

CROWN REINFORCEMENT FOR METROPOLITAN TYPE TYRE

5 **[0001]** The present invention relates to a tyre having a radial carcass reinforcement, and more particularly to a tyre intended to be fitted to mass transit guided vehicles, which can run in dedicated lanes, and more particularly rapid transit vehicles of the heavy or light, monorail, type, or other vehicles of this type.

10 **[0002]** In tyres having a radial carcass reinforcement for the transport of heavy loads, said carcass reinforcement is generally anchored on either side in the region of the bead and is surmounted radially by a crown reinforcement made up of at least two layers that are superimposed and formed of threads or cords that are parallel in each layer and crossed from one layer to the next, making angles of between 10° and 45° with the circumferential direction. Said working layers that form the working reinforcement may also be covered with at least one layer, referred to as the protective layer. The crown reinforcement may also comprise a layer of metal threads or cords of low extensibility that make an angle of between
15 45° and 90° with the circumferential direction, this ply, referred to as the triangulation ply, being situated radially between the carcass reinforcement and the radially innermost crown layer, referred to as the working layer.

[0003] Cords are said to be inextensible when said cords exhibit, under a tensile force equal to 10% of the breaking force, a relative elongation at most equal to 0.2%.

20 **[0004]** Cords are said to be elastic when said cords exhibit, under a tensile force equal to the breaking load, a relative elongation at least equal to 3% with a maximum tangent modulus of less than 150 GPa.

[0005] Circumferential reinforcing elements are reinforcing elements that make angles in the range $+2.5^\circ$, -2.5° with the circumferential direction.

25 **[0006]** The circumferential direction of the tyre, or longitudinal direction, is the direction that corresponds to the periphery of the tyre and is defined by the direction of running of the tyre.

[0007] The axis of rotation of the tyre is the axis about which it turns in normal use.

[0008] A radial or meridian plane is a plane that contains the axis of rotation of the tyre.

[0009] The circumferential median plane, or equatorial plane, is a plane that is perpendicular to the axis of rotation of the tyre and divides the tyre into two halves.

5 [0010] The transverse or axial direction of the tyre is parallel to the axis of rotation of the tyre. An axial distance is measured along the axial direction. The expression “axially on the inside of or axially on the outside of, respectively” means “the axial distance of which, measured from the equatorial plane, is less than or greater than, respectively”.

10 [0011] The radial direction is a direction that intersects the axis of rotation of the tyre and is perpendicular thereto. A radial distance is measured along the radial direction. The expression “radially on the inside of or radially on the outside of, respectively” means “the radial distance of which, measured from the axis of rotation of the tyre, is less than or greater than, respectively”.

[0012] For metal threads or cords, force at break (maximum load in N), breaking strength (in MPa), elongation at break (total elongation in %) and modulus (in GPa) are measured under tension in accordance with the standard ISO 6892 of 1984.

15 [0013] In combination with the internal tyre structure, it is known to provide the tread, that is to say the part of the tyre intended to come into contact with the ground during running and to become worn during running, with a tread pattern formed of raised elements delimited by grooves, in particular circumferentially oriented grooves.

20 [0014] It is also known to form a plurality of transversely or obliquely oriented edge corners on the tread surface. One means of obtaining such edge corners consists in providing the tread with a plurality of cuts, these cuts having the form of grooves or the form of sipes. A distinction is made, in the present application, between sipes and grooves in that sipes have a width suitable for allowing, during running, at least partial contact between the facing walls delimiting these sipes and in particular when in the contact patch in contact with the ground, which would not be the case for grooves under normal conditions of use of the tyre.

[0015] The transversely or obliquely oriented edge corners of the tread ensure in particular the grip of the tyre on the lanes on which the rapid transit vehicle is made to travel.

30 [0016] When the crown reinforcement is made up of two working layers, the reinforcing elements of which are crossed with one another and form angles of between 10° and 45°, stresses arise in use at the crown reinforcement and in particular shear stresses between the

crown layers, which may result, under certain use conditions, in separation of the working layers at the shoulders of the tyre, and this may result in deterioration of the tyre.

[0017] The proximity of electrical conductors that are necessary for supplying electric power to the vehicles brings about a non-zero risk of the occurrence of electric arcs between these conductors and metal debris from the tyre in the event of deterioration of the latter.

[0018] To eliminate this risk and avoid the presence of metal debris, crown reinforcement solutions having only reinforcing elements made of textile material have been developed. The patent application WO 97/15463 thus describes a crown reinforcement made up of one or more layers of circumferentially oriented textile reinforcing elements.

