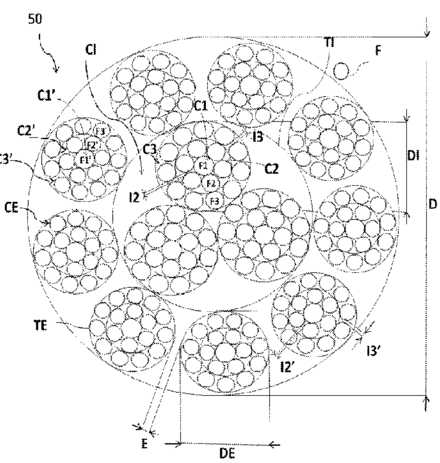


Fig. 3

**(57) Abstract:** The disclosed cord (50) comprises: - K > 1 inner strands (TI) comprising an inner layer (C1) and an outer layer (C3); - L > 1 outer strands (TE) comprising an inner layer (C1') consisting of Q'=1 inner wire (F1'), an intermediate layer (C2') consisting of M' intermediate wires (F2') wound around the inner layer (C1') at a pitch p2', and an outer layer (C3') consisting of N' outer wires (F3') wound around the intermediate layer (C2') at a pitch p3'; the average inter-strand distance E separating two adjacent outer strands is at least 30 μm; the intermediate layer (C2') of each outer strand (TE) is desaturated; the outer layer (C3') of each outer strand (TE) is desaturated; and 0.36 ≤ (p3'-p2')/p3' ≤ 0.57.

**(57) Abrégé :** Le câble (50) comprend: -K> 1 torons internes (TI) comprenant: une couche interne (C1), une couche externe (C3), -L>1 torons externes (TE) comprenant: une couche interne (C1') de Q'=1 fil interne (F1'), une couche intermédiaire (C2') de M' fils intermédiaires (F2') enroulés autour de la couche interne (C1') au pas p2', une couche externe (C3') de N' fils externes (F3') enroulés autour de la couche intermédiaire (C2') aupas p3', la distance E inter-torons moyenne séparant deux torons externes adjacents est supérieure ou égale à 30 μm la couche intermédiaire (C2') de chaque toron externe (TE) est désaturée; la couche externe (C3') de chaque toron externe (TE) est désaturée; et 0,36 ≤ (p3'-p2')/p3'≤ 0,57.

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# Double-layer multi-strand cord with improved penetrability

## Technical Field

**[001]** The invention relates to multi-strand cords that can be used notably for reinforcing tyres, particularly tyres for heavy industrial vehicles.

## Background Art

**[002]** A tyre having a radial carcass reinforcement comprises a tread, two inextensible beads, two sidewalls connecting the beads to the tread and a belt, or crown reinforcement, arranged circumferentially between the carcass reinforcement and the tread. The carcass reinforcement and the crown reinforcement comprise a plurality of plies made of elastomer compound, possibly reinforced with reinforcing elements such as cords or monofilaments, of the metal or textile type.

**[003]** The carcass reinforcement is anchored in each bead and surmounted radially by the crown reinforcement. The carcass reinforcement comprises a single carcass ply comprising carcass reinforcing metal filamentary elements. Each carcass reinforcing metal filamentary element makes an angle of between 80° and 90° with the circumferential direction of the tyre

**[004]** The crown reinforcement may also comprise various other auxiliary plies or layers of elastomer compound, with widths that may vary as the case may be, and which may or may not contain reinforcing elements. Mention may be made by way of example of what are known as protective plies which have the role of protecting the remainder of the belt from external attack or perforations, or also of what are known as hooping plies which contain reinforcing elements that are oriented substantially in the circumferential direction (what are known as "zero-degree" plies), whether these be radially on the outside or on the inside with respect to the working plies. The protective plies generally comprise reinforcing elements that exhibit a high elongation so that they deform under the effect of a stress applied by an indenter, for example a rock.

**[005]** A working ply reinforcing element comprising a two-layer multi-strand metal cord as disclosed in the examples of WO2015090920 is known from the prior art. This cord comprises an internal layer of the cord made up of an internal strand and an external layer of the cord made up of six external strands wrapped in a helix around the internal layer of the cord.

**[006]** Each internal and external strand comprises an internal layer of the strand, which layer is made up of a single internal thread, an intermediate layer made up of six threads and an external layer of the strand, which layer is made up of eleven external threads. The intermediate and external layers of the internal strand are wound in the S-direction around the internal and intermediate layers of the internal strand respectively. The intermediate and external layers of each external strand are wound in the Z-direction around the internal and intermediate layers of each external strand respectively. The external strands are wound in a helix around the internal strand in a direction of winding of the cord, this direction being the S-direction. Each pitch p2, p2' of the intermediate layers of each internal and external strand is equal to 14 mm, and each pitch p3, p3' of the external layer of each internal and external strand is equal to 20 mm.

**[007]** A tyre of a heavy industrial vehicle, notably of construction plant type, is subjected to numerous attacks. Specifically, this type of tyre usually runs on an uneven road surface, sometimes resulting in perforations of the tread. These perforations allow the entry of corrosive agents, for example air and water, which oxidize the metal reinforcing elements of the crown reinforcement, in particular of the crown plies, and considerably reduce the life of the tyre.

**[008]** One solution for increasing the life of the tyre is to combat the spread of these corrosive agents. Provision may thus be made to cover each internal and intermediate layer with an elastomer compound during the manufacture of the cord. During this process, the elastomer compound present penetrates the capillaries that are present between each layer of each strand and thus prevents the corrosive agents from spreading. Such cords, generally referred to as cords rubberized in situ, are well known from the prior art.

**[009]** Another solution for increasing the life of the tyre is to increase the cord's breaking strength. In general, the breaking strength is increased by increasing the diameter of the threads that make up the cord and/or by increasing the number of threads and/or the individual strength of each thread. However, increasing the diameter of the threads still further, for example beyond 0.50 mm, of necessity leads to a lowering of the flexibility of the cord, and this is not desirable. Increasing the number of threads usually leads to a lowering of the ability of the elastomer compound to penetrate the strands. Finally, increasing the individual strength of each thread entails significant investment in the installations used to manufacture the threads.

**[010]** It may be seen as desirable to provide a cord exhibiting improved penetrability of its external strands and better accessibility by the elastomer compound to the internal strand as compared with the cord of the prior art, thus making it possible to reduce the ingress and spread of corrosive agents into and along the cord.

**Summary**

**[011]** **<u>CORD ACCORDING TO THE INVENTION</u>**

**[012]** To this end, one subject of the invention is a two-layer multi-strand cord, comprising:

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- an internal layer of the cord made up of K > 1 internal strands wound in a helix, each internal strand being an at least two-layer strand and comprising:
  - an internal layer made up of Q internal thread(s), and
  - an external layer made up of N external threads wound around the internal layer,

- an external layer of the cord made up of L > 1 external strands wound around the internal layer of the cord, each external strand being a three-layer strand and comprising:
  - an internal layer made up of Q '= 1 internal thread,
  - an intermediate layer made up of M' intermediate threads wound around the internal layer with a pitch p2', and
  - an external layer made up of N' external threads wound around the intermediate layer with a pitch p3',

wherein:

- the mean inter-strand distance E separating two adjacent external strands is greater than or equal to 30 µm;
- the intermediate layer (C2') of each external strand (TE) is desaturated;
- the external layer (C3') of each external strand (TE) is desaturated; and
- the pitches p2' and p3' satisfy the relationship:

$$0.36 \leq (p3'-p2')/p3' \leq 0.57.$$

**[013]** It will be recalled that, as is known, the pitch of a strand represents the length of this strand, measured parallel to the axis of the cord, after which the strand that has this pitch has made a complete turn around the said axis of the cord. Similarly, the pitch of a thread represents the length of this thread, measured parallel to the axis of the strand in which it is located, after which the thread that has this pitch has made a complete turn around the said axis of the strand.

**[014]** What is meant by the direction of winding of a layer of strands or of threads is the direction that the strands or the threads form with respect to the axis of the cord or of the strand. The direction of winding is commonly designated by the letter Z or S.

**[015]** The pitches, directions of winding, and diameters of the threads and of the strands are determined in accordance with standard ASTM D2969-04 of 2014.

**[016]** According to the invention, the external layer of the cord is desaturated.

**[017]** By definition, a desaturated layer of strands is one such that there is enough space left between the strands to allow an elastomer compound to pass. An external layer of strands that is desaturated means that the external strands do not touch and that there is enough space between two adjacent external strands to allow an elastomer compound to pass as far as the internal strands. By contrast, a layer of strands that is saturated is such that there is not enough space between the strands of the layer to allow an elastomer compound to pass, for example because each pair of two strands of the layer touch one another.

**[018]** According to the invention, the inter-strand distance of the external layer of external strands, defined, on a cross section of the cord perpendicular to the main axis of the cord, as being the shortest distance separating, on average, the circular envelopes in which two adjacent external strands are inscribed, is greater than or equal to 30 µm.

**[019]** As a preference, the mean inter-strand distance E separating two adjacent external strands is greater than or equal to 70 µm, more preferably, than/to 100 µm, more preferably still, than/to 150 µm, and highly preferably, than/to 200 µm.

**[020]** What is meant by “at least two layers” is that each internal strand may, in certain embodiments, comprise two layers, which means to say that it comprises only two layers, but does not comprise just one or three of them; and that, in other embodiments, each internal strand may comprise three layers, which means to say that it comprises only three layers, but does not comprise just two or four of them.

**[021]** In the invention, the cord has two layers of strands, which means to say that it comprises an assembly made up of two layers of strands, neither more nor less, which means to say that the assembly has two layers of strands, not one, not three, but only two. The external layer of the cord is wound around the internal layer of the cord in contact with the internal layer of the cord.

**[022]** The cord according to the invention has improved penetrability in comparison with a cord of which the ratio (p3'-p2')/p3’ is outside of the range of ratios according to the invention, such as for example the cord in the examples of WO2015090920 for which the ratio (p3'-p2')/p3’ is equal to 0.30, and of which the penetrability can be improved by virtue of the invention. The inventors instigating the invention postulate the hypothesis that this ratio makes it possible to obtain relatively large radial passage windows for the passage of the elastomer compound within each external strand. The radial passage windows are defined as being the intersection between, on the one hand, the space projected onto a plane parallel to the main axis of the cord between two adjacent threads of the external layer of an external strand and, on the other hand, the space projected onto a plane parallel to the main axis of the cord between two adjacent threads of the intermediate layer of this external strand. Such a radial passage window is illustrated in Figure 16.

**[023]** In addition, thanks to the fact that the external layer of the cord is desaturated, the cord according to the invention has spaces between the external strands that allow the elastomer compound to pass. Cords having a relatively high breaking strength because the external layer of the cord is saturated (because the external strands are in contact with one another in pairs), thereby forming an arch that absorbs the tensile forces applied to the cord, are known from the prior art. In the cord according to the invention, although the arch around the internal layer is broken, the high penetrability of the external strands rendered possible by the ratio (p3'-p2')/p3' and the desaturated nature of the external layer of the cord allows the elastomer compound to penetrate, on the one hand, between the external strands and, on the other hand, between the external strands and each internal strand. In this way, the arch is at least partially restored and the drop in breaking strength of the cord is therefore limited while at the same time giving the cord its excellent penetrability. Furthermore, this feature allows the elastomer compound to infiltrate between the external layers of the internal and external strands so as to create a cushion of elastomer compound that at least partially absorbs the radial component of the force between the internal and external strands.

**[024]** In a cord of the prior art comprising an internal layer of the cord, which layer is made up of a single internal strand, significant desaturation of the external layer of the cord for the purposes of promoting the penetrability of the cord leads to a significant drop in the mass of metal and therefore to a relatively substantial reduction in the breaking strength of the cord. In the cord of the invention, significant desaturation of the external layer of the cord for the purposes of promoting the penetrability of the cord leads, because of the presence of K internal strands, to a less significant drop in the mass of metal and therefore to a controlled reduction in the breaking strength, unlike the cords of the prior art in which the contribution made by each external strand to the breaking strength is greater than in the cords according to the invention.

**[025]** Because of the invention and because of the relationship between p2' and p3', each external strand is a strand with cylindrical layers. Very advantageously, each internal strand is a strand with cylindrical layers such that regardless as to whether this internal strand has two layers or three. A strand with cylindrical layers is very highly penetrable, unlike a strand with compact layers in which the pitches of all the layers are the same and the directions of winding of all the layers are the same and exhibits far lower penetrability.

**[026]** As an option and a preference, in one embodiment, the cord does not have any polymer compound, notably the cord does not have any sheath of any polymer compound covering the internal layer of the cord and therefore each internal strand. In another embodiment, the cord does not have any elastomer compound, notably the cord does not have any sheath of any elastomer compound covering the internal layer of the cord and therefore each internal strand.

**[027]** Advantageously, the cord is made of metal. The term "metal cord" is understood

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by definition to mean a cord formed of threads made up predominantly (i.e. more than 50% of these threads) or entirely (100% of the threads) of a metallic material. Such a metal cord is preferably implemented with a steel cord, more preferably a cord made of pearlitic (or ferritic-pearlitic) carbon steel referred to as “carbon steel” below, or else made of stainless steel (by definition steel comprising at least 11% chromium and at least 50% iron). However, it is of course possible to use other steels or other alloys.

**[028]** When a carbon steel is advantageously used, its carbon content (% by weight of steel) is preferably between 0.4% and 1.2%, in particular between 0.5% and 1.1%; these contents represent a good compromise between the mechanical properties required for the tyre and the feasibility of the threads.

**[029]** The metal or the steel used, whether it is in particular a carbon steel or a stainless steel, may itself be coated with a metallic layer which improves for example the workability of the metallic cord and/or of its constituent elements, or the use properties of the cord and/or of the tyre themselves, such as properties of adhesion, corrosion resistance or resistance to ageing. According to a preferred embodiment, the steel used is covered with a layer of brass (Zn-Cu alloy) or of zinc.

**[030]** For preference, the threads of the one same layer of a predetermined (internal or external) strand all have substantially the same diameter. Advantageously, the internal strands all have substantially the same diameter. Advantageously, the external strands all have substantially the same diameter. What is meant by “substantially the same diameter” is that the threads or the strands have the same diameter to within the industrial tolerances.

**[031]** Advantageously, each thread of each strand has a diameter ranging from 0.15 mm to 0.60 mm, preferably from 0.20 mm to 0.50 mm, more preferentially from 0.22 mm to 0.40 mm, and more preferably still from 0.24 mm to 0.35 mm.

**[032]** What is meant by a polymer compound or a polymeric compound is that the compound contains at least one polymer. For preference, such a polymer may be a thermoplastic, for example a polyester or a polyamide, a thermosetting polymer, an elastomer, for example natural rubber, a thermoplastic elastomer or a combination of these polymers.

**[033]** What is meant by an elastomer compound or an elastomeric compound is that the compound contains at least one elastomer or one rubber (the two terms being synonyms) and at least one other component. For preference, the elastomer compound also contains a vulcanization system and a filler. More preferentially, the elastomer is a diene elastomer.

**[034]** Advantageously, the pitches p2' and p3' satisfy the relationship $0.38 \leq (p3'-p2')/p3'$; for preference $0.40 \leq (p3'-p2')/p3'$; more preferably $0.43 \leq (p3'-p2')/p3'$; and

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more preferably still 0.45 ≤ (p3'-p2')/p3'. The higher the ratio (p3'-p2')/p3' or, in other words, the greater the difference between p3’ and p2', the better the architectural stability of each external strand. Specifically, the greater the extent to which the pitches of the intermediate and external layers of each external strand differ, the greater the crossing of the intermediate and external threads with respect to one another (contacts between the intermediate and external threads are then relatively point-like contacts), the better the external threads will mechanically hold the intermediate threads and the better will be the penetrability of each external strand of which the threads of intermediate and external layers will then be evenly distributed within each intermediate and external layer. This mechanical integrity makes it possible to avoid, on the one hand, during manufacture of the cord, all the threads of the intermediate layer all grouping together in contact with one another under the effect of the mechanical forces exerted by the assembly tools and, on the other hand, during manufacture of a ply containing the cord or of the tyre containing the cord, all the threads of the intermediate layer grouping together all in contact with one another under the effect of the pressure of the elastomer compound penetrating the cord.

**[035]** Furthermore, for a given pitch p3', by increasing the ratio (p3'-p2')/p3', the inter-thread distance of the intermediate layer of each external strand is reduced. A person skilled in the art would expect to see a drop in the penetrability of each external strand. Yet, entirely unexpectedly, as the comparative tests described hereinafter show, by increasing the ratio (p3'-p2')/p3', although the inter-thread distance of the intermediate layer of each external strand is admittedly reduced, the size of the radial passage windows for the elastomer compound is increased which means that the penetrability of each external strand is appreciably improved.

**[036]** Advantageously, the pitches p2' and p3' satisfy the relationship (p3'-p2')/p3' ≤ 0.55 and for preference (p3'-p2')/p3' ≤ 0.53. Below these values, the size of the radial passage windows for the elastomer compound is at a maximum and makes it possible to optimize the penetrability of each external strand.

**[037]** Advantageously, the pitch p2' is such that 8 mm ≤ p2' ≤ 16 mm, for preference 8 mm ≤ p2' ≤ 14 mm and more preferably 8 mm ≤ p2' ≤ 12 mm.

**[038]** Advantageously, the pitch p3' is such that 10 mm ≤ p3' ≤ 40 mm, for preference 15 mm ≤ p3' ≤ 35 mm, more preferably 15 mm ≤ p3' ≤ 25 mm and more preferably still 17 mm ≤ p3' ≤ 23 mm.

**[039]** Pitches p2’ and p3’ within these preferred ranges make it possible to obtain a cord that exhibits mechanical properties compatible with tyre use, a relatively low cost and a relatively low linear cord weight.

**[040]** By definition, the diameter of a strand is the diameter of the smallest circle inside

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which the strand can be circumscribed.

**[041]** Advantageously, K=2, 3 or 4, and preferably K=3 or 4.

**[042]** In one embodiment, L is equal to 7, 8, 9 or 10, and preferably L=8, 9 or 10 and more preferably L=8 or 9.

**[043]** In a first variant, K=2, and L=7 or 8.

**[044]** In a second variant, K=3 and L=7, 8 or 9, and preferably K=3, L=8 or 9. Instances in which L=8 favour the desaturation of the external layer of the cord and therefore the penetrability of the cord between the external strands. Instances in which L=9 maximize the number of external strands and therefore the breaking strength of the cord.

**[045]** In a third variant, K=4 and L=7, 8, 9 or 10, and preferably K=4, L=9 or 10.

**[046]** In these embodiments, notably those in which K=3 or 4, there is a risk of seeing a significant spread of corrosive agents between the K=3 or 4 internal strands which delimit a central capillary which very much encourages them to spread along the cord, when the cord is insufficiently penetrated. This disadvantage can be overcome by rendering the cord capable of being penetrated by the elastomer compound which then prevents the corrosive agents from accessing the central capillary and, in the best of cases in which the central capillary is itself penetrated, prevents these corrosive agents from spreading along the cord.

**[047]** As already explained hereinabove, as the cords according to the invention have an architecture in which K > 1, the most severe transverse loadings applied to the cord when the latter is tensioned are the transverse loadings applied between the internal strands, unlike in a cord in which K=1 and in which the most severe transverse loadings are the transverse loadings applied by the external strands to the internal strands. Cords exhibiting an architecture in which K > 1 and comprising a number of external strands such that the external layer of the cord is saturated so as to maximize the breaking strength by adding a maximum number of external strands are known from the prior art. Here, thanks to the fact that the external layer of the cord is desaturated, the cord has, on the one hand, spaces between the external strands that allow the elastomer compound to pass, therefore allowing the cord to be rendered less sensitive to corrosion. On the other hand, although the number of external strands is reduced, the desaturation of the external layer of the cord allows the elastomer compound to penetrate, on the one hand, between the external strands and, on the other hand, between the internal strands so as to form a cushion of the elastomer compound that at least partially absorbs the transverse loads applied between the internal strands. Thus, by comparison with a similar cord having a saturated external layer of the cord, a better compromise between breaking strength and corrosion resistance is achieved.

