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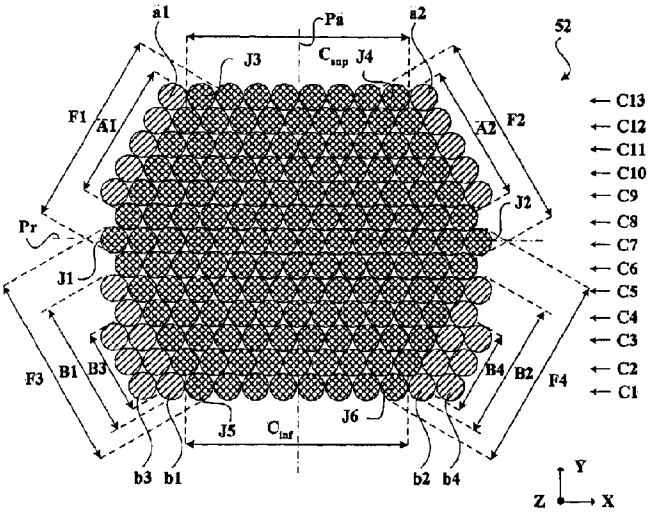
(54) Titre : TRINGLE POUR PNEUMATIQUE, PNEUMATIQUE ET PROCEDE DE FABRICATION
(54) Title: BEAD WIRE FOR A TYRE, TYRE AND MANUFACTURING METHOD



(57) Abrégé/Abstract:
The invention relates to a bead wire (52) which includes a plurality of wire windings and a base hexagonal bead wire (56) including: two axially and radially external side alignments (F1, F2) of N2 windings; two axially external and radially internal side alignments (F3, F4) of N2 windings, where N1=N2 + 1 or N1=N2; two junctions (J1, J2) each formed by a common winding between an axially and radially external side alignment (F1, F2) and an axially external and radially internal side alignment (F3, F4), each common winding being axially devoid of a winding of the wire, externally. The bead wire (52) includes two additional axially external and radially internal side alignments (B1, B2, B3, B4) which are substantially parallel to each axially external and radially internal side alignment (F3, F4), respectively.

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(54) Title : BEAD WIRE FOR A TIRE, TIRE AND MANUFACTURING METHOD

(54) Titre : TRINGLE POUR PNEUMATIQUE, PNEUMATIQUE ET PROCÉDÉ DE FABRICATION

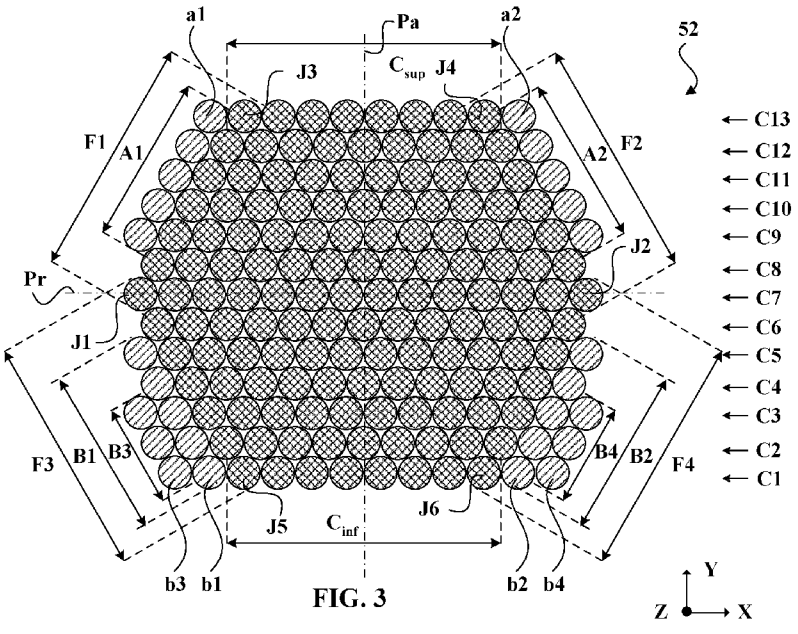

FIG. 3

(57) Abstract : The invention relates to a bead wire (52) which includes a plurality of wire windings and a base hexagonal bead wire (56) including: two axially and radially external side alignments (F1, F2) of N2 windings; two axially external and radially internal side alignments (F3, F4) of N2 windings, where N1=N2 + 1 or N1=N2; two junctions (J1, J2) each formed by a common winding between an axially and radially external side alignment (F1, F2) and an axially external and radially internal side alignment (F3, F4), each common winding being axially devoid of a winding of the wire, externally. The bead wire (52) includes two additional axially external and radially internal side alignments (B1, B2, B3, B4) which are substantially parallel to each axially external and radially internal side alignment (F3, F4), respectively.

(57) Abrégé : La tringle (52) comprend plusieurs enroulements de fil et une tringle hexagonale de base (56) comprenant : - deux alignements latéraux

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(F1, F2) axialement et radialement externe de N2 enroulements, - deux alignements latéraux (F3, F4) axialement externes et radialement internes de N2 enroulements, avec N1=N2 + 1 ou N1=N2, - deux jonctions (J1, J2) chacune formée par un enroulement commun entre un alignement latéral axialement et radialement externe (F1, F2) et un alignement latéral axialement externe et radialement interne (F3, F4), chaque enroulement commun étant dépourvu, axialement à l'extérieur, d'enroulement du fil. La tringle (52) comprend deux alignements additionnels latéraux (B1, B2, B3, B4) axialement externes et radialement internes sensiblement parallèle respectivement à chaque alignement latéral (F3, F4) axialement externe et radialement interne.

Bead wire for a tyre, tyre and manufacturing method

FIELD

[001] The invention relates to a bead wire for a tyre, to a tyre and to the method of manufacturing same. The invention applies to any type of tyre, notably to tyres of industrial vehicles selected from motor vehicles of the passenger car type, SUVs (*Sport Utility Vehicles*), two wheeled vehicles (notably bicycles, motorbikes), heavy vehicles such as heavy goods vehicles - i.e., metro vehicles, buses, road haulage vehicles (lorries, tractors, trailers), off the road vehicles – agricultural vehicles or construction plant vehicles, aircraft, other transport or handling vehicles.

BACKGROUND

[002] A tyre comprising a crown comprising a crown reinforcement surmounted by a tread is known from the prior art. Two sidewalls extend the crown radially inwards. The tyre comprises two beads radially on the inside of the sidewalls and each comprising an annular reinforcing structure. The annular reinforcing structure comprises a bead wire substantially of revolution about an axis comprising several windings of at least one wire which are arranged axially next to one another over several layers radially superposed on one another. The wire has a substantially circular cross section. Such a bead wire is generally referred to as a round bead bundle. The bead wire of the prior art, illustrated in Figure 9, may be bare or encased in a mass of encasing rubber.

[003] The tyre also comprises a radial carcass reinforcement extending from the beads to the sidewalls towards the crown. The carcass reinforcement comprises one or more carcass plies, at least one of these carcass plies being anchored in each of the beads by being folded around the annular reinforcing structure, in contact with the bead wire or the encasement thereof, so as to form, within each bead, a main strand extending radially between each bead through the sidewalls and the crown and a turnup extending radially from each bead through each sidewall.

[004] Each bead comprises a mass of filling rubber arranged in contact with the bead wire or the encasement thereof, in a space delimited by the main strand and turnup. Each bead also comprises additional masses of rubber arranged axially on the outside of the turnup.

[005] When the tyre is in use on a vehicle, the tyre is mounted on a wheel comprising a rim. The motive force of the vehicle, generally generated by the engine or motor thereof, is transmitted to the tyre by a transmission. If the motive force is very high, the tyre may slip relative to the rim such that the motive force cannot be transmitted in full to the tyre, thereby reducing the efficiency of the vehicle. This

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phenomenon, which is known as tyre-rim slip, is all the more penalizing when the vehicles are vehicles that generate a high motive force.

[006] Furthermore, during the manufacture of the tyre of the prior art, which is performed for example on a tyre-building drum, the bead wire is placed on the carcass ply and the turnup is folded around the bead wire. The carcass ply and the bead wire are then turned relative to one another. During this rotation, the mass of filling rubber and the folding of the carcass ply comprising the main strand and the turnup rub against the bead wire or the encasement thereof, thereby creating what is referred to as a braking torque that prevents the relative rotation of the bead wire with respect to the rest of the tyre, notably with respect to the carcass ply.

[007] The braking torque causes the turnup of the carcass ply and the additional masses of rubber arranged axially on the outside of the turnup to be placed in compression. The braking torque also causes the main strand of the carcass ply to be placed in overtension. Under the effect of the overtension in the main strand, the windings of the bead wire, notably the windings in contact with the overtensioned main strand become disorganized. In addition, the friction leads to limited relative rotation which prevents the bead wire from adopting a correct orientation within the tyre.

[008] When they occur, these potential problems, which have been deliberately exaggerated in Figure 10, cause the tyre to have to be scrapped.

SUMMARY

[009] It is an object of the invention to reduce the tyre-rim slip under the effect of the motive force and to provide a bead wire that makes it possible to reduce the number of tyres that have to be scrapped as a result of a problem generated by the braking torque.