[0019] While such tyres effectively provide a solution to the risks associated with the presence of metal debris, running has brought to light wear-related problems of the tyres, more specifically irregular wear. Specifically, the strong traction of this type of vehicle associated with the use made thereof and in particular the very significant variations in loads that exist for example between the rush hour with a maximum load and off-peak hours during which the vehicle travels with few or no passengers, these variations in load being associated with intensive and repetitive braking and acceleration phases, cause very pronounced wear at the shoulders of the tyre, requiring frequent replacement of the tyres.

[0020] Furthermore, in the field of tyres for heavy-duty vehicles, it is notably known practice to introduce a layer of rubber compound between the ends of the working layers in order to create a decoupling between said ends in order to limit the shear stresses. Such decoupling layers need to exhibit a very good cohesion, however. Such layers of rubber compounds are described, for example, in the patent application WO 2004/076204.

[0021] The patent FR 2 222 232 teaches, in order to avoid separations between crown reinforcement plies, coating the ends of the reinforcement in a cushion of rubber with a Shore A hardness different from that of the tread surmounting said reinforcement, and greater than the Shore A hardness of the profiled element of rubber compound disposed between the edges of crown reinforcement and carcass reinforcement plies.

[0022] Moreover, in order to produce tyres with a very wide tread or in order to confer greater load-bearing capacity on tyres of a given dimension, it is known practice to introduce a layer of circumferential reinforcing elements. The patent application WO 99/24269 describes, for example, the presence of such a layer of circumferential reinforcing elements.

[0023] Moreover, a tyre for a heavy-duty vehicle in which a protective reinforcement made up of a layer of circumferential reinforcing elements is positioned radially on the outside of the working reinforcement is known from the patent application WO 99/00260.

[0024] The inventors thus set themselves the task of providing tyres for vehicles of the rapid transit type which do not have risks associated with the proximity of electrical conductors and which exhibit satisfactory performance in terms of wear.

[0025] This aim has been achieved according to the invention by a tyre for a vehicle of the rapid transit type, comprising a radial carcass reinforcement, said tyre comprising a crown reinforcement, comprising two working crown layers with metal reinforcing elements that are crossed from one layer to the next, making angles of between 10° and 45° with the circumferential direction, said angles being oriented on either side of the circumferential direction, the crown reinforcement being capped radially by a tread having at least one circumferential cut, said tread being joined to two beads via two sidewalls, the crown reinforcement comprising at least one layer of metal circumferential reinforcing elements radially on the outside of the two working layers, the two working crown layers and said at least one layer of circumferential reinforcing elements being the only layers present to make up the crown reinforcement across the entire axial width of the crown reinforcement, and, in a meridian plane, the distance D between the radially innermost point of the circumferential cut axially the closest to the equatorial plane and a point on the outer surface of said at least one layer of circumferential reinforcing elements being less than 8 mm, said distance D being measured along the direction of the orthogonal projection of the radially innermost point of the circumferential cut axially the closest to the equatorial plane onto the radially outer surface of said at least one layer of circumferential reinforcing elements.

[0026] Within the meaning of the invention, the radially outer surface of the layer of circumferential reinforcing elements is defined by the surface extrapolated from the radially outermost points of the reinforcing elements that make up the layer of circumferential reinforcing elements.

[0027] In accordance with the invention, the crown reinforcement may comprise one or more layers of metal circumferential reinforcing elements. When there are a plurality of layers of metal circumferential reinforcing elements, the two working crown layers and said plurality of layers of circumferential reinforcing elements are the only layers present to form the crown reinforcement across the entire axial width of the crown reinforcement.

5 **[0028]** The distance D is measured on a cross section of a tyre, the tyre therefore being in a non-inflated state. When there are a plurality of layers of metal circumferential reinforcing elements radially on the outside of the two working layers, the distance D is measured between the radially innermost point of the cut axially the closest to the equatorial plane and a point on the outer surface of the radially outermost layer of circumferential reinforcing elements.

[0029] The angles, expressed in degrees, are measured on a cross section of the tyre. According to the invention, angles are measured at the circumferential median plane.

10 **[0030]** Advantageously according to the invention, the tyre is intended to be inflated to an inflation pressure greater than or equal to 11.5 bar.

[0031] According to a preferred embodiment of the invention, the circumferential cut axially the closest to the equatorial plane is a circumferential groove.

[0032] Advantageously according to the invention, the distance D is less than 5 mm.

15 **[0033]** Also advantageously, the angle formed by the reinforcing elements of the working crown layers with the circumferential direction is less than 30° and preferably less than 25°.

