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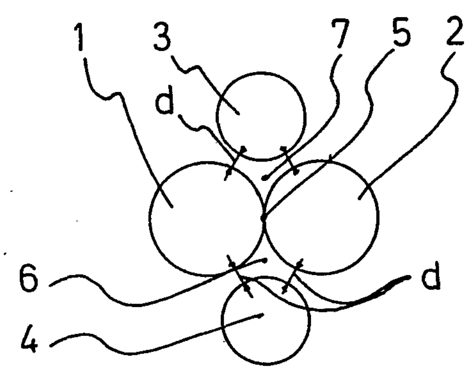
(54) **Steel cord construction.**

(57) A steel cord for the reinforcement of resilient articles comprises a bundle of four wires twisted together with the same pitch, a first pair 1, 2 of said wires having a substantially similar diameter, a second pair 3, 4 of said wires each having a diameter not greater than the average diameter of the first pair 1, 2, a wire of one pair being adjacent a wire of the other pair along the circumference of the bundle, and in a stretched condition of the cord, the wires of the first pair 1, 2 are tightly twisted together so as to touch along the axis 5 while each wire of the second pair 3, 4 is at a spacing d from the circumferentially adjacent wires of the first pair.



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STEEL CORD CONSTRUCTION

The invention relates to a steel cord for reinforcement of resilient articles, such as rubber vehicle tyres. Such cord will generally be a cord with wires having a diameter ranging from 0.03 to 0.80 mm, in general in the range from 0.14 to 0.40 mm, and the steel being in general carbon steel (preferably 0.65 to 0.95 % carbon) in its ferritic state, having a tensile strength of at least 2000 N/mm^2, in some high-tensile applications more than 3000 N/mm^2, and an elongation at rupture of at least 1 %, preferably about 2 %. The cord wires will generally further comprise, in order to obtain the necessary rubber adherability for reinforcement purposes, a rubber adherable coating, such as copper, zinc, brass or ternary brass alloy, or a combination thereof, the coating having a thickness ranging from 0.05 to 0.40 micron, preferably from 0.12 to 0.22 micron. The coating can also be present in the form of a thin film of chemical primer material for ensuring good rubber penetration and adhesion.

In this respect, cord constructions are known in the form of a bundle of four wires, twisted together with a same pitch. This construction is most frequently used in a wire diameter range of 0.14 to 0.40 mm, preferably 0.19 to 0.31 mm, with a twist pitch between 35 and 100 times the wire diameter, for use in truck or passenger car tyres.

Such cord was normally made in a closed 4x1-configuration, i.e. a cross-sectional configuration where the centres of the wires are arranged in the corners of a square with a side equal to the wire diameter. This cord however leaves a hollow cavity inside, which is not filled up with rubber during vulcanizing, and moist can easily travel lengthwise through this cavity thereby provoking corrosion. For that reason it was proposed to make an open 4x1-configuration, where the centres of the wires are again arranged in the corners of a square, or thereabout, this square having a side larger than the wire diameter so that the wires are kept apart from each other and make the hollow cavity inside accessible for the penetrating rubber during vulcanization. This cord is however difficult to introduce into the rubber during vulcanization. During its introduction indeed, the open cord comes under tension and is elongated so that the wires are drawn together into a closed cord. For this reason, a closed 2+2-construction was further proposed as an alternative, comprising two strands twisted around each other with a certain pitch p, the first strand comprising two wires, helicoidally deformed and running side by side in parallel with each other without twist around each other, and the second strand comprising two wires twisted around each other with the same pitch p with which this strand is twisted around the first strand. This cord, although showing good rubber penetration, is however less good for applications where extra good fatigue resistance is aimed at, and, as is important for fuel consumption, also low tyre weight. Indeed this cord is rather wide, because it is not particularly round, so that then less cords can be laid side by side in a ply, and furthermore the ply is then required to be thicker.

It appears consequently that low tyre weight, good fatigue resistance and good rubber penetration for corrosion resistance, are difficult to reconcile with each other in one and the same cord. And it is therefore an object of the present invention to procure an alternative cord construction, where these three characteristics are all three sufficiently good.

