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(54) Flat cord for the reinforcement of pneumatic tires.

(57) A cord with an elongated cross-section and adapted for the reinforcement of plies in a pneumatic tire, comprises a layer of steel filaments that are wound around an untwisted monofilament core, the monofilament core having a tensile strength of at least 1800 N/mm^2, an elongation at rupture of at least 2 per cent and a breadth-to-thickness ratio of at least 2. This structure combines the properties of flat wires with those of steel cords having substantially round cross-sections.

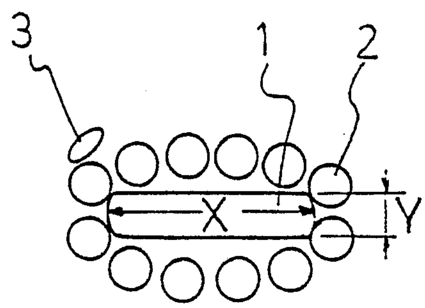

FIG.1

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FLAT CORD FOR THE REINFORCEMENT OF PNEUMATIC TIRES

This invention relates to cords adapted for the reinforcement of pneumatic tires and more particularly to cords for use as reinforcing elements for the carcass and the belt structure of pneumatic radial tires, especially pneumatic radial truck tires.

Pneumatic vehicle tires are generally reinforced with steel cords having substantailly round cross-sections. A plurality of single filaments or strands are twisted together to form such a cord. By substantially round cross-sections is meant cross-sections where the enveloping curve is approximatively a circle.

Flat wires for the reinforcement of pneumatic tires have an improved lateral stiffness, require a thinner rubber ply, have a better compression performance and a greater elongation at break than cords having substantially round cross-sections ; however the latter have a better tensile strength and better fatigue performance than flat wires.

Attempts have previously been made to combine the properties of the above-mentioned structures with two or three single filaments or strands, lying in one plane in contact with each other, forming the core and being wound around by a plurality of single wires (DE-A-2.941.541). These cords have a poor twisting stability and the breadth-to-thickness ration of the core of these cords is limited to a maximum of 3. The twisting stability can be improved by using only strands for the core and by laying the strands of the core in alternating directions (FR-A-2.472.040), but this complicates the construction, does not provide complete twisting stability and does not allow breadth to thickness ratios greater than 3.

It is an object of the invention to avoid the drawbacks of the prior art and to provide a cord structure that combines the advantages of flat wire with the advantages of steel cords having substantially round cross-sections.

Thus according to one feature the invention provides a cord, with an elongated cross-section, adapted for the reinforcement of plies in a pneumatic tire, comprising a layer of steel filaments that are wound around a core, the core having a tensile strength of at least 1800 N/mm^2 and an elongation at rupture of at least 2 per cent, characterized in that the core is an untwisted monofilament which has an elongated cross-section, preferably a substantially rectangular cross-section, and a breadth-to-thickness ratio of at least 2.

By an elongated cross-section is meant a cross-section that is not round and where the longest axis is at least 1.5 times the length of the shortest axis.

By plies in a pneumatic tire is meant the carcass and the belt reinforcement structure.

By a layer of steel filaments around a core is meant a plurality of filaments disposed side by side so as to form around said core a sheath of a thickness equal to the diameter of a filament.

By a substantially rectangular cross-section is meant a cross-section with two rectilinear parallel long sides. The extremities of these long sides are connected to each other by two short sides, which are not necessarily rectilinear. Rectangular cross-sections with rounded edges are also substantailly rectangular cross-sections.

The longest cross-sectional dimension (for a rectilinear cross-section), the maximum distance between the two short sides, measured along a line parallel to the long sides, is called the breadth, the minimum cross-sectional dimension (for a rectilinear cross-section the distance between the two long sides) is called the thickness.

The breadth-to-thickness ratio of the monofilament core is greater than 2, and, by preference, lies between 4 and 10. A minimum breadth-to-thickness ratio is necessary to keep the cord in place during its manufacturing process. The maximum ratio 10 is determined by stability considerations.