[010] To this end, one subject of the invention is a bead wire for a tyre rotating about an axis, the bead wire comprising: several windings of at least one wire which are arranged axially next to one another over N layers Ci radially superposed on one another; a basic hexagonal bead wire comprising: a radially external layer of N1 windings, a radially internal layer of N1 windings, two axially external and radially external lateral rows of N2 windings axially opposite one another, two axially external and radially internal lateral rows of N2 windings axially opposite one another, with N1=N2 + 1 or N1=N2, and two junctions each one formed by a winding common to one of the axially external and radially external lateral rows and to one of the axially external and radially internal lateral rows, each winding in common and forming each of said junctions having no axially external adjacent winding. Also provided are at least two axially external and radially internal additional lateral rows, each of said two axially

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external and radially internal additional lateral rows being respectively substantially parallel to each of said axially external and radially internal lateral rows.

[011] A row means a juxtaposition in a substantially rectilinear main direction of several windings arranged so that each is in contact with the next.

[012] A lateral row means a row the main direction of which is inclined with respect to the axial direction of the tyre.

[013] A layer means a row extending in a main direction substantially parallel to the axial direction of the tyre.

[014] Two rows are substantially parallel if the main directions in which they extend are substantially parallel to one another.

[015] A layer of the hexagonal base bead wire is said to be “radially external” if the main direction in which it extends is further away from the axis of rotation of the tyre than those of the other layers of the hexagonal base bead wire. Conversely, a layer of hexagonal base bead wire is said to be “radially internal” if the main direction in which it extends is closer to the axis of rotation of the tyre than those of the other layers of the hexagonal base bead wire.

[016] A lateral row of the hexagonal base bead wire is said to be “axially and radially external” if the main direction in which it extends is axially and radially further away from the centre of the hexagonal base bead wire than those of the other lateral rows of the hexagonal base bead wire when progressing axially from the inside towards the outside of the hexagonal base bead wire and radially from the inside towards the outside of the tyre. Conversely, a lateral row of the hexagonal base bead wire is said to be “axially external and radially internal” if the main direction in which it extends is axially and radially further away from the centre of the hexagonal base bead wire than those of the other lateral rows of the hexagonal base bead wire when progressing axially from the inside towards the outside of the hexagonal base bead wire and radially from the outside towards the inside of the tyre.

[017] The same definitions will be applied to the additional coverings, rows and layers of the bead wire for a tyre.

[018] The bead wire according to the invention exhibits little tyre-rim slip, thereby improving the efficiency of the vehicle on which a tyre comprising it is mounted. Specifically, each axially external and radially internal additional lateral row improves the anchorage of the bead in the rim and reduces potential slippage between rim and tyre. Furthermore, the low tyre-rim slip makes it possible to avoid rubbing of the tyre against the rim and therefore degradation of the bead which could impair the durability

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of the tyre.

[019] Furthermore, the bead wire according to the invention makes it possible to reduce or even eliminate the number of tyres scrapped as a result of a problem generated by the braking torque. Specifically, the bead wire according to the invention has a dimension in the axial direction that is relatively close to the dimension in the radial direction. Thus, the cross section of the bead wire according to the invention is relatively close to a cross section of circular overall shape, which encourages the relative rotation and therefore limits the braking torque, unlike the bead wire of the prior art.

[020] The particular shape of the bead wire according to the invention encouraging relative rotation is due, on the one hand, to the hexagonal shape of the base bead wire and, on the other hand, to the axially external and radially internal additional lateral rows which in combination allow the cross section of the bead wire according to the invention to better approximate to a cross section of circular overall shape.

[021] Implicitly, each axially external and radially internal additional lateral row is arranged axially on the outside respectively with respect to each axially external and radially internal lateral row.

[022] A first row is said to be arranged axially on the outside of a second row if the main direction in which it extends is further away from the centre of the bead wire than that of the second row when progressing in a direction substantially parallel to the axial direction of the tyre. Conversely, a first row is said to be arranged axially on the inside of a second row if the main direction in which it extends is closer to the centre of the bead wire than that of the second row when progressing in a direction substantially parallel to the axial direction of the tyre.

[023] Advantageously, the bead wire for a tyre comprises two pairs of axially external and radially internal additional lateral rows respectively of N5 and N6 windings, each axially external and radially internal additional lateral row being substantially parallel respectively to each axially external and radially internal lateral row. Thanks to the two pairs of axially external and radially internal additional lateral rows, the tyre-rim slip of the tyre is reduced still further.

[024] Optionally, $N5 \geq N6$, preferably $N5 > N6$, and more preferably, $N5 = N6 + 2$.

[025] In one embodiment, each radially internal winding of each axially external and radially internal additional lateral row is radially substantially aligned with the radially internal layer.

[026] In another embodiment, the bead wire for a tyre comprises at least one axially external and radially internal additional covering of windings in the overall shape of a

U.

[027] Advantageously, the bead wire comprises such an additional covering when N1<7 and preferably when N1<6. This is because reducing N1 leads to an increase in the risk of tyre-rim slip and in the pressure of the rim on each winding of the bead wire. It is therefore preferable to add a covering in order to reduce this risk and better spread the pressure applied by the rim to the bead wire.

[028] Implicitly, the windings of the axially external and radially internal additional covering are arranged axially on the outside of each axially external and radially internal lateral row and radially on the inside of the radially internal layer.

[029] The windings of a covering are said to be arranged axially on the outside of a row if the main direction in which the windings of the covering extend parallel to that of the row is further away from the centre of the bead wire than that of the row that they are covering when progressing in a direction substantially parallel to the axial direction of the tyre.

[030] The windings of a covering are said to be arranged radially on the inside of a layer if the main direction in which the windings of the covering extend parallel to that of the layer is closer to the axis of the tyre than that of the layer that they are covering when progressing in a direction substantially parallel to the radial direction of the tyre.

[031] For preference, the axially external and radially internal additional covering comprises:

- a radially internal additional layer of N7 windings, and substantially parallel to the radially internal layer,
- at least two axially external and radially internal additional lateral rows.

[032] Implicitly, the radially internal additional layer is arranged radially on the inside of the radially internal layer.

[033] A first layer is said to be arranged radially on the inside of a second layer if the main direction in which it extends is closer to the axis of the tyre than that of the second layer in a direction substantially parallel to the radial direction of the tyre.

[034] For preference, the axially external and radially internal additional covering comprises a single radially internal additional layer of N7 windings substantially parallel to the radially internal layer.

[035] For preference, N7=N1+1.

[036] Advantageously, with each axially external and radially internal additional lateral row comprising N5 windings, N5≤N2, preferably N5=N2, N5+1=N2 or N5+2=N2.

[037] Preferably, $\max(L_i)=N-1$, $\max(L_i)=N$ or $\max(L_i)=N+1$ where L_i is the number of

windings of each layer C_i, i varying from 1 to N inclusive. Thus, the bead wire has a dimension in the axial direction that is as close as possible to the dimension in the radial direction.

[038] Advantageously, the bead wire for a tyre comprises at least one layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. Thus, the bead wire is more robust when handled. Specifically, by virtue of this feature, pressure is brought to bear on several axially external windings, in this instance those of the layers C_{k+1} and C_{k-1}, unlike in the bead wire of the prior art on which pressure is brought to bear on just one axially external winding. Thus the load applied to each of these axially external windings and the risk of disorganizing the bead wire are limited.

[039] For preference, for each layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$.

[040] Optionally, the bead wire for a tyre also comprises at least two axially and radially external additional lateral rows, each axially and radially external additional lateral row being substantially parallel respectively to each axially and radially external lateral row.

[041] This then further reduces the braking torque during the method of manufacture. Specifically, the specific shape of the bead wire further encourages relative rotation because, on the one hand, of the hexagonal shape of the base bead wire and, on the other hand, of the axially and radially external additional lateral rows which, in combination, allow the cross section of the bead wire according to the invention to better approximate to a cross section of circular overall shape.

[042] Implicitly, each axially and radially external additional lateral row is arranged axially on the outside respectively of each axially and radially external lateral row.

[043] For preference, the bead wire comprises two, and only two, axially and radially external additional lateral rows, each axially and radially external additional lateral row being substantially parallel respectively to each axially and radially external lateral row.

[044] In one embodiment, each radially external winding of each axially and radially external additional lateral row is radially substantially aligned with the radially external layer.

[045] In another embodiment, the bead wire comprises at least one axially and radially external additional covering of windings in the overall shape of a U.

[046] Advantageously, the covering thus allows the cross section of the bead wire to approximate still further to a cross section of circular overall shape.

[047] Implicitly, the windings of the axially and radially external additional covering are arranged axially on the outside of each axially and radially external lateral row and

radially on the outside of the radially external layer.

[048] The windings of a covering are said to be arranged radially on the outside of a layer if the main direction in which the windings of the covering extend parallel to that of the layer is further away from the axis of the tyre than that of the layer they are covering when progressing in a direction substantially parallel to the radial direction of the tyre.