According to the invention, there is provided a steel cord for the reinforcement of resilient articles, in the form of a bundle of four wires twisted together with the same pitch, a first pair of said wires comprising two wires of substantially similar diameter, a second pair of said wires each having a diameter not greater than the average diameter of the first pair, a wire of one pair being succeeded by a wire of the other pair along the circumference of the bundle, and is characterized by the fact that, in a stretched condition of the cord, the wires of the first pair are tightly twisted together while each wire of the second pair is spaced from the wires of the first pair.

Preferably, the diameter of each of said wires of the second pair is smaller than the average diameter of the first pair, e.g. in a range of 0.6 to 0.85 of said average diameter.

In other words, the wires of the first pair are twisted as tightly as possible, whereas the wires of the second pair are loosely twisted and preferably thinner. When it is necessary to introduce such a cord in the stretched condition into vulcanizing rubber, the cord can hardly elongate any further by tightening its structure because the wires of the first pair are practically completely tight. But in such a stretched condition the two wires of the second pair are loosely twisted and keep a distance, so that rubber penetration is ensured. Furthermore this cord construction shows a sufficient roundness, and these changes in geometry appear not to be at the expense of fatigue resistance, as measured by the Hunter fatigue test.

The two wires of the first pair mustnot necessarily have the same diameter. It is sufficient that the diameters be "substantially similar", i.e. in the case of different diameter, the thicker one mustnot be more than 120 % of the diameter of the other one, preferably not more than 110 %.

Although it is not essential, it is preferred that, in free condition, the wires of the first pair are as tight as possible, so that the structural elongation (i.e. the percentage ε of elongation due to the tightening of the structure when passing from the straight unstretched to the stretched condition) be at any rate not more than ε_m , as given by the formula

$$\varepsilon_m (\%) = 34.5 \left(\frac{\pi D_a}{p}\right)^2$$

or preferably, as given by the formula

$$\varepsilon_m (\%) = 16.125 \left(\frac{\pi D_a}{p}\right)^2$$

in which D_a is the average diameter of these two wires and p the twist pitch.

For a geometrically regular twist along the length, this corresponds to saying that the distance between the two wires of the first pair in straight unstretched condition be not more than 0.3, preferably not more than 0.15 times the average diameter of the two wires.

Preferably, in the stretched condition of the cord, the spacing of each wire from the wires of the second pair, the first pair is in a range from 0.05 to 0.30 of said average diameter of the first pair. The lower limit is set by a sufficient guarantee that rubber penetration will be ensured, and the upper limit by the necessity that under normal loads, the two loose wires participate substantially in taking up these loads. As the cord is not precisely geometrically regular along the length of the cord, this spacing means the average spacing along the length.

The cord is preferably used in its dimension range usable for light truck and passenger car tyres, i.e. with an average diameter of the first pair of wires in the range of 0.14 to 0.40 mm and with a twist pitch ranging from 35 to 80 times the average diameter, as an alternative of the 4x1 cords with 0.25 to 0.38 mm wire diameter.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which :

Figure 1 is a cross-sectional view of a cord according to the invention, in stretched condition ;

Figure 2 shows a twisting machine for making the cord according to the invention.

Figure 3 shows the predeformation part of the twisting machine.

Figure 1 shows a cross-sectional configuration of the cord according to the invention, and in stretched condition. It comprises a first pair of steel wires 1 and 2 of a diameter of 0.28 mm and a second pair of steel wires 3 and 4 of a diameter of 0.22 mm. The four wires form a bundle of four wires twisted together with a same pitch of 14 mm. In this stretched condition, the wires 1 and 2 are in contact with each other along a contact line, which runs in an axial direction of the cord, perpendicular to the plane of the drawing, through contact point 5 between the two cross-sections. At either side of this contact line, the wires leave two opposite V-shaped or wedge-shaped recesses 6, respectively 7. These wedge shapes run helicoidally with the pitch of the wires, along the contact line. The two other wires 3 and 4 fit these wedge shapes and run helicoidally along these recesses without contacting the wires 1 and 2, but keeping a distance d of about 0.04 mm from each of these wires, this distance being an average over the length of the cord. A wire of the pair 1 and 2 therefore alternates with a wire of the pair 3 and 4 along the circumference of the cord.

In a non-stretched condition, it is not necessary that the wires of the first pair be completely tightly twisted ; rather it is the looseness of the wires of the second pair in stretched condition, when introduced in the rubber, that is important.