[0034] The results obtained with tyres according to the invention have effectively shown that the performance in terms of endurance is improved, the tyres consequently exhibiting no risk with regard to the electrical conductors present in the environment, and furthermore
20 that the performance in terms of wear is satisfactory.

[0035] Specifically, the inventors have been able to show that the combination of two working layers having metal reinforcing elements associated with at least one layer of metal circumferential reinforcing elements positioned radially on the outside of the two working layers makes it possible to ensure the endurance of the crown reinforcement in spite of the
25 shear stresses imposed on the working layers. The tyre according to the invention thus exhibits no risk of generating metal debris in the proximity of the electrical conductors.

[0036] Furthermore, the presence of said at least one layer of circumferential reinforcing elements positioned radially outermost in the crown reinforcement would make it possible to contain the entire tyre and therefore to avoid the generation of metal debris in the unlikely
30 event of separation of the working layers subjected to the shear stresses.

[0037] Moreover, the combination of the positioning of said at least one layer of circumferential reinforcing elements and the distance D, corresponding to the thickness of rubber material in the region radially on the inside of the bottom of the tread pattern voids, which is considerably reduced compared with more conventional tyre designs, has a positive effect on the performance in terms of wear of the tyre. Specifically, the inventors have been able to show that the resultant bringing closer together of the layer of circumferential reinforcing elements and the radially outer surface of the tread of the tyre which comes into contact with the ground makes it possible to limit the shear undergone by the compounds making up the tread when running and makes the forces on the tread more uniform, thereby contributing to better performance in terms of wear, regardless of the load conditions or variations in load of the rapid transit vehicle.

[0038] According to one embodiment of the invention, the reinforcing elements of the working crown layers are inextensible metal cords.

[0039] According to an advantageous embodiment variant of the invention, said at least one layer of circumferential reinforcing elements has an axial width greater than $0.5xL$.

[0040] L is the maximum axial width of the tyre when the latter is mounted on its service rim and inflated to its recommended pressure.

[0041] The axial widths of the layers of reinforcing elements are measured on a cross section of a tyre, the tyre therefore being in an uninflated state.

[0042] According to a preferred embodiment of the invention, the two working crown layers have different axial widths, the difference between the axial width of the axially widest working crown layer and the axial width of the axially narrowest working crown layer being between 10 and 30 mm.

[0043] According to an advantageous embodiment of the invention, the reinforcing elements of said at least one layer of circumferential reinforcing elements are metal reinforcing elements that have a secant modulus at 0.7% elongation of between 10 and 120 GPa and a maximum tangent modulus of less than 150 GPa.

[0044] According to a preferred embodiment, the secant modulus of the reinforcing elements at 0.7% elongation is less than 100 GPa and greater than 20 GPa, preferably between 30 and 90 GPa, and more preferably less than 80 GPa.

[0045] Also preferably, the maximum tangent modulus of the reinforcing elements is less than 130 GPa and more preferably less than 120 GPa.

[0046] The moduli expressed above are measured on a curve of tensile stress as a function of elongation determined with a preload of 20 MPa, the tensile stress corresponding to a measured tension corrected for the cross section of metal of the reinforcing element. The measurements are carried out on cords removed from the tyre over a part of the layer of circumferential reinforcing elements extending from an axial end of said layer over an axial width of 50 mm toward the inside of said layer.

[0047] The moduli for the same reinforcing elements may be measured on a curve of tensile stress as a function of elongation determined with a preload of 10 MPa, the tensile stress corresponding to a measured tension corrected for the overall cross section of the reinforcing element. The overall cross section of the reinforcing element is the cross section of a composite element made up of metal and of rubber, the latter notably having penetrated the reinforcing element during the phase of curing the tyre; this overall cross section of the reinforcing element in question is approximately twice the cross section of metal of the reinforcing element.

[0048] According to this formulation relating to the overall cross section of the reinforcing element, the reinforcing elements of the axially outer parts and of the central part of at least one layer of circumferential reinforcing elements are metal reinforcing elements having a secant modulus at 0.7% elongation of between 5 and 60 GPa and a maximum tangent modulus of less than 75 GPa.

[0049] According to a preferred embodiment, the secant modulus of the reinforcing elements at 0.7% elongation is less than 50 GPa and greater than 10 GPa, preferably between 15 and 45 GPa, and more preferably less than 40 GPa.

[0050] Also preferably, the maximum tangent modulus of the reinforcing elements is less than 65 GPa and more preferably less than 60 GPa.

[0051] According to a preferred embodiment, the reinforcing elements of said at least one layer of circumferential reinforcing elements are metal reinforcing elements that have a curve of tensile stress as a function of relative elongation that exhibits a shallow gradient for small elongations and a gradient that is substantially constant and steep for greater elongations.