[049] Advantageously, the axially and radially external additional covering comprises:

- a radially external additional layer of N4 windings, substantially parallel to the radially external layer,
- at least the two axially and radially external additional lateral rows.

[050] Implicitly, the radially external additional layer is arranged radially on the outside of the radially external layer.

[051] A first layer is said to be arranged radially on the outside of a second layer if the main direction in which it extends is further away from the axis of the tyre than that of the second layer in a direction substantially parallel to the radial direction of the tyre.

[052] For preference, the axially and radially external additional covering comprises a single radially external additional layer of N4 windings, substantially parallel to the radially external layer.

[053] Advantageously, in order for the cross section of the bead wire to approximate still further to a cross section of circular overall shape, $\max(L_i)-N1\leq 6$, i varying from 1 to N. Preferably, $\max(L_i)-N1\leq 2$, i varying from 1 to N for $\max(L_i)\leq 9$ and $\max(L_i)-N1\leq 6$, i varying from 1 to N for $\max(L_i)>9$.

[054] For preference, N4=N1+1. Thus, the additional covering espouses the overall shape of the hexagonal base bead wire, encouraging relative rotation of the carcass ply on the radially external additional layer.

[055] Advantageously, with each axially and radially external additional lateral row comprising N3 windings, N3≤N2, preferably N3=N2, N3+1=N2 or N3+2=N2.

[056] N3≤N2, preferably N3=N2, N3+1=N2 or N3+2=N2. Similarly, the additional covering espouses the overall shape of the hexagonal base bead wire thereby encouraging relative rotation of the carcass ply on the axially and radially external additional lateral rows.

[057] According to other optional features of the bead wire for a tyre which features are independent of one another:

- The hexangonal base bead wire has an axial plane of symmetry.
- The hexagonal base bead wire has a radial plane of symmetry.
- The bead wire for a tyre has an axial plane of symmetry.

- The bead wire for a tyre is obtained by successive superpositions of the N layers C_i, each layer C_i being obtained by successive axial windings of at least one wire.
- The bead wire for a tyre comprises a single wire forming the windings of the N layers C_i.
- The or each wire is made of metal.
- The or each wire is made of a carbon steel containing between 0.6 and 0.9 wt% of carbon.
- The or each wire has a substantially circular cross section.
- The or each wire has a diameter of between 1 and 3.2 mm, preferably between 1.2 and 2.2 mm and more preferably between 1.2 and 2 mm.
- $N \geq 5$, preferably $N \geq 7$ and more preferably $N \geq 9$.
- $\max(L_i) \geq 4$, preferably $\max(L_i) \geq 6$ and more preferably, $\max(L_i) \geq 9$.
- The total number of windings of the bead wire is greater than or equal to 30, preferably greater than or equal to 50 and more preferably greater than or equal to 70.
- $|L_{k+1} - L_k| = 1$ for i varying from 1 to N inclusive.

[058] Another subject of the invention is a tyre comprising:

- at least one bead comprising at least one bead wire for a tyre as defined hereinabove,
- a carcass reinforcement comprising at least one carcass ply anchored in each bead by a turnup around the bead wire.

[059] Another subject of the invention is a method of manufacturing a tyre as defined hereinabove, in which method:

- the bead wire is placed on the carcass ply,
- part of the carcass ply is folded around the bead wire, and
- the carcass ply and the bead wire are turned relative to one another.

BRIEF DESCRIPTION OF THE DRAWINGS

[060] The invention will be better understood from reading the following description, given solely by way of nonlimiting example and made with reference to the drawings in which:

– Figure 1 is a view in radial section of a tyre according to the invention;

– Figure 2 is a detailed view in cross section of region I of the tyre of Figure 1;

– Figure 3 is a view in cross section of a bead wire according to a first embodiment of the invention;

– Figures 4a, 4b, 4c and 4d are views in cross section illustrating various steps in the method of manufacture according to the invention;

– Figures 5 to 8 are views similar to that of Figure 3 of bead wires respectively according to second, third, fourth and fifth embodiments;

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– Figure 9 is a view similar to that of Figure 3 of a bead wire of the prior art;

– Figure 10 is a view similar to that of Figure 2 of a bead of a tyre of the prior art comprising the bead wire of Figure 9.

DETAILED DESCRIPTION

[061] The tyre according to the invention has a toroidal overall shape about an axis of rotation. This axis of rotation defines the axial direction.

[062] When using the term "radial" it is appropriate to make a distinction between the various different uses made of this word by those skilled in the art when referring to tyres.

[063] Firstly, the expression refers to a radius of the tyre. It is in this sense that an element A is said to be "radially inside" an element B (or "radially on the inside of" the element B) if it is closer to the axis of rotation of the tyre than is the element B. Conversely, an element C is said to be "radially outside" an element D (or "radially on the outside of" the element D) if it is further away from the axis of rotation of the tyre than is the element D. Progress is said to be "radially inwards (or outwards)" when it is in the direction towards smaller (or larger) radii.

[064] Secondly, a reinforcing element or a reinforcement is said to be "radial" when the reinforcing element or the reinforcing elements of the reinforcement make an angle greater than or equal to 65° and less than or equal to 90° with the circumferential direction.

[065] Thirdly, a "radial section" or "radial cross section" here means a section or cross section on a plane containing the axis of rotation of the tyre.

[066] An "axial" direction is a direction parallel to the axis of rotation of the tyre. An element E is said to be "axially inside" an element F (or "axially on the inside of" the element F) if it is closer to the midplane of the tyre than is the element F. Conversely, an element G is said to be "axially outside" an element H (or "axially on the outside of" the element H) if it is further from the midplane of the tyre than is the element H.

[067] The "midplane" of the tyre is the plane which is perpendicular to the axis of rotation of the tyre and lies equal distances from the annular reinforcing structures of each bead.

[068] A "circumferential" direction is a direction which is perpendicular both to a radius of the tyre and to the axial direction.

[069] EXAMPLE OF A TYRE AND BEAD WIRE ACCORDING TO THE INVENTION

[070] The figures that follow depict directions X, Y, Z corresponding to the usual axial (X), radial (Y) and circumferential (Z) orientations of a tyre.

[071] Figures 1 and 2 depict an example of a tyre according to the invention and

denoted by the general reference 10. The tyre 10 is preferably intended for an industrial vehicle selected from motor vehicles of the passenger car type, SUVs (*Sport Utility Vehicles*), two-wheeled vehicles (notably bicycles, motorbikes), heavy vehicles such as heavy goods vehicles - i.e. metro vehicles, buses, road haulage vehicles (lorries, tractors, trailers), off the road vehicles – agricultural vehicles or construction plant vehicles, aircraft, other transport or handling vehicles. In this particular instance, the tyre 10 is intended for an agricultural vehicle, for example a tractor.

[072] The tyre 10 has a nominal rim diameter as defined by the ETRTO (European Tyre and Rim Technical Organisation) of between 24 and 54 inches endpoints inclusive (between 60.96 cm and 137.16 cm). The tyre 10 has a nominal aspect ratio as defined by the ETRTO of between 0.7 and 0.9, endpoints inclusive.

[073] The tyre 10 comprises a crown 12 comprising a crown reinforcement 14 comprising one or more crown plies 16 of reinforcing elements. The crown reinforcement 14 is surmounted by a tread 18. The crown reinforcement 14 is arranged radially in the inside of the tread 18. Two sidewalls 20 extend the crown 12 radially inwards. The tyre 10 comprises two beads 22 radially on the inside of the sidewalls 20 and each comprising an annular reinforcing structure 24.

[074] The tyre 10 also comprises a radial carcass reinforcement 26. The carcass reinforcement 26 extends from the beads 22 through the sidewalls 20 towards the crown 12. The carcass reinforcement 26 comprises one or more carcass plies 28, at least one of these carcass plies 28 being anchored in each of the beads 22 by being folded 30 around the annular reinforcing structure 24 to form, within each bead 22, a main strand 32 extending radially between each bead 22 through the sidewalls 20 and the crown 12, and a turnup 34 extending radially from each bead 22 through each sidewall 20, the radially external end 36 of the turnup 34 being situated radially on the outside of the annular reinforcing structure 24 and axially on the outside of the main strand 32.

[075] The tyre 10 also comprises an airtight inner ply 38 arranged radially and axially on the inside of the carcass reinforcement 26. The inner ply 38 extends between each bead 22, passing via the sidewalls 20 and the crown 12.

[076] Each bead 22 comprises, in addition to the annular reinforcing structure 24, a mass 40 of filling rubber arranged in a space delimited by the main strand 32 and the turnup 34. Each bead 22 also comprises a first mass 42 of cushioning rubber protecting the bead 22 around the folding 30 of the carcass reinforcement 26.

[077] In addition, each bead 22 also comprises a mass 44 of filling rubber arranged axially outside the carcass reinforcement 26, particularly axially outside the turnup 34.

Each sidewall 20 comprises a mass 46 of axially external rubber delimiting an axially external surface 48 of the sidewall 20 and arranged axially on the outside of the mass 44 of filling rubber. Finally, each bead 22 comprises a second mass 50 of cushioning for the bead 22, arranged axially between the mass 44 of filling rubber and the axially external mass 46 of rubber of the sidewall 20.