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**[048]** In an embodiment that promotes the penetrability of the cord, the external layer of the cord is incompletely unsaturated.

**[049]** By definition, a completely unsaturated layer of strands is, as opposed to an incompletely unsaturated layer, such that there is sufficient space in this layer to add in at least one (X+1)th strand having the same diameter as the X strands of the layer, it thus being possible for a plurality of strands to be, or to not be, in contact with one another. In this particular instance, there is enough space in the external layer of the cord to add in at least one (L+1)th strand having the same diameter as the L external strands of the external layer of the cord.

**[050]** Thus, advantageously, the sum SIE of the inter-strand distances E of the external layer of the cord is such that $SIE \geq DE$. The sum SIE is the sum of the inter-strand distances E separating each pair of adjacent strands in the layer. The inter-strand distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent strands of the layer. Thus, the inter-strand distance E is calculated by dividing the sum SIE by the number of spaces separating the strands in the layer.

**[051]** In another embodiment that promotes the compromise between penetrability and breaking strength, the external layer of the cord is incompletely unsaturated.

**[052]** A layer that is incompletely unsaturated with strands is such that there is not enough space in this layer to add in at least one (X+1)th strand having the same diameter as the X strands of the layer. In this particular instance, there is not enough space in the external layer to add in at least one (L+1)th external strand having the same diameter as the L external strands of the external layer of the cord. Thus, the sum SIE of the inter-strand distances E of the external layer of the cord is such that $SIE < DE$. The sum SIE is the sum of the inter-strand distances E separating each pair of adjacent strands in the layer. The inter-strand distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent strands of the layer. Thus, the inter-strand distance E is calculated by dividing the sum SIE by the number of spaces separating the strands in the layer.

**[053]** By definition, the diameter of an internal strand DI is the diameter of the smallest circle inside which the internal strand can be circumscribed. The diameter of an external strand DE is the diameter of the smallest circle inside which the external strand can be circumscribed.

**[054]** In one preferred embodiment, the internal layer of the cord is wound in a helix with a non-zero pitch pi, and the external layer of the cord is wound in a helix around the internal layer of the cord with a non-zero pitch pe.

**[055]** In one embodiment that is particularly advantageous for the penetrability of the cord, the internal layer of the cord is wound in a helix in a cord internal-layer direction with a pitch pi, and the external layer of the cord is wound in a helix in a cord external-layer direction with a pitch pe, and the cord satisfies one and/or another of the following features:

- the cord internal-layer direction is different from the cord external-layer direction,
- pi is different from pe.

**[056]** In this embodiment, the cord has a cylindrical-layers structure (as opposed to a compact structure), promoting the penetrability of the cord.

**[057]** In another embodiment, the internal layer of the cord is wound in a helix in a cord internal-layer direction with a pitch pi, and the external layer of the cord is wound in a helix in a cord external-layer direction with a pitch pe, and the cord satisfies following features:

- the cord internal-layer direction is identical to the cord external-layer direction,
- pi is equal to pe.

**[058]** In this embodiment, despite the compact structure of the cord, which is difficult to penetrate, the high penetrability of the external strands nevertheless makes it possible to obtain a cord exhibiting satisfactory penetration.

**[059]** Optionally, each internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d1' of each internal thread of each external strand, for preference each internal thread of each internal strand has a diameter d1 equal to the diameter d1' of each internal thread of each external strand. Thus, the same diameter of thread is used in the internal layers of each internal and external strand, thereby limiting the number of different threads that need to be managed during the manufacture of the cord.

**[060]** Optionally, each internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d2' of each intermediate thread of each external strand, for preference each internal thread of each internal strand has a diameter d1 greater than the diameter d2' of each intermediate thread of each external strand.

**[061]** Optionally, each internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d3' of each external thread of each external strand, for preference each internal thread of each internal strand has a diameter d1 greater than the diameter d3' of each external thread of each external strand.

**[062]** Optionally, each external thread of each internal strand has a diameter d3 greater than or equal to the diameter d3' of each external thread of each external strand, for preference each external thread of each internal strand has a diameter d3 greater than the diameter d3' of each external thread of each external strand. For preference, by virtue of the characteristic d3 > d3', each external thread of each internal strand may be able to withstand the radial component of the force exerted by the external strands on each internal strand when the cord is under tension. This characteristic d3 > d3' makes it possible to restore, or even to improve, the breaking force of the cord by comparison with a cord comprising an arch formed by the external strands or by comparison with a cord in which d3 ≤ d3'. For preference, 1 < d3/d3' ≤ 2, more preferably 1 < d3/d3' ≤ 1.5 and more preferably still 1 < d3/d3' ≤ 1.25 or 1.25 < d3/d3' ≤ 1.5.

**[063]** In one advantageous embodiment, the external layer of the cord is wound around the internal layer of the cord in a cord external-layer direction of winding, and each external layer of each internal and external strand is wound respectively around the internal and intermediate layer of each internal and external strand respectively in a same direction of winding that is the opposite to the direction of winding of the cord. In this embodiment, the direction of winding of the cord that is the opposite to the directions of winding of each external layer of each internal and external strand gives the cord better penetrability, notably between the external strands. The inventors postulate the hypothesis that, by virtue of these directions of winding, the external threads of the external strands cross the external threads of each internal strand to form a relatively point-like contact zone unlike cords in which the direction of winding of the cord is identical to the directions of winding of the external layers of each internal and external strand and in which the external threads of the external strands cross the external threads of the internal strand to form a less point-like and more linear contact zone, preventing the elastomer compound from passing as far as the internal strand.

**[064]** <u>External strands of the cord according to the invention</u>

**[065]** Advantageously, the sum SI2' of the inter-thread distances of the intermediate layer of each external strand is such that SI2' < d3' where d3' is the diameter of each external thread of each external strand, preferably SI2' ≤ 0.8 x d3'. The sum SI2' is the sum of the inter-thread distances separating each pair of adjacent threads in the layer. The inter-thread distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent threads of the layer. Thus, the inter-thread distance is calculated by dividing the sum SI2' by the number of spaces separating the threads in the layer.

**[066]** Because the diameter d3' of the external threads of the external layer of each external strand is preferably greater than the sum SI2', the external threads are prevented from penetrating the intermediate layer. This then ensures good architectural stability, thereby reducing the risk of alteration to the radial passage windows for elastomer compound and therefore the risk of degrading the good penetrability of each external strand.

**[067]** Advantageously, the intermediate layer of each external strand is desaturated.

**[068]** By definition, a desaturated layer of threads is one such that there is enough space left between the threads to allow an elastomer compound to pass. Thus, a layer that is desaturated means that the threads in this layer do not touch and that there is enough space between two adjacent threads in the layer to allow an elastomer compound to pass through the layer. By contrast, a layer of threads that is saturated is such that there is not enough space between the threads of the layer to allow an elastomer compound to pass, for example because each pair of two threads of the layer touch one another.

**[069]** Advantageously, the inter-thread distance of the intermediate layer of each external strand is greater than or equal to 5 µm. For preference, the inter-thread distance in the intermediate layer of each external strand is greater than or equal to 15 µm, more preferably greater than or equal to 35 µm, more preferably still greater than or equal to 50 µm and highly preferably greater than or equal to 60 µm.

**[070]** The fact that the intermediate layer of each external strand is desaturated advantageously makes it easier for the elastomer compound to pass into and through each external strand, and thus render each external strand less sensitive to corrosion.

**[071]** In an embodiment that promotes the compromise between penetrability of each external strand and breaking strength, the intermediate layer of each external strand is incompletely unsaturated.

**[072]** By definition, a layer that is incompletely unsaturated is such that there is not enough space in this layer to add in at least one (X+1)th thread having the same diameter as the X threads of the layer. In this particular instance, there is not enough space in the intermediate layer to add in at least one (M'+1)th intermediate thread having the same diameter as the M' intermediate threads of the intermediate layer. In other words, what is meant by an incompletely unsaturated intermediate layer of external strands is that the sum SI2' of the inter-thread distances I2' of the intermediate layer is less than the diameter d2' of the intermediate threads of the intermediate layer. Thus, advantageously, the sum SI2' of the inter-thread distances of the intermediate layer of each external strand is such that $SI2' < d2'$.

**[073]** The fact that the intermediate layer of each external strand is incompletely unsaturated makes it possible to ensure the architectural stability of the intermediate layer. This then reduces the risk of an external thread penetrating the intermediate layer, something which would alter the radial passage windows for the elastomer compound and therefore degrade the good penetrability of each external strand.

**[074]** Furthermore, the fact that the intermediate layer of each external strand is incompletely unsaturated makes it possible to ensure that each external strand comprises a relatively high number of intermediate threads and therefore exhibits a relatively high breaking strength.

**[075]** In another embodiment that promotes the penetrability of each external strand, the intermediate layer of each external strand is completely unsaturated.

**[076]** By definition, a completely unsaturated layer of threads is such that there is sufficient room in this layer to add at least one (X+1)th thread having the same diameter as the X threads of the layer thereto, it thus being possible for a plurality of threads to be in contact, or not in contact, with one another. In this particular instance, there is enough space in the intermediate layer of each external strand to add in at least one (M’+1)th intermediate thread having the same diameter as the M’ intermediate threads of the intermediate layer. In other words, what is meant by a completely unsaturated intermediate layer of external strands is that the sum SI2’ of the inter-thread distances I2’ of the intermediate layer is greater than or equal to the diameter d2’ of the intermediate threads of the intermediate layer. Thus, advantageously, the sum SI2’ of the inter-thread distances of the intermediate layer of each external strand is such that $SI2' \geq d2'$.

**[077]** Advantageously, the external layer of each external strand is desaturated, preferably completely unsaturated. In a way similar to the case with the intermediate layer, the fact that the external layer of each external strand is desaturated advantageously makes it easier for the elastomer compound to pass into and through each external strand, and thus render each external strand less sensitive to corrosion.

**[078]** Advantageously, the inter-thread distance of the external layer of each external strand is greater than or equal to 5 µm. For preference, the inter-thread distance of the external layer of each external strand is greater than or equal to 15 µm, more preferably greater than or equal to 35 µm, more preferably still greater than or equal to 50 µm and highly preferably greater than or equal to 60 µm.

**[079]** By definition, a completely unsaturated layer is, as opposed to an incompletely unsaturated layer, such that there is sufficient space in this layer to add in at least one (X+1)th thread having the same diameter as the X threads of the layer, it thus being possible for a plurality of threads to be, or to not be, in contact with one another. In this particular instance, there is enough space in the external layer of each external strand to add in at least one (N'+1)th thread having the same diameter as the N’ external threads of the external layer. In other words, what is meant by a completely unsaturated external layer of external strands is that the sum SI3’ of the inter-thread distances I3’ of the external layer is greater than or equal to the diameter d3’ of the external threads

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of the external layer. Thus, advantageously, the sum SI3' of the inter-thread distances of the external layer of each external strand is such that SI3' ≥ d3'. The sum SI3' is the sum of the inter-thread distances separating each pair of adjacent threads in the external layer. The inter-thread distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent threads of the layer. Thus, the inter-thread distance is calculated by dividing the sum SI3' by the number of spaces separating the threads in the external layer.

**[080]** The fact that the external layer of each external strand is completely unsaturated makes it possible to maximize the penetration of the elastomer compound into each external strand, and thus render each external strand even less sensitive to corrosion.

**[081]** In one advantageous embodiment, each internal thread of each external strand has a diameter d1' greater than or equal to the diameter d3' of each external thread of each external strand, and highly preferably 1 ≤ d1'/d3' ≤ 1.30. The use of diameters such that d1' > d3' makes it possible to promote the penetrability of the elastomer compound through the external layer. When d1' > d3', then very preferably d1'/d3' ≤ 1.30, which makes it possible, on the one hand, to control the architectural stability of the external layer and, on the other hand, render the present invention even more beneficial because of the relatively small amount of desaturation created by the difference between d1' and d3'. The use of diameters such that d1'=d3' makes it possible to limit the number of different threads to be managed in the manufacture of the cord, and also makes it possible to render the present invention even more beneficial because of the lack of desaturation created by the equality between d1' and d3'.

**[082]** In another advantageous embodiment, each internal thread of each external strand has a diameter d1' greater than or equal to the diameter d2' of each intermediate thread of each external strand, and highly preferably 1 ≤ d1'/d2' ≤ 1.30. The use of diameters such that d1' > d2' makes it possible to promote the penetrability of the elastomer compound through the intermediate layer. When d1' > d2', then very preferably d1'/d2' ≤ 1.30, which makes it possible, on the one hand, to control the architectural stability of the intermediate layer and, on the other hand, render the present invention even more beneficial because of the relatively small amount of desaturation created by the difference between d1' and d2'. The use of diameters such that d1'=d2' makes it possible to limit the number of different threads to be managed in the manufacture of the cord, and also makes it possible to render the present invention even more beneficial because of the lack of desaturation created by the equality between d1’ and d2’.

**[083]** In preferred embodiments, Q'=1, M'= 5 or 6 and N'=10, 11 or 12, for preference Q'=1, M'=5 or 6, N'=10 or 11 and more preferably Q'=1, M'=6 and N'=11.

**[084]** More advantageously, Q'=1, M'=5 or 6, N'=10 or 11,

– the internal thread of each external strand has a diameter d1’ greater than or equal to the diameter d2’ of each intermediate thread of the said external strand, and

– the internal thread of each external strand has a diameter d1’ greater than or equal to the diameter d3’ of each external thread of the said external strand.

**[085]** More advantageously still, Q'=1, M'=6, N'= 11,

– the internal thread of each external strand has a diameter d1’ greater than the diameter d2’ of each intermediate thread of the said external strand, and

– the internal thread of each external strand has a diameter d1’ greater than the diameter d3’ of each external thread of the said external strand.

**[086]** Such an external strand exhibits the advantages of architectural stability and of penetrability as set out hereinabove. In particular, the facts that the intermediate and external layers are desaturated, the intermediate layer is incompletely saturated and the external layer is completely unsaturated are obtained by using different diameters of thread.

**[087]** Highly advantageously, with each intermediate thread of each external strand having a diameter d2’ and each external thread of each external strand having a diameter d3’, d2’=d3’. Thus, the same diameter of thread is used in the intermediate and external layers of each external strand, thereby limiting the number of different threads that need to be managed during the manufacture of the cord.

**[088]** Advantageously, each external strand is of the type not rubberized in situ. What is meant by not rubberized in situ is that, prior to the assembly of the external layer of the cord, and prior to the assembly of the cord, each external strand is made up of the threads of the various layers and does not have any polymer compound, notably any elastomer compound.

**[089]** <u>Internal strands of the cord according to the invention</u>

**[090]** Advantageously, the external layer of each internal strand is desaturated, preferably completely unsaturated. The fact that the external layer of each internal strand is desaturated advantageously makes it easier for the elastomer compound to pass as far as the centre of each internal strand, and thus render each internal strand less sensitive to corrosion.

**[091]** Advantageously, the inter-thread distance of the external layer of each internal strand is greater than or equal to 5 µm. For preference, the inter-thread distance of the

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external layer of each internal strand is greater than or equal to 15 μm, more preferably greater than or equal to 35 μm, more preferably still greater than or equal to 50 μm and highly preferably greater than or equal to 60 μm.

**[092]** The external layer of each internal strand is preferably completely unsaturated, that is to say there is enough space in the external layer to add in at least one (N+1)th thread having the same diameter as the N threads of the external layer. In other words, what is meant by a completely unsaturated external layer of internal strands is that the sum SI3 of the inter-thread distances I3 of the external layer is greater than or equal to the diameter d3 of the external threads of the external layer. Thus, advantageously, the sum SI3 of the inter-thread distances of the external layer of each internal strand is such that $SI3 \geq d3$. The sum SI3 is the sum of the inter-thread distances separating each pair of adjacent threads in the external layer. The inter-thread distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent threads of the layer. Thus, the inter-thread distance is calculated by dividing the sum SI3 by the number of spaces separating the threads in the external layer.

**[093]** The fact that the external layer of each internal strand is completely unsaturated makes it easier for the elastomer compound to penetrate each internal strand, and thus render each internal strand even less sensitive to corrosion.

**[094]** In some preferred embodiments, each internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d3 of each external thread of each internal strand, and highly preferably $1 \leq d1/d3 \leq 1.30$. The use of diameters such that $d1 > d3$ makes it possible to promote the penetrability of the elastomer compound through the external layer. When $d1 > d3$, then very preferably $d1/d3 \leq 1.30$, which makes it possible, on the one hand, to control the architectural stability of the external layer and, on the other hand, render good penetrability of each internal strand even more beneficial because of the relatively small amount of desaturation created by the difference between d1 and d3. The use of diameters such that $d1=d3$ makes it possible to limit the number of different threads to be managed in the manufacture of the cord, and also makes it possible to render the present invention even more beneficial because of the lack of desaturation created by the equality between d1 and d3.

**[095]** <u>Two-layer internal strands</u>

**[096]** In one embodiment which favours the compromise between the diameter of the cord and the breaking strength, each internal strand has two layers. In this embodiment, the external layer of each internal strand is wound around the internal layer of each internal strand in contact with the internal layer of each internal strand. In this embodiment, each internal strand comprises a collection of threads which is made up of two layers of threads, neither more nor less, which means to say that the collection of threads has two layers of threads, not one, not three, but only two.

**[097]** In preferred embodiments, Q=1, 2, 3 or 4.

**[098]** In embodiments which make it possible to reduce the diameter of the cord, Q=1, N=5 or 6, and preferably, Q=1 and N=6.

**[099]** In preferred embodiments that make it possible to increase the breaking strength of the cord with respect to the embodiment in which Q=1, Q=2, 3 or 4, preferably Q=3 or 4. Unlike in the embodiment in which Q=1 and in which there is a risk of seeing the internal thread of the internal strand pop radially out of the internal strand and even out of the cord, under the effect of the repeated compressive loadings applied to the cord, the presence of several threads in the internal layer of each internal strand (Q > 1) makes it possible to reduce this risk as the compressive forces are then distributed over the plurality of threads of the internal layer.

**[0100]** In these preferred embodiments in which Q > 1, notably those in which Q=3 or 4, there is a risk, when the cord is insufficiently penetrated, of seeing a significant spread of corrosive agents between the Q=3 or 4 internal threads which delimit a central capillary which very much encourages them to spread along each strand. This disadvantage can be overcome by rendering the strand capable of being penetrated by the elastomer compound which then prevents the corrosive agents from accessing the central capillary and, in the best of cases in which the central capillary is itself penetrated, prevents these corrosive agents from spreading along the strand.

**[0101]** In preferred embodiments in which Q > 1, N=7, 8, 9 or 10, for preference N=8, 9 or 10 and more preferably N=8 or 9.

**[0102]** In these embodiments in which Q > 1, advantageously each internal strand has cylindrical layers, that is to say is a strand in which the Q internal threads are wound with a pitch p1 and in an internal layer direction of each internal strand and the N external threads are wound around the intermediate layer with a pitch p3 and in an external layer direction of each internal strand, p1 being different from p3 and/or the internal layer direction of the internal strand being different from the internal strand external layer direction.

**[0103]** In a first alternative form, Q=2 and N=7 or 8, for preference Q=2, N=7.

**[0104]** In a second alternative form, Q=3 and N=7, 8 or 9, for preference Q=3, N=8.

**[0105]** In a third alternative form, Q=4 and N=7, 8, 9 or 10, for preference Q=4, N=9.

**[0106]** Advantageously, the internal layer of the cord is wound in a cord internal-layer direction, and each internal layer (when Q > 1), intermediate layer and external layer of each internal strand is wound in the same direction of winding as the cord internal-layer direction.

**[0107]** Advantageously, the external layer of the cord is wound in a cord external-layer direction, and each intermediate layer and external layer of each external strand is wound in the same direction of winding as the cord external layer direction.

