



- (51) International Patent Classification:
B60C 13/00 (2006.01) B60C 13/04 (2006.01)
- (21) International Application Number:
PCT/US2014/043332
- (22) International Filing Date:
20 June 2014 (20.06.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/947,695 22 July 2013 (22.07.2013) US
- (71) Applicant: BRIDGESTONE AMERICAS TIRE OPERATIONS, LLC [US/US]; 535 Marriott Drive, Nashville, TN 37214 (US).
- (72) Inventors: STUCKEY, Jon; 5317 Gargasz Drive, Lorain, OH 44053 (US). CLEMMER, Kathleen; 168 Ido Avenue, Akron, OH 44301 (US). WEATHERWAX, Kent; 224 E. Dresden Avenue, Akron, OH 44301 (US).
- (74) Agents: JUPINA, Matthew et al.; 10 East Firestone Blvd., Akron, OH 44317 (US).

- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))

(54) Title: LOW-METAL TIRE

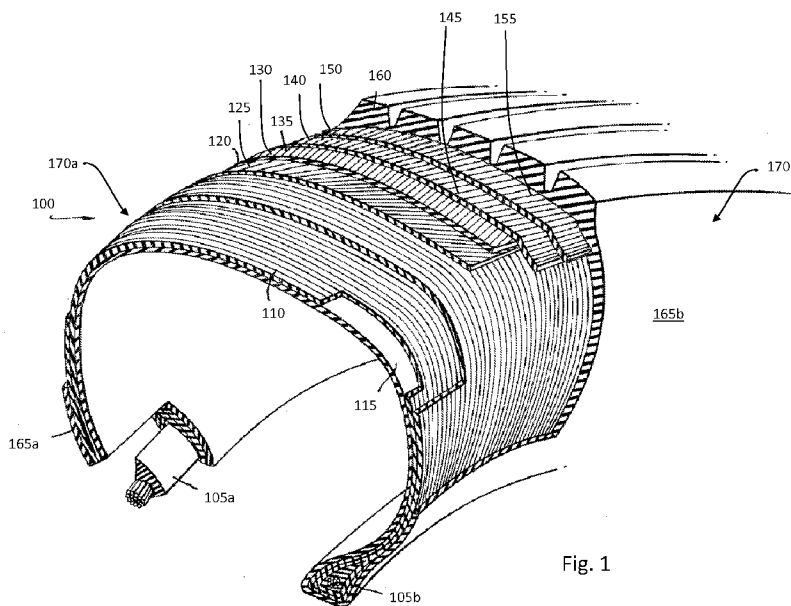


Fig. 1

(57) Abstract: A tire includes a carcass ply and at least one annular structure associated with the carcass ply. The tire further includes a metal-free circumferential belt region comprising a first metal-free belt ply and a second metal-free belt ply. The tire also has a metal-free cap ply disposed radially outward of the first metal-free belt ply and the second metal-free belt ply. The tire also includes a metal-free circumferential tread that contacts a road, and a pair of sidewalls associated with at least one annular structure and the metal-free circumferential tread.

WO 2015/012980 A1

LOW-METAL TIRE

FIELD OF INVENTION

[0001] This disclosure relates to the field of tire constructions. More particularly, the disclosure relates to tires made without large amounts of steel or other metal. Even more particularly, the disclosure describes tires made with reduced amounts of steel or other metal in the belts, reinforcements, cap plies, treads, shoulders, and sidewalls.

BACKGROUND

[0002] Current tire constructions employ body plies having reinforcing cords that extend transversely from bead to bead. Such tires are referred to as radial tires, because the reinforcement cords are in a substantially radial orientation. A radial tire employs an inextensible, circumferential belt that contains steel reinforcement cords. The belt is disposed on top of the body plies, below the tread. It had been understood in the art that a steel belt was required in radial tires to prevent undesired expansion of the tire that would result in poor cornering performance. Additionally, prior non-steel tire constructions tend to deform easily and wear faster. Prior non-steel tire constructions are also unable to travel at high speeds. Given these concerns, prior non-steel constructions were not viable alternatives to steel-belted tires.