[0052] The various abovementioned characteristics of the reinforcing elements are measured on reinforcing elements taken from tyres.

[0053] Reinforcing elements more particularly suited to the creation of at least one layer of circumferential reinforcing elements according to the invention are, for example, assemblies of formula 21.23, the construction of which is $3 \times (0.26 + 6 \times 0.23)$ 4.8/7.5 SS; this stranded cord consists of 21 elementary threads of formula $3 \times (1 + 6)$, with 3 strands twisted together, each one consisting of 7 threads, one thread forming a central core with a diameter equal to 26/100 mm, and 6 wound threads with a diameter equal to 23/100 mm. Such a cord has a secant modulus at 0.7% equal to 45 GPa and a maximum tangent modulus equal to 98 GPa, these being measured on a curve of tensile stress as a function of elongation determined with a preload of 20 MPa corrected for the cross section of metal of the reinforcing element, the tensile stress corresponding to a measured tension corrected for the cross section of metal of the reinforcing element. On a curve of tensile stress as a function of elongation determined with a preload of 10 MPa corrected for the overall cross section of the reinforcing element, the tensile stress corresponding to a measured tension corrected for the overall cross section of the reinforcing element, this cord of formula 21.23 has a secant modulus at 0.7% equal to 23 GPa and a maximum tangent modulus equal to 49 GPa.

[0054] In the same way, another example of reinforcing elements is an assembly of formula 21.28, the construction of which is $3 \times (0.32 + 6 \times 0.28)$ 5.6/9.3 SS. This cord has a secant modulus at 0.7% equal to 56 GPa and a maximum tangent modulus equal to 102 GPa, these being measured on a curve of tensile stress as a function of elongation determined with a preload of 20 MPa corrected for the cross section of metal of the reinforcing element, the tensile stress corresponding to a measured tension corrected for the cross section of metal of the reinforcing element. On a curve of tensile stress as a function of elongation determined with a preload of 10 MPa corrected for the overall cross section of the reinforcing element, the tensile stress corresponding to a measured tension corrected for the overall cross section of the reinforcing element, this cord of formula 21.28 has a secant modulus at 0.7% equal to 27 GPa and a maximum tangent modulus equal to 49 GPa.

[0055] The use of such reinforcing elements in at least one layer of circumferential reinforcing elements notably makes it possible to maintain satisfactory stiffnesses of the layer even after the shaping and curing stages in conventional manufacturing methods.

[0056] According to a second embodiment of the invention, the circumferential reinforcing elements may be formed of metal elements that are inextensible and cut in such a way as to form portions with a length very much less than the circumference of the shortest layer, but preferably greater than 0.1 times said circumference, the cuts between portions
5 being axially offset from one another. Preferably again, the tensile elastic modulus per unit width of the additional layer is less than the tensile elastic modulus, measured under the same conditions, of the most extensible working crown layer. Such an embodiment makes it possible, in a simple way, to confer on the layer of circumferential reinforcing elements a modulus which can be easily adjusted (by the choice of the intervals between portions of one
10 and the same row) but which in all cases is lower than the modulus of the layer consisting of the same metal elements but with the latter being continuous, the modulus of the additional layer being measured on a vulcanized layer of cut elements which has been removed from the tyre.

[0057] According to a third embodiment of the invention, the circumferential
15 reinforcing elements are wavy metal elements, the ratio a/λ of the wave amplitude to the wavelength being at most equal to 0.09. Preferably, the tensile elastic modulus per unit width of the additional layer is less than the tensile elastic modulus, measured under the same conditions, of the most extensible working crown layer.

[0058] Further details and advantageous features of the invention will become apparent
20 in the following text from the description of an exemplary embodiment of the invention in particular with reference to the figure, which shows a meridian view of a design of a tyre according to the invention.

[0059] For ease of understanding, the figure is not drawn to scale.

[0060] In the figure, the tyre 1 is of size 305/70 R 22.5. Said tyre 1 comprises a radial
25 carcass reinforcement 2 anchored in two beads, not shown in the figure. The carcass reinforcement is formed of a single layer of metal cords. This carcass reinforcement 2 is radially surmounted by a crown reinforcement 5 formed radially, from the inside to the outside:

- of a first working layer 51 formed of non-wrapped 11.35 inextensible metal cords,
30 which are continuous across the entire width of the layer and oriented at an angle equal to 18° ,

- of a second working layer 52 formed of non-wrapped 11.35 inextensible metal cords, which are continuous across the entire width of the layer, oriented at an angle equal to 18° and crossed with the metal cords of the layer 51,
- of a layer of circumferential reinforcing elements 53, comprising 21x28 steel metal cords.