**[0108]** In one embodiment, the internal-layer direction of the cord and the external-layer direction of the cord are the same. In this embodiment, manufacture is relatively easy because, unlike in the previous embodiment, there is no need to differentiate between the directions of winding of the internal and external layers of the cord. Nevertheless, contact between the external threads of the external layers of the internal and external strands are relatively long and this may, with certain combinations of pitch, diameter and architecture of the cords, give rise to assembly defects caused, for example, by undesired slippage of the external strands in the grooves formed between the internal strands.

**[0109]** In another embodiment, the internal-layer direction of the cord and the external-layer direction of the cord are opposite directions. In this embodiment, the risk of potential undesired slippage of the external strands in the grooves formed between the internal strands as a result of a crossing between the internal and external strands is reduced

**[0110]** <u>Three-layer internal strands</u>

**[0111]** In another particularly advantageous embodiment that improves the breaking strength of the cord, each internal strand has three layers and comprises:

- an intermediate layer made up of M intermediate threads wound around the internal layer, and
- an external layer made up of N external threads wound around the intermediate layer.

**[0112]** In this embodiment, the external layer of each internal strand is wound around the intermediate layer of each internal strand in contact with the intermediate layer of each internal strand and the intermediate layer of each internal strand is wound around the internal layer of each internal strand in contact with the internal layer of each internal strand. In this embodiment, each internal strand comprises a collection of threads which is made up of three layers of threads, neither more nor less, which means to say that the collection of threads has three layers of threads, not two, not four, but only three.

**[0113]** Advantageously, the sum SI2 of the inter-thread distances of the intermediate layer is such that $SI2 < d3$ where d3 is the diameter of each external thread of each internal strand, preferably $SI2 \leq 0.8 \times d3$. In a similar way to the external strand, because the diameter d3 of the external threads of the external layer of each internal strand is preferably greater than the sum SI2, the external threads are prevented from penetrating the intermediate layer. This then ensures good architectural stability, thereby reducing the risk of alteration to the radial passage windows for elastomer compound and therefore the risk of degrading the good penetrability of each internal strand. The sum SI2 is the sum of the inter-thread distances separating each pair of adjacent threads in the intermediate layer. The inter-thread distance of a layer is defined, in a section of the cord perpendicular to the main axis of the cord, as being the shortest distance, which, on average, separates two adjacent threads of the layer. Thus, the inter-thread distance is calculated by dividing the sum SI2 by the number of spaces separating the threads in the intermediate layer.

**[0114]** Advantageously, the intermediate layer of each internal strand is desaturated.

**[0115]** For preference, the inter-thread distance of the intermediate layer of each internal strand is greater than or equal to 5 µm. For preference, the inter-thread distance in the intermediate layer of each internal strand is greater than or equal to 15 µm, more preferably greater than or equal to 35 µm, more preferably still greater than or equal to 50 µm and highly preferably greater than or equal to 60 µm.

**[0116]** The fact that the intermediate layer of each internal strand is desaturated advantageously makes it easier for the elastomer compound to pass as far as the centre of each internal strand, and thus render each internal strand less sensitive to corrosion.

**[0117]** In an embodiment that promotes the compromise between penetrability of each internal strand and breaking strength, the intermediate layer of the each internal strand is incompletely unsaturated.

**[0118]** In this embodiment, the intermediate layer of each internal strand is preferably incompletely unsaturated, that is to say there is not enough space in the intermediate layer to add in at least one (M+1)th thread having the same diameter as the M threads of the intermediate layer. In other words, what is meant by an incompletely unsaturated intermediate layer each internal strand is that the sum SI2 of the inter-thread distances I2 of the intermediate layer is less than the diameter d2 of the intermediate threads of the intermediate layer. In other words, what is meant by an incompletely unsaturated intermediate layer of internal strands is that the sum SI2 of the inter-thread distances I2 of the intermediate layer is less than the diameter d2 of the intermediate threads of the intermediate layer. Thus, advantageously, the sum SI2 of the inter-thread distances of the intermediate layer of the internal strand is such that $SI2 < d2$.

**[0119]** The fact that the intermediate layer of each internal strand is incompletely unsaturated makes it possible to ensure the architectural stability of the intermediate layer. Furthermore, the fact that the intermediate layer of each internal strand is incompletely unsaturated makes it possible to ensure that each internal strand comprises a relatively high number of intermediate threads and therefore exhibits a relatively high breaking strength.

**[0120]** In another embodiment that promotes the penetrability of each internal strand, the intermediate layer of each internal strand is incompletely unsaturated.

**[0121]** By definition, a completely unsaturated layer of threads is such that there is sufficient room in this layer to add at least one (X+1)th thread having the same diameter as the X threads of the layer thereto, it thus being possible for a plurality of threads to be in contact, or not in contact, with one another. In this particular instance, there is enough space in the intermediate layer of each internal strand to add in at least one (M+1)th intermediate thread having the same diameter as the M intermediate threads of the intermediate layer. In other words, what is meant by a completely unsaturated intermediate layer of internal strands is that the sum SI2 of the inter-thread distances I2 of the intermediate layer is greater than or equal to the diameter d2 of the intermediate threads of the intermediate layer. Thus, advantageously, the sum SI2 of the inter-thread distances of the intermediate layer of the internal strand is such that $SI2 \geq d2$.

**[0122]** In some preferred embodiments, each internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d2 of each intermediate thread of each internal strand, and highly preferably $1 \leq d1/d2 \leq 1.30$. The use of diameters such that $d1 > d2$ makes it possible to promote the penetrability of the elastomer compound through the intermediate layer. When $d1 > d2$, then very preferably $d1/d2 \leq 1.30$, which makes it possible, on the one hand, to control the architectural stability of the intermediate layer and, on the other hand, render good penetrability of each internal strand even more beneficial because of the relatively small amount of desaturation created by the difference between d1 and d2. The use of diameters such that $d1=d2$ makes it possible to limit the number of different threads to be managed in the manufacture of the cord, and also makes it possible to render the present invention even more beneficial because of the lack of desaturation created by the equality between d1 and d2.

**[0123]** Highly advantageously, with each intermediate thread of each internal strand having a diameter d2 and each external thread of each internal strand having a diameter d3, $d2=d3$. Thus, the same diameter of thread is used in the intermediate and external layers of each internal strand, thereby limiting the number of different threads that need to be managed during the manufacture of the cord.

**[0124]** In preferred alternative forms of this embodiment,Q=1, 2, 3 or 4, for preference Q=1, 2 or 3 and more preferably Q=1 or 3.

**[0125]** In one preferred embodiment, Q=1. In the embodiment in which Q=1, and when the cord, unlike that of the invention, is insufficiently penetrated, there is a risk of seeing the internal thread of each internal strand radially leave each internal strand and even the cord, under the effect of the repeated compressive loadings applied to the cord. By virtue of the invention, because of the excellent penetration of each internal strand and despite the fact that Q=1, the elastomer compound acts like a wrapping layer around the internal strand, notably around the external and intermediate layers of the internal strand, preventing the internal thread from coming out, even under the repeated compressive loadings.

**[0126]** In these embodiments in which Q=1, each internal strand advantageously has cylindrical layers, that is to say is a strand in which the M intermediate threads are wound around the internal layer with a pitch p2 and in an internal strand intermediate layer direction and the N external threads are wound around the intermediate layer with a pitch p3 and in an internal strand external layer direction, p2 being different from p3 and/or the internal strand intermediate layer direction being different from the internal strand external layer direction.

**[0127]** In the embodiment in which Q=1, the M intermediate threads are wound around the internal layer with a pitch p2 and the N external threads are wound around the intermediate layer with a pitch p3, the pitches p2 and p3 then advantageously satisfying: $0.36 \leq (p3-p2)/p3 \leq 0.57$. Such a ratio (p3-p2)/p3 makes it possible to obtain relatively large radial passage windows for the elastomer compound within each internal strand.

**[0128]** Advantageously, the pitches p2 and p3 satisfy the relationship $0.38 \leq (p3-p2)/p3$; for preference $0.40 \leq (p3-p2)/p3$; more preferably $0.43 \leq (p3-p2)/p3$; and more preferably still $0.45 \leq (p3-p2)/p3$. In a similar way to the external strand, the higher the ratio (p3-p2)/p3 or, in other words, the greater the difference between p3 and p2, the better the architectural stability of each internal strand.

**[0129]** Advantageously, the pitches p2 and p3 satisfy the relationship $(p3-p2)/p3 \leq 0.55$ and for preference $(p3-p2)/p3 \leq 0.53$. Below these values, the size of the radial passage windows for the elastomer compound is at a maximum and makes it possible to optimize the penetrability each internal strand.

**[0130]** Advantageously, the pitch p2 is such that 8 mm ≤ p2 ≤ 16 mm, for preference 8 mm ≤ p2 ≤ 14 mm and more preferably 8 mm ≤ p2 ≤ 12 mm.

**[0131]** Advantageously, the pitch p3 is such that 10 mm ≤ p3 ≤ 40 mm, for preference 15 mm ≤ p3 ≤ 35 mm, more preferably 15 mm ≤ p3 ≤ 25 mm and more preferably still 17 mm ≤ p3 ≤ 23 mm.

**[0132]** Pitches p2 and p3 within these preferred ranges make it possible to obtain a

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cord that exhibits mechanical properties compatible with tyre use, a relatively low cost and a relatively low linear cord weight.

**[0133]** In one preferred embodiment, Q=1, M= 5 or 6 and N=10, 11 or 12, for preference Q=1, M=5 or 6, N=10 or 11 and more preferably Q=1, M=6 and N=11.

**[0134]** More advantageously

- Q=1, M=5 or 6, N=10 or 11,
- the internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d2 of each intermediate thread of each internal strand, and
- the internal thread of each internal strand has a diameter d1 greater than or equal to the diameter d3 of each external thread of each internal strand.

**[0135]** More advantageously still,

- Q=1, M=6, N=11,
- the internal thread of each internal strand has a diameter d1 greater than the diameter d2 of each intermediate thread of each internal strand, and
- the internal thread of each internal strand has a diameter d1 greater than the diameter d3 of each external thread of each internal strand.

**[0136]** Such an internal strand exhibits the advantages of architectural stability and of penetrability as set out hereinabove. In particular, the facts that the intermediate and external layers are desaturated, the intermediate layer is incompletely saturated and the external layer is completely unsaturated are obtained by using different diameters of thread.

**[0137]** In preferred embodiments that make it possible to increase the breaking strength of the cord with respect to the embodiment in which Q=1, Q=2, 3 or 4, preferably Q=3 or 4.

**[0138]** In these embodiments in which Q > 1, each internal strand advantageously has cylindrical layers, that is to say is a strand in which the Q internal threads are wound with a pitch p1 and in an internal strand internal layer direction and the M intermediate threads are wound around the internal layer with a pitch p2 and in an internal strand intermediate layer direction, the N external threads are wound around the intermediate layer with a pitch p3 and in an internal strand external layer direction, p1, p2 and p3 each being different one from another and/or the directions of the adjacent layers of the internal strand being different.

**[0139]** In another preferred embodiment, Q=3, M= 8 or 9 and N=13, 14 or 15, for preference Q=3, M=8 or 9, N=14 or 15, more preferably Q=3, M=9, N=14 or 15 and more preferably still Q=3, M=9 and N=15. In the embodiment in which Q=3, and when the cord, unlike that of the invention, is insufficiently penetrated, there is a risk of seeing a significant spread of corrosive agents between the Q=3 internal threads which delimit a central capillary which very much encourages them to spread along the cord. By virtue of the invention and in the embodiment in which Q=3 with the cord being excellently very well penetrated, the elastomer compound prevents the corrosive agents from accessing the central capillary and, in the best of cases in which the central capillary is itself penetrated, prevents these corrosive agents from spreading along the cord.

**[0140]** More advantageously

- Q=3, M=8 or 9, N=14 or 15,
- the internal threads of each internal strand have a diameter d1 greater than or equal to the diameter d2 of each intermediate thread of each internal strand, and
- the internal threads of each internal strand have a diameter d1 greater than or equal to the diameter d3 of each external thread of each internal strand.

**[0141]** More advantageously still,

- Q=3, M=9, N=14 or 15,
- the internal threads of each internal strand have a diameter d1 greater than the diameter d2 of each intermediate thread of each internal strand, and
- the internal threads of each internal strand have a diameter d1 greater than the diameter d3 of each external thread of each internal strand.

**[0142]** Such an internal strand exhibits the advantages of architectural stability and of penetrability as set out hereinabove. In particular, the facts that the intermediate and external layers are desaturated, the intermediate layer is incompletely saturated and the external layer is completely unsaturated are obtained by using different diameters of thread.

**[0143]** In another advantageous embodiment, each intermediate thread of each internal strand has a diameter d2 greater than or equal to the diameter d2’ of each intermediate thread of each external strand, for preference each intermediate thread of each internal strand has a diameter d2 greater than the diameter d2’ of each intermediate thread of each external strand.

**[0144]** In one embodiment, each internal strand is of the type rubberized in situ. Such a strand comprises, prior to assembly of the cord, a layer of a polymer compound, notably an elastomer compound, arranged between at least two radially adjacent layers of threads, possibly between each of the radially adjacent layers of threads. Such a strand that is rubberized in situ is notably described in WO2010054790.

**[0145]** In another embodiment, each internal strand is of the type not rubberized in situ. What is meant by not rubberized in situ is that, prior to the assembly of the cord, each internal strand is made up of the threads of the various layers and does not have any polymer compound, notably any elastomer compound.

**[0146] TYRE ACCORDING TO THE INVENTION**

**[0147]** Another subject of the invention is a tyre comprising a cord as defined above.

**[0148]** The cord is most particularly intended for industrial vehicles selected from heavy vehicles such as “heavy-duty vehicles” – i.e. underground trains, buses, road haulage vehicles (lorries, tractors, trailers), off-road vehicles, agricultural vehicles or construction plant vehicles, or other transport or handling vehicles.

**[0149]** As a preference, the tyre is for a vehicle of the construction plant type. The layer has a size of the W R U type in which, as is known to those skilled in the art, W denotes:
- the nominal aspect ratio H/B as defined by the ETRTO, when in the form H/B, H being the cross-sectional height of the tyre and B being the cross-sectional width of the tyre,
- H.00 or B.00 when it is in the form H.00 or B.00, in which H=B, H and B being as defined above,

U represents the diameter, in inches, of the rim seat on which the tyre is intended to be mounted, and R denotes the type of carcass reinforcement of the tyre, in this case radial.

Examples of such dimensions are, for example, 40.00 R 57 or else 59/80 R 63.

**[0150]** Preferably, U ≥ 35, more preferably U ≥ 49 and even more preferably, U ≥ 57.

**[0151]** In one embodiment, the tyre has a carcass reinforcement anchored in two beads and surmounted radially by a crown reinforcement which is itself surmounted by a tread, the crown reinforcement being joined to the said beads by two sidewalls, the carcass reinforcement comprising at least one cord as defined above.

**[0152]** In another embodiment, the tyre has a carcass reinforcement anchored in two beads and surmounted radially by a crown reinforcement which is itself surmounted by a tread, the crown reinforcement being joined to the said beads by two sidewalls, and comprising at least one cord as defined above.

**[0153]** Advantageously, the carcass reinforcement comprises at least one carcass ply comprising filamentary metal carcass reinforcing elements, each filamentary metal carcass reinforcing element making an angle of between 80° and 90° with the circumferential direction of the tyre.

**[0154]** Advantageously, the crown reinforcement comprises a working reinforcement comprising at least one cord as defined hereinabove.

**[0155]** Advantageously, the working reinforcement comprises at least one working ply comprising filamentary metal working reinforcing elements arranged substantially parallel to one another, each filamentary metal working reinforcing element making an angle at most equal to 60°, preferably ranging from 15° to 40° with the circumferential direction of the tyre and being formed of a cord as defined hereinabove.

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**[0156]** In one advantageous embodiment, the working reinforcement comprises at least a first and a second working ply, each first and second working ply respectively comprising first and second filamentary metal working reinforcing elements arranged substantially parallel to one another in each first and second working ply, each first and second filamentary metal working reinforcing element making an angle at most equal to 60°, preferably ranging from 15° to 40° with the circumferential direction of the tyre and being formed of a cord as defined hereinabove.

**[0157]** Advantageously, the crown reinforcement comprises a protective reinforcement comprising at least one protective ply comprising filamentary metal protective reinforcing elements arranged substantially parallel to one another, each filamentary metal protective reinforcing element making an angle at most equal to 10°, preferably ranging from 10° to 35° and preferentially from 15° to 30° with the circumferential direction of the tyre.

**[0158]** In one advantageous embodiment, the protective reinforcement comprises a first and a second protective ply, each first and second protective ply respectively comprising first and second filamentary metal protective reinforcing elements arranged substantially parallel to one another in each first and second protective ply, each first and second filamentary metal protective reinforcing element making an angle at least equal to 10°, preferably ranging from 10° to 35° and preferentially from 15° to 30° with the circumferential direction of the tyre.

**[0159]** In a preferred embodiment, the protective reinforcement is interposed radially between the tread and the working reinforcement.

**[0160]** Advantageously, the crown reinforcement comprises an additional reinforcement comprising at least one additional ply comprising additional filamentary metal reinforcing elements arranged substantially parallel to one another in the additional ply, each additional filamentary metal reinforcing element making an angle at most equal to 10°, preferably ranging from 5° to 10° with the circumferential direction of the tyre.

**[0161]** In one advantageous embodiment, the additional reinforcement comprises a first and a second additional ply, each first and second additional ply respectively comprising first and second additional filamentary metal reinforcing elements arranged substantially parallel to one another in each first and second additional ply, each first and second additional filamentary metal reinforcing element making an angle at most equal to 10°, preferably ranging  from 5° to 10° with the circumferential direction of the tyre.

**Brief Description of the Drawings**

**[0162]** The invention will be understood better from reading the following description, which is given solely by way of non-limiting example and with reference to the drawings, in which:

– Figure 1 is a view in cross section perpendicular to the circumferential direction of a tyre according to the invention;

– Figure 2 is a detail view of the region II of Figure 1;

– Figure 3 is a schematic view in section perpendicular to the axis of the cord (which is assumed to be straight and at rest) of a [3x(0.38+(6+11)x0.35)+9x(0.38+(6+11)x0.30)]+0.28 cord according to a first embodiment of the invention;

– Figure 4 is a schematic view in section perpendicular to the axis of the cord (which is assumed to be straight and at rest) of a [2x(0.38+(6+11)x0.35)+8x(0.38+(6+11)x0.30)]+0.28 cord according to a second embodiment of the invention;

– Figure 5 is a schematic view in section perpendicular to the axis of the cord (which is assumed to be straight and at rest) of a [4x(0.38+(6+11)x0.35)+10x(0.38+(6+11)x0.30)]+0.28 cord according to a third embodiment of the invention;

– Figure 6 is a view, similar to that of Figure 3, of a [3x(0.38+(6+12)x0.35)+9x(0.38+(6+12)x0.30)]+0.28 cord according to a fourth embodiment of the invention;

– Figure 7 is a view, similar to that of Figure 3, of a [3x(0.38+(6+11)x0.35)+9x(0.30+(5x0.30+11x0.26)]+0.28 cord according to a fifth embodiment of the invention;

– Figure 8 is a view, similar to that of Figure 3, of a [3x(1+6+12)x0.40+9x(0.32+(6+11)x0.26)]+0.28 cord according to a sixth embodiment of the invention;

– Figure 9 is a view, similar to that of Figure 3, of a [3x(3+9+15)x0.38+9x(0.45+(6+11)x0.38)]+0.28 cord according to a seventh embodiment of the invention;

– Figure 10 is a view, similar to that of Figure 3, of a [3x(0.38+(6+11)x0.35)+9x(0.38+(6+11)x0.30)]+0.28 cord according to an eighth embodiment of the invention;

– Figure 11 is a view, similar to that of Figure 3, of a [3x(0.60+6x0.50+11x0.45)+9x(0.45+(6+11)x0.38)]+0.28 cord according to a ninth embodiment of the invention;

– Figure 12 is a view, similar to that of Figure 3, of a [3x((2+7)x0.45) +9x(0.38+(6+11)x0.30)]+0.28 cord according to a tenth embodiment of the invention;

– Figure 13 is a view, similar to that of Figure 3, of a [3x((3+8)x0.42) +9x(0.38+(6+11)x0.30)]+0.28 cord according to an eleventh embodiment of the invention;

– Figure 14 is a view, similar to that of Figure 3, of a [3x((4+9)x0.40) +9x(0.38+(6+11)x0.30)]+0.28 cord according to a twelfth embodiment of the invention;

– Figure 15 is a schematic view in projection onto a plane containing the axis of an external strand prior to assembly of the cord according to the first embodiment of the invention; and

– Figure 16 is a detailed view of the region XV depicting a radial passage window delimited by threads of an intermediate layer and threads of an external layer of the external strand of Figure 15.