SUMMARY OF THE INVENTION

[0003] In one embodiment, a tire includes a first annular bead, a second annular bead, and a body ply extending between the first annular bead and the second annular bead. The tire further includes a circumferential belt disposed radially outward of the body ply and extending axially across a portion of the body ply. The tire also has a first reinforcement ply disposed radially outward of the circumferential belt and extending axially across a portion of the body ply. A circumferential tread is disposed radially outward of the first reinforcement ply and extends axially across a portion of the body ply. A first sidewall extends between the first annular bead and a first shoulder. The first shoulder is associated with the circumferential tread. A second sidewall extends between

the second annular bead and a second shoulder. The second shoulder is associated with the circumferential tread. The tire has a 1 degree cornering coefficient of between 0.09 and 0.40, and only the first and second annular beads contain metal.

[0004] In another embodiment, a tire includes a carcass ply and at least one annular structure associated with the carcass ply. The tire further includes a metal-free circumferential belt region comprising a first metal-free belt ply and a second metal-free belt ply. The tire also has a metal-free cap ply disposed radially outward of the first metal-free belt ply and the second metal-free belt ply. The tire also includes a metal-free circumferential tread that contacts a road, and a pair of sidewalls associated with at least one annular structure and the metal-free circumferential tread.

[0005] In yet another embodiment, a tire includes a pair of annular beads configured to secure the tire to a vehicle wheel, and a non-metallic body ply associated with the annular beads. The non-metallic body ply forms a radially inner portion of the tire. The tire further includes a non-metallic annular belt disposed radially outward of the non-metallic body ply. The non-metallic annular belt forms a radially intermediate portion of the tire. A first non-metallic reinforcement further forms a radially intermediate portion of the tire. A second non-metallic reinforcement further forms a radially intermediate portion of the tire. A tread is disposed radially outward of the first and second non-metallic reinforcements, and forms a radially outer portion of the tire. A pair of sidewalls form axially outer portions of the tire.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the accompanying drawings, structures are illustrated that, together with the detailed description provided below, describe exemplary embodiments of the claimed invention. Like elements are identified with the same reference numerals. It should be understood that elements shown as a single component may be replaced with multiple components, and elements shown as multiple components may be replaced with a single component. The drawings are not to scale and the proportion of certain elements may be exaggerated for the purpose of illustration.

[0007] **Figure 1** is a peel-away cross-sectional perspective view of an embodiment of a tire;

[0008] **Figure 2** is a cross-sectional view of a second embodiment of a tire;

[0009] **Figure 3** is a schematic drawing of a cross-sectional view of a representative embodiment of a radial tire;

[0010] **Figure 4** is a schematic drawing of a cross-sectional side view of the representative embodiment of the radial tire shown in **Figure 3**;

[0011] **Figure 5** is a schematic drawing of a cross-sectional top view of ply layers and reinforcement cords disposed in the representative embodiment of the radial tire shown in **Figure 3**;

[0012] **Figure 6** is a schematic drawing of a cross-sectional view of a representative embodiment of a bias tire;

[0013] **Figure 7** is a schematic drawing of a cross-sectional side view of a representative embodiment of the bias tire shown in **Figure 6**; and

[0014] **Figure 8** is a schematic drawing of a cross-sectional top view of ply layers and reinforcement cords disposed in the representative embodiment of the bias tire shown in **Figure 6**.

DETAILED DESCRIPTION

[0015] The following includes definitions of selected terms employed herein. The definitions include various examples and/or forms of components that fall within the scope of a term and that may be used for implementation. The examples are not intended to be limiting. Both singular and plural forms of terms may be within the definitions.

[0016] “Axial” and “axially” refer to a direction that is parallel to the axis of rotation of a tire.

[0017] “Circumferential” and “circumferentially” refer to a direction extending along the perimeter of the surface of the tread perpendicular to the axial direction.

[0018] “Equatorial plane” refers to the plane that is perpendicular to the tire’s axis of rotation and passes through the center of the tire’s tread.

[0019] “Radial” and “radially” refer to a direction perpendicular to the axis of rotation of a tire.

[0020] “Sidewall” as used herein, refers to that portion of the tire between the tread and the bead.

[0021] “Tread” as used herein, refers to that portion of the tire that comes into contact with the road under normal inflation and load.

[0022] While similar terms used in the following descriptions describe common tire components, it is understood that because the terms carry slightly different connotations, one of ordinary skill in the art would not consider any one of the following terms to be purely interchangeable with another term used to describe a common tire component.

[0023] **Figure 1** shows a peel-away cross-sectional perspective view of tire **100**. Tire **100** includes a first annular bead **105a** and a second annular bead **105b**. In the construction shown in **Figure 1**, the annular beads **105a** and **105b** contain metallic cords (not labeled). The annular beads are configured to secure the tire to a vehicle wheel.