The monofilament core has an elongation at rupture of at least 2 per cent, and, by preference, lies between 2.5 and 3.3 per cent. A core with an elongation at rupture of less than 2 per cent is too crisp. The monofilament core has a tensile strength of at least 1800 N/mm^2 in order to give the whole cord a sufficient strength.

The monofilament core can be preferably made of steel.

"A cord adapted for the reinforcement in a pneumatic tire" means that the steel filaments of the layer conveniently have a carbon content between 0.70 and 0.90 per cent by weight, a tensile strength between 2700 N/mm^2 and 3500 N/mm^2 or even more, by preference between 2900 and 3400 N/mm^2, and a coating that favours the adhesion to rubber, for example brass. Said steel filaments can have by preference a round cross-section with a diameter suitably between 0.12 and 0.40 mm, by preference between 0.175 and 0.300 mm, but they can also have a substantially rectangular cross-section with a breadth-to-thickness ratio between 1.3 and 4. If said steel filaments have a substantially rectangular cross-section, then the long sides of the cross-section of the steel filaments will lie parallel to the nearest touching line of the cross-section of the core.

The pitch of the steel filaments is expressed as p, the axial distance required to make a 360 degree revolution of a steel filament of the layer. If the steel filaments are wound in the S-direction p is positive, if the steel filaments are wound in the Z-direction p is negative.

The layer of steel filaments may be surrounded by a second layer of steel filaments. The pitch of the steel filaments in the second layer may be the same as, or different from, the pitch of the first layer.

A steel filament can be wrapped helicoidally around the layer (or outer layer where there is more than one layer) of steel filaments with a pitch q different from the pitch of the steel filaments in the layer (or outer layer).

The wrapped helicoid filament is not necessarily a round steel filament with a high carbon content, but can also be a filament with a carbon content of e.g. less than 0.20 per cent by weight, or a filament with a flat or oval shape.

The invention provides a "hybrid" structure : elements having different cross-sections are combined. The core has an elongated and substantially rectangular cross-section. The steel filaments have a round cross-section or a substantially rectangular cross-section with a breadth-to-thickness ratio which is smaller than the breadth-to-thickness ratio of the core. The fatigue resistance of the steel filaments is greater than that of the core ; however, in a cord adapted for the reinforcement of a pneumatic tire the core requires less fatigue resistance than the layers. Thus the fatigue performance of the entire cord is not weakened by the comparatively small fatigue resistance of the core.

The steel filaments in the layer or in the layers around the core have, by preference, line contacts with the adjoining filaments. This has the advantage that loads are spread over all the filaments.

The distance from the steel filaments in the layer or in the layers to the central long axis of the structure is small in comparison with the distance from the steel filaments to the center in steel cords having a substantially round cross-section and having the same cross-section surface as the cord of the invention. This results in smaller tensile and compressive tensions in the filaments of the layer of the cord according to the invention.

The proposed structure is also flexible to deformations perpendicular to the plane of the core. This means that the stiffness in the plane perpendicular to the plane of the core is small. Due to the elongated and preferably substantially rectangular cross-section of the core, the stiffness in the plane of the core, however, is great. Consequently the cord according to the invention has a stiffness which is advantageous for its use in pneumatic radial tires.

The cords according to the invention may be used in the carcass or in the belt structure of pneumatic radial tires, and are particularly useful for use in truck tires. In both applications the long side of the cross-section of the cord is parallel to the surface of the tire.

Referring to the accompanying drawings,

Figure 1 and Figure 2 illustrate the cross-sections of two steel cords according to the invention ;
Figure 3 is a side view of a cord according to the invention;
Figure 4 illustrates apparatus for making a cord according to the invention ;
Figure 5 illustrates the cross-section of a forming die on the plane V-V of Figure 4 ;
Figure 6 illustrates the cross-section of straightener pulleys on the plane VI-VI of Figure 4.

Figure 1 illustrates a cross-section of a cord according to the invention. The monofilament core (1) is made of steel. It has a breadth X of 1 mm and a thickness Y of 0.25 mm. The breadth-to-thickness ratio X/Y is 4. Twelve steel filaments (2) with a diameter of 0.25 mm are wound with pitch p of 18 mm in the S-direction around the monofilament core (1). A steel filament (3) with an original diameter of 0.15 mm is wrapped around the layer of steel filaments (2) in the Z-direction with a pitch q of -3.5 mm. The above structure can be notated as :

[1x0.25] + 12x0.25 + 1x0.15 ; = /18 S / 3.5 Z

where the dimensions of the monofilament core are given inside the rectangular brackets. The "="-sign corresponds to the monofilament core and means that the monofilament core is not twisted.