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[0061] The crown reinforcement is itself capped by a tread 6.

[0062] The carcass reinforcement 2, formed by a single layer of metal cords, is wound, in each of the beads 3, around a bead wire 4 and forms, in each of the beads 3, a turn-up 7.

[0063] The tyre is inflated to a pressure of 11.5 bar.

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[0064] The axial width L_{51} of the first working layer 51 is equal to 200 mm.

[0065] The axial width L_{52} of the second working layer 52 is equal to 180 mm.

[0066] The axial width L_{53} of the layer of circumferential reinforcing elements 53 is equal to 136 mm.

[0067] The axial width L_6 of the tread is equal to 221 mm.

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[0068] The distance D is measured between the radially innermost point 8 of the cut 10, axially closest to the equatorial plane XX', and a point 9 on the outer surface of the layer of circumferential reinforcing elements 53. The distance D is measured along the direction of the orthogonal projection of the point 8 onto the outer surface of the layer of circumferential reinforcing elements 53. The distance D is equal to 2.1 mm and therefore less than 8 mm.

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[0069] Tests were carried out with tyres I produced according to the invention and with reference tyres T.

[0070] The reference tyres T differ from the tyres according to the invention by having a crown reinforcement made up of a stack of three layers of circumferential reinforcing elements made of aromatic polyamide.

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[0071] Endurance tests were carried out by running the tyres on a test rolling road with a load of 7000 daN, inflated with a pressure of 13.5 bar at a speed of 40 km/h. The same type of test was carried out with a cycle of variable pressures and loads, still at 40 km/h.

[0072] During these tests, the tyres I according to the invention exhibited better results than the reference tyres T. The tyres I according to the invention travelled a distance close to twice that achieved with the reference tyres T.

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[0073] Another type of tests was carried out to test the different tyres in terms of wear.

[0074] These tests were carried out on flat ground and consisted in measuring the shape and the stresses in the contact patch. They were supplemented by direct comparisons on the vehicle, making it possible to assess the performance of the tyres in terms of lifetime.

5 [0075] With regard to the reference tyres T, irregular wear arose, the edges of the tread being highly worn, this appearing to be the consequence of non-uniform flattening between the centre and the shoulders.

[0076] In the tyres I according to the invention, the deformations of the contact surface during flattening are more uniform, thereby ensuring regular wear. They can therefore travel
10 a greater distance without exhibiting excessively marked irregular wear requiring a tyre change. The tyres I according to the invention thus travelled a distance 40% greater than that achieved by the reference tyres T.

CLAIMS

1 – Tyre (1) for a vehicle of the rapid transit type, comprising a radial carcass reinforcement (2), said tyre comprising a crown reinforcement (5), comprising two working crown layers (51, 52) with metal reinforcing elements that are crossed from one layer to the next, making angles of between 10° and 45° with the circumferential direction, said angles being oriented on either side of the circumferential direction, the crown reinforcement (5) being capped radially by a tread (6) having at least one circumferential cut (10), said tread being joined to two beads (3) via two sidewalls, **characterized in that** the crown reinforcement comprises at least one layer of metal circumferential reinforcing elements (53) radially on the outside of the two working layers, **in that** the two working crown layers and said at least one layer of circumferential reinforcing elements are the only layers present to make up the crown reinforcement across the entire axial width of the crown reinforcement, and **in that**, in a meridian plane, the distance D between the radially innermost point of the circumferential cut axially the closest to the equatorial plane and a point on the outer surface of said at least one layer of circumferential reinforcing elements is less than 5 mm, said distance D being measured along the direction of the orthogonal projection (9) of the radially innermost point (8) of the circumferential cut (10) axially the closest to the equatorial plane (XX') onto the radially outer surface of said at least one layer of circumferential reinforcing elements (53).

2 - Tyre (1) according to Claim 1, **characterized in that** the cut (10) axially the closest to the equatorial plane is a circumferential groove.

3 - Tyre (1) according to Claims 1 or 2, **characterized in that** the reinforcing elements of the working crown layers (51, 52) are inextensible.

4 - Tyre (1) according to one of Claims 1 to 3, **characterized in that** the reinforcing elements of said at least one layer of circumferential reinforcing elements (53) are metal reinforcing elements having a secant modulus at 0.7% elongation of between 10 and 120 GPa and a maximum tangent modulus of less than 150 GPa.

5 - Tyre (1) according to Claim 4, **characterized in that** the angle formed by the reinforcing elements of the working crown layers (51, 52) with the circumferential direction is less than 30° and preferably less than 25°.