[0024] Body ply **110** extends between the first and second annular beads **105a,b**. As one of ordinary skill in the art would understand, the body ply **110** can extend between and around the pair of annular beads **105a,b** in a variety of manners. In alternative embodiments, body ply **110**, also known as a carcass ply, is associated with an annular structure such as an annular bead via physical proximity, direct physical contact, industrial mixing process, or chemical interaction. Although not shown, body ply **110** may have a plurality of non-metallic reinforcement cords.

[0025] The illustrated embodiment includes an inner liner **115** that is the innermost tire element and is adjacent to body ply **110**. In an alternative embodiment (not shown), reinforcement layers or other layers may be disposed between the inner liner and the body ply. In another alternative embodiment (not shown), the inner liner is omitted and the body ply is the innermost tire element.

[0026] In additional embodiments, body ply **110** forms a radially inner portion of the tire. Generally speaking, the radially inner portion of the tire constitutes an area between an inner liner and a circumferential belt. The radially inner portion can include, amongst other things: a body ply, an inner liner or other bonding and sealing layers, a noise damper, electronic and/or sensory components, fluid media used to prevent air leakage, and other features or components not specifically recited herein.

[0027] A first circumferential belt **120** is disposed radially outward of the body ply **110**. The first circumferential belt **120** includes a first plurality of non-metallic reinforcement cords **125**. A second circumferential belt **130** is disposed radially outward

of the first circumferential belt **120**. The second circumferential belt **130** includes a second plurality of non-metallic reinforcement cords **135**. In an alternative embodiment, the belt region (*i.e.*, the region containing a circumferential belt and reinforcements such as cap plies and reinforcement plies) contains additional plies that are also devoid of metal and other rigid, slow-decomposing materials.

[0028] In additional alternative embodiments not shown herein, the circumferential belt forms a radially intermediate portion of the tire. Generally speaking, the radially intermediate portion of the tire constitutes an area between the body ply and a tread base layer (not shown). The radially intermediate portion can include, amongst other things: belt(s), reinforcement(s), rubber and rubber alternatives, adhesive or bonding layers, electronic and/or sensory components and other features or components not specifically recited herein. Thus, in these additional alternative embodiments, the circumferential belt need not be the sole intermediate tire element, although it can be.

[0029] In the embodiment shown in **Figure 1**, tire **100** further contains a first reinforcement ply **140** having first reinforcement cords **145** or a first cord substitute (not shown), and a second reinforcement ply **150** having second reinforcement cords **155** or a second cord substitute (not shown). . The first reinforcement ply **140** is disposed radially outward of body ply **110**, the first circumferential belt **120** and the second circumferential belt **130**. The second reinforcement ply **150** is disposed radially outward of first reinforcement ply **140**. Both the first and second reinforcement plies **140** and **150** extend axially across a portion of body ply **110**. Both first reinforcement ply **140** and second reinforcement ply **150** are devoid of metal and other rigid, slow-decomposing materials. As one of ordinary skill in the art would understand, rigid, slow-decomposing materials may present a safety danger once a tire goes through a recovery or recycling process. In an alternative embodiment not shown in **Figure 1**, tire **100** contains no reinforcement plies.

[0030] In one alternative embodiment, not shown, tire **100** only contains a first reinforcement ply **140** disposed between circumferential tread **160** and body ply **110**.

[0031] Circumferential tread **160** is disposed radially outward of first and second reinforcement plies **140**, **150**. Circumferential tread **160** extends axially across a portion of body ply **110**. As shown, circumferential tread **160** extends between the shoulders,

although in certain constructions, such as those used for motorcycle tires, the tread can be understood to comprise part of the shoulder or extend beyond a shoulder. Circumferential tread **160** contains no large particulate metal, metal solids, or other metal reinforcement. Large particulate metal includes metal particles similar in size to silt, very fine sand, medium sand, coarse sand, very coarse sand, and very fine gravel.

[0032] In alternative embodiments (not shown), the circumferential tread forms a radially outer portion of the tire. Generally speaking, the radially outer portion of the tire constitutes an area between the tread base layer (not shown) and that portion of the tire that comes into contact with the road. A radially outer portion can include, amongst other things: a tread base layer, a tread layer, sprues, metal-free studs or similar traction enhancers, electronic and/or sensory components, fluid media used to prevent air leakage, adhesive or bonding layers, and other features or components not specifically recited herein. Thus, in these additional alternative embodiments, the circumferential tread need not be the sole radially outer tire element, although it may be.