Figure 2 corresponds to :

[1.3x0.22] + 14x0.25 + 1x0.15 ; = /18 S / 3.5 Z.

Other examples are ;

[1.1x0.22] + 14x0.22 + 1x0.15 ; = /16 S / 3.5 Z.

[1.25x0.25] + 14x0.25 + 1x0.15 ; = /18 S / 3.5 Z.

The last example has particularly good rubber penetration.

Figure 4 illustrates apparatus for manufacturing a cord according to the invention.

The steel filaments (2) are wound around the monofilament core (1) by a tubular stranding machine (4) at the forming die (5). A steel filament (3) is wrapped around the cord at (6). The cord then passes through a pair of grooved rollers (7), and, eventually, through a straightener (8), before it is wound up on a drum (9).

The monofilament core (1) of the cord is supplied by a spool (41) with a horizontal axle. The steel filaments (2) of the layer have a round cross-section or, at least, have a breadth-to-thickness ratio that is lower than the breadth-to-thickness ration of the monofilament core. Consequently the steel filaments (2) need not be delivered from spools with horizontal axles. The delivering spools (42) of the steel filaments (2) may have vertical axles. The forming die (5) must have a profile that is adapted to the profile of the cross-section of the steel cord to be formed. Figurae 5 illustrates the cross-section of the forming die (5). The grooves of the rollers (7) and of the rollers (81) of the straightener (8) also have an adapted profile as illustrated in Figure 6.

The cord according to the invention is pressed together in the rollers (7). If the cord is provided with a filament (3) made of low carbon steel, the rollers (7) subject the filament (3) to plastic deformation, as can be seen on Figures 1 and 2. A straightener (8) can be used to diminish the torsion of the steel cord. Such a straightener is disclosed in GB patent 2.092.629.

Normally such a straightener has two sets of rollers situated in considerably different planes. This is the case with cables having substantially round cross-sections. Because of the elongated cross-section of the cord according to the invention only one set of rollers is used. The rollers are so situated that their profile is parallel to the long central axis of the cord according to the invention.It can be easily understood that the greater the breadth-to-thickness ratio of the cord the more easily the cord can be kept in a horizontal plane and the more easily torsions can be avoided.

The performance of the steel cord according to Figure 1 has been examined and compared to the performance of existing steel cords for truck tire reinforcement. The structure [1.00x0.25] + 12x0.25 + 1x0.15 = /18 S / 3.5 Z (I) was compared to the following structures :

1. (3 + 9 + 15) x 0.22 + 1x0.15 ; 6.3S/12.5S/18Z/3.5S
2. compact cord 27x0.22 + 1x0.15 25S/3.5Z
3. compact cord 12x0.25 + 1x0.15 12.5S/5Z
4. 7x4x0.175 + 11x0.15 10S/20Z/3.5S

<u>Tensile test</u>

The tensile strength is the breaking load of a filament per unit of unstrained cross-sectional area expressed in Newtons per square millimetre. The elongation at rupture is the increase in length, which results from subjecting the cord to the breaking force in a tensile test and is expressed as a percentage of the initial length of the cord measured under a defined pre-tension.

