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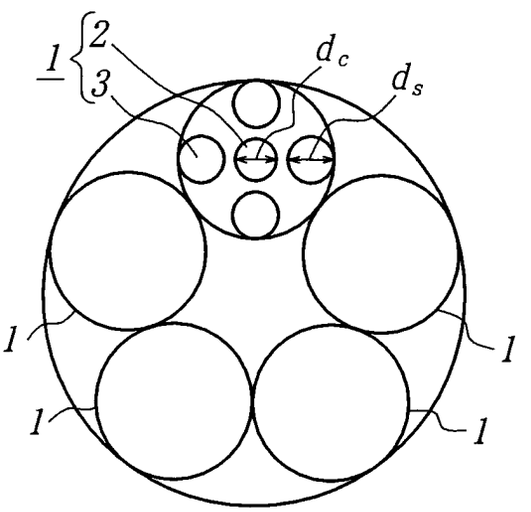
(54) Steel cords for the reinforcement of rubber articles and pneumatic tires

(57) A steel cord for the reinforcement of rubber articles is formed by twisting 4-5 strands, each strand (1) being formed by twisting a sheath (3) of 4-5 steel filaments around a core (2) of a single steel filament, wherein a ratio of diameter d_S of the steel filament constituting the sheath to diameter d_C of the steel filament constituting the core is within a range of 1.00 - 1.75, and a twisting direction of the sheath in the strand is the same as a twisting direction of the strand in the cord, and a twisting angle a of the sheath in the strand with respect to an axis of the cord, as calculated by a certain defined equation, is within a range of 30 - 52°.

FIG. 1



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Description

[0001] This invention relates to a steel cord used as a reinforcing member for rubber articles such as pneumatic tires, industrial belts and the like, and more particularly to steel cords having an excellent durability.

[0002] Pneumatic tires as a typical example of the rubber articles, particularly tires for construction vehicles are mounted onto a large-size dump truck or the like used on, for example, large-scale civil engineering site or ore working site and subjected to severer service conditions on wasteland surface under heavy loading. In general, this type of the tire has a structure that a carcass is toroidally extended between a pair of bead cores as a casing skeleton and a belt of plural layers is disposed on an outside of the carcass in a radial direction of the tire.

[0003] Since the above tire for construction vehicle is run on considerably uneven places under heavy loading, the tread is subjected to a large deformation and hence bottoms of grooves formed in the tread such as lug grooves and the like are repeatedly subjected to a large compression force. When the large compression force is applied to the bottom of the groove formed in the tread, compression strain is created in an outermost belt layer constituting the belt near to the tread. Such a compression strain is repeatedly created during the running of the tire over a long time, whereby fatigue is particularly stored in cords of the outermost belt layer to induce cord breaking. By such a cord breaking is decreased the strength of the tire, so that there is a possibility that the tire is broken in the riding on projection such as rock or the like.

[0004] It is, therefore, an object of the invention to provide steel cords capable of developing a sufficient durability even in the use under the severe condition subjected to repetitive compression deformation as well as a pneumatic tire having an excellent durability.

[0005] In the belt of the tire for construction vehicle, it is usual that the steel cord constituting the belt layer adopts so-called strand construction formed by twisting plural strands each being formed by twisting plural steel filaments. Particularly, steel cords of the strand construction having 1 x n structure, wherein the cord is formed by twisting n-strands of a layer construction formed by twisting plural steel filaments around a core of one or more steel filaments, are preferably used in the outermost belt layer constituting the belt of the tire for construction vehicle in order that the outermost belt layer is followed to the tread deformation when the tread rides on the projection during the running of the tire.

[0006] As a result of the inventors' studies, it has been confirmed that when the cords of the above strand construction are subjected to compression strain, sheath filaments of each strand are precedentially broken or a large compression strain is caused in the sheath filaments of the strand. And also, it has been confirmed that once the sheath filament is broken, the large compression strain is caused even in the remaining filaments and hence these filaments are successively broken to finally bring about the cord breaking. Furthermore, the cords of the outermost belt layer are successively broken by successively causing the above course of cord breaking in the other cords to bring about the lowering of the tire strength. When the tire is subjected to large shock at the above state in the riding over projections, there is increased a risk of causing the tire breakage.