[0033] As shown in **Figure 1**, first sidewall **165a** extends between the first annular bead **105a** and a first shoulder **170a**. Second sidewall **165b** extends between the second annular bead **105b** and a second shoulder **170b**. The sidewalls, shoulders, and tread are associated via physical proximity, direct physical contact, industrial mixing process, or chemical interaction. As one of ordinary skill in the art would understand, sidewalls **165a** and **165b** may be made of a different rubber than the tread or other parts of the tire. Sidewalls **165a** and **165b** may also have various inserts, chippers, flippers, cooling fins, reinforcements, protectors, electronic and/or sensory components, and/or other functional or ornamental features not specifically shown in **Figure 1**. In additional embodiments, which may or may not use the sidewall elements described above, the sidewalls **165a** and **165b** form an axially outer portion of the tire. Thus, in these additional alternative embodiments, the sidewalls **165a** and **165b** need not be the sole axially outer tire elements, although they may be. Regardless of whether additional sidewall features are utilized in a given construction, the first sidewall **165a** and the second sidewall **165b** shown in **Figure 1** are metal-free sidewalls. The sidewalls are metal-free sidewalls because they contain no large particulate metal, metal solids, or other metal reinforcement.

[0034] Because only the first and second annular beads **105a** and **105b** of tire **100** contain metal, tire **100** is substantially free of metal.

[0035] **Figure 2** shows a cross-sectional view of a section of a second embodiment of a tire **200**. Tire **200** contains beads **205**. The beads, which are a type of annular structure, are configured to secure the tire to a vehicle wheel. It should be understood that other annular structures may be employed instead of beads.

[0036] Carcass ply **210**, sometimes referred to as a body ply, is associated with beads **205** via physical proximity, direct physical contact, industrial mixing process or chemical interaction. The beads **205** and carcass ply **210** give the tire a toroid shape. In an alternative embodiment not specifically shown in **Figure 2**, an inner liner or other component connects beads **205** so that the components form a unitary annular structure. In such an embodiment, the tire would have at least one annular structure. Further, although not shown, an inner liner or other inner coating may be utilized in addition to the carcass ply **210** or single annular structure.

[0037] Metal-free circumferential belt **215** occupies belt region **220**. In one embodiment, belt region **220** further contains a first metal-free belt ply **225** and a second metal-free belt ply **230**. In one alternative embodiment, not shown, metal-free circumferential belt **215** further comprises a second metal-free base ply. In additional alternative embodiments, also not shown, tire **200** contains additional metal-free belt plies.

[0038] First metal-free cap ply **235** is disposed radially outward of the metal-free circumferential belt **215**. Tire **200** further contains a second metal-free cap ply **240** disposed between the circumferential tread and the carcass ply. In another alternative embodiment, the second metal-free cap ply is disposed between various other plies. In additional alternative embodiments, two or more metal-free cap piles are distributed radially throughout the tire **200**.

[0039] Metal-free circumferential tread **245** is disposed radially outward of metal-free cap ply **235**. Metal-free circumferential tread **245** also extends axially across a surface of tire **200**. As shown, metal-free circumferential tread **245** is the radially outermost tire element. Thus, metal-free circumferential tread **245** is a portion of the tire **200** that contacts a road.

[0040] In addition to metal-free circumferential tread **245**, sidewalls **250** form additional surfaces of tire **200**. Sidewalls **250** extend from the edges of metal-free circumferential tread **245** to beads **205**. Sidewalls **250** associate with the edges of metal-free circumferential tread **245** via physical proximity, direct physical contact, industrial mixing process, or chemical interaction. In the case of a single annular structure, sidewalls **250** extend from the edges of metal-free circumferential tread **245** to the single annular structure. Sidewalls **250** associate with beads **205** or the single annular structure via physical proximity, direct physical contact, industrial mixing process, or chemical interaction.

[0041] In one embodiment, sidewalls **250** are metal-free sidewalls. The sidewalls are metal-free sidewalls because they contain no large particulate metal, metal solids, or other metal reinforcement. In a second embodiment, sidewalls **250** contain a non-metallic reinforcement.