<u>Compression test</u>

To measure the compression performance of a cord, the cord is embedded in the center of a rubber cylinder with a diameter of 30 mm and a height of 48.25 mm and submitted to an axial compression force. A force versus deformation diagram is recorded. The compression modulus is defined as the secant modulus at a specified axial stress and can be derived from the diagram. The compression stress is obtained by the equation

$$S_k = \frac{P_{tot} - P_{rubber}}{S_{eff}}$$

where $P_{rubber} = 0.4825\, w_k\, V_r$ (N)

S_k = compression stress (N/mm^2)

P_{tot} = total compressive load of the sample at deformation w_k (N)

V_r = rubber spring constant (N/mm)

S_{eff} = cross-sectional area of the cord without the wrapped steel filament (mm^2)

w_k = deformation at instability or at maximum load sustained by the cord (%)

Impact test

A transverse impact test method for (steel) cord was developed to determine the resistance to cutting with a view to their use as tire belt reinforcement (puncture resistance). The test consists in a modified "charpy test" adapted with a sharp knife. The sample is a rubber cylinder with a 3 mm diameter, reinforced in the center with a steel cord. The total amount of absorbed energy is measured and is expressed in energy per unit cross-sectional area (Joule/mm^2).

A more complete description of these tests can be found in the paper of Bourgois L., "Survey of Mechanical Properties of Steel Cord and related Test Methods", Tire Reinforcement and Tire Performance, ASTM STP694, (R.A. Fleming and D.I. Livingstone, Eds., American Society for Testing and Materials, 1979, pp.19-46.

The results obtained in each test for the cord according to the invention and the four comparison cords are summarized in Table 1 :

Table 1

	I	1	2	3	4
mass per length (g/m)	6.85	8.45	8.30	4.85	5.60
tensile strength (N/mm^2)	2590	2645	2825	3145	2740
elongation at rupture (%)	3.4	2.0	2.2	2.5	2.0
compression modulus (kN/mm^2)	128	71	44	40	78
compression stress (N/mm^2)	380	140	140	225	200
impact energy (J/mm^2)	9.81	6.13	8.4	10.2	7.0

I = cord according to the invention.

As can be seen from Table 1 the tensile strength of the cord according to the invention is lower than the tensile strength of existing steel cords 1 - 4 with substantially round cross-sections but greater than the tensile strength of flat wires with substantially rectangular cross-section, the tensile strength of flat steel wires lying usually between 1800 N/mm^2 and 2400 N/mm^2.

The elongation at rupture of the cord according to the invention is equal or greater than the elongation at rupture of steel cords 1 to 4.

The cord according to the invention has better compression performance than the steel cords 1 to 4, as can be seen from the higher compression modulus and compression stress.

The cord according to the invention is comparable with the existing steel cords 1-4 regarding impact properties, in spite of a lower tensile strength.

It is clear that the invention is not limited to specific examples as herein described and illustrated, but extends to all structures and materials of steel cords in which the teaching of the present invention is used.

Claims

1. A cord, with an elongated cross-section, adapted for the reinforcement of plies in a pneumatic tire, comprising a layer of steel filaments that are wound around a core, the core having a tensile strength of at least 1800 N/mm^2 and an elongation at rupture of at least 2 per cent, characterized in that the core is an untwisted monofilament which has an elongated cross-section and a breadth-to-thickness ratio of at least 2.

2. A cord according to claim 1, characterized in that the core has a substantially rectangular cross-section.

3. A cord according to claim 1 or 2, characterized by an elongation at rupture between 2.5 and 3.3 per cent.

4. A cord according to claim 1 to 3, characterized by a breadth-to-thickness ratio between 4 and 10.

5. A cord according to claims 1 to 4, characterized in that the monofilament core is made of steel.

6. A cord according to any of claims 1 to 5, characterized in that the filaments in the layer around the core have a round cross-section.

7. A cord according to any of claims 1 to 5, characterized in that the filaments in the layer around the core have a substantially rectangular cross-section with a breadth-to-thickness ratio between 1.3 and 4.

8. A cord according to any of claims 1 to 7, characterized in that the layer of steel filaments is surrounded by a second layer of steel filaments.

9. A cord according to any of claims 1 to 7, characterized in that a steel filament is wrapped helicoidally around the layer (or outer layer when there is more than one layer) of steel filaments with a pitch different from the pitch of the steel filaments in the layer (or outer layer).

10. A cord according to claim 9, characterized in that the helicoid steel filament that is wrapped around the layer (or outer layer) has a carbon content of less than 0.20 per cent by weight.