Thus, in an unstretched free condition the wires 1 and 2 can either be apart or not be apart, according to the helicoidal deformation given to the wires in the twisting process. They are however twisted sufficiently tightly so as not be further apart than a distance of 0.042 mm. For these cord dimensions, this corresponds to a structural elongation from the unstretched to the stretched condition of maximum 0.0636 %.

The cord is made by a process using a conventional double-twister 11 as shown in figure 2. The four wires 1, 2, 3 and 4 are unwound from a creel, pass through a guiding plate 12, and converge towards a twisting-die 13 into a bundle. From there, the bundle further travels towards the double-twister 11, where it enters axially through the rotation axis 15 of the twister, over the rotating flyer 16 back to the rotation axis on the other side, where it enters axially into the stationary cradle 17 inside the twister over capstan 19 for winding up on the bobbin 18. The bundle is drawn from the unwinding creel through the machine by capstan 19. As well known, such twister twists the four wires 1 to 4 together to a bundle with a pitch depending on the relationship between the traveling speed given by the capstan 19 and the rotation speed of the flyer 16. Although the double twister of Figure 2 is of the type with winding-up bobbin inside the twister, it is clear that the type with winding-up bobbin outside the twister can be used in an analogous way.

The method by which the predeformation is given to the wires 1 to 4 is shown in greater detail on Figure 3. It shows the wires 1, 2, 3, 4 passing through the holes 21, 22, 23, 24 respectively, of the guiding plate 12, which has a circular form. On the exit from the plate, the wires 1 and 2 are deformed into a helicoidal form, because the wires rotate around their own axis when passing through the hole: the torsion given to each wire by the double twister 11 is transmitted back through the twisting-die. The degree of predeformation of wires 1 and 2 is determined by the distance of the holes 21 and 22 from the centre of the plate, and by the distance of the guiding plate from the twisting-die, as is well known in the art. A further possibility of adjusting the predeformation of wires 1 and 2, is provided by making holes 21 and 22, as shown in Figure 3c, in the form of hollow screws, screwed in the plate so as to make the distance between the exit of the hole and the twisting-die adjustable. The degree of deformation (openness) of wires 3 and 4 is obtained by the fact that these wires, after leaving holes 23 and 24, slightly diverge and pass over the rim of a deformation wheel 25, from where they suddenly converge towards the twisting-die 13. This deformation wheel has an axis 26, screwed in the guiding plate, and the distance from the plate can be changed by rotation of the wheel. The degree of deformation of wires 3 and 4 can be adjusted by adjusting this distance.

For evaluating the properties of this cord, relative to its alternatives, four cords were compared :

Cord A : is a conventional 4 x 0.25 mm tight cord, pitch 12.5 mm ;

Cord B : is a 4 x 0.25 mm open cord, pitch 14 mm ;

Cord C : is a 2 + 2 x 0.25 mm cord, as described in U.S.-patent 4.408.444, pitch 14 mm.

Cord D : is a cord which is an embodiment of the invention : 2 x 0.28 mm + 2 x 0.22 mm, pitch 14 mm.

Cord E : is a cord which is another embodiment of the invention : 2 x 0.25 mm + 2 x 0.25 mm, pitch 14 mm.

Of these five cords, a number of properties were measured :

Penetration degree : is expressed in terms of air flow (liter per hour). A cylindrical rubber rod of 220 mm length and 15 mm thickness is formed around 4 axially running cords, by vulcanizing under a pressure of 20 bar under standard conditions. Both ends of the rod are then submitted to a gradually raising pressure difference from 0 to 9 bar and the air flow curve is recorded or calculated by regression analysis. The penetration degree is then expressed by the air flow at 4 bar. A large air flow consequently means poor rubber penetration.

Fatigue resistance : is the value in Newton/mm^2 of the fatigue resistance of the cord, as measured by the Hunter rotating-beam fatigue test.

Cord thickness : is the average, over the cord length, of the cord thickness, measured according to the standard ASTM-test D2969-76, i.e. : between two parallel surfaces, having a length of at least the lay length of the pitch, and at three locations where in each two measurements are made in orientation which are 90 degrees apart.

Diameter fluctuation : is half the difference between the maximum and minimum cord thickness, (measured according to the standard test above : i.e. at the location which has the greatest spread between maximum and minimum thickness) and as such a measure of the ovality of the cross-section.