[0042] **Figure 3** shows a schematic drawing of a cross-sectional view of an embodiment of a radial tire **300**. **Figure 4** is a schematic drawing of a cross-sectional side view of an embodiment of the radial tire **300** depicted in **Figure 3**. **Figure 5** is a schematic drawing of a cross-sectional top view of the cords disposed in the radial tire **300** depicted in **Figure 3**. The tire **300** is described with reference to **Figures 3–5**.

[0043] The tire **300** is substantially the same as the tire **100** described above with reference to **Figure 1**, except for the differences described herein. Body ply **305** is disposed radially inward of first reinforcement ply **315**. First reinforcement ply **315** is disposed radially inward of second reinforcement ply **325**. Cap ply **335** is disposed radially outward of second reinforcement ply **325**. Cap ply **335** contains cap ply fibers **340** that run parallel to the tire's equatorial plane, **E**. Circumferential tread **345** is disposed radially outward of cap ply **335**.

[0044] Body ply **305** contains body ply cords **310** that extend radially from radial tire **300**'s bead region toward circumferential tread **345**. First reinforcement ply **315** contains first reinforcement cords **320**, and second reinforcement ply **325** contains second reinforcement cords **330**.

[0045] As best shown in **Figure 5**, body ply cords **310** generally intersect the tire's equatorial plane, **E**, at a right angle. However, as one of ordinary skill in the art would

understand, body ply cords **310** may also intersect the equatorial plane **E** at an angle slightly less than or greater to 90 degrees such that tire **300** is still considered a radial tire. Thus, one of ordinary skill in the art would understand that the body ply cords **310** in a radial tire intersect the equatorial plane **E** at a substantially right angle.

[0046] As also shown in **Figure 5**, first reinforcement cords **320** intersect the equatorial plane **E** at a first angle **350**, and the second reinforcement cords **330** intersect the equatorial plane **E** at a second angle **355**. In a first embodiment, the first angle is greater than the second angle. In a second embodiment, the first angle is between 45 and 74 degrees and the second angle is between 45 and 74 degrees. In an alternative embodiment, the first angle is greater than the second angle and the first angle is between 45 and 74 degrees and the second angle is between 45 and 74 degrees. In an additional embodiment, the first angle is between 60 and 74 degrees and the second angle is between 60 and 74 degrees. In yet another embodiment, the first angle is greater than the second angle and the first angle is between 60 and 74 degrees and the second angle is between 60 and 74 degrees.

[0047] **Figure 3** shows a schematic drawing of a cross-sectional view of an embodiment of a radial tire **300**. **Figure 4** is a schematic drawing of a cross-sectional side view of an embodiment of the radial tire **300** depicted in **Figure 3**. **Figure 5** is a schematic drawing of a cross-sectional top view of the cords disposed in the radial tire **300** depicted in **Figure 3**. The tire **300** is described with reference to **Figures 3–5**.

[0048] **Figure 6** shows a schematic drawing of a cross-sectional view of an embodiment of bias tire **400**. **Figure 7** is a schematic drawing of a cross-sectional side view of an embodiment of the radial tire **400** depicted in **Figure 6**. **Figure 8** is a schematic drawing of a cross-sectional top view of the cords disposed in the radial tire **400** depicted in **Figure 6**. The tire **400** is described with reference to **Figures 6–8**. The tire **400** is substantially the same as the tire **300** described above with reference to **Figures 3–5**, except for the differences described herein. Body ply **405** is disposed radially inward of first reinforcement ply **415**. First reinforcement ply **415** is disposed radially inward of second reinforcement ply **425**. Cap ply **435** is disposed radially outward of second reinforcement ply **425**. Cap ply **435** contains cap ply fibers **440** that

run parallel to the tire's equatorial plane, **E**. Circumferential tread **445** is disposed radially outward of cap ply **435**.

[0049] **Figure 7** is a schematic drawing of a cross-sectional side view of an embodiment of the bias tire depicted in **Figure 6**. Body ply **405** contains body ply cords **410** that extend at an angle from an annular bead region (not shown) toward circumferential tread **445**. First reinforcement ply **415** contains first reinforcement cords **420**, and second reinforcement ply **425** contains second reinforcement cords **430**.