[078] Each annular reinforcing structure 24 comprises an annular bead wire 52 coated in an encasing mass 54, for example containing rubber. The bead wire 52 is arranged radially on the inside of the mass 40 of filling rubber. The bead wire 52 is in accordance with a first embodiment of the invention.

[079] Figure 3 depicts the bead wire 52 according to the first embodiment of the invention.

[080] The bead wire 52 has an overall shape of revolution about the axis of revolution of the tyre 10 which is substantially parallel to the axial direction X.

[081] The bead wire 52 has an axial plane of symmetry Pa, namely a plane of symmetry that is perpendicular to the axial direction X (parallel to the midplane M).

[082] The bead wire 52 comprises P windings of at least one wire which are arranged axially next to one another over N layers C_i radially superposed on one another. The bead wire 52 is obtained by successive superpositions of the N layers C_i with i varying from 1 to N inclusive, each layer C_i being obtained by axially successive windings of at least one wire. The total number of windings P of the bead wire 52 is greater than or equal to 30, preferably greater than or equal to 50, and more preferably, greater than or equal to 70 and here P=166.

[083] In the example of Figure 3, the bead wire 52 comprises P windings of a single wire. For preference, the wire is made of metal, has a substantially circular cross section and advantageously a diameter of between 1 and 3.2 mm, preferably between 1.2 and 2.2 mm, and more preferably, between 1.2 and 2 mm, here a diameter equal to 1.55 mm. The wire is made of a carbon steel containing 0.7 wt% of carbon.

[084] The bead wire 52 thus comprises, starting from the radially innermost layer C_1 to the radially outermost layer C_N, N radially successive layers with $N \geq 5$, preferably $N \geq 7$ and more preferably $N \geq 9$, and here N=13.

[085] Table 1 below collates the number of windings L_i of each layer C_i. The maximum number of windings $\max(L_i)$ of the N layers C_i is such that $\max(L_i) \geq 4$, preferably $\max(L_i) \geq 6$, and more preferably, $\max(L_i) \geq 9$. Here, $\max(L_i)=14$. In addition, $\max(L_i)=N-1$, $\max(L_i)=N$ or $\max(L_i)=N+1$. Here, $\max(L_i)=N+1$.

Number of the layer Ci	Number of windings Li	Number of the layer Ci	Number of windings Li
C1	12	C8	13
C2	13	C9	14
C3	14	C10	13
C4	13	C11	12
C5	14	C12	11
C6	13	C13	10
C7	14		

Table 1

[086] The bead wire 52 comprises at least one layer C_k where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. In addition, for i varying from 1 to N inclusive, $|L_{k+1} - L_k| = 1$. Furthermore, for each layer C_k, where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$. Here, each layer C_4, C_6 and C_8 comprises $L_4=L_6=L_8=13$ windings and each layer C_3, C_5, C_7 and C_9 comprises $L_3=L_5=L_7=L_9=14$ windings.

[087] The bead wire 52 comprises a base bead wire 56 of which the windings are depicted in the various Figures 3 and 5-8 by circles filled with a pattern of crosshatching. The bead wire 56 has an axial plane of symmetry Pa, namely a plane of symmetry perpendicular to the axial direction X (parallel to the midplane M). The bead wire 56 also has a radial plane of symmetry Pr, namely a plane of symmetry perpendicular to the radial direction Y.

[088] The base bead wire 56 has a hexagonal shape, namely a shape comprising six sides each one defined by a layer or a row of windings each one meeting the next at six junctions J1 to J6 each one formed by a winding that a layer and a row or two rows that form the corresponding junction have in common.

[089] Thus, the base bead wire 56 comprises a radially internal side defined by a radially internal layer C_{inf} of N1 windings and a radially external side defined by a radially external layer C_{sup} of N1 windings. The base bead wire 56 also comprises two radially external axial sides each one defined by an axially and radially external lateral row F1, F2 of N2 windings. The base bead wire 56 additionally comprises two radially internal axial sides each one defined by an axially external and radially internal lateral row F3, F4 of N2 windings. The pairs of radially external and internal axial sides are axially opposite one another, namely face one another about the axial direction X.

[090] N1=N2+1 or N1=N2 and here N1=N2+1. Specifically, N1=8 and N2=7.

[091] Each junction J1, J2 is formed by a winding that each axially and radially

external lateral row F1, F2 and each axially external and radially internal lateral row F3, F4 have in common. Each winding in common that forms each junction J1, J2 has no winding of the wire axially on the outside of it.

[092] Each junction J3, J4 is formed by a winding that each axially and radially external lateral row F1, F2 and the radially external layer C_{sup} have in common.

[093] Each junction J5, J6 is formed by a winding that each axially external and radially internal lateral row F3, F4 and the radially external layer C_{inf} have in common.

[094] The bead wire 52 also comprises at least two axially and radially external additional lateral rows A1, A2 of N3 windings. Each axially and radially external additional lateral row A1, A2 is substantially parallel respectively to each axially and radially external lateral row F1, F2.

[095] Each axially and radially external additional lateral row A1, A2 is arranged axially on the outside respectively of each axially and radially external lateral row F1, F2. Here N3=5.

[096] In this embodiment, each axially and radially external additional lateral row A1, A2 comprises a radially external winding a1, a2 radially substantially aligned with the radially external layer C_{sup}.

[097] $N3 \leq N2$ and for preference N3=N2, N3+1=N2 or N3+2=N2. In this instance, N3+2=N2.

[098] In this embodiment, the bead wire 52 also comprises at least two axially external and radially internal additional lateral rows B1, B2, B3, B4. The bead wire 52 comprises two pairs of axially external and radially internal additional lateral rows, B1, B2 on the one hand, and B3, B4 on the other hand, of N5 and N6 windings respectively. Each axially external and radially internal additional lateral row B1, B3 on the one hand, and B2, B4 on the other hand, is substantially parallel respectively to each axially external and radially internal lateral row F3, F4.

[099] Each axially external and radially internal additional lateral row, B1, B3 on the one hand, and B2, B4 on the other hand, is arranged axially on the outside respectively of each axially external and radially internal lateral row B3, F4. Each axially external and radially internal additional lateral row B3, B4 is arranged axially on the outside respectively of each axially external and radially internal additional lateral row B1, B2.

[0100] In this embodiment, each axially external and radially internal additional lateral row B1, B2, B3, B4 comprises a radially internal winding b1, b2, b3, b4 radially substantially aligned with the radially internal layer C_{inf}.

[0101] $N5 \geq N6$, preferably N5>N6 and here N5=N6+2 with N5=5 and N6=3. Also,

N5≤N2, preferably N5=N2, N5+1=N2 or N5+2=N2 and here N5+2=N2.

[0102] Also, max(L_i)-N1≤6.

[0103] The windings of the additional lateral rows A1, A2, B1, B2, B3 and B4 are depicted as circles filled with a pattern of parallel hatching.

[0104] EXAMPLE OF THE METHOD ACCORDING TO THE INVENTION

[0105] A method of manufacturing a tyre according to the invention will now be described with reference to Figures 4a to 4d.

[0106] First of all, in a first tyre-building phase, the various plies, masses of rubber and other elements described hereinabove are built up to form a green tyre on a tyre-building drum already known to those skilled in the art.

[0107] Thus, the first mass 42 of cushioning rubber, airtight inner ply 38, one or more carcass plies 28 intended to be anchored in the bead 20, the mass 40 of filling rubber and the annular reinforcing structure 24 comprising the bead wire 52 and the encasing mass 54 are laid in succession and in that order. Thus, the bead wire 52 has been placed on the carcass ply or plies 28. This results in the intermediate green tyre form depicted in Figure 4a.

[0108] The first mass 42 of cushioning rubber and part of the carcas ply or plies 28, in this instance the turnup 34, is then folded around the annular reinforcing structure 24. This then results in the intermediate green tyre form depicted in Figure 4b.

[0109] Next, the mass 44 of filling rubber, the second cushioning mass 50 and finally the axially external mass 46 of rubber delimiting the axially external surface 48 of the sidewall 20 are placed in succession and in that order. This then results in the intermediate green tyre form depicted in Figure 4c.

[0110] Finally, the carcass ply or plies 28 and the bead wire 52 are turned relative to one another. In this instance, the entire intermediate green tyre form with the exception of the annular reinforcing structure 24 is turned about the latter which remains substantially fixed during rotation. As an alternative, the bead wire 52 could be turned keeping the remainder of the green tyre form fixed. This then results in the intermediate green tyre form depicted in figure 4d. It may be noted that following the rotation, the bead wire 52 has the same orientation that it had before rotation and that the various plies and masses of rubber have not been deformed under the effect of the rotation.

[0111] In a subsequent second finishing phase, the crown 12 and the tread 18 are added to the intermediate green tyre form previously obtained.

[0112] In a third, curing, phase, the final green tyre is cured in order to obtain the

cured tyre.