[0007] As seen from the above, the breakage of the cord having the strand construction results from the fact that the large compression strain is caused in the sheath filament constituting the strand to precedentially break the sheath filament. For this end, the inventors have made various studies with respect to means for controlling the large compression strain produced in the sheath filament and found that it is very effective to adequately define a twisting angle of the sheath filament for improving the fatigue resistance of the cord.

[0008] Moreover, since the outermost belt layer of the belt is apt to cause corrosion due to incorporation of water passed through cut damage or the like in the tire into the inside of the cord constituting the belt layer, it is important to arrange the filaments of the cord so as to surely penetrate rubber into a gap between the filaments.

[0009] The invention is based on the above knowledge and lies in a steel cord for the reinforcement of rubber article formed by twisting 4-5 strands, each strand being formed by twisting a sheath of 4-5 steel filaments around a core of a single steel filament, characterized in that a ratio of diameter d_S of the steel filament constituting the sheath to diameter d_C of the steel filament constituting the core is within a range of 1.00-1.75, and a twisting direction of the sheath in the strand is the same as a twisting direction of the strand in the cord, and a twisting angle a of the sheath in the strand with respect to an axis of the cord as calculated by the following equation (1) is within a range of 30-52°:

$$\alpha=\alpha_1+\alpha_2-90 \quad (1)$$

wherein

$\alpha_1 = \tan^{-1}\{P_1/\pi\cdot(d_C + d_S)\}$
$\alpha_2 = \tan^{-1}\{P_2/\pi\cdot(A - d_C - 2d_S)\}$

P_1: twisting pitch of strand (mm),
P_2: twisting pitch of cord (mm),
A: cord diameter (mm).

[0010] Moreover, the twisting angle a is represented by an average in a longitudinal direction of the cord.

[0011] Further, the invention lies in a pneumatic tire comprising a carcass toroidally extended between a pair of bead cores as a casing skeleton and a belt of plural layers disposed on an outside of the carcass in a radial direction of the tire, wherein the above defined steel cords are applied to at least an outermost belt layer in the belt.

[0012] The invention will be described with reference to the accompanying drawings, wherein:

Fig. 1 is a diagrammatically section view of a steel cord having a twisting structure of 5 x (1 + 4) according to the invention; and
Fig. 2 is a diagrammatically partial section view of an embodiment of the pneumatic tire according to the invention.

[0013] In the steel cord for the reinforcement of rubber article according to the invention, when the cord has a basic structure of m x (1 + n), the number of strands m is 4 to 5 and the number of filaments n in the sheath is 4 to 5.

[0014] When the number of strands m is 3 or less, if the cord is used as a cord in an outermost belt layer constituting a belt for a large-size tire such as construction vehicle tire or the like, it is necessary to make the diameter of the filament in order to obtain a given tire strength, and as the filament diameter becomes thick, strain on the surface of the filament becomes large due to local bending between the filaments when the cord is subjected to bending deformation by riding on the projection, and hence it is easy to cause the cord breaking. On the other hand, when the number of strands m is 6 or more, it is difficult to arrange the strands on a concentric circle and the twisting property is degraded to make a breaking load of the cord small.

[0015] The reason why the core in the strand is made of a single filament is due to the fact that the number of filaments in the core is naturally 1 or 2 in order to penetrate rubber into the inside of the cord, but when two filaments are used in the core, poor twisting is apt to be caused due to the difference of twisting shrink amount between the core and the sheath in the step of producing the cord by twisting the strands.

[0016] When the diameters of the core filament and sheath filament are within the ranges defined in the invention as mentioned below, if the number of filaments n for the sheath is 3 or less, the gap between the filaments in the sheath is too large and the twisting shape become unstable, while when it is 6 or more, the gap enough to penetrate rubber can not be ensured.

[0017] A typical example of the cord having a basic structure of m x (1 + n) according to the invention is sectionally shown in Fig. 1. This cord has a twisting construction of 5 x (1 + 4) formed by twisting five strands 1 of 1+4 structure. Each strand 1 is formed by twisting four steel filaments arranged adjacent to each other as a sheath 3 around a core 2 made of a single steel filament.