[0050] **Figure 8** is a schematic drawing of a cross-sectional top view of the cords disposed in the radial tire depicted in **Figure 6**. As shown in **Figure 8**, body ply cords **410** intersect the tire's equatorial plane, **E**, at an acute angle. In one embodiment, the body ply cords **410** intersect the equatorial plane **E** at an angle between 1 and 10 degrees. In another embodiment, the body ply cords **410** intersect the equatorial plane **E** at an angle between 1.5 and 5 degrees. In yet another embodiment, the body ply cords **410** intersect the equatorial plane **E** at an angle of about 2 degrees.

[0051] As also shown in **Figure 8**, first reinforcement cords **420** intersect the equatorial plane **E** at a first angle **450**, and the second reinforcement cords **430** intersect the equatorial plane **E** at a second angle **455**. In a first embodiment, the first angle is greater than the second angle. In a second embodiment, the first angle is between 45 and 74 degrees and the second angle is between 45 and 74 degrees. In an alternative embodiment, the first angle is greater than the second angle and the first angle is between 45 and 74 degrees and the second angle is between 45 and 74 degrees. In an additional embodiment, the first angle is between 60 and 74 degrees and the second angle is between 60 and 74 degrees. In yet another embodiment, the first angle is greater than the second angle and the first angle is between 60 and 74 degrees and the second angle is between 60 and 74 degrees.

[0052] While the reinforcement plies shown in **Figures 3–8** have reinforcement cords (**320, 330, 420, 430**), one of ordinary skill in the art would understand a cord-based reinforcement ply could be replaced with high-density, metal-free reinforcement fibers, a woven fabric ply design, a mesh ply design, a honeycomb ply design, and/or other ply designs and variations thereof. Further, the reinforcements described above may be made of a different materials. Thus, a second reinforcement may be made of a different

material than the first reinforcement. When the reinforcements are made of different materials, the reinforcements may be disposed at different angles or the same angle.

[0053] Non-metallic materials suitable for use in the above embodiments include, without limitation, synthetic materials such as nylon, rayon, aramid, para-aramid, polyester, polyethylene naphthalate (PEN), polyethylene terephthalate (PET), polyvinyl alcohol (PVOH or PVA), polybenzobisoxazole (PBO or Zylon), ethylene—carbon monoxide copolymer (POK), carbon fiber, and fiberglass. Similar synthetic materials, known within the art, may also be suitable for use in the above embodiments. As one of ordinary skill in the art would further understand, alternative non-metallic materials not specifically identified herein may also be used in the above embodiments. In one embodiment, such alternative materials can also be processed in a tire recovery or recycling process.

[0054] In order to demonstrate several embodiments of the present disclosure, the following examples were prepared and tested. The examples should not, however, be viewed as limiting the scope of the invention. The claims will serve to define the invention.

EXAMPLES

[0055] Exemplary tires with the six following constructions were built: Tire 1 (a control tire that was previously available) had two steel belts and two cap plies; Tire 2 had two low angle, 45 degree, nylon belts (orientated at opposing angles) and two nylon cap plies; Tire 3 had two nylon belts (orientated at the same angle) and two nylon cap plies; Tire 4 one nylon belt and two nylon cap plies; Tire 5 had no belt and two nylon cap plies; Tire 6 had one nylon belt and four nylon cap plies. The exemplary tires were then subjected to performance tests described below.

[0056] The tires were weighed on a scale without a wheel to show a reduction of -0.9 kg (*i.e.* -6.1%) to -2.3 kg (*i.e.* -12.5%) relative to the control tire build number 1.

[0057] Hydraulic burst testing was conducted by inflating the tire cavity with water until a pressure was achieved at which one or more components of the tire failed and the construction could no longer maintain the pressure. For the reference conventional tire of build 1, the maximum inflation pressure marked on the sidewall was 51 PSI. The builds 2 through 6 ranged from 210PSI (412% of max inflation) to 295 PSI (578% of max

sidewall inflation). Thus an inflation safety factor of at least 4 was achieved for all builds 2 through 6.

[0058] The ISO Rolling Resistance Coefficient, or RRC, was determined as per the International Standards Organization, or ISO, tire test procedure 28580. The reported value is the tire drag force divided by the tire vertical load. Tire Inflation, Load and Speed are set as per the standard. A lower number indicates lower drag forces on the tire and thus, a reduction in the energy required to overcome this drag force when utilized on a vehicle. For these builds, the RRC is a reduction in drag force between 3% to 9% of the reference tire build 1.