[0113] OTHER EXAMPLES OF BEAD WIRES ACCORDING TO THE INVENTION

[0114] Figures 5, 6, 7 and 8 depict bead wires according to other embodiments of the invention. In these figures, elements similar to those of Figure 3 are denoted by identical references.

[0115] Figure 5 depicts a bead wire according to a second embodiment of the invention.

[0116] Unlike the bead wire according to the first embodiment, the bead wire 52 according to the second embodiment comprises N=9 layers and P=76 windings.

[0117] Table 2 below collates the number of windings L_i of each layer C_i. $\max(L_i)=N+1=10$.

Number of the layer Ci	Number of windings Li	Number of the layer Ci	Number of windings Li
C1	8	C6	9
C2	9	C7	8
C3	10	C8	7
C4	9	C9	6
C5	10		

Table 2

[0118] The bead wire 52 comprises at least one layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. Furthermore, for each layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$. Here, the layer C_4 comprises $L_4=9$ windings and each layer C_3, C_5 comprises $L_3=L_5=10$ windings.

[0119] The base bead wire 56 is such that N1=N2+1. Specifically, N1=6, N2=5.

[0120] Unlike the bead wire of the first embodiment, the bead wire 52 according to the second embodiment comprises just one pair of axially external and radially internal additional lateral rows B1, B2 of N5=3 windings.

[0121] $N5 \leq N2$, preferably N5=N2, N5+1=N2 or N5+2=N2 and here N5+2=N2.

[0122] Also, $\max(L_i)-N1 \leq 6$.

[0123] Figure 6 depicts a bead wire according to a third embodiment of the invention.

[0124] The bead wire 52 according to the third embodiment comprises N=7 layers and

P=42 windings.

[0125] Table 3 below collates the number of windings L_i of each layer C_i. $\max(L_i)=N=7$.

Number of the layer Ci	Number of windings Li	Number of the layer Ci	Nombre d'enroulements Li
C1	5	C5	7
C2	6	C6	6
C3	7	C7	5
C4	6		

Table 3

[0126] The bead wire 52 comprises at least one layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. Furthermore, for each layer C_k where $k \in]1, N[$ such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$. Here, the layer C_4 comprises $L_4=6$ windings and each layer C_3, C_5 comprises $L_3=L_5=7$ windings.

[0127] The bead wire 52 according to the third embodiment is such that N1=N2+1. Specifically, N1=4 and N2=3. Additionally, N3≤N2 and here N3=N2=3. Furthermore, N4=N1+1 with N4=5 and N1=4.

[0128] Unlike the bead wire according to the first embodiment, the bead wire 52 according to the third embodiment comprises at least one axially and radially external additional covering D_{sup} of windings in the overall shape of a U. The windings of the axially and radially external additional covering D_{sup} are depicted as circles filled with a pattern of parallel hatching.

[0129] The windings of the axially and radially external additional covering D_{sup} are arranged axially on the outside of each axially external lateral row and radially on the outside of the radially external layer C_{sup}.

[0130] The axially and radially external additional covering D_{sup} comprises a radially external additional layer E_{sup} of N4 windings, substantially parallel to the radially external layer C_{sup}. The additional layer E_{sup} is radially arranged on the outside of the radially external layer C_{sup}. The bead wire 52 according to the third embodiment is such that N4=N1+1.

[0131] The axially and radially external additional covering D_{sup} also comprises two axially and radially external additional lateral rows A1, A2 of N3 windings. Each additional lateral row A1, A2 is substantially parallel respectively to each axially and radially external lateral row F1, F2. Each axially and radially external additional lateral

row A1, A2 is arranged axially on the outside respectively of each axially and radially external lateral row F1, F2.

[0132] Here, N3=4. N3≤N2 and here N3=N2.

[0133] Furthermore, the bead wire 52 according to the third embodiment comprises at least one axially external and radially internal additional covering D_{inf} of windings in the overall shape of a U. The windings of the axially external and radially internal additional covering D_{inf} are depicted as circles filled with a pattern of parallel hatching.

[0134] The windings of the axially external and radially internal additional covering D_{inf} are arranged axially on the outside of each axially internal and radially external lateral row and radially on the inside of the radially internal layer C_{inf}.

[0135] The axially external and radially internal additional covering D_{inf} comprises a radially internal additional layer E_{inf} of N7 windings substantially parallel to the radially internal layer C_{inf}. The radially internal additional layer E_{inf} is arranged radially on the inside of the radially internal layer C_{inf}.

[0136] The axially external and radially internal additional covering D_{inf} also comprises two axially external and radially internal additional lateral rows B1, B2 of N5 windings. This axially external and radially internal additional lateral row B1, B2 is substantially parallel respectively to each axially external and radially internal lateral row F3, F4. Each axially external and radially internal additional lateral row B1, B2 is axially arranged on the outside respectively of each axially external and radially internal lateral row F3, F4.

[0137] N5≤N2, and here, N5=N2=3 and N7=N1+1 with N7=5.

[0138] Also, $\max(L_i)$-N1≤6 and preferably $\max(L_i)$-N1≤2.

[0139] Figure 7 depicts a bead wire according to a fourth embodiment of the invention.

[0140] The bead wire 52 according to the fourth embodiment comprises N=7 layers and P=35 windings.

[0141] Table 4 below collates the number of windings L_i of each layer C_i. $\max(L_i)$=N-1=6.

Number of the layer Ci	Number of windings Li	Number of the layer Ci	Number of windings Li
C1	4	C5	6
C2	5	C6	5
C3	6	C7	4
C4	5		

Table 4

[0142] The bead wire 52 comprises at least one layer C_k where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. Furthermore, for each layer C_k where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$. Here, the layer C_4 comprises $L_4=5$ windings and each layer C_3, C_5 comprises $L_3=L_5=6$ windings.

[0143] Unlike the bead wire 52 according to the third embodiment, N1=N2=3. In addition, N3≤N2 and here N3=N2=3. Furthermore, N4=N1+1 with N4=4 and N1=3. Also, N5≤N2 and here N5=N2=3 and N7=N1+1 with N7=4.

[0144] Also, $\max(L_i)$-N1≤6 and preferably N1-$\max(L_i)$≤2.

[0145] Figure 8 depicts a bead wire according to a fifth embodiment of the invention.

[0146] The bead wire 52 according to the fifth embodiment comprises N=12 layers and P=35 windings. N1=N2=6.

[0147] Table 5 below collates the number of windings L_i of each layer C_i. $\max(L_i)$=N=12.

Number of the layer Ci	Number of windings Li	Number of the layer Ci	Number of windings Li
C1	10	C7	12
C2	11	C8	11
C3	12	C9	10
C4	11	C10	9
C5	12	C11	8
C6	11	C12	7

Table 5

[0148] The bead wire 52 comprises at least one layer C_k where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$. Furthermore, for each layer C_k, where k $\in$]1, N[such that $L_{k+1} > L_k$ and $L_k < L_{k-1}$, $L_{k+1}=L_k+1$ and $L_k+1=L_{k-1}$. Here, each layer C_4, C_6 comprises $L_4=L_6=11$ windings and each layer C_3, C_5, C_7 comprises $L_3=L_5=L_7=12$ windings.

[0149] In a similar way to the bead wire according to the third and fourth embodiments of Figures 6 and 7, the bead wire 52 according to the fifth embodiment comprises an axially and radially external additional covering D_{sup} of windings in the overall shape of a U.

[0150] The axially and radially external additional covering D_{sup} comprises a radially external additional layer E_{sup} of N4 windings, substantially parallel to the radially external layer C_{sup}. The radially external additional layer E_{sup} is radially arranged on the outside of the radially external layer C_{sup}.

[0151] The axially and radially external additional covering D_{sup} also comprises two axially and radially external additional lateral rows A1, A2 of N3 windings substantially parallel respectively to each axially and radially external row F1, F2. Each axially external and radially internal additional lateral row A1, A2 is axially arranged on the outside respectively of each axially external and radially internal lateral row F1, F2.

[0152] The bead wire 52 according to the second embodiment is such that N3≤N2 and here N3=N2=6. Furthermore N4=N1+1 with N4=7 and N1=6.

[0153] In a similar way to the bead wire according to the first embodiment, the bead wire 52 according to the fifth embodiment also comprises two pairs of axially external and radially internal additional lateral rows, B1, B2 on the one hand, and B3, B4 on the other hand, respectively of N5 and N6 windings.

[0154] In this embodiment, each axially external and radially internal additional lateral row B1, B2, B3, B4 comprises a radially internal winding b1, b2, b3, b4 radially substantially aligned with the radially internal layer C_{inf}.

[0155] The axially external and radially internal additional lateral rows, B1, B2, on the one hand, and B3, B4 on the other hand, are respectively substantially parallel to each axially external and radially internal row F3, F4.

[0156] Each axially external and radially internal additional lateral row, B1, B2 on the one hand, and B3, B4 on the other hand, is axially arranged on the outside respectively of each axially external and radially internal lateral row F3, F4.

[0157] N5≥N6, preferably N5>N6 and here N5=N6+2 with N5=5 and N6=3. Also, N5≤N2 and here N5+1=N2.