Breaking load : is the tensile load limit where the cord breaks.

Stiffness in rubber : is a value for evaluating tyre wear versus driving comfort. If too high, comfort is low but tyre wear too, and the inverse occurs when the stiffness is too low. A value in the range 100-200 is generally preferred.

The stiffness value ε_k is given by the formula

$$\varepsilon_k = 6,63\ (M_o - M'_o)$$

in which M_o and M'_o are the values, in Newton millimeter, of the Taber Stiffness and the Taber counter Moment respectively, of a cord sample of 75 mm, bent over 15° and unbent in a Taber V-5 Stiffness Tester. The sample is embedded in rubber to form a diameter of 3 mm.

The results are given in the table below :

	A	B	C	D	E
Penetration degree (1/h)	>20	0	0	0	0
Fatigue resistance (N/mm^2)	870	980	630	950	950
Cord diameter (mm)	0.60	0.63	0.66	0.60	0.63
Diameter fluctuation (mm)	0.014	0.022	0.19	0.027	0.022
Breaking load (N)	523	519	524	520	520
Cord stiffness in rubber ε_k (N/mm^2)	175	178	251	183	180

From this table, it can be seen that cord B and the cords which are an embodiment of the invention can well reconcile penetration degree, fatigue resistance and sufficient compactness (as to B to a lower degree). But, what is important : the other necessary properties, such as cord stiffness, are not lost. The good penetration degree of cord B was however obtained at the expense of special precautions to avoid tension during vulcanizing, which is not necessary with the cord which is an embodiment of the invention.

CLAIMS :

1. A steel cord for the reinforcement of resilient articles, in the form of a bundle of four wires twisted together with the same pitch, a first pair of said wires comprising two wires of substantially similar diameter, a second pair of said wires each having a diameter not greater than the average diameter of the first pair, a wire of one pair being succeeded by a wire of the other pair along the circumference of the bundle, characterized by the fact that, in a stretched condition of the cord, the wires of the first pair are tightly twisted together while each wire of the second pair is spaced from the wires of the first pair.

2. A steel cord as claimed in claim 1, characterized in that the diameter of each of said wires of the second pair is smaller than the average diameter of the first pair.

3. A steel cord as claimed in claim 2, characterized in that the diameter of each of said wires of the second pair is in a range of 0.6 to 0.85 of the average diameter of the first pair.

4. A steel cord as claimed in any of claims 1 to 3, characterized in that, in the stretched condition of the cord the spacing of each wire of the second pair from the wires of the first pair is in a range from 0.05 to 0.30 of said average diameter of the first pair.

5. A steel cord as claimed in any of claims 1 to 4, characterized in that said average diameter lies in a range from 0.14 to 0.40 mm and the twist pitch in a range from 35 to 80 times said average diameter.