[0059] The tires were tested for static spring rate by affixing the tires to a wheel whose width is recommended based on the Tire and Rim Association's reference manual, inflating the tire to 26 PSI and loading the tire to 100% of the Tire and Rim Association's reference manual's recommendation at 26 PSI inflation. During loading, the displacements for corresponding loads were recorded. The slope of that curve at the full load condition is defined as the vertical spring rate and is an indication of carcass stiffness. The units of vertical spring rate in Table 1 are in N/mm. For builds 2-6, the vertical spring rate is a reduction of 4% to 6% relative to the reference build number 1.

[0060] Once the tire was loaded, the tire was then deflected laterally (in the direction perpendicular to the axis of rotation), and the lateral force and displacement was recorded. The calculated slope of the load deflection curve at lateral load equal to zero is known as the lateral spring rate. The lateral load was relieved and the tire was loaded in the fore/aft direction (perpendicular to the lateral direction and in the direction of travel of the tire).

[0061] Fore/aft spring rate is calculated using the same method as the lateral spring rate and the units for both are the same as vertical spring rate. The lateral spring rate is an indicator of the tires capability to generate lateral force as a steering angle is applied to steer the vehicle. There is a reduction in lateral spring rate of 24% to 45%. The fore/aft spring rate is an indication of the ability of a tire to generate acceleration or braking forces when the vehicle operator desires to go or stop. The fore/aft spring rate is reduced more so than the vertical spring rate but not as much as the lateral spring rate. The fore/aft spring rate is reduced between 7% to 11% of the reference build 1.

[0062] Based on the results in Table 1 and 2, builds 2 and 3, which only substitute the steel belts of the control with low angle nylon belts are able to deliver a 9% reduction in mass with a 6% to 7% reduction in Rolling Resistance while having a small reduction in Vertical and Fore-Aft spring rate. However, builds 2 and 3 have a 24% reduction in lateral stiffness which can impact the ability of the vehicle to generate cornering force. In order to define the full impact to the cornering capability of the tire, additional testing was conducted.

Tire Build	Mass (kg)	Hydraulic Burst Pressure (PSI)	Rolling Resistance Coefficient (ISO Rolling Res. Coefficient)	Lateral Stiffness (Static Spring)	Fore/Aft Stiffness (Static Spring)	Vertical Stiffness (Static Spring)
1	14.8	--	0.0118	206	436	252
2	13.4	240	0.0110	156	394	240
3	13.4	230	0.0111	157	405	242
4	12.9	215	0.0108	138	392	241
5	12.5	210	0.0107	113	387	238
6	13.9	295	0.0114	135	396	242

Tire Build	Mass (% Control)	Hydraulic Burst Pressure (% Control)	Rolling Resistance Coefficient (% Control)	Lateral Stiffness (% Control)	Fore/Aft Stiffness (% Control)	Vertical Stiffness (% Control)
1	100	--	100	100	100	100
2	91	--	93	76	90	95
3	91	--	94	76	93	96
4	87	--	92	57	90	96
5	84	--	91	55	89	94
6	94	--	97	66	91	96

[0063] Tables 3 and 4 show the result of testing the dynamic cornering capability of the tires. An MTS flat track machine was utilized to roll the tires mounted on wheels specified in the aforementioned testing and loaded to the same load as specified in the load deflection testing. For this test, the tire inflation was changed from a low level of 15 PSI to a middle range level of 30 PSI, which is representative of many commercially available passenger car vehicles. The tire inflation level was also changed to an elevated inflation level of 45 PSI. While affixed to the test machine, the tire was turned at a constant rate of 5 miles per hour. The machine applied a slip angle to the tire by slowly rotating it about an axis of the center of the tire contact patch through the center of the wheel to an angle of 1 degree. At this angle, the tire generated a lateral force due to out of plane bending of the tire carcass. This force level was then recorded. The tire was then turned in the opposite angle 1 degree from straight ahead rotation, and the force was again recorded.

[0064] The tire cornering coefficient, or CC was then calculated by averaging the two force levels at a positive and negative rotation of 1 degree and then dividing that number by the vertical load of the tire. For example, if a tire had a CC of 0.30 and the tire was loaded to 1000lbs, when 1 degree of slip angle was applied, the tire, on average generated 300 lbs of lateral force.