[0158] Also $\max(L_i)$-N1≤6.

[0159] COMPARATIVE TESTS AND TRIALS

[0160] Performance of the method of manufacture

[0161] Figure 9 depicts a bead wire 100 of the prior art. This bead wire has none of the features essential to the invention that allow easy relative rotation of the bead wire with respect to the carcass ply.

[0162] Figure 10 depicts a tyre 200 of the prior art comprising a bead wire 100 and manufactured by employing steps similar to the steps described with reference to Figures 4a to 4d. The tyre 200 has defects that have been deliberately exaggerated for the purposes of illustrating the advantages of the invention.

[0163] Note the presence of the region in which the turnup 34' and the masses of rubber 44', 46' and 50' arranged axially on the outside of the turnup have been placed in compression. The overtensioning of the main strand 32' causes the windings in contact with the main strand 32' but also those in contact with the turnup 34' to become disorganized. In addition, the relative rotation falls short by an angle α.

[0164] Comparing Figures 2 (or 4d) and 10, it may be noted that use of the method of manufacture of the tyre according to the invention leads to a tyre that does not have the potential defects unlike the tyre 200.

[0165] Tyre-rim slip performance

[0166] The tyre-rim slip performance of each tyre was tested. Specifically, in order for the tyre to be able to transfer all of the force applied by the engine or motor of the vehicle to the ground, it is preferable that the tyre-rim slip be as low as possible.

[0167] The co-efficient of friction μ between the rim and tyre is therefore measured. To do so, use is made of a vehicle with a total mass of 2 tonnes provided with two tyres to be tested. A weight of equal mass, in this instance 2 tonnes, is then hauled over bitumen. Between the weight that is to be hauled and the vehicle is positioned a dynamometric sensor that enables the force F, expressed in kg applied by the vehicle to the weight to be hauled to be measured as the tyre begins to slip relative to the rim. Thus, for a force F=500 kg applied in order to cause the tyre to slip relative to the rim, a co-efficient of friction μ=0.5 is obtained. A score of between 0 and 5.0 is assigned according to the force recorded, zero indicating a tyre exhibiting a great deal of tyre-rim slip and 5 indicating a tyre with the best possible tyre-rim slip performance. The results of these tests are collated in Table 6 below.

Bead wire	Score	Bead wire	Score

100	5	52 – Fig.6	5
52 – Fig.3	5	52 – Fig.7	4
52 – Fig. 5	5	52 – Fig.8	5

Table 6

[0168] The scores of 4 and 5 are considered to indicate a low tyre-rim slip and therefore that the corresponding tyres meet the required tyre-rim slip performance criterion. Note that all the tyres according to the invention have a score of 4 or higher.

[0169] Thus, the tyres according to the invention make it possible to avoid the need to take special precautions during the method of manufacture and exhibit low tyre-rim slip.

[0170] The invention is not restricted to the embodiments described hereinabove.

[0171] Thus, the axially external and radially internal additional covering D_{inf} may comprise several radially internal additional layers E_{inf} substantially parallel to the radially internal layer C_{inf} as well as several pairs of axially external and radially internal additional lateral rows.

[0172] The features of the various embodiments described hereinabove may be combined in so far as they are mutually compatible.

CLAIMS

1. A bead wire for a tyre rotating about an axis, the bead wire comprising:

- several windings of at least one wire which are arranged axially next to one another over N layers Ci radially superposed on one another;

-a basic hexagonal bead wire comprising:

-a radially external layer (C_{sup}) of N1 windings,

- a radially internal layer (C_{inf}) of N1 windings,

- two axially external and radially external lateral rows (F1, F2) of N2 windings axially opposite one another,

- two axially external and radially internal lateral rows (F3, F4) of N2 windings axially opposite one another, with N1=N2 + 1 or N1=N2, and

- two junctions (J1, J2) each one formed by a winding common to one of the axially external and radially external lateral rows (F1, F2) and to one of the axially external and radially internal lateral rows (F3, F4), each winding in common and forming each of said junctions (J1, J2) having no axially external adjacent winding, and

-at least two axially external and radially internal additional lateral rows (B1, B2, B3, B4), each of said two axially external and radially internal additional lateral rows (B1, B2, B3, B4) being respectively substantially parallel to each of said axially external and radially internal lateral rows (F3, F4).

2. The bead wire according to Claim 1, in which each radially internal winding (b1, b2, b3, b4) of each of said axially external and radially internal additional lateral rows (B1, B2) is radially substantially aligned with the radially internal layer (C_{inf}).

3. The bead wire according to Claim 1, comprising at least one axially external and radially internal additional covering (D_{inf}) of windings in the overall shape of a U.

4. The bead wire according to claim 3, in which the at least one axially external and radially internal additional covering (D_{inf}) comprises:

- a radially internal additional layer (E_{inf}) of N7 windings, and substantially parallel to the radially internal layer (C_{inf}), and

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- said at least two axially external and radially internal additional lateral rows (B1, B2, B3, B4).

5. The bead wire according to claim 4, in which N7=N1+1.

6. The bead wire according to any one of claims 1 to 5, in which, with each axially external and radially internal additional lateral row (B1, B2) comprising N5 windings, N5≤N2.

7. The bead wire according to claim 6, in which N5=N2, N5+1=N2 or N5+2=N2.

8. The bead wire according to any one of claims 1 to 7, in which max(Li)=N-1, max(L_i)=N or max(L_i)=N+1 where L_i is a number of windings of each layer C_i, i varying from 1 to N inclusive.

9. The bead wire according to any one of claims 1 to 8, comprising at least one layer C_k where k Є]1, N[such that $L_{k+1} > L_k$ and Lk < L_{k-1}.

10. A tyre, comprising:

- at least one bead comprising at least one bead wire according to any one of claims 1 to 9, and

- a carcass reinforcement comprising at least one carcass ply anchored in each bead by a turnup around the bead wire.

11. A method of manufacturing the tyre defined in claim 10, comprising the steps of:

- placing the at least one bead wire on the at least one carcass ply,

- folding a part of the at least one carcass ply around the at least one bead wire, and

- turning the at least one carcass ply and the at least one bead wire relative to one another.