**[0163]** Any range of values denoted by the expression “between a and b” represents the range of values extending from more than a to less than b (namely excluding the end-points a and b), whereas any range of values denoted by the expression “from a to b” means the range of values extending from the end-point “a” as far as the end-point “b”, namely including the strict end-points “a” and “b”.

**Detailed Description of Specific Embodiments**

**[0164] EXAMPLE OF A TYRE ACCORDING TO THE INVENTION**

**[0165]** A frame of reference X, Y, Z corresponding to the usual respectively axial (X), radial (Y) and circumferential (Z) orientations of a tyre has been depicted in the figures.

**[0166]** The “median circumferential plane” M of the tyre is the plane which is normal to the axis of rotation of the tyre and which is situated equidistant from the annular reinforcing structures of each bead, and passes through the middle of the crown reinforcement.

**[0167]** Figures 1 and 2 depict a tyre according to the invention and denoted by the general reference 10.

**[0168]** The tyre 10 is for a heavy vehicle of construction plant type, for example of “dumper” type. Thus, the tyre 10 has a dimension of the type 53/80R63.

**[0169]** The tyre 10 has a crown 12 reinforced by a crown reinforcement 14, two sidewalls 16 and two beads 18, each of these beads 18 being reinforced with an annular structure, in this instance a bead thread 20. The crown reinforcement 14 is surmounted radially by a tread 22 and connected to the beads 18 by the sidewalls 16. A carcass reinforcement 24 is anchored in the two beads 18 and in this instance wound around the two bead threads 20 and comprises a turnup 26 positioned towards the outside of the tyre 20, which is shown here fitted onto a wheel rim 28. The carcass reinforcement 24 is surmounted radially by the crown reinforcement 14.

**[0170]** The carcass reinforcement 24 comprises at least one carcass ply 30 comprising filamentary metal carcass reinforcing elements 31 and extending from one bead 18 to the other so as to form an angle of between 80° and 90° with the circumferential direction Z of the tyre 10.

**[0171]** The tyre 10 also comprises a sealing ply 32 made up of an elastomer (commonly known as “inner liner”) which defines the radially internal face 34 of the tyre 10 and which is intended to protect the carcass ply 30 from the diffusion of air coming from the space inside the tyre 10.

**[0172]** The crown reinforcement 14 comprises, radially from the outside towards the inside of the tyre 10, a protective reinforcement 36 arranged radially on the inside of the tread 22, a working reinforcement 38 arranged radially on the inside of the protective reinforcement 36 and an additional reinforcement 80 arranged radially on the inside of the working reinforcement 38. The protective reinforcement 36 is thus interposed radially between the tread 22 and the working reinforcement 38. The working reinforcement 38 is interposed radially between the protective reinforcement 36 and the additional reinforcement 80.

**[0173]** The protective reinforcement 36 comprises first and second protective plies 42, 44, the first ply 42 being arranged radially on the inside of the second ply 44. Each first and second protective ply 42, 44 respectively comprises first and second filamentary metal protective reinforcing elements 43, 45 arranged substantially parallel to one another in each first and second protective ply 42, 44. Each first and second filamentary metal protective reinforcing element 43, 45 makes an angle at least equal to 10°, preferably in the range from 10° to 35° and more preferably from 15° to 30°, with the circumferential direction Z of the tyre.

**[0174]** The working reinforcement 38 comprises first and second working plies 46, 48, the first ply 46 being arranged radially on the inside of the second ply 48. Each first and second working ply 46, 48 respectively comprises first and second filamentary metal working reinforcing elements 47, 49 arranged substantially parallel to one another in each first and second working ply 46, 48. Each first and second filamentary metal working reinforcing element 47, 49 makes an angle at most equal to 60°, preferably in the range from 15° to 40°, with the circumferential direction Z of the tyre 10. Optionally, the first and second filamentary metal working reinforcing elements 47, 49 are crossed from one working ply to the other.

**[0175]** The additional reinforcement 80, also referred to as the limiting block, the function of which is to at least partially react the mechanical stresses of inflation, comprises first and second additional plies 82, 84, each first and second additional ply 82, 84 respectively comprising first and second additional filamentary metal reinforcing elements 83, 85 arranged substantially parallel to one another in each first and second additional ply 82, 84. Each first and second additional filamentary metal reinforcing element 83, 85 makes an angle at most equal to 10°, preferably in the range from 5° to 10°, with the circumferential direction Z of the tyre 10. The additional filamentary metal reinforcing elements are, for example, as described in FR 2 419 181 or FR 2 419 182.

**[0176]** In one embodiment, each first and second filamentary metal reinforcing element 47, 49 is formed by a cord according to the invention, for example the cord 50 described hereinbelow.

**[0177]** In another embodiment, each filamentary metal carcass reinforcing element 31 is formed by a cord according to the invention, for example the cord 50 described hereinbelow.

**[0178]** In yet another embodiment, each first and second filamentary metal working reinforcing element 47, 49 and each filamentary metal carcass reinforcing element 31 is formed by a cord according to the invention, it being possible for these cords to be identical or different according to whether they are filamentary metal reinforcing elements 31, 47 or 49.

**[0179] CORD ACCORDING TO A FIRST EMBODIMENT OF THE INVENTION**

**[0180]** Figure 3 depicts the cord 50 according to a first embodiment of the invention.

**[0181]** The cord 50 is metal and of the multi-strand type with two cylindrical layers. Thus, it will be understood that there are two layers, not more, not less, of strands of which the cord 50 is made. The layers of strands are adjacent and concentric. The cord 50 is devoid of polymer compound and of elastomer compound when it is not integrated into the tyre.

**[0182]** The cord 50 comprises an internal layer CI of the cord 50, and an external layer CE of the cord 50. The internal layer CI is made up of K > 1 internal strands TI wound in a helix. In this instance, K=2, 3 or 4, and preferably K=3 or 4 and here K=3. The external layer CE is made up of L > 1 external strands TE wound around the internal layer CI of the cord. In this particular instance, L=7, 8, 9 or 10; for preference L=8, 9 or 10, and more preferably, L=8 or 9 and here L=9.

**[0183]** The cord 50 also comprises a wrapper F made up of a single wrapping thread.

**[0184]** The internal layer CI is wound in a helix in a cord internal-layer direction, in this instance Z, with a pitch pi, and here pi=80 mm, and the external layer CE is wound in a helix in a cord external-layer direction, in this instance Z, with a pitch pe, and here pi=100 mm. Because pi is different from pe, the cord has layers which are cylindrical.

**[0185]** The wrapper F is wound around the external layer CE in a direction of winding of the wrapper, in this instance opposite to the direction of winding of the external layer CE, in this instance in the S-direction. The wrapping thread is wound in a helix around the external strands TE with a pitch pf such that 2 mm ≤ pf ≤ 10 mm and, preferably, 3 mm ≤ pf ≤ 8 mm. Here, pf=5.1 mm.

**[0186]** The assembly made up of the internal CI and external CE layers, which means to say the cord 50 without the wrapper F, has a diameter D=7.0 mm.

**[0187]** The external layer CE of the cord 50 is desaturated. The mean inter-strand distance E separating two adjacent external strands TE is greater than or equal to 30 µm. As a preference, the mean inter-strand distance E separating two adjacent external strands TE is greater than or equal to 70 µm, more preferably, than/to 100 µm, more preferably still, than/to 150 µm, highly preferably, than/to 200 µm. In this embodiment, the inter-strand distance of the external layer of external strands is greater than or equal to 200 µm. Here, E=255 µm.

**[0188]** Each internal strand TI has a diameter DI and each external strand TE has a diameter DE. In this particular instance, DI=1.78 mm, and DE=1.58 mm.

**[0189]** The external layer CE of the cord 50 is desaturated. Specifically, SIE=9 x 0.255=2.3 mm, which is a value higher than DE=1.58 mm.

**[0190]** <u>Internal strands TI of the cord 50</u>

**[0191]** Each internal strand TI has at least two layers. In this instance, each internal strand TI has three layers. Each internal strand TI comprises, in this instance is made up of, three layers, not more, not less.

**[0192]** Each internal strand TI comprises an internal layer C1 made up of Q internal thread(s) F1, an intermediate layer C2 made up of M intermediate threads F2 wound in a helix around the internal layer C1, and an external layer C3 made up of N external threads F3 wound in a helix around the internal layer C1 and around and in contact with the intermediate layer C2.

**[0193]** Q=1, 2, 3 or 4, for preference Q=1, 2 or 3 and more preferably here Q=1.

**[0194]** Where Q=1, M= 5 or 6 and N=10, 11 or 12, for preference Q=1, M=5 or 6 and N=10 or 11 and here Q=1, M=6 and N=11.

**[0195]** The internal thread F1 has an infinite pitch.

**[0196]** The intermediate layer C2 of each internal strand TI is wound around the internal layer C1 of each internal strand TI in a direction of winding Z. The M intermediate threads F2 are wound in a helix around the internal thread F1 with a pitch p2 such that 8 mm ≤ p2 ≤ 16 mm and, for preference, 8 mm ≤ p2 ≤ 14 mm. Here, p2=14 mm.

**[0197]** The external layer C3 of each internal strand TI is wound around the internal C1 and intermediate C2 layers of each internal strand TI in a direction of winding Z. The N external threads F3 are wound in a helix around the M intermediate threads F2 with a pitch p3 such that 10 mm ≤ p3 ≤ 40 mm, for preference 15 mm ≤ p3 ≤ 35 mm, more preferably 15 mm ≤ p3 ≤ 25 mm and more preferably still, 17 mm ≤ p3 ≤ 23 mm. Here p3=20 mm.

**[0198]** Because p1 is different from p2 and p2 is different from p3, each internal strand TI is cylindrically-layered.

**[0199]** The intermediate layer C2 of each internal strand TI is desaturated and incompletely unsaturated. The inter-thread distance I2 of the intermediate layer C2 which on average separates the M intermediate threads is greater than or equal to 5 μm. The inter-thread distance I2 is preferably greater than or equal to 10 μm and is here equal to 11.6 μm. Because the intermediate layer C2 is incompletely unsaturated, the sum SI2 of the inter-thread distances I2 of the intermediate layer C2 is less than the diameter d2 of the intermediate threads F2 of the intermediate layer C2. Here, the sum SI2=6 x 0.0116 = 0.07 mm, which is a value strictly less than d2 = 0.35 mm.

**[0200]** The sum SI2 of the inter-thread distances I2 of the intermediate layer C2 is less than the diameter d3 of the external threads F3 of the external layer C3 and preferably less than or equal to 0.8 x d3. Here, the sum SI2=6 x 0.0116 = 0.07 mm, which is a value strictly less than d3 = 0.35 mm.

**[0201]** The external layer C3 of each internal strand TI is desaturated and completely unsaturated. The inter-thread distance I3 of the external layer C3 which on average separates the N external threads is greater than or equal to 5 μm. The inter-thread distance I3 is preferably greater than or equal to 15 μm, more preferably greater than or equal to 35 μm, and in this embodiment is here equal to 45 μm. The sum SI3 of the inter-thread distances I3 of the external layer C3 is greater than the diameter d3 of the external threads F3 of the external layer C3. Here, the sum SI3=11 x 0.045 = 0.50 mm, which is a value strictly greater than d3 = 0.35 mm.

**[0202]** Each internal, intermediate and external thread of each internal strand TI respectively has a diameter d1, d2 and d3. Each internal thread diameter d1, intermediate thread diameter d2 and external thread diameter d3 of each internal strand TI ranges from 0.15 mm to 0.60 mm, preferably from 0.20 mm to 0.50 mm, more preferably from 0.25 mm to 0.45 mm, and more preferably still from 0.28 mm to 0.42 mm.

**[0203]** The internal thread F1 of each internal strand TI has a diameter d1 greater than or equal to the diameter d2 of each intermediate thread F2 of each internal strand TI, and highly preferably, 1 ≤ d1/d2 ≤ 1.30. The internal thread F1 of each internal strand TI has a diameter d1 greater than or equal to the diameter d3 of each external thread F3 of each internal strand TI, and highly preferably, 1 ≤ d1/d3 ≤ 1.30. Each diameter d2 of each intermediate thread F2 of each internal strand TI and each diameter d3 of each external thread F3 of each internal strand TI are such that d2=d3.

**[0204]** In this instance, d1 > d2 and d1 > d3, d1/d2=d1/d3=1.27 and d1=0.38 mm, d2=d3=0.35 mm.

**[0205]** External strands TE of the cord 50

**[0206]** Each external strand TE has three layers. Thus, each external strand TE comprises, in this instance is made up of, three layers, not more, not less.

**[0207]** Each external strand TE comprises an internal layer C1' made up of Q'=1 internal thread, an intermediate layer C2' made up of M' intermediate threads F2' wound in a helix around the internal layer C1', and an external layer C3' made up of N' external threads F3' wound in a helix around the internal layer C1' and around and in contact with the intermediate layer C2'.

**[0208]** Q'=1, M'= 5 or 6 and N'=10, 11 or 12, for preference here Q'=1, M'=5 or 6 and N'=10 or 11 and here Q'=1, M'=6, N'=11.

**[0209]** The internal thread F1' has an infinite pitch.

**[0210]** The intermediate layer C2 of each external strand TE is wound around the internal layer C1' of each external strand TE in a direction of winding Z. The M' intermediate threads F2' are wound in a helix around the internal thread(s) F1' with a pitch p2' such that 8 mm ≤ p2' ≤ 16 mm and, for preference, 8 mm ≤ p2' ≤ 14 mm, and more preferably still, 8 mm ≤ p2' ≤ 12 mm. Here, p2'=10 mm.

**[0211]** The external layer C3' of each external strand TE is wound around the intermediate layer C2' of each external strand TE in a direction of winding Z. The N' external threads F3' are wound in a helix around the M' intermediate threads F2' with a pitch p3' such that 10 mm ≤ p3' ≤ 40 mm, for preference 15 mm ≤ p3' ≤ 35 mm, more preferably 15 mm ≤ p3' ≤ 25 mm and more preferably still, 17 mm ≤ p3' ≤ 23 mm. Here p3'=20 mm.

**[0212]** Because p1' is different from p2' and p2' is different from p3', each external strand TE is cylindrically-layered.

**[0213]** The pitches p2' and p3' satisfy 0.36 ≤ (p3'-p2')/p3' ≤ 0.57.

**[0214]** 0.38 ≤ (p3'-p2')/p3'; for preference 0.40 ≤ (p3'-p2')/p3'; more preferably 0.43 ≤ (p3'-p2')/p3'; and more preferably still 0.45 ≤ (p3'-p2')/p3'.

**[0215]** (p3'-p2')/p3' ≤ 0.55 and for preference (p3'-p2')/p3' ≤ 0.53.

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**[0216]** In this instance (p3'-p2')/p3'=0.50.

**[0217]** The intermediate layer C2' of each external strand TE is desaturated and incompletely unsaturated. The inter-thread distance I2' of the intermediate layer C2' which on average separates the M' intermediate threads is greater than or equal to 5 µm. The inter-thread distance I2' is preferably greater than or equal to 15 µm, more preferably greater than or equal to 35 µm, and in this embodiment is here equal to 35.4 µm. Because the intermediate layer C2' is incompletely unsaturated, the sum SI2' of the inter-thread distances I2' of the intermediate layer C2' is less than the diameter d2' of the intermediate threads F2' of the intermediate layer C2'. Here, the sum SI2'=6 x 0.0354 = 0.21 mm, which is a value strictly less than d2' = 0.30 mm.

**[0218]** Furthermore, the sum SI2' of the inter-thread distances I2' of the intermediate layer C2' is less than the diameter d3' of the external threads F3' of the external layer C3' and preferably less than or equal to 0.8 x d3'. Here, the sum SI2'=6 x 0.0354 = 0.21 mm, which is a value strictly less than d3' = 0.30 mm.

**[0219]** The external layer C3' of each external strand TE is desaturated and completely unsaturated. The inter-thread distance I3' of the external layer C3' which on average separates the N' external threads is greater than or equal to 5 µm. The inter-thread distance I3' is greater than or equal to 15 µm, more preferably greater than or equal to 35 µm, more preferably still greater than or equal to 50 µm, and in this embodiment here is equal to 55.4 µm. The sum SI3' of the inter-thread distances I3' of the external layer C3' is greater than the diameter d3' of the external threads F3' of the external layer C3'. Here, the sum SI3'=11 x 0.0554 = 0.61 mm, which is a value strictly greater than d3' = 0.30 mm.

**[0220]** Each internal, intermediate and external thread of each external strand TE respectively has a diameter d1', d2' and d3'. Each internal thread diameter d1', intermediate thread diameter d2' and external thread diameter d3' of each internal strand TI ranges from 0.15 mm to 0.60 mm, preferably from 0.20 mm to 0.50 mm, more preferably from 0.25 mm to 0.45 mm, and more preferably still from 0.28 mm to 0.42 mm.

**[0221]** The internal thread F1' of each external strand TE has a diameter d1' greater than or equal to the diameter d2' of each intermediate thread F2' of each external strand TE, and very preferably, 1 ≤ d1'/d2' ≤ 1.30. The internal thread F1' of each external strand TE has a diameter d1' greater than or equal to the diameter d3' of each external thread F3' of each external strand TE, and very preferably, 1 ≤ d1'/d3' ≤ 1.30. Each diameter d2' of each intermediate thread F2' of each external strand TE and each diameter d3' of each external thread F3' of each external strand TE are such that d2'=d3'.

**[0222]** In this instance, d1’ > d2' and d1’ > d3', d1'/d2'=d1'/d3'=1.27 and d1'=0.38 mm, d2'=d3'=0.30 mm.

**[0223]** Each internal thread F1 of each internal strand TI has a diameter d1 greater than or equal to the diameter d1’ of each internal thread F1’ of each external strand TE, for preference each internal thread F1 of each internal strand TI has a diameter d1 equal to the diameter d1’ of each internal thread F1’ of each external strand TE. Here, d1=d1'=0.38 mm.

**[0224]** Each internal thread F1 of each internal strand TI has a diameter d1 greater than or equal to the diameter d2’ of each intermediate thread F2’ of each external strand TE, for preference each internal thread F1 of each internal strand TI has a diameter d1 greater than the diameter d2’ of each intermediate thread F2’ of each external strand TE. Here, d1=0.38 mm > d2'=0.30 mm.

**[0225]** Each internal thread F1 of each internal strand TI has a diameter d1 greater than or equal to the diameter d3’ of each external thread F3’ of each external strand TE, for preference each internal thread F1 of each internal strand TI has a diameter d1 greater than the diameter d3’ of each external thread F3’ of each external strand TE. Here, d1=0.38 mm > d3'=0.30 mm.

**[0226]** Each intermediate thread F2 of each internal strand TI has a diameter d2 greater than or equal to the diameter d2’ of each intermediate thread F2’ of each external strand TE. For preference, here, d2=0.35 mm > d2'=0.30 mm.

**[0227]** Each external thread F3 of each internal strand TI has a diameter d3 greater than or equal to the diameter d3' of each external thread F3 of each external strand TE. For preference, here, d3=0.35 mm > d3'=0.30 mm.