6. A rubber product reinforced with a steel cord as claimed in any of the preceding claims.

7. A vehicle tyre reinforced with a steel cord as claimed in any of claims 1 to 5.

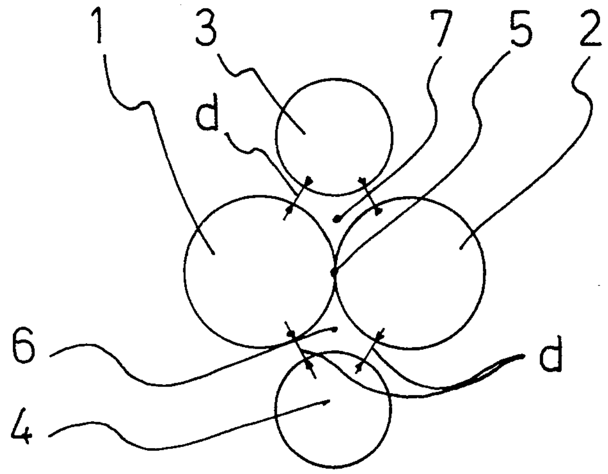

FIG.1

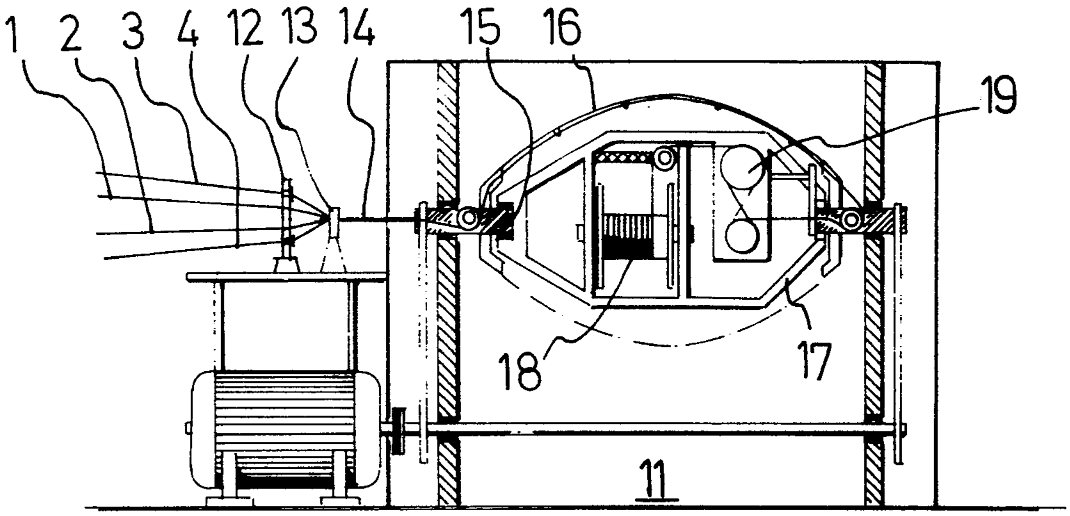

FIG. 2

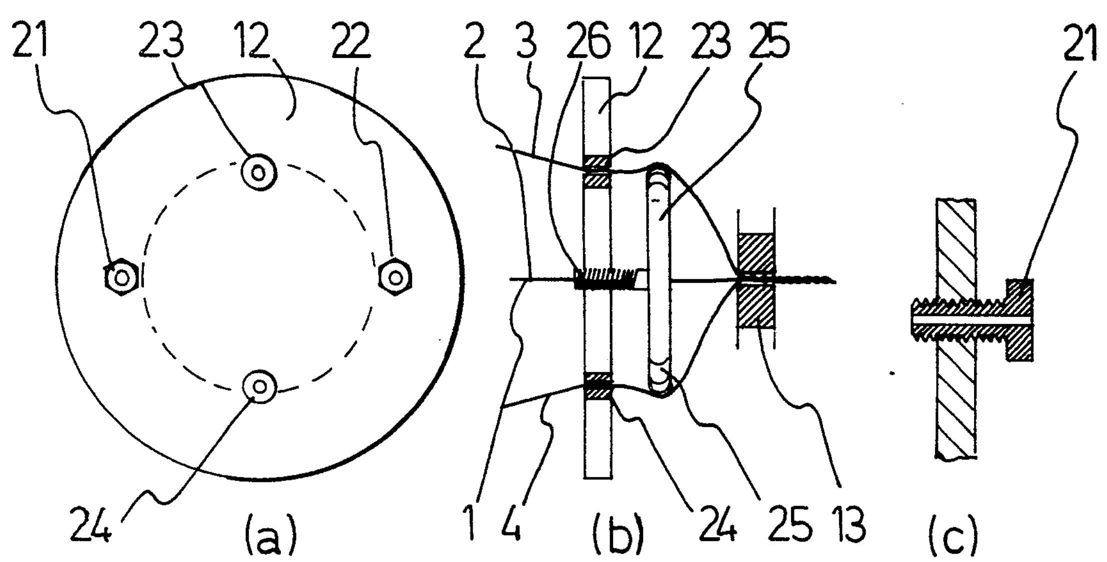

FIG.3

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EUROPEAN SEARCH REPORT

EP 85 20 0930

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)
A	RESEARCH DISCLOSURE, no. 224, December 1982, no. 22404, Havant, Hampshire, GB: "Bi-diameter construction of steel tire cord" * Whole document * ---	1-3,5-7	D 07 B 1/06
A	GB-A-2 081 765 (BRIDGESTONE) * Page 1, lines 18-28; page 2, lines 19-42 * ---	1,4,5	
A	FR-A-2 476 548 (UNIROYAL ENGLEBERT) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			D 07 B B 60 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10-10-1985	D'HULSTER E.W.F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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