Date Reçue/Date Received 2020-06-30

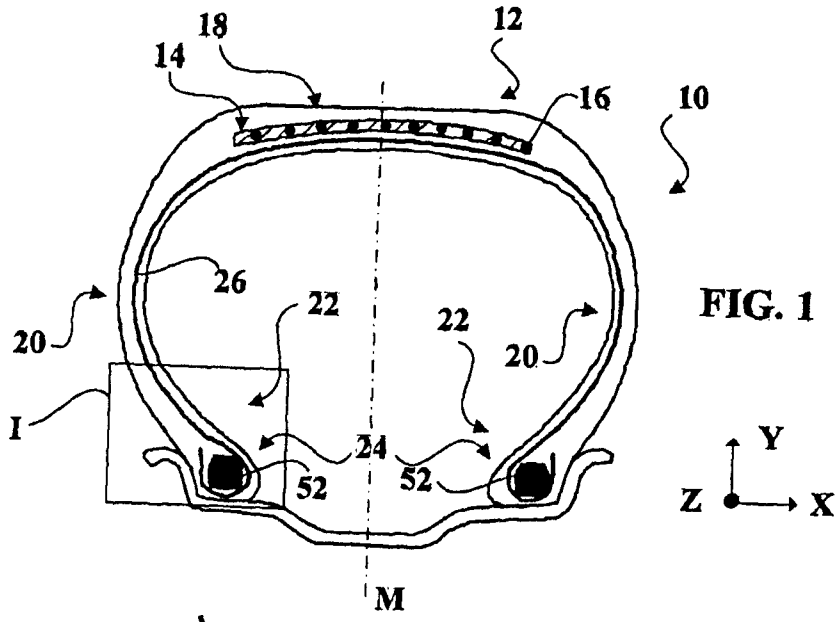

18
12
14
16
10
26
22
22
20
20
I
24
52
52
Y
Z
X
M

FIG. 1

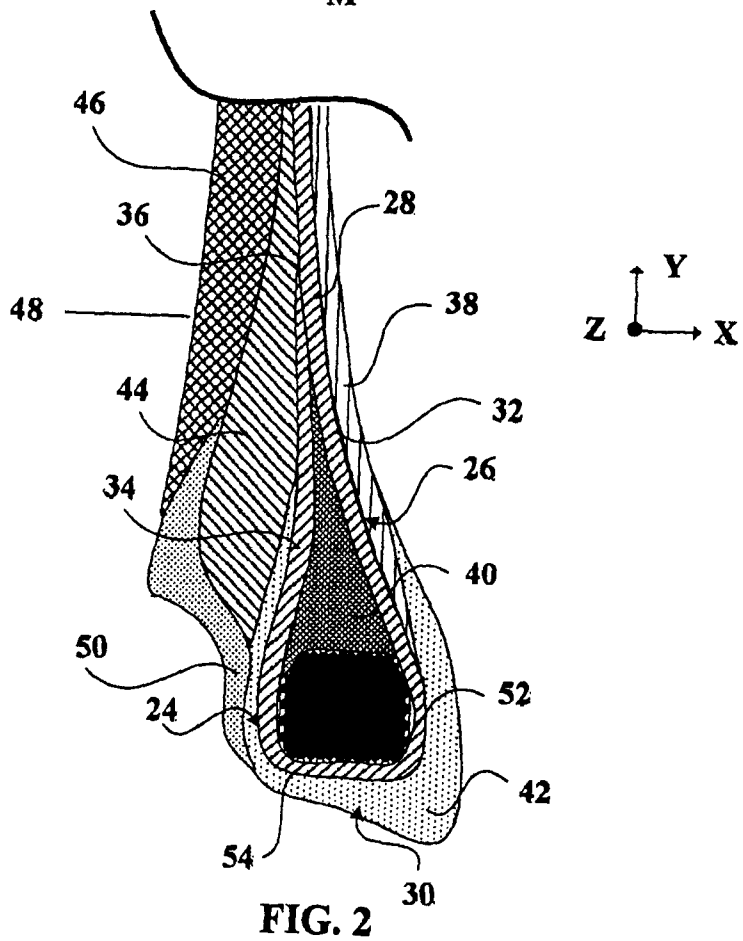

46
36
28
48
38
44
32
26
34
40
50
52
24
42
54
30
Y
Z
X

FIG. 2

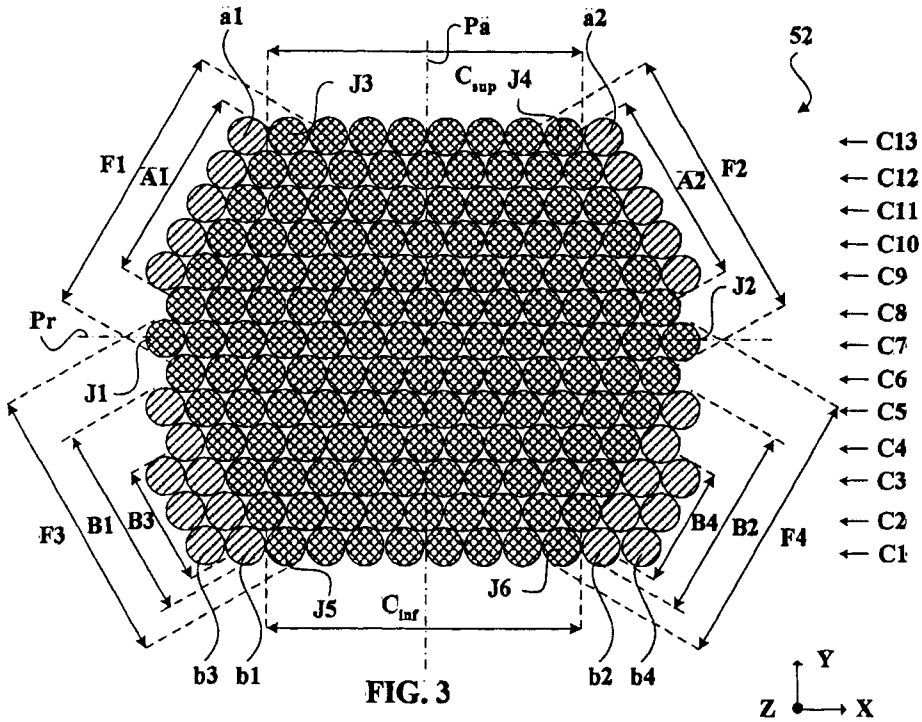

a1
Pa
a2
52
J3
C_{sup} J4
C13
C12
C11
C10
C9
C8
C7
C6
C5
C4
C3
C2
C1
F1
A1
A2
F2
J2
Pr
J1
F3
B1
B3
B4
B2
F4
J5
C_{inf}
J6
b3
b1
b2
b4
Y
Z
X

FIG. 3

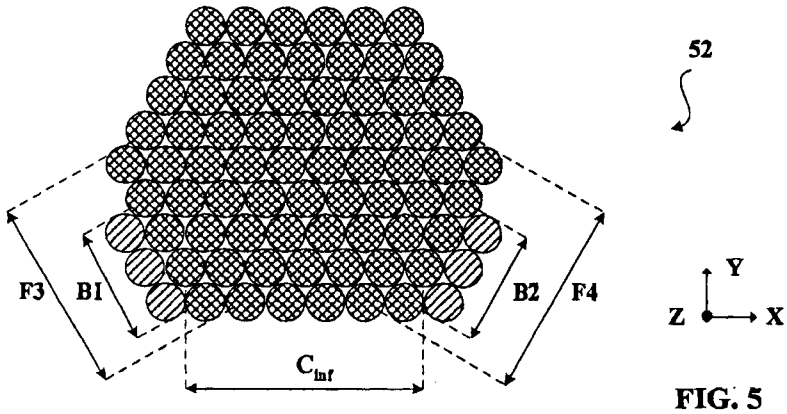

52
F3
B1
B2
F4
C_{inf}
Y
Z
X

FIG. 5

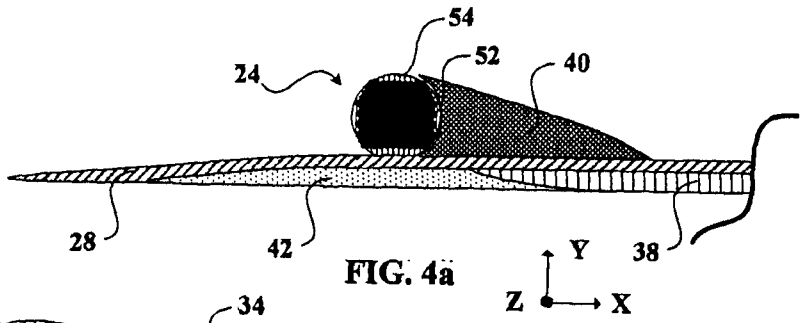


FIG. 4a

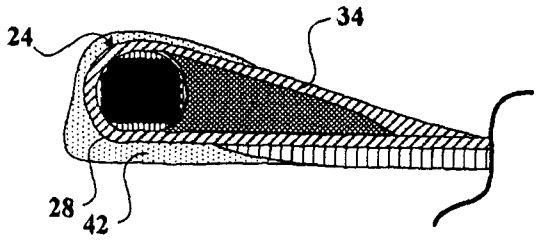
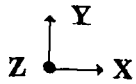
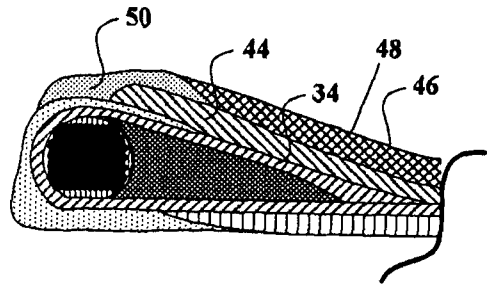


FIG. 4b

FIG. 4c





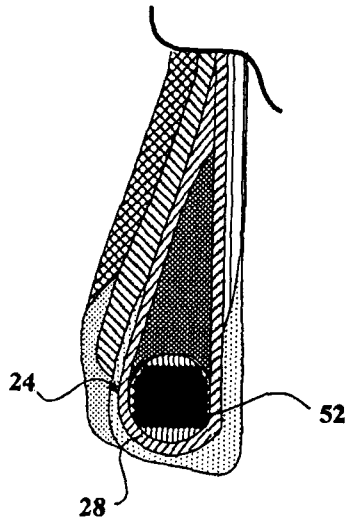
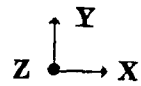