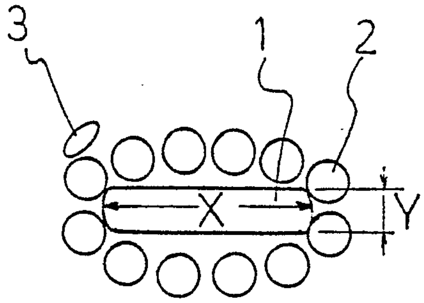

FIG.1

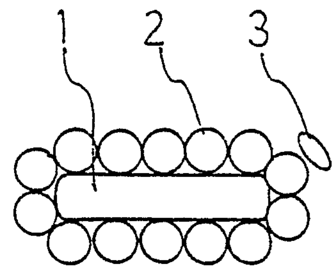

FIG. 2

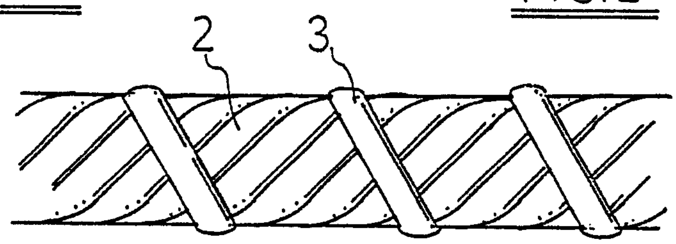

FIG. 3

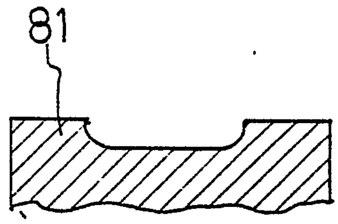

FIG.6

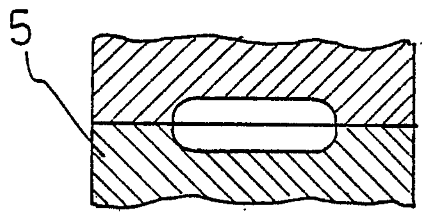

FIG.5

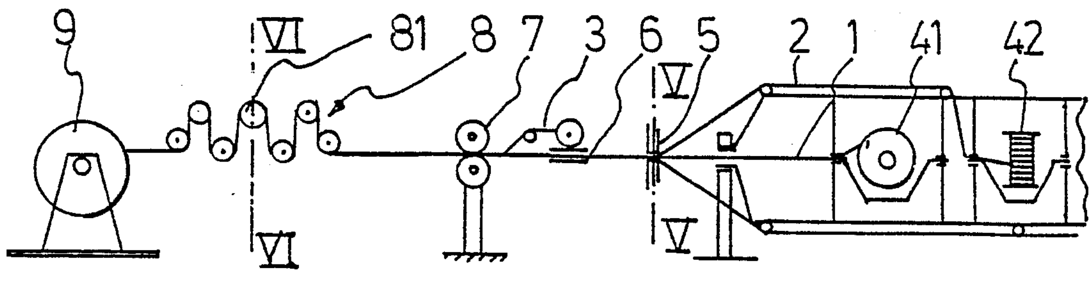

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number

EP 87 20 1615

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
D,Y	DE-A-2 941 541 (CONTINENTAL GUMMI-WERKE AG) * Claims *	1-6	D 07 B 1/06 B 60 C 9/00
Y A	FR-A-2 369 106 (HAHN & CO. KG) * Page 3, lines 35-38; page 4, lines 1-7 *	1-6 8	
A	US-A-1 774 748 (GORE) * Whole document *	1-7	
A	RESEARCH DISCLOSURE, no. 184, August 1979, pages 430,431, no. 18441, Industrial opportunities ltd, homewell havant, Hampshire, GB; "Rubber articles reinforced with high tensile steel cord"	1,3	
D,A	FR-A-2 472 040 (BRIDGESTONE TIRE CO. LTD) * Page 4, lines 9-13; page 2, lines 13-29; figures *	1,7,9	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	JP-U-53 070 002 * Figure 4 *	1-6,9	D 07 B B 60 C
A	EP-A-0 125 517 (AKZO GmbH) * Page 3, lines 3-26 *	9,10	
A	EP-A-0 125 518 (AKZO GmbH) * Claims 1,2,14-19 *	1-6	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07-12-1987	D HULSTER E.W.F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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