**[0228]** Each thread has a breaking strength, denoted Rm, such that $2500 \leq Rm \leq 3100$ MPa. The steel for these threads is said to be of SHT (“Super High Tensile”) grade. Other threads may be used, for example threads of an inferior grade, for example of NT (“Normal Tensile”) or HT (“High Tensile”) grade, just as may threads of a superior grade, for example of UT (“Ultra Tensile”) or MT (“Mega Tensile”) grade.

**[0229] METHOD FOR MANUFACTURING THE CORD ACCORDING TO THE INVENTION**

**[0230]** The cord according to the invention is manufactured using a method comprising steps well known to those skilled in the art.

**[0231]** In a step for manufacturing the internal strands using the following steps, preferably carried out in line and continuously:

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– first of all, a first step of assembling, by cabling, the Q internal threads F1 of the internal layer C1 at the pitch p1 and in the Z-direction to form the internal layer C1 at a first assembling point; in embodiments in which Q=1, the first assembling step is omitted;

– followed by a second step of assembling, by cabling or by twisting, the M intermediate threads F2 around the Q internal threads F1 of the internal layer C1 at the pitch p2 and in the Z-direction to form the intermediate layer C2 at a second assembling point;

– followed by a third step of assembling, by cabling or by twisting, the N external threads F3 around the M intermediate threads F2 of the intermediate layer C2 at the pitch p3 and in the Z-direction to form the external layer C3 and each internal strand TI at a third assembling point;

– preferably a final twist-balancing step.

**[0232]** In a step for manufacturing the external strands using the following steps, preferably carried out in line and continuously:

– first of all, a first step of assembling, by cabling, the M' intermediate threads F2' around the Q'=1 internal thread F1' of the internal layer C1' at the pitch p2' and in the Z-direction to form the intermediate layer C2' at a first assembling point;

– followed by a second step of assembling, by cabling, the N' external threads F3' around the M' intermediate threads F2' of the intermediate layer C2' at the pitch p3' and in the Z-direction to form the external layer C3' and each external strand TE at a second assembling point;

– preferably a final twist-balancing step.

**[0233]** What is meant here by “twist balancing” is, as is well known to those skilled in the art, the cancellation of the residual torque (or the elastic return of the twist) applied to each thread of the strand, in the intermediate layer as in the external layer.

**[0234]** After this final twist-balancing step, the manufacture of the strand is complete. Each strand is wound onto one or more receiving reels, for storage, prior to the later operation of assembling the elementary strands by cabling in order to obtain the multi-strand cord.

**[0235]** In a step of manufacturing the internal layer CI, the K internal strands TI are assembled by cabling at the pitch pi and in the Z-direction to form the internal layer CI at a first assembling point.

**[0236]** Then, in a later manufacturing step, the L external strands TE are assembled by cabling around the internal layer CI at the pitch pe and in the Z-direction to form the assembly of the layers CI and CE.

**[0237]** Possibly, in a last assembly step, the wrapper F is wound, at the pitch pf and in the S-direction, around the assembly previously obtained.

**[0238]** The cord is then incorporated by skimming into composite fabrics formed from a known composition based on natural rubber and carbon black as reinforcing filler, conventionally used for manufacturing crown reinforcements of radial tyres. This compound essentially contains, in addition to the elastomer and the reinforcing filler (carbon black), an antioxidant, stearic acid, an extender oil, cobalt naphthenate as adhesion promoter, and finally a vulcanization system (sulfur, accelerator and ZnO).

**[0239]** The composite fabrics reinforced by these cords have an elastomer compound matrix formed from two thin layers of elastomer compound which are superposed on either side of the cords and which have a thickness of between 1 and 4 mm, inclusive, respectively. The skim-coating pitch (the pitch at which the cords are laid in the elastomer compound fabric) ranges from 4 mm to 8 mm.

**[0240]** These composite fabrics are then used as working ply in the crown reinforcement during the method of manufacturing the tyre, the steps of which are otherwise known to a person skilled in the art.

**[0241] CORD ACCORDING TO A SECOND EMBODIMENT OF THE INVENTION**

**[0242]** Figure 4 depicts a cord 50' according to a second embodiment of the invention. Elements similar to those of the first embodiment are denoted by identical references.

**[0243]** Unlike in the first embodiment described hereinabove, the cord 50' according to the second embodiment is such that K=2 and L=8.

**[0244] CORD ACCORDING TO A THIRD EMBODIMENT OF THE INVENTION**

**[0245]** Figure 5 depicts a cord 50'' according to a third embodiment of the invention. Elements similar to those of the first embodiment are denoted by identical references.

**[0246]** Unlike in the first embodiment described hereinabove, the cord 50'' according to the third embodiment is such that K=4 and L=10.

**[0247]** Table A below summarizes the characteristics of the various cords 50, 50' and 50''.

| | Cord | 50 | 50' | 50'' |
|---|---|---|---|---|
| TI | Q/M/N | 1/6/11 | 1/6/11 | 1/6/11 |
| | d1/d2/d3 | 0.38/0.35/0.35 | 0.38/0.35/0.35 | 0.38/0.35/0.35 |

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| | | | | |
|---|---|---|---|---|
| | direction for C1/pitch p1 (mm) | -/Inf | -/Inf | -/Inf |
| | direction for C2/pitch p2 (mm) | Z/14 | Z/14 | Z/14 |
| | direction for C3/pitch p3 (mm) | Z/20 | Z/20 | Z/20 |
| | (p3-p2)/p3 | 0.30 | 0.30 | 0.30 |
| | I2 (µm)/SI2 (mm) | 11.6/0.07 | 11.6/0.07 | 11.6/0.07 |
| | I3 (µm)/SI3 (mm) | 45.0/0.50 | 45.0/0.50 | 45.0/0.50 |
| | DI (mm) | 1.78 | 1.78 | 1.78 |
| TE | Q'/M'/N' | 1/6/11 | 1/6/11 | 1/6/11 |
| | d1'/d2'/d3' | 0.38/0.30/0.30 | 0.38/0.30/0.30 | 0.38/0.30/0.30 |
| | direction for C1'/pitch p1' (mm) | inf | inf | inf |
| | direction for C2'/pitch p2' (mm) | Z/10 | Z/10 | Z/10 |
| | direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 |
| | (p3'-p2')/p3' | 0.50 | 0.50 | 0.50 |
| | I2' (µm)/SI2' (mm) | 35.4/0.21 | 35.4/0.21 | 35.4/0.21 |
| | I3' (µm)/SI3' (mm) | 55.4/0.61 | 55.4/0.61 | 55.4/0.61 |
| | DE (mm) | 1.58 | 1.58 | 1.58 |
| K | | 3 | 2 | 4 |
| L | | 9 | 8 | 10 |
| D (mm) | | 7.0 | 6.7 | 7.5 |
| E (µm) | | 255 | 374 | 215 |
| SIE (mm) | | 2.3 | 3.0 | 2.2 |
| Direction of winding for CI/CE and pitch pi/pe | | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 |

**Table A**

**[0248] CORDS ACCORDING TO THE FOURTH TO TWELFTH EMBODIMENTS OF THE INVENTION**

**[0249]** Figures 6 to 14 depict the cords 51 to 59 according to the fourth to twelfth embodiments of the invention.

**[0250]** The features of the various cords 51 to 59 according to the fourth to twelfth embodiments of the invention have been summarized in Tables B and C hereinbelow.

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| Cord | | 51 | 52 | 53 | 54 | 55 | 56 |
|---|---|---|---|---|---|---|---|
| TI | Q/M/N | 1/6/12 | 1/6/11 | 1/6/12 | 3/9/15 | 1/6/11 | 1/6/11 |
| | d1/d2/d3 | 0.38/0.35/0.35 | 0.38/0.35/0.35 | 0.40/0.40/0.40 | 0.38/0.38/0.38 | 0.38/0.35/0.35 | 0.60/0.50/0.45 |
| | direction for C1/pitch p1 (mm) | -/Inf | -/Inf | -/Inf | Z/6.5 | -/Inf | -/Inf |
| | direction for C2/pitch p2 (mm) | Z/14 | Z/14 | Z/14 | Z/12 | Z/10 | Z/14 |
| | direction for C3/pitch p3 (mm) | Z/20 | Z/20 | Z/20 | Z/18 | Z/20 | Z/20 |
| | (p3-p2)/p3 | 0.30 | 0.30 | 0.30 | 0.33 | 0.50 | 0.30 |
| | I2 (μm)/SI2 (mm) | 11.6/0.07 | 11.6/0.07 | 0/0 | 14.6/0.13 | 8.2/0.05 | 39.1/0.23 |
| | I3 (μm)/SI3 (mm) | 12.0/0.14 | 45.0/0.50 | 4.9/0.06 | 7.0/0.11 | 45.0/0.50 | 107.2/1.18 |
| | DI (mm) | 1.78 | 1.78 | 2.00 | 2.34 | 1.78 | 2.5 |
| TE | Q'/M'/N' | 1/6/12 | 1/5/11 | 1/6/11 | 1/6/11 | 1/6/11 | 1/6/11 |
| | d1'/d2'/d3' | 0.38/0.30/0.30 | 0.30/0.30/0.26 | 0.32/0.26/0.26 | 0.45/0.38/0.38 | 0.38/0.30/0.30 | 0.45/0.38/0.38 |
| | direction for C1'/pitch p1' (mm) | inf | inf | inf | inf | inf | inf |
| | direction for C2'/pitch p2' (mm) | Z/10 | Z/10 | Z/10 | Z/10 | Z/10 | Z/12.5 |
| | direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/25 |
| | (p3'-p2')/p3' | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| | I2' (μm)/SI2' (mm) | 35.4/0.21 | 50.6/0.25 | 27.1/0.16 | 25.7/0.15 | 35.4/0.21 | 29.1/0.17 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | I3' (µm)/SI3' (mm) | 25.7/0.31 | 63.3/0.70 | 46.6/0.51 | 57.5/0.63 | 55.4/0.61 | 61.3/0.67 |
| | DE (mm) | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| K | | 3 | 3 | 3 | 3 | 3 | 3 |
| L | | 9 | 9 | 9 | 9 | 9 | 9 |
| D (mm) | | 7.0 | 7.0 | 7.5 | 8.2 | 7.0 | 8.6 |
| E (µm) | | 255 | 255 | 423 | 665 | 255 | 782 |
| SIE (mm) | | 2.3 | 2.3 | 3.8 | 6.0 | 2.3 | 7.0 |
| Direction of winding for CI/CE and pitch pi/pe | | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 |

**Table B**

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| Cord | | 57 | 58 | 59 |
|---|---|---|---|---|
| TI | Q/-/N | 2/-/7 | 3/-/8 | 4/-/9 |
| | d1/-/d3 | 0.45/-/0.45 | 0.42/-/0.42 | 0.40/-/0.40 |
| | direction for C1/pitch p1 (mm) | Z/7.7 | Z/7.7 | Z/7.7 |
| | direction for C2/pitch p2 (mm) | -/- | -/- | -/- |
| | direction for C3/pitch p3 (mm) | Z/15.4 | Z/15.4 | Z/15.4 |
| | I3 (µm)/SI3 (mm) | 124.2/0.87 | 75.8/0.61 | 56.4/0.51 |
| | DI (mm) | 1.80 | 1.75 | 1.77 |
| TE | Q'/M'/N' | 1/6/11 | 1/6/11 | 1/6/11 |
| | d1'/d2'/d3' | 0.38/0.30/0.30 | 0.38/0.30/0.30 | 0.38/0.30/0.30 |
| | direction for C1'/pitch p1' (mm) | inf | inf | inf |
| | direction for C2'/pitch p2' (mm) | Z/10 | Z/10 | Z/10 |
| | direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 |
| | (p3'-p2')/p3' | 0.50 | 0.50 | 0.50 |
| | I2' (µm)/SI2' (mm) | 35.4/0.21 | 35.4/0.21 | 35.4/0.21 |
| | I3' (µm)/SI3' (mm) | 55.4/0.61 | 55.4/0.61 | 55.4/0.61 |
| | DE (mm) | 1.58 | 1.58 | 1.58 |
| K | | 3 | 3 | 3 |
| L | | 9 | 9 | 9 |
| D (mm) | | 7.0 | 6.9 | 7.0 |
| E (µm) | | 269 | 231 | 250 |
| SIE (mm) | | 2.4 | 2.1 | 2.3 |

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| | | | |
|---|---|---|---|
| Direction of winding for CI/CE and pitch pi/pe | Z/Z 80/100 | Z/Z 80/100 | Z/Z 80/100 |

**Table C**

**[0251] COMPARATIVE TESTS**

**[0252]** Indicator of the penetrability of the strands by an elastomer compound

**[0253]** The ability of a strand to be penetrated by an elastomer compound was determined in the following tests by simulating the size of the radial passage windows formed by two adjacent threads F2' of the intermediate layer C2' and by two adjacent threads F3' of the external layer C3'. Such windows are illustrated in Figure 15 which depicts a schematic view of an external strand along its main axis P and in Figure 16 which depicts the radial passage window S defined hereinabove.

**[0254]** Such an indicator of the penetrability of the strand gives an image of the impermeability of the strand to air. Specifically, the larger the size of the windows, the higher the penetrability indicator, the more elastomer compound is liable to penetrate the strand and the more impermeable the strand is to air. The permeability could also be determined using the permeability test that makes it possible to determine the longitudinal permeability to air of the strands or cords tested, by measuring the volume of air passing along a test specimen under constant pressure over a given period of time. The principle of such a test, which is well known to those skilled in the art, is to demonstrate the effectiveness of the treatment of a strand or of a cord to make it impermeable to air; it has been described for example in standard ASTM D2692-98. Such a test is carried out on as-manufactured and non-aged strands or cords. The raw strands or cords are coated on the outside beforehand with an elastomer compound referred to as coating compound. For this purpose, a series of 10 strands or cords laid parallel (distance between cords: 20 mm) is placed between two layers or "skims" (two rectangles measuring 80 x 200 mm) of a diene elastomer compound in the raw state, each skim having a thickness of 5 mm; all of this is then immobilized in a mould, with each of the strands or cords being kept under sufficient tension (for example 3 daN) to guarantee that it lies straight as it is being placed in the mould, using clamping modules; it is then vulcanized (cured) for around 10 to 12 hours at a temperature of around 120°C and at a pressure of 15 bar (rectangular piston measuring 80 x 200 mm). After that, the entirety is removed from the mould and 10 test specimens of strands or cords thus coated are cut out, for characterizing, in the shape of parallelepipeds measuring 7x7x60 mm. The compound used as a coating elastomer compound is a diene elastomer compound conventionally used in tyres, based on natural (peptized) rubber and carbon black N330 (65 phr), also containing the following usual additives: sulfur (7 phr), sulfenamide accelerator (1 phr), ZnO (8 phr), stearic acid (0.7 phr), antioxidant (1.5 phr), cobalt naphthenate (1.5 phr) (phr meaning parts by weight per hundred parts of elastomer); the E10 modulus of the coating elastomer compound is around 10 MPa. The test is carried out on a 6 cm length of strand or cord, which is therefore coated with its surrounding elastomer compound (or coating elastomer compound) in the cured state, in the following way: air is injected into the inlet end of the strand or cord at a pressure of 1 bar and the volume of air at the outlet end is measured using a flow meter (calibrated for example from 0 to 500 $cm^3$/min). During the measurement, the sample of strand or cord is immobilized in a compressed airtight seal (for example, a seal made of dense foam or of rubber) so that only the amount of air passing along the strand or cord from one end to the other, along its longitudinal axis, is taken into account by the measurement; the airtightness of the airtight seal itself is checked beforehand using a solid elastomer-compound test specimen, that is to say one devoid of both strand and cord. The higher the longitudinal impermeability of the strand or cord, the lower the mean air flow rate measured (averaged over the ten specimens). As the measurement is taken with a precision of ±0.2 cm3/min, measured values of less than or equal to 0.2 cm3/min are considered to be zero; they correspond to a strand or cord that can be described as airtight (completely airtight) along its axis (i.e. in its longitudinal direction).

**[0255]** Nevertheless, for the sake of the speed at which the strands can be evaluated, the inventors favoured simulation and calculation of the windows S over the permeability test.

**[0256]** Evaluation of the penetrability indicator for the external strands according to the pitch p3' of the cord 50

**[0257]** Various external strands analogous to the external strand of the cord 50 according to the invention were simulated by varying the value of p2' for various values of p3', with all the other structural features of the cord remaining unchanged in comparison with the above description.

**[0258]** The results of these simulations are collated in the various Tables 1 to 5 in base 100 with respect, in each instance, to a control strand such that (p3'-p2')/p3'=0.30. Thus, for a window size value St for the tested strand and for a window size value S0 for the control strand, the penetrability indicator is equal to St*100/S0. Thus, a result higher than 100 means that the strand tested exhibits superior penetrability to the corresponding control strand. It is estimated that the size of the windows is significantly higher when the penetrability indicator is greater than or equal to 120, which means to say when the size of the windows in the strand tested is 20% higher than that of the control strand.

**[0259]** Each Table 1 to 5 respectively corresponds to a pitch p3' equal to 15, 17, 20, 23, 25 mm.

**[0260]** It will be noted that, although the inter-thread distance I2' increases when p2' increases, the maximum value for the radial passage windows is obtained for I2' values which are not necessarily the highest values. Thus, before carrying out the invention, a person skilled in the art, starting from the assumption that the lower I2', the lower the penetrability of the strand, would have difficulty in predicting a maximum penetrability for p2' values that yield relatively low values for I2'.

**[0261]** Within the interval for the ratio (p3'-p2')/p3' that ranges from 0.36 to 0.57, and for each p3' value tested, the value for the penetrability indicator is significantly higher than that obtained for the corresponding control strand.