[0018] In the cord according to the invention, it is necessary that the twisting direction of m strands or the twisting direction of the cord is the same as the twisting direction of sheath filaments in the strand or the twisting direction of the strand. Because, when the twisting direction of the cord is different from the twisting direction of the strand, the filaments between the strands contact at a point and hence the twisting loss or the lowering ratio of the breaking load of the cord when a sum of breaking loads of the filaments is 100% becomes large, and as a result, even when the breaking load of the cord is made large, it can not be developed.

[0019] In the cord according to the invention, the ratio d_S/d_C of diameter of the filament d_S constituting the sheath to diameter of the filament d_C constituting the core is within a range of 1.00-1.75, preferably 1.5-1.75. When the ratio d_S/d_C is less than 1.00, the core is protruded from the strand due to the difference of the twisting shrink amount between the core and the sheath in the step of producing the cord by twisting the strands, while when the ratio d_S/d_C exceeds 1.75, the arrangement of the sheath filaments is eccentric and the twisting property in the cord becomes ununiform.

[0020] Finally, it is important that the twisting angle a of the sheath in each strand with respect to the axis of the cord as calculated by the equation (1) is within a range of 30-52°, preferably 35-45°. When the twisting angle a is less than 30°, the twisting pitch should be made considerably short, and hence the filament is unavoidably subjected to strong work in the production step of the cord and troubles such as breakage and the like are apt to be caused, while when the twisting angle a exceeds 52°, the fatigue life of the cord becomes shorter than that of steel cord of $4 \times (1 + 5 \times 0.25)$ frequently used in an outermost layer of the belt in the tire for construction vehicle and hence there is a risk of causing tire breakage in a short time.

[0021] Then, the cords according to the invention are used for the reinforcement of the carcass by arranging a plurality of the cords side by side and embedding in a rubber sheet to form a rubberized belt layer for a belt of the tire. As the structure of the tire, it is sufficient to have the same as in the conventional pneumatic tire for the construction vehicle. For example, the belt structure shown in Fig. 2 is advantageously adaptable. In Fig. 2, numeral 4 is a carcass toroidally extending between a pair of bead cores (not shown) and turned around the bead core from an inside of the tire toward

the outside thereof, numeral 5 a belt disposed on the carcass 4 and comprised of 4-6 belt layers, a belt of 6 belt layers in the illustrated embodiment, numeral 6 a tread disposed on the belt, and numeral 7 a lug groove.

[0022] The belt 5 has a structure that 6 belt layers each containing many steel cords arranged at a certain inclination angle, preferably angle of 50-80° with respect to the cord in the carcass 4 are lain one upon the other so as to cross the cords of these layers with each other. The cords according to the invention are applied to at least an outermost belt layer of the belt.

[0023] The following examples are given in illustration of the invention and are not intended as limitations thereof.

[0024] At first, the durability is measured with respect to steel cords having a construction shown in Table 1. That is, a fatigue test of repeatedly causing a given compression strain in a direction of cord axis is carried out with respect to each of these cords to measure the repetitive number of compression strain until the breakage of any one of the filaments constituting the cord. The measured results are also shown in Table 1.

[0025] Further, each of the steel cords shown in Table 1 is used in an outermost belt layer among 6 belt layers constituting a belt of an off-the-road radial tire having a tire size of 40.00R57 at an end count of 13.1 cords/5 cm. Moreover, steel cords of $7 \times (3 + 9 \times 0.32$ mm) are used in two middle belt layers among the remaining five belt layers and steel cords of $7 \times (3 + 9 \times 0.23$ mm) are used in three inner belt layers. Each of the tires is inflated under an inner pressure of 7.0 kgf/cm^2 and actually run on road till the tread is completely worn. Thereafter, the tire is cut to take out 50 cords and the number of broken filaments is measured to obtain results as shown in Table 1 wherein the tire durability is represented by an index on the basis that the conventional example is 100.