FIG. 4d



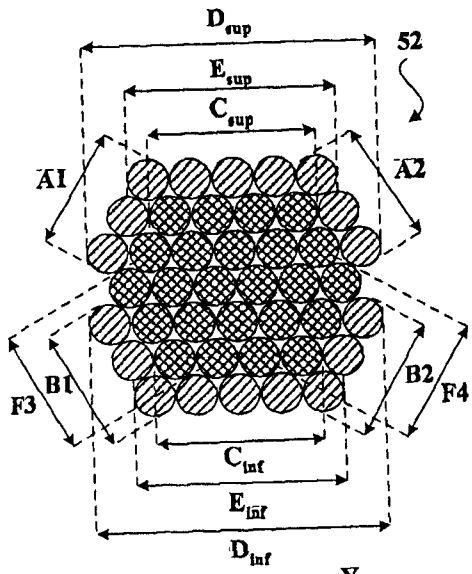


FIG. 6

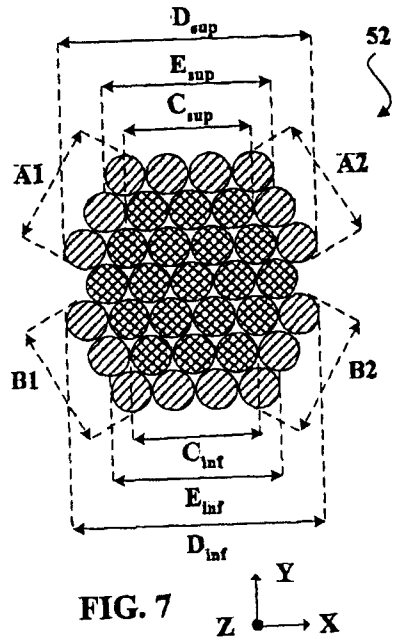


FIG. 7

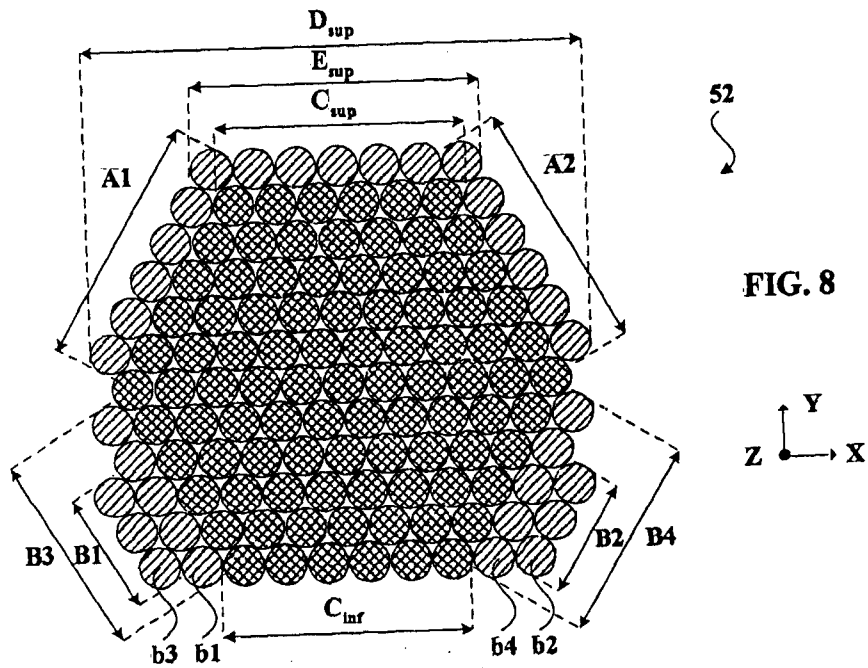


FIG. 8

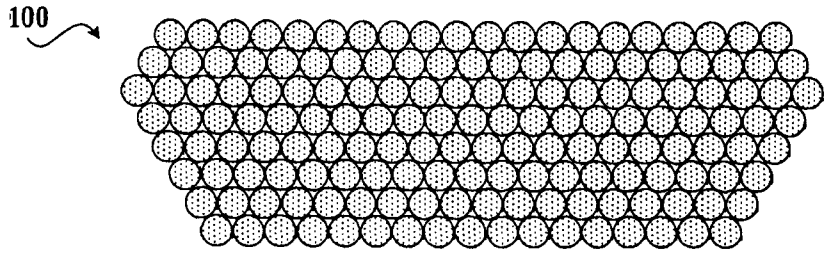
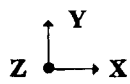


FIG. 9 – Prior art



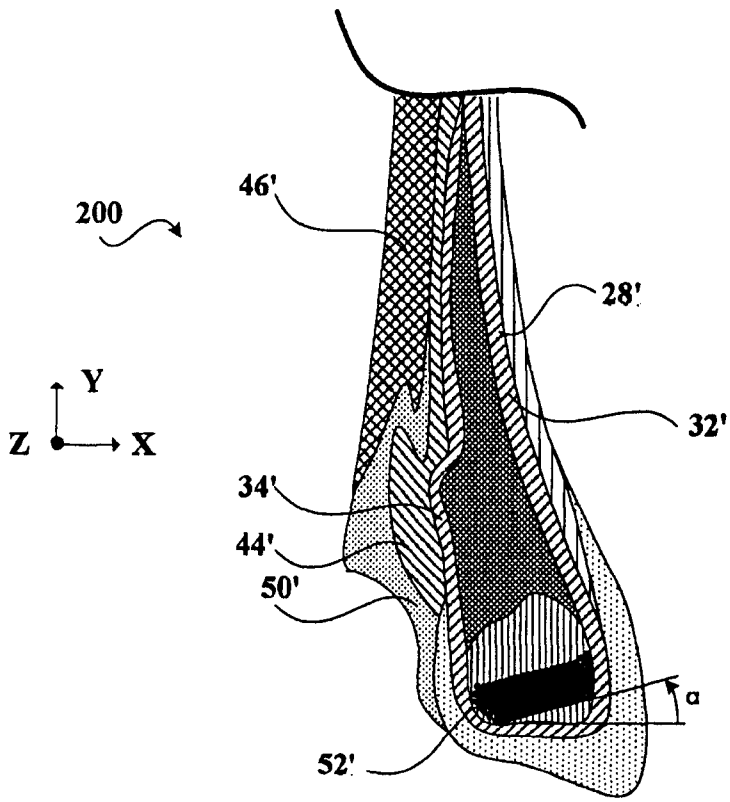
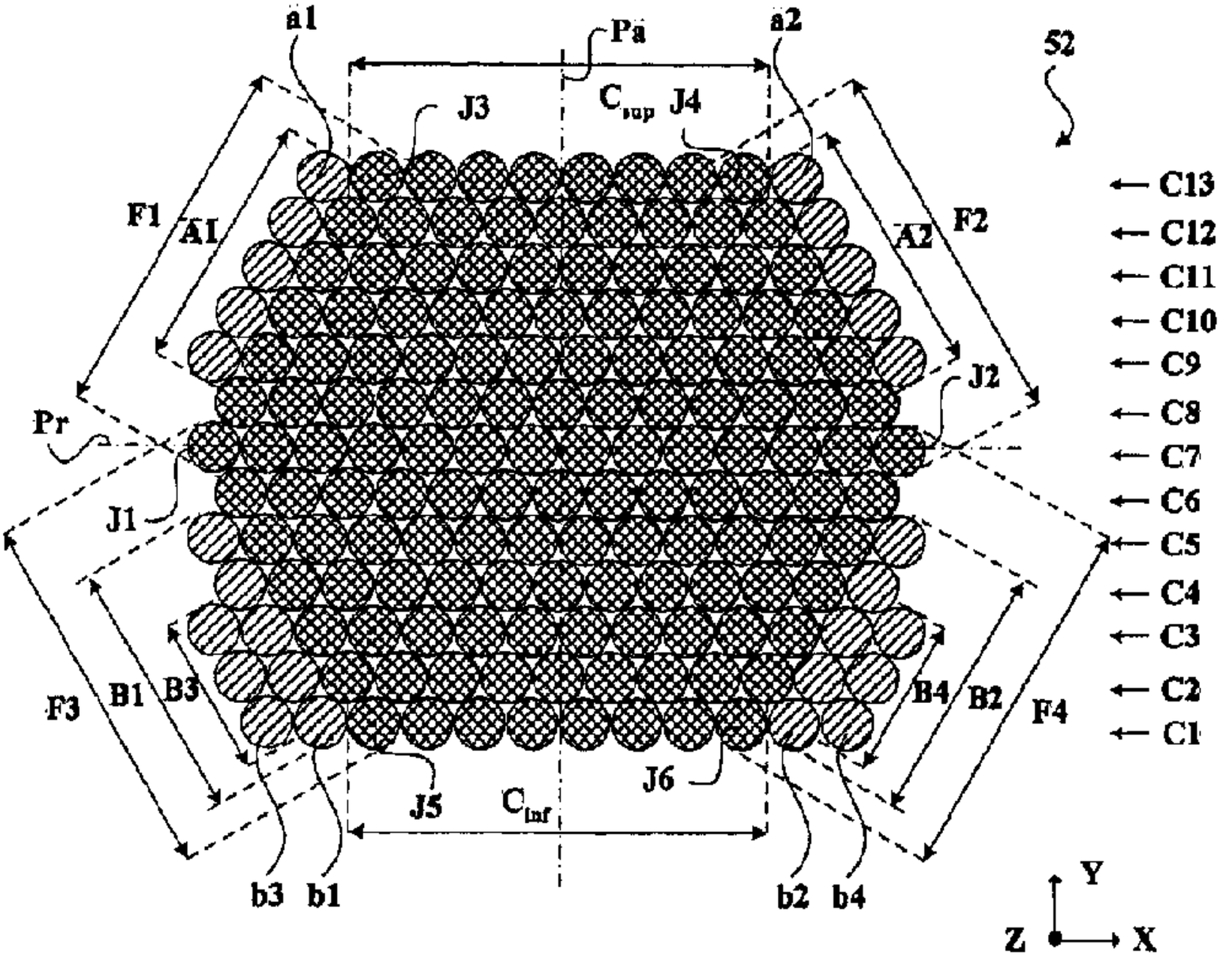


FIG. 10 – Prior art


a1
Pa
a2
52
J3
C_{sup}
J4
C13
C12
C11
C10
C9
C8
C7
C6
C5
C4
C3
C2
C1
F1
A1
A2
F2
J2
Pr
J1
F3
B1
B3
B4
B2
F4
J5
C_{inf}
J6
b3
b1
b2
b4
Y
Z
X