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| | External strands of the cord 50 which were tested with p3'=15 mm | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/12 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.6 | Z/9.5 | Z/9.0 | Z/8.5 | Z/8.0 | Z/7.5 | Z/7.0 | Z/6.5 | Z/6.0 |
| direction for C3'/pitch p3' (mm) | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 | Z/15 |
| (p3'-p2')/p3' | 0.20 | 0.23 | 0.27 | 0.30 | 0.33 | 0.36 | 0.37 | 0.40 | 0.43 | 0.47 | 0.50 | 0.53 | 0.57 | 0.60 |
| I2' (µm) | 37 | 36.7 | 36.3 | 35.9 | 35.4 | 34.8 | 34.8 | 34.2 | 33.4 | 32.5 | 31.4 | 30.1 | 28.4 | 26.3 |
| Penetrability indicator for the external strand | 74 | 80 | 89 | 100 | 109 | 140 | 145 | 200 | 359 | 5590 | 337 | 146 | 125 | 54 |

**Table 1**

| | External strands of the cord 50 which were tested with p3'=17 mm | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/14.0 | Z/13.0 | Z/12.5 | Z/12.0 | Z/11.9 | Z/11.5 | Z/11.0 | Z/10.8 | Z/10.0 | Z/9.0 | Z/8.0 | Z/7.3 | Z/6.5 |
| direction for C3'/pitch p3' (mm) | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 | Z/17 |
| (p3'-p2')/p3' | 0.18 | 0.24 | 0.26 | 0.29 | 0.30 | 0.32 | 0.35 | 0.36 | 0.41 | 0.47 | 0.53 | 0.57 | 0.62 |
| I2' (µm) | 38.0 | 37.5 | 37.3 | 37 | 36.9 | 36.7 | 36.3 | 36.1 | 35.4 | 34.2 | 32.5 | 30.9 | 28.4 |
| Penetrability indicator for the external strand | 70 | 80 | 88 | 98 | 100 | 108 | 111 | 144 | 239 | 6261 | 165 | 123 | 68 |

**Table 2**

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| | External strands of the cord 50 which were tested with p3'=20 mm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/16.0 | Z/14.0 | Z/13.0 | Z/12.8 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.5 | Z/9.0 | Z/8.6 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 |
| (p3'-p2')/p3' | 0.20 | 0.30 | 0.35 | 0.36 | 0.38 | 0.40 | 0.43 | 0.45 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.65 |
| I2' (µm) | 38.6 | 38 | 37.5 | 37.2 | 37 | 36.8 | 36.7 | 36.3 | 35.9 | 35.4 | 34.8 | 34.2 | 33.4 | 32.5 | 30.1 |
| Penetrability indicator for the external strand | 73 | 100 | 108 | 135 | 158 | 205 | 306 | 676 | 1914 | 360 | 187 | 129 | 122 | 69 | 37 |

**Table 3**

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| | External strands of the cord 50 which were tested with p3'=23 mm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/19.0 | Z/17.0 | Z/16.1 | Z/15.0 | Z/14.7 | Z/14.0 | Z/13.0 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.0 | Z/9.0 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 | Z/23 |
| (p3'-p2')/p3' | 0.17 | 0.26 | 0.30 | 0.35 | 0.36 | 0.39 | 0.43 | 0.46 | 0.48 | 0.50 | 0.52 | 0.57 | 0.61 | 0.65 | 0.70 |
| I2' (µm) | 39.2 | 38.8 | 38.6 | 38.3 | 38.2 | 38 | 37.5 | 37.3 | 37 | 36.7 | 36.3 | 35.4 | 34.2 | 32.5 | 30.1 |
| Penetrability indicator for the external strand | 69 | 86 | 100 | 107 | 141 | 186 | 390 | 1034 | 1267 | 366 | 205 | 125 | 70 | 38 | 25 |

**Table 4**

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| | External strands of the cord 50 which were tested with p3'=25 mm | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/18.0 | Z/17.5 | Z/17.0 | Z/16.5 | Z/16.0 | Z/15.0 | Z/14.0 | Z/13.0 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.8 | Z/10.5 | Z/10.0 |
| direction for C3'/pitch p3' (mm) | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 |
| (p3'-p2')/p3' | 0.28 | 0.30 | 0.32 | 0.34 | 0.36 | 0.40 | 0.44 | 0.48 | 0.52 | 0.54 | 0.56 | 0.57 | 0.58 | 0.60 |
| I2' (µm) | 39 | 38.9 | 38.8 | 38.7 | 38.6 | 38.3 | 38 | 37.5 | 37 | 36.7 | 36.7 | 36.1 | 35.9 | 35.4 |
| Penetrability indicator for the external strand | 92 | 100 | 109 | 108 | 140 | 206 | 456 | 1069 | 213 | 166 | 148 | 127 | 93 | 66 |

**Table 5**

**[0262]** Evaluation of the penetrability indicator for the external strands of the cords 50', 50" and 51 to 59

**[0263]** In a way similar to the cord 50 according to the first embodiment of the invention, various external strands of the cords 52 to 59 according to the various embodiments of the invention were simulated by varying the value of p2’ while fixing the value of p3’ to the value described hereinabove, with all the other structural features of each cord remaining unchanged in comparison with the above description.

**[0264]** Since the external strands of the cords 50', 50’’ and 51 are identical to those of the cord 50, the conclusion remains the same, namely that within the interval for the ratio (p3'-p2')/p3' that ranges from 0.36 to 0.57, and for each p3’ value tested, the value for the penetrability indicator is significantly higher than that obtained for the corresponding control strand.

**[0265]** The results of these simulations are collated in the various Tables 6 to 10 in base 100 with respect, in each instance, to a control strand such that (p3'-p2')/p3'=0.30. Thus, for a window size value St for the tested strand and for a window size value S0 for the control strand, the penetrability indicator is equal to St*100/S0. Thus, a result higher than 100 means that the strand tested exhibits superior penetrability to the corresponding control strand. It is estimated that the size of the windows is significantly higher when the penetrability indicator is greater than or equal to 120, which means to say when the size of the windows in the strand tested is 20% higher than that of the control strand.

**[0266]** It will be noted that, although the inter-thread distance I2’ increases when p2’ increases, the maximum value for the size of the radial passage windows is obtained for I2’ values which are not necessarily the highest values. Thus, before carrying out the invention, a person skilled in the art, starting from the assumption that the lower I2’, the lower the penetrability of the strand, would have difficulty in predicting a maximum penetrability for p2’ values that yield relatively low values for I2’.

**[0267]** Within the interval for the ratio (p3’-p2’)/p3’ that ranges from 0.36 to 0.57, and for each p3’ value tested, the value for the penetrability indicator is significantly higher than that obtained for the corresponding control strand.

| | External strands of the cord 52 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/16.0 | Z/14.0 | Z/13.0 | Z/12.8 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.5 | Z/9.0 | Z/8.6 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 |
| (p3'-p2')/p3' | 0.20 | 0.30 | 0.35 | 0.36 | 0.38 | 0.40 | 0.43 | 0.45 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.65 |
| I2' (µm) | 61.1 | 60.4 | 59.9 | 59.8 | 59.6 | 59.3 | 58.9 | 58.5 | 58 | 57.5 | 56.9 | 56.2 | 55.5 | 54.3 | 51.6 |
| Penetrability indicator for the external strand | 75 | 100 | 108 | 135 | 150 | 188 | 258 | 439 | 2020 | 667 | 267 | 158 | 126 | 79 | 48 |

**Table 6**

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| | External strands of the cord 53 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/15.0 | Z/14.0 | Z/13.0 | Z/12.8 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.5 | Z/9.0 | Z/8.6 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 |
| (p3'-p2')/p3' | 0.25 | 0.30 | 0.35 | 0.36 | 0.38 | 0.40 | 0.43 | 0.45 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.65 |
| I2' (µm) | 29 | 28.8 | 28.5 | 28.4 | 28.3 | 28.1 | 27.9 | 27.7 | 27.4 | 27.1 | 26.8 | 26.4 | 26 | 25.3 | 23.7 |
| Penetrability indicator for the external strand | 84 | 100 | 109 | 138 | 155 | 199 | 289 | 575 | 5438 | 427 | 209 | 142 | 123 | 85 | 40 |

**Table 7**

| | External strands of the cord 54 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/15.0 | Z/14.0 | Z/13.0 | Z/12.8 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.5 | Z/9.0 | Z/8.6 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 |
| (p3'-p2')/p3' | 0.25 | 0.30 | 0.35 | 0.36 | 0.38 | 0.40 | 0.43 | 0.45 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.65 |
| I2' (μm) | 31.1 | 30.4 | 29.6 | 29.4 | 29.1 | 28.6 | 28 | 27.3 | 26.6 | 25.7 | 24.6 | 23.4 | 22.3 | 20.3 | 15.8 |
| Penetrability indicator for the external strand | 85 | 100 | 107 | 133 | 148 | 185 | 254 | 449 | 3901 | 487 | 208 | 152 | 127 | 76 | 40 |

**Table 8**

| | External strands of the cords 55, 57, 58, 59 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/16.0 | Z/14.0 | Z/13.0 | Z/12.8 | Z/12.5 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.5 | Z/10.0 | Z/9.5 | Z/9.0 | Z/8.6 | Z/8.0 | Z/7.0 |
| direction for C3'/pitch p3' (mm) | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 | Z/20 |
| (p3'-p2')/p3' | 0.20 | 0.30 | 0.35 | 0.36 | 0.38 | 0.40 | 0.43 | 0.45 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.65 |
| I2' (µm) | 38.6 | 38 | 37.5 | 37.2 | 37 | 36.8 | 36.7 | 36.3 | 35.9 | 35.4 | 34.8 | 34.2 | 33.4 | 32.5 | 30.1 |
| Penetrability indicator for the external strand | 73 | 100 | 108 | 135 | 158 | 205 | 306 | 676 | 1914 | 360 | 187 | 129 | 122 | 69 | 37 |

**Table 9**

| | External strands of the cord 56 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| direction for C1'/pitch p1' (mm) | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf | -/inf |
| direction for C2'/pitch p2' (mm) | Z/20.0 | Z/18.0 | Z/17.5 | Z/17.0 | Z/16.5 | Z/16.0 | Z/15.0 | Z/14.0 | Z/13.0 | Z/12.0 | Z/11.5 | Z/11.0 | Z/10.8 | Z/10.0 | Z/9.0 |
| direction for C3'/pitch p3' (mm) | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 | Z/25 |
| (p3'-p2')/p3' | 0.20 | 0.28 | 0.30 | 0.32 | 0.34 | 0.36 | 0.40 | 0.44 | 0.48 | 0.52 | 0.54 | 0.56 | 0.57 | 0.60 | 0.64 |
| I2' (µm) | 33 | 32.4 | 32.2 | 32 | 31.8 | 31.6 | 31.1 | 30.4 | 29.6 | 28.6 | 28 | 27.3 | 27 | 25.7 | 23.4 |
| Penetrability indicator for the external strand | 75 | 93 | 100 | 109 | 114 | 135 | 189 | 354 | 6039 | 258 | 164 | 125 | 123 | 66 | 41 |

**Table 10**

**[0268]** Tables 6 to 10 show that, for varying cord constructions, the penetration of the elastomer compound into the external strands, and therefore the ability this elastomer compound has to access each internal strand, is significantly improved for a ratio (p3'-p2')/p3' ranging from 0.36 to 0.57 by comparison with the control cords for which (p3'-p2')/p3'=0.30.

**[0269]** Of course, the invention is not restricted to the exemplary embodiments described above.

**[0270]** For reasons of industrial feasibility, of cost and of overall performance, it is preferable to implement the invention with linear threads, that is to say straight threads, having a conventional circular cross section.

**[0271]** It will also be possible to combine the characteristics of the various embodiments described or envisaged above, with the proviso that these characteristics are compatible with one another.

**[0272]** It is to be understood that, if any prior art is referred to herein, such reference does not constitute an admission that the prior art forms a part of the common general knowledge in the art, in Australia or any other country.

**[0273]** In the claims which follow and in the preceding description, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

## CLAIMS

1.Two-layer multi-strand cord, wherein the cord comprises:

an internal layer of the cord made up of K > 1 internal strands wound in a helix, each internal strand being an at least two-layer strand and comprising:

- an internal layer made up of Q internal thread(s), and
- an external layer made up of N external threads wound around the internal layer,

– an external layer of the cord made up of L > 1 external strands wound around the internal layer of the cord, each external strand being a three-layer strand and comprising:

- an internal layer made up of Q'=1 internal thread,
- an intermediate layer made up of M' intermediate threads wound around the internal layer with a pitch p2', and
- an external layer made up of N' external threads wound around the intermediate layer with a pitch p3',

wherein:

- the intermediate layer of each external strand is desaturated;
- the external layer of each external strand is desaturated; and
- the pitches p2' and p3' satisfy the relationship:

$0.36 \leq (p3'-p2')/p3' \leq 0.57$;

wherein the mean inter-strand distance E separating two adjacent external strands is greater than or equal to 70 µm; and

wherein the inter-thread distance of the intermediate layer of the external strand is greater than or equal to 50 µm.

2. Cord according to the preceding claim, in which the mean inter-strand distance E separating two adjacent external strands is greater than or equal to 100 µm, more preferably still, than/to 150 µm, highly preferably, than/to 200 µm.

3. Cord according to either one of the preceding claims, in which: $0.38 \leq (p3'-p2')/p3'$; for preference $0.40 \leq (p3'-p2')/p3'$; more preferably $0.43 \leq (p3'-p2')/p3'$; and more preferably still $0.45 \leq (p3'-p2')/p3'$.

4. Cord according to any one of the preceding claims, in which $(p3'-p2')/p3' \leq 0.55$ and for preference $(p3'-p2')/p3' \leq 0.53$.

5. Cord according to any one of the preceding claims, in which the pitch p2' is such that 8 mm ≤ p2' ≤ 16 mm,

for preference 8 mm ≤ p2’ ≤ 14 mm, and more preferably 8 mm ≤ p2’ ≤ 12 mm.

6. Cord according to any one of the preceding claims, in which the pitch p3’ is such that 10 mm ≤ p3’ ≤ 40 mm, for preference 15 mm ≤ p3’ ≤ 35 mm, more preferably, 15 mm ≤ p3’ ≤ 25 mm, and more preferably still, 17 mm ≤ p3’ ≤ 23 mm.

7. Cord according to any one of the preceding claims, in which: K=2, 3 or 4, preferably K=3 or 4.

8. Cord according to any one of the preceding claims, in which L=7, 8, 9 or 10, and preferably L=8, 9 or 10 and more preferably L=8 or 9.

9. Cord according to any one of the preceding claims, in which the internal layer of the cord is wound in a helix in a cord internal-layer direction with a pitch pi, and the external layer of the cord is wound in a helix in a cord external-layer direction with a pitch pe, and the cord satisfies one and/or another of the following features:

- the cord internal-layer direction is different from the cord external-layer direction,
- pi is different from pe.

10. Cord according to any one of the preceding claims, in which the sum SI2’ of the inter-thread distances of the intermediate layer of each external strand is such that SI2' < d3' where d3’ is the diameter of each external thread of each external strand, preferably SI2' ≤ 0.8 x d3'.

11. Cord according to any one of the preceding claims, in which the external layer of each external strand is completely unsaturated.

12. Cord according to any one of the preceding claims, in which:

- Q'=1, M'=6, N'=11,
- the internal thread of each external strand has a diameter d1’ greater than the diameter d2’ of each intermediate thread of the said external strand, and
- the internal thread of each external strand has a diameter d1’ greater than the diameter d3’ of each external thread of the said external strand.

13. Cord according to any one of the preceding claims, in which, with each intermediate thread of each external strand having a diameter d2’, and each external thread of each external strand having a diameter d3', d2'=d3'.

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14. Cord according to any one of the preceding claims, in which the external layer of each internal strand is desaturated, preferably completely unsaturated.

15. Tyre comprising at least one cord according to any one of the preceding claims.

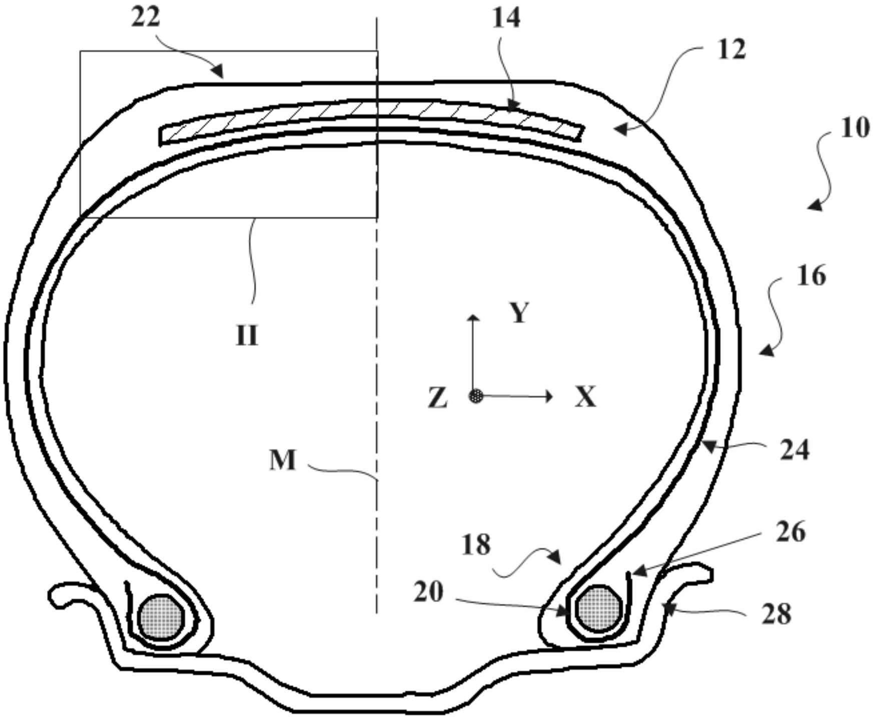
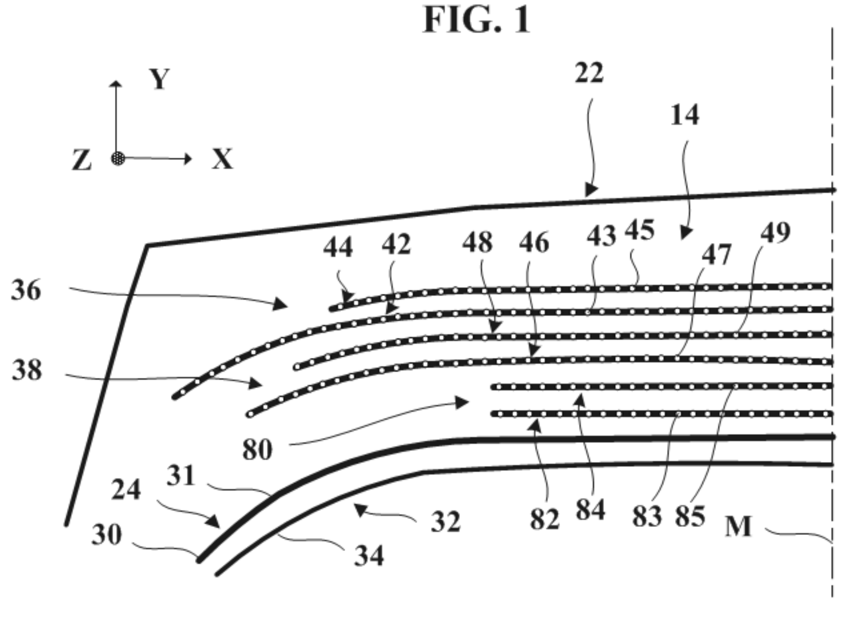

22
14
12
10
16
II
Y
Z
X
M
24
26
18
20
28

FIG. 1


Y
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X
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84
83
85
M