[0065] Under most day-to-day driving maneuvers, tires will operate in a range of 0 to 2 degrees of slip angle. In this range, there is a linear relationship between the input slip angle from the driver turning the wheel to the lateral force generated by the tire to turn the car. Typical ranges of commercially passenger car tires range from 0.25 to 0.45 where 0.25 is representative of a general use tire and 0.45 is representative of a ultra-high performance tire. Like the lateral spring rate already discussed, there is a significant reduction in CC for the tires of builds 2-6 at low inflations of 15 PSI, but as higher inflations (which are more representative of commercially available passenger cars of today), the differential between the reference tire of build 1 and the tires of builds 2-6 is reduced.

[0066] If we specifically look at builds 2 and 3 at 30 PSI, we see a reduction of 23% to 31% respectively, but the CC levels of those tires at that condition is 0.30 and 0.28, respectively, which is well within the operational ranges of commercially available passenger car tires. Even at 15 PSI, which is well below any known recommended inflation pressure for a passenger car tire, builds 2 and 3 generated CC levels 0.21 and 0.19 which is only slightly lower than some commercially available passenger car tires.

Tire Build	Corner Coefficient @ 15 PSI	Corner Coefficient @ 30 PSI	Corner Coefficient @ 45 PSI
1	0.37	0.40	0.31
2	.021	0.30	0.30
3	0.19	0.27	0.28
4	0.16	0.24	0.26
5	0.09	0.15	0.19
6	0.17	0.23	0.24

Table 4			
Tire Build	Corner Coefficient @ 15 PSI (% Control)	Corner Coefficient @ 30 PSI (% Control)	Corner Coefficient @ 45 PSI (% Control)
1	100	100	100
2	56	77	87
3	50	69	82
4	44	61	77
5	25	38	56
6	46	59	71

[0067] As one of ordinary skill in the art would understand, the tire embodiments described in this disclosure may be configured for use on a vehicle selected from the group consisting of motorcycles, tractors, agricultural vehicles, lawnmowers, golf carts, scooters, airplanes, military vehicles, passenger vehicles, hybrid vehicles, high-performance vehicles, sport-utility vehicles, light trucks, heavy trucks, heavy-duty vehicles, and buses. One of ordinary skill in the art would also understand that the embodiments described in this disclosure may be utilized with a variety of tread patterns, including, without limitation, symmetrical, asymmetrical, directional, studded, and stud-less tread patterns. One of ordinary skill in the art would also understand that the embodiments described in this disclosure may be utilized in retreading applications.

[0068] To the extent that the term “includes” or “including” is used in the specification or the claims, it is intended to be inclusive in a manner similar to the term “comprising” as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term “or” is employed (e.g., A or B) it is intended to mean “A or B or both.” When the applicants intend to indicate “only A or B but not both” then the term “only A or B but not both” will be employed. Thus, use of the term “or” herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, *A Dictionary of Modern Legal Usage* 624 (2d. Ed. 1995). Also, to the extent that the terms “in” or “into” are used in the specification or the claims, it is intended to additionally mean “on” or “onto.” Furthermore, to the extent the term “connect” is used in the specification or claims, it is intended to mean not only “directly connected to,” but also “indirectly connected to” such as connected through another component or components.

[0069] While the present disclosure has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the disclosure, in its broader aspects, is not limited to the specific details, the representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's general inventive concept.

CLAIMS

What is claimed is:

1. A tire comprising:
 - a first annular bead and a second annular bead;
 - a body ply extending between the first annular bead and the second annular bead;
 - a circumferential belt disposed radially outward of the body ply and extending axially across a portion of the body ply;
 - a first reinforcement ply disposed radially outward of the circumferential belt and extending axially across a portion of the body ply;
 - a circumferential tread disposed radially outward of the first reinforcement ply and extending axially across a portion of the body ply;
 - a first sidewall extending between the first annular bead and a first shoulder, the first shoulder being associated with the circumferential tread; and
 - a second sidewall extending between the second annular bead and a second shoulder, the second shoulder being associated with the circumferential tread,wherein the tire has a 1 degree cornering coefficient of between 0.09 and 0.40, and only the first and second annular beads contain metal.
2. The tire of claim 1, further comprising a second circumferential belt disposed radially between the circumferential belt and the first reinforcement ply.
3. The tire of claim 1, further comprising a second reinforcement ply disposed between the circumferential tread and the body ply.
4. The tire of claim 3, wherein the tire has a 1 degree cornering coefficient of 0.15 to 0.30.
5. The tire of claim 3, wherein the first reinforcement ply has first reinforcement cords that intersect an equatorial plane of the tire at a first angle and the second

reinforcement ply has second reinforcement cords that