Table 1

	Conventional Example	Comparative Example 1	Comparative Example 2	Example 1	Example 2
Cord construction	4 x (1+5)	4 x (1+4)	5 x (1+4)	5 x (1+4)	5 x (1+4)
Filament diameter in core d_C (mm)	0.25	0.18	0.21	0.21	0.21
Filament diameter in sheath d_S (mm)	0.25	0.285	0.34	0.34	0.34
d_S/d_C	1.00	1.58	1.62	1.62	1.62
Twisting pitch of strand P_1 (mm)	5.02	4.98	6.83	5.24	5.02
Twisting pitch in cord P_2 (mm)	11.26	8.13	12.20	12.25	11.26
Twisting direction	S/S/S	Z/Z/Z	Z/Z/Z	Z/Z/Z	Z/Z/Z
Cord diameter A (mm)	1.687	1.702	2.201	2.555	2.658
Twisting angle of sheath with respect to axis of strand α_1	72.5°	73.6°	75.8°	71.7°	71.0°
Twisting angle of strand with respect to axis of cord α_2	70.0°	69.9°	71.4°	66.9°	63.7°
Twisting angle of sheath with respect to axis of cord a	52.5°	53.5°	57.2°	48.6°	44.7°
Compression strain: 4.0%	34175	39678	4995	286730	255000

Table 1 (continued)

	Conventional Example	Comparative Example 1	Comparative Example 2	Example 1	Example 2
Compression strain: -6.0% *	7875	8048	3945	34315	41175
Compression strain: -8.0% *	2993	1974	1985	10640	16763
Evaluation of cord durability**	-	Δ	×	○	○
Evaluation of tire durability	100	103	66	no breakage	no breakage

*: Repetitive number until the breakage of filament (times)

**: Superiority or inferiority with respect to conventional example

○ superior

Δ equal

× inferior

[0026] According to the invention, there can be provided steel cords capable of developing the sufficient durability even in the use under severe condition repeatedly subjected to compression deformation. Therefore, when such steel cords are applied to at least an outermost belt layer in a belt of a tire, the durability against compression strain particularly concentrated in the groove bottom of the tread is considerably improved and hence it is possible to provide a tire having an excellent tire durability.

Claims

1. A steel cord for the reinforcement of rubber articles formed by twisting 4-5 strands, each strand (1) being formed by twisting a sheath (3) of 4-5 steel filaments around a core (2) of a single steel filament, characterized in that a ratio of diameter d_S of the steel filament constituting the sheath to diameter d_C of the steel filament constituting the core is within a range of 1.00-1.75, and a twisting direction of the sheath in the strand is the same as a twisting direction of the strand in the cord, and a twisting angle a of the sheath in the strand with respect to an axis of the cord as calculated by the following equation (1) is within a range of 30-52°:

$$\alpha = \alpha_1 + \alpha_2 - 90 \quad (1)$$

wherein

$\alpha_1 = \tan^{-1} \{P_1/\pi \cdot (d_C + d_S)\}$
$\alpha_2 = \tan^{-1} \{P_2/\pi \cdot (A - d_C - 2d_S)\}$
P_1: twisting pitch of strand (mm),
P_2 : twisting pitch of cord (mm),
A: cord diameter (mm).

2. A steel cord as claimed in claim 1, characterized in that the said ratio d_S/d_C of diameter of the filament d_S constituting the sheath (3) to diameter of the filament dc constituting the core (2) is within a range of1.5- 1.75.

3. A steel cord as claimed in claim 1 or 2, characterized in that the said twisting angle α as calculated by the equation (1) is 35 - 45°.

4. A pneumatic tire comprising a carcass (4) toroidally extended between a pair of bead cores as a casing skeleton and a belt (5) of plural layers disposed on an outside of the carcass in a radial direction of the tire, characterized in that steel cords as claimed in any of claims 1 to 3 are applied to at least an outermost belt layer in the belt.

FIG. 1

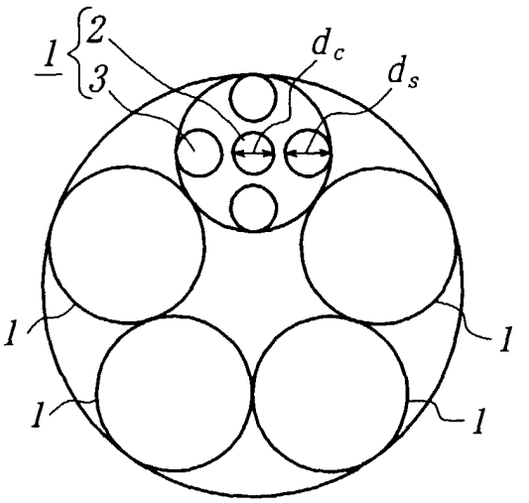

FIG. 2