FIG. 2

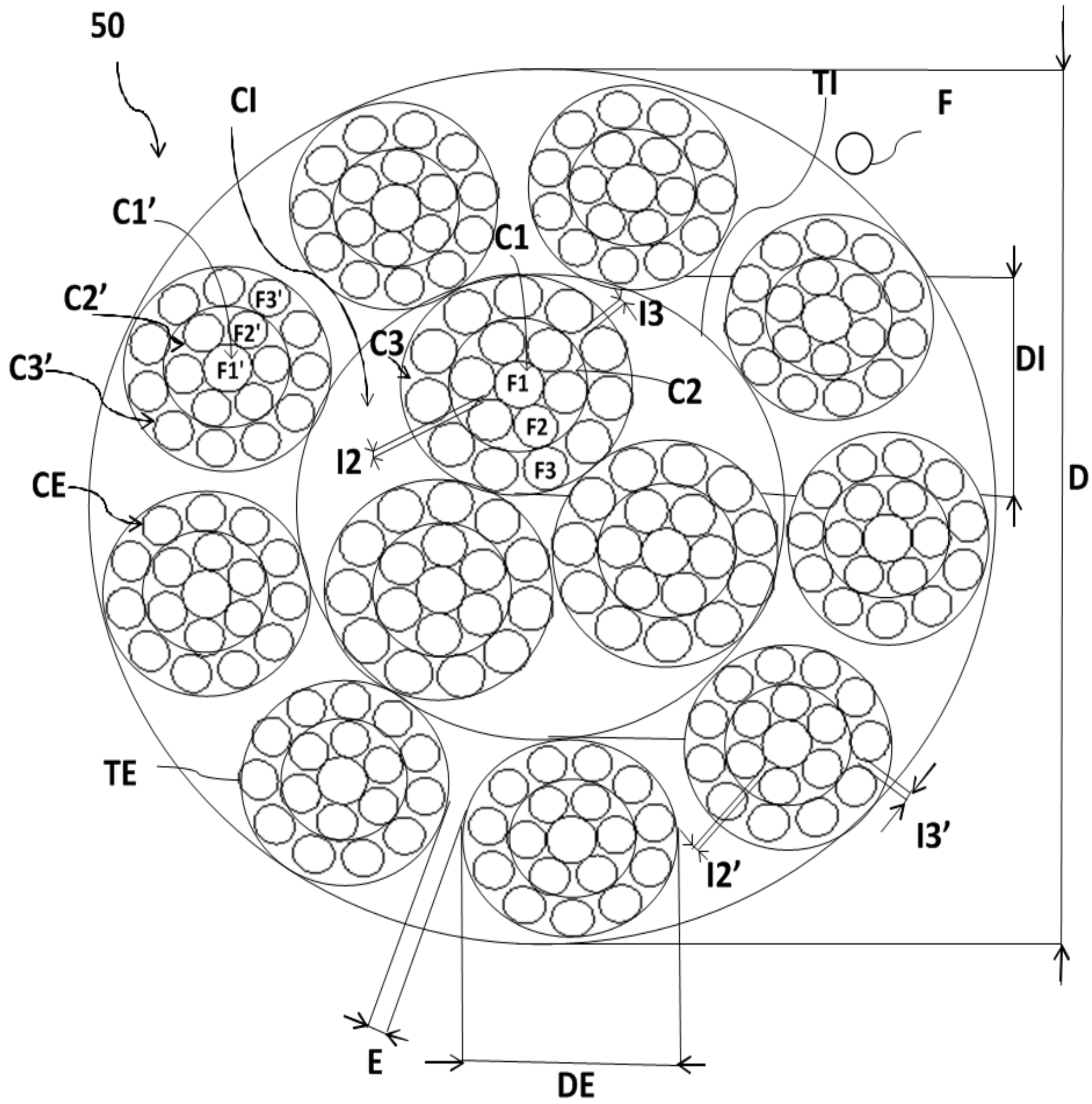


Fig. 3

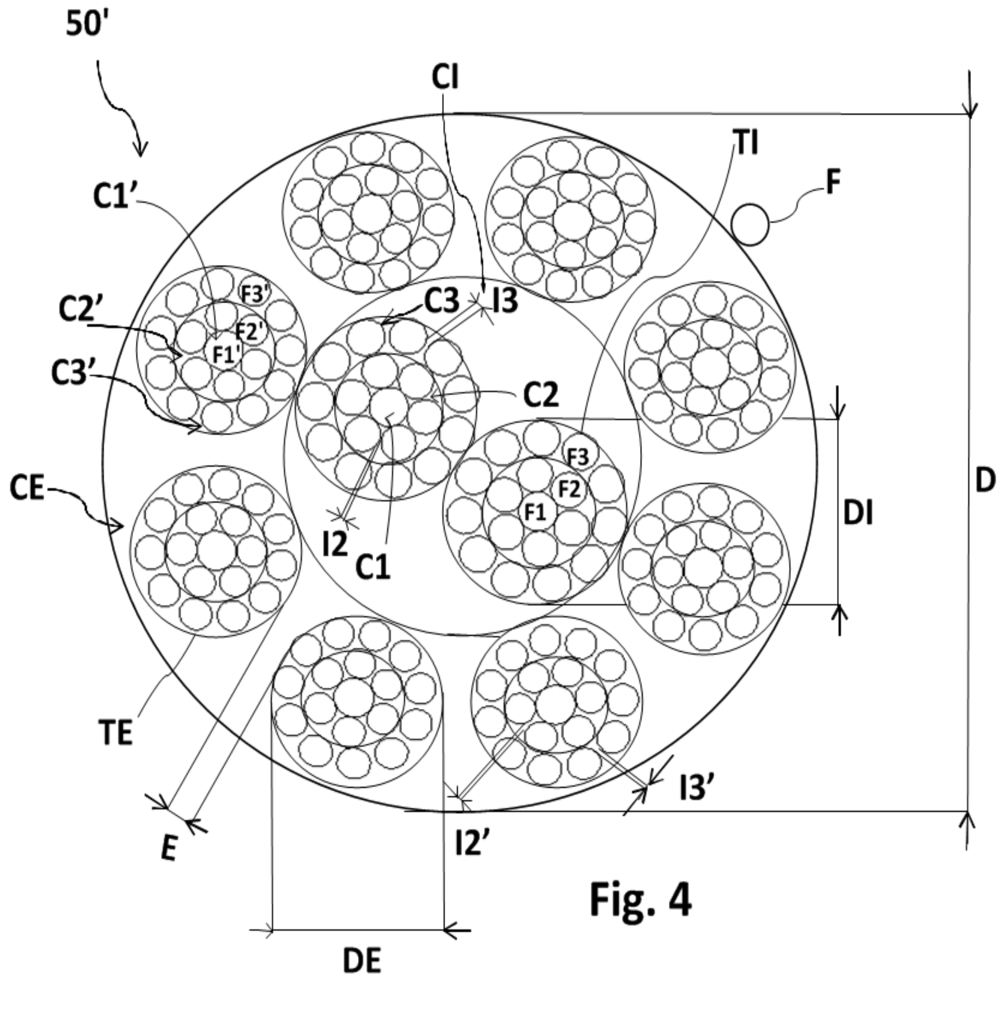


Fig. 4

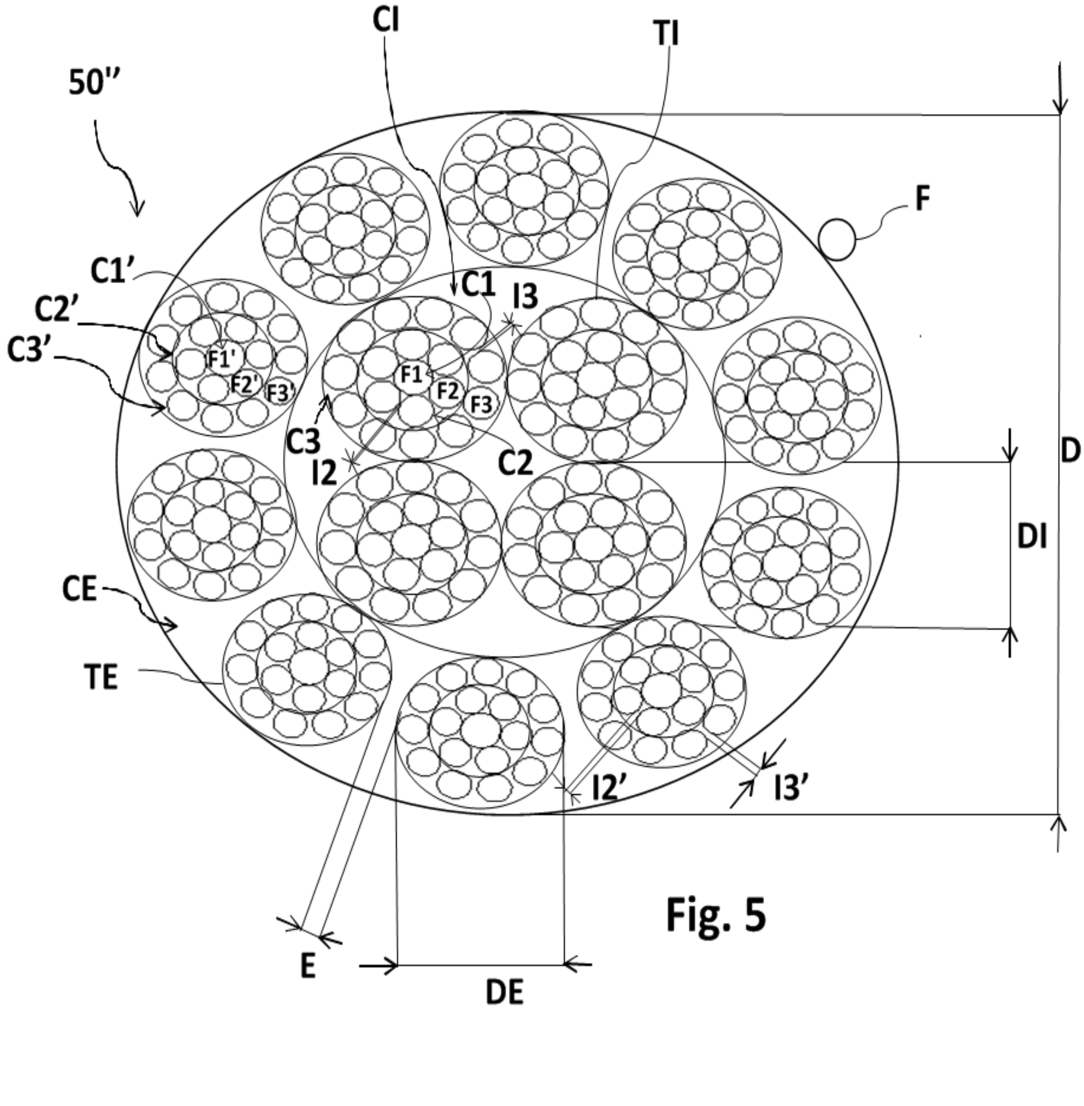


Fig. 5

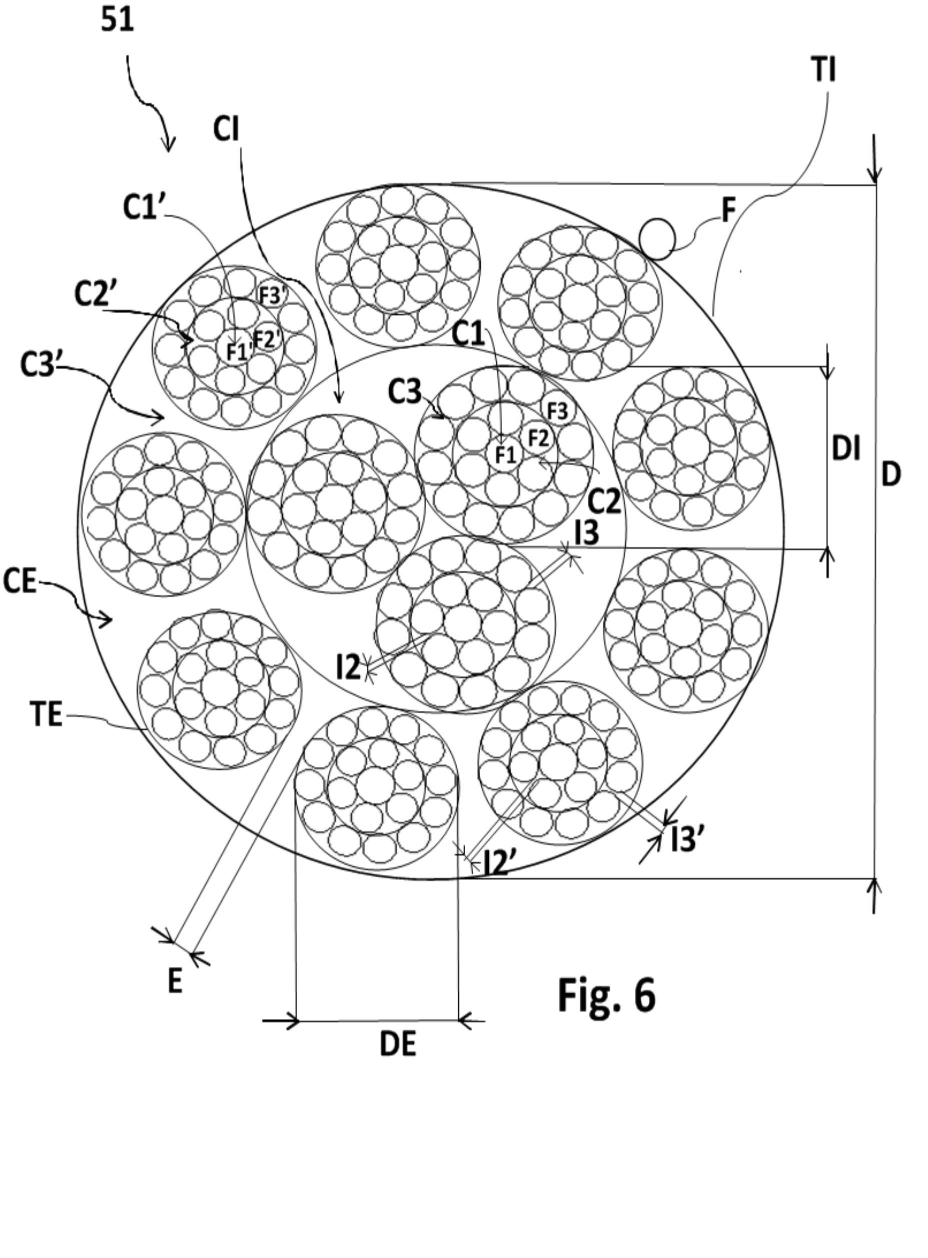


Fig. 6

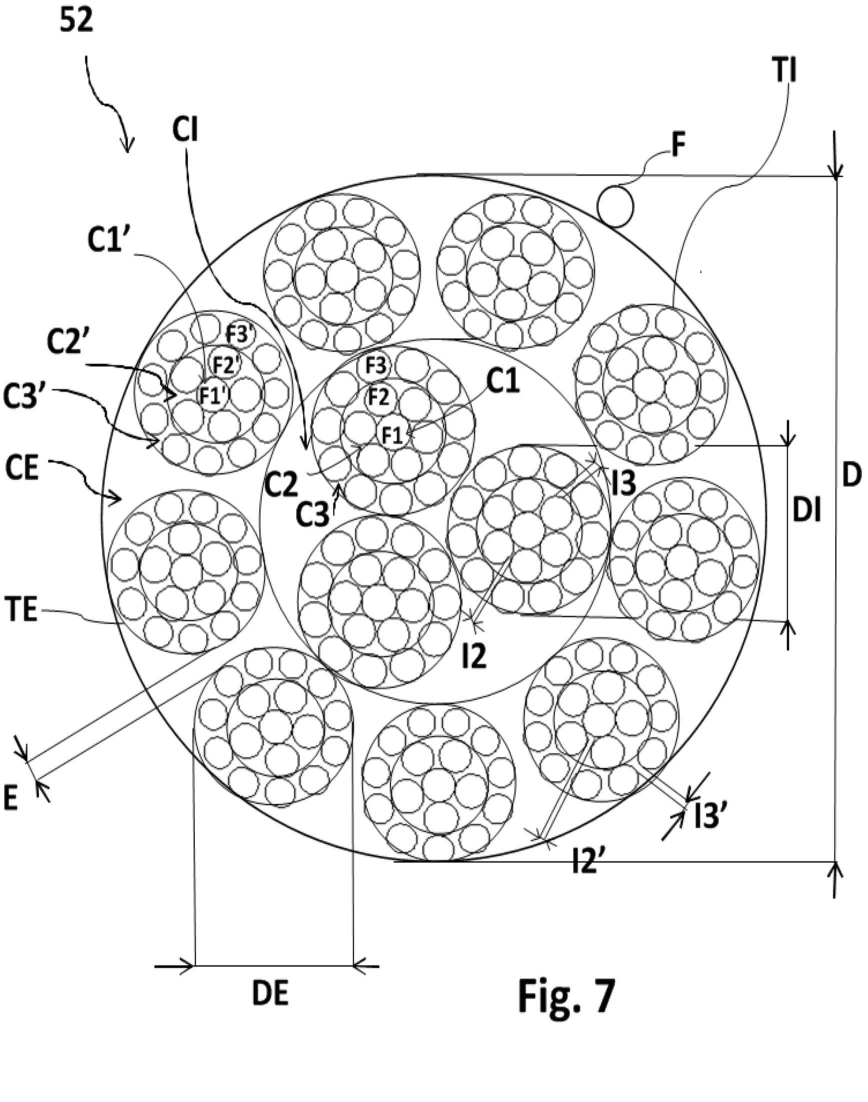


Fig. 7

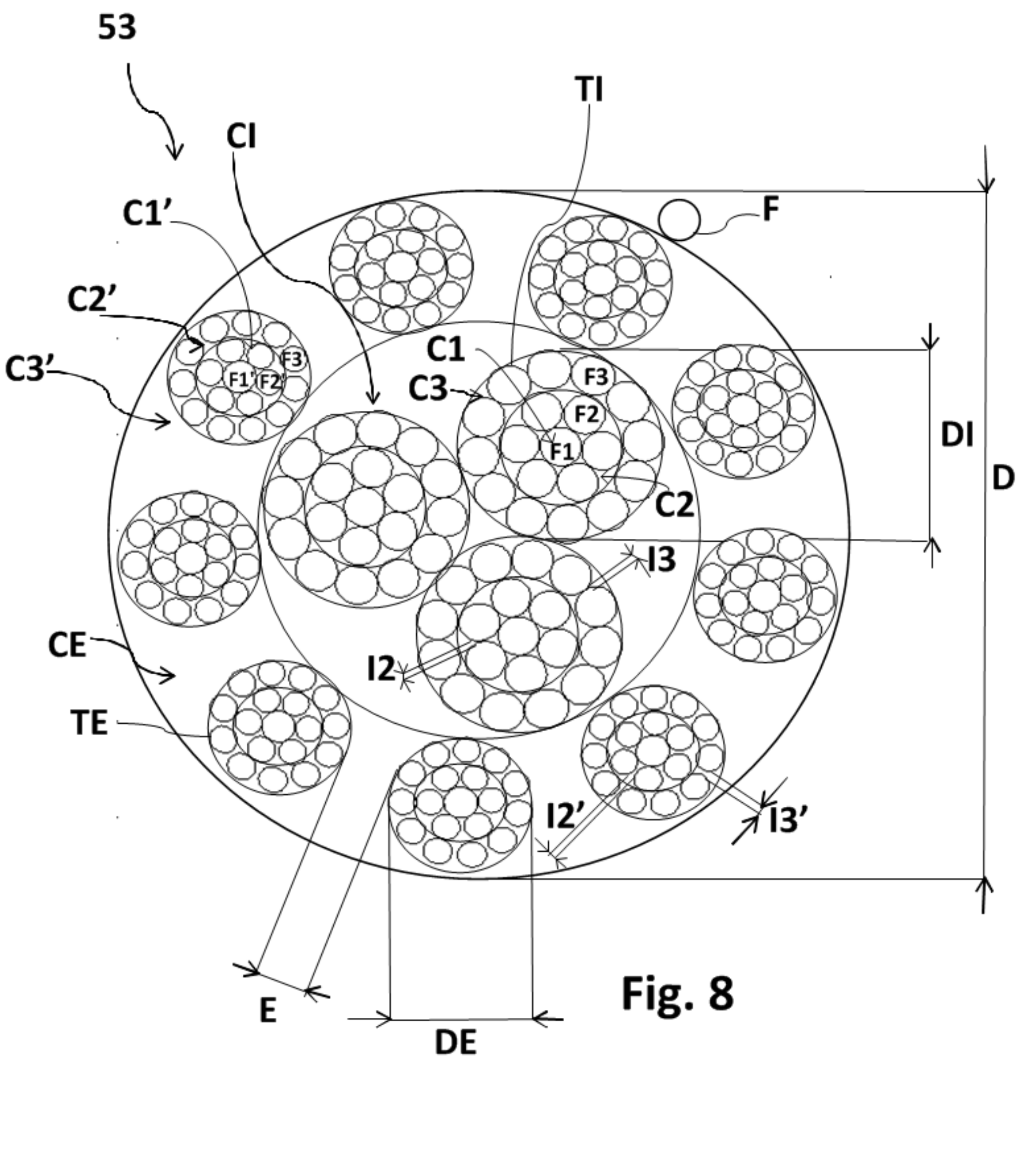


Fig. 8

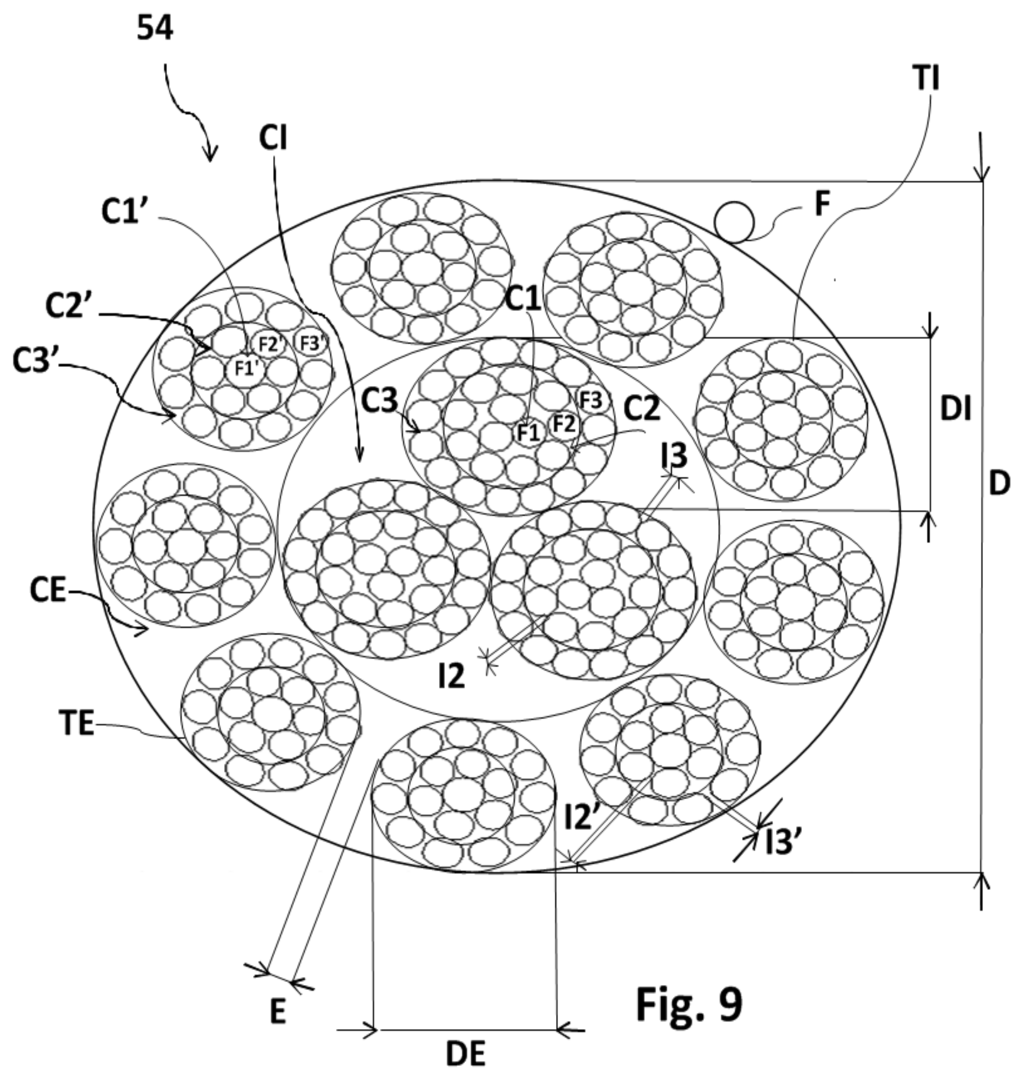


Fig. 9

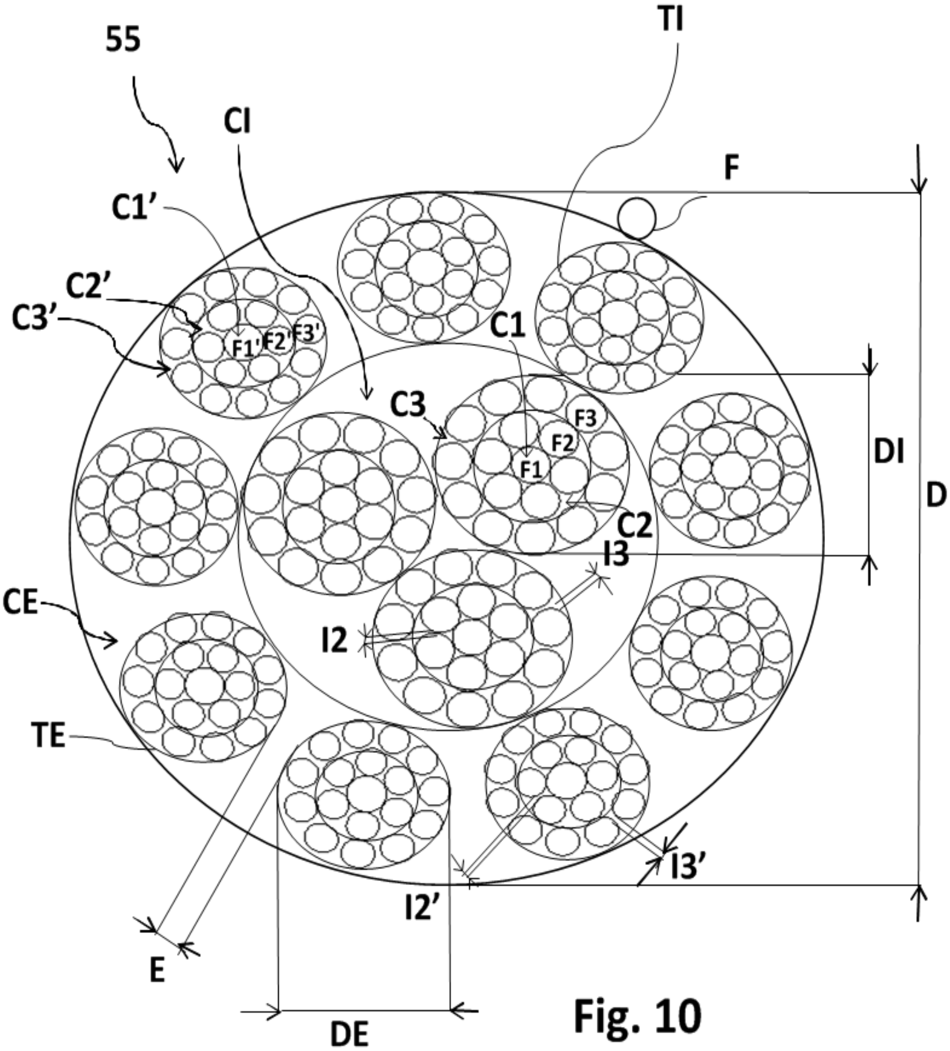


Fig. 10

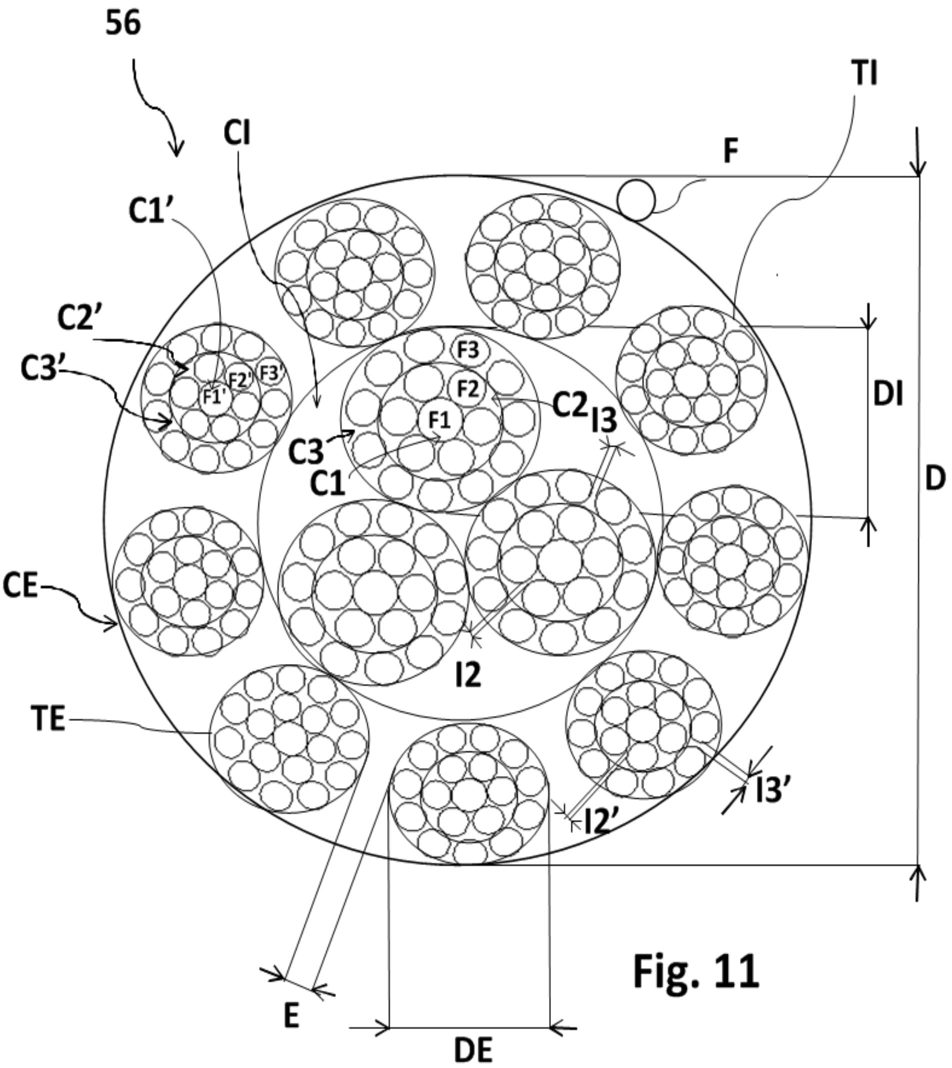


Fig. 11

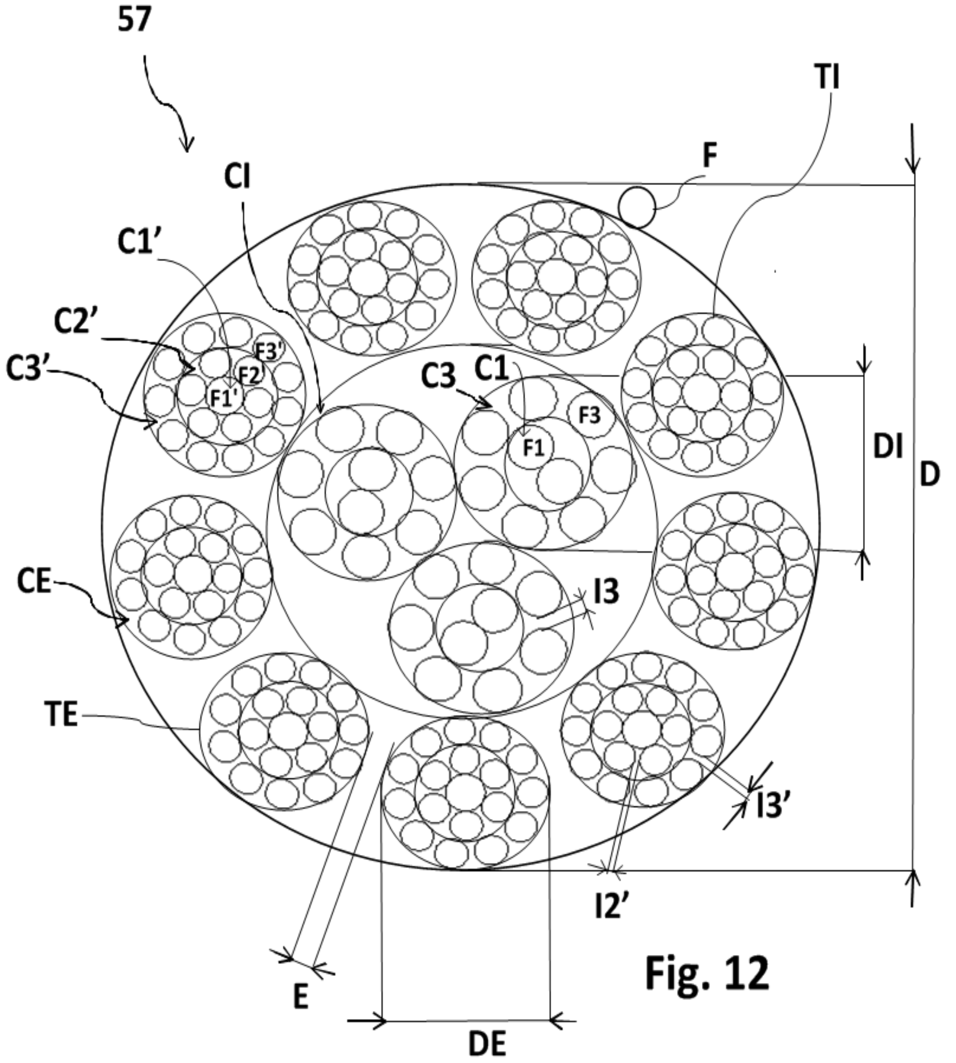


Fig. 12

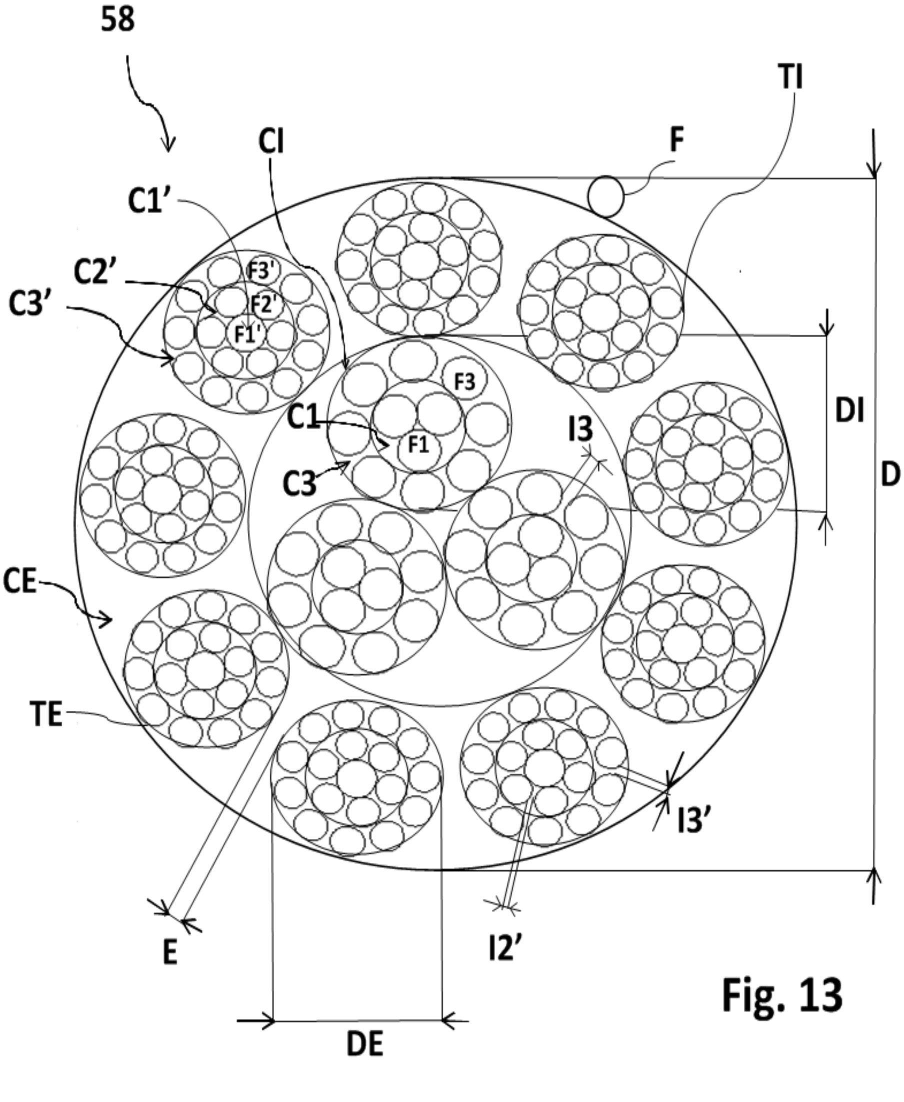


Fig. 13

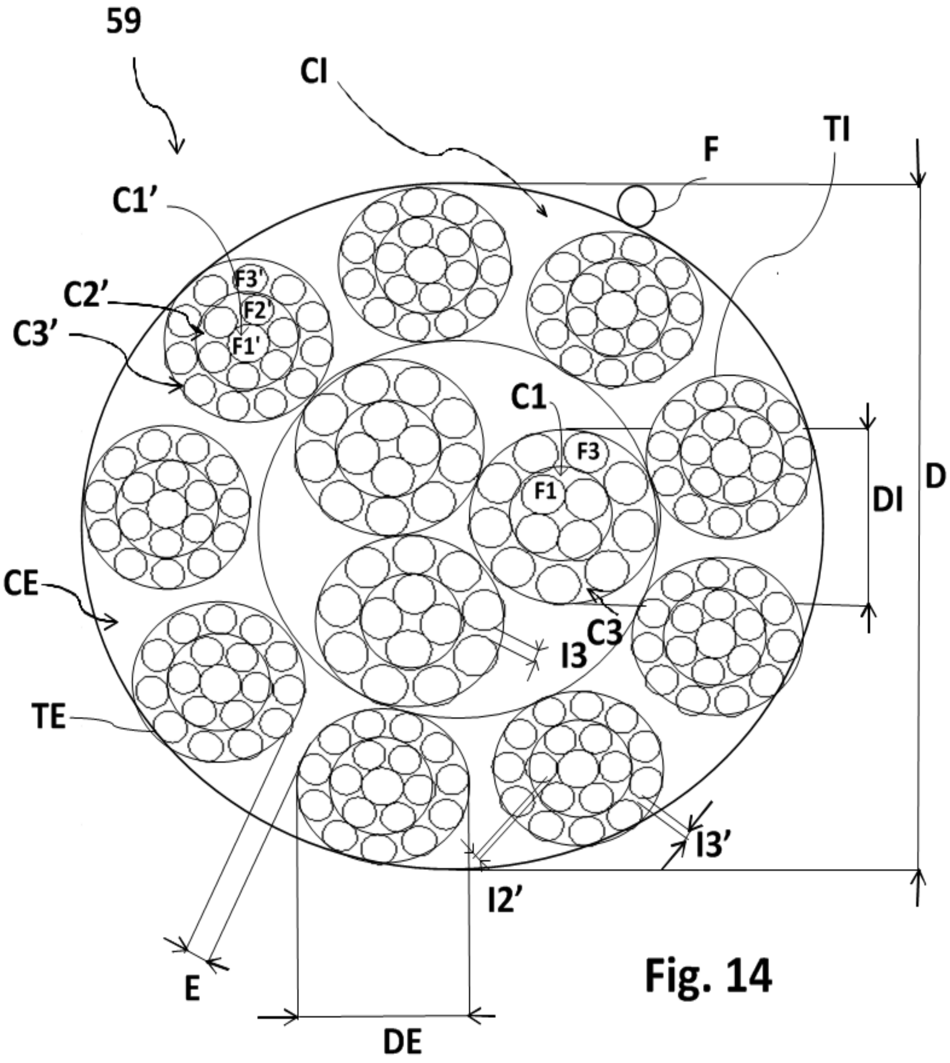


Fig. 14

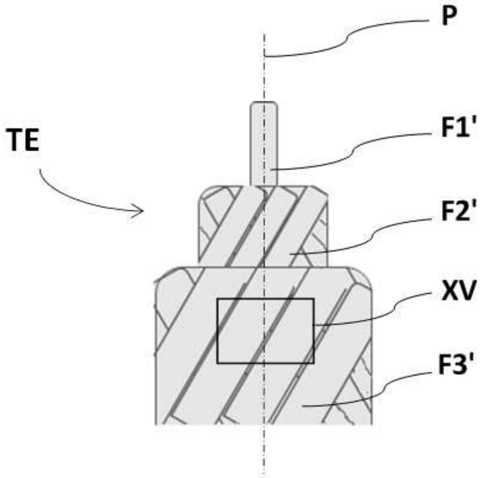


Fig. 15

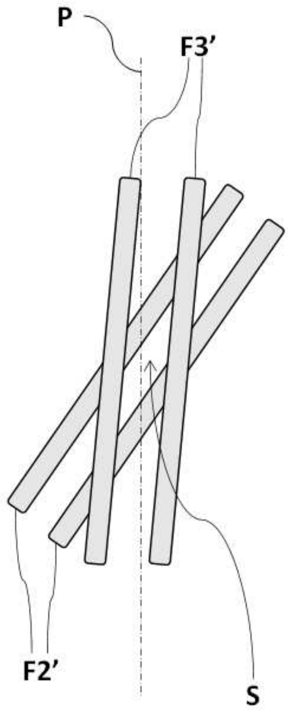


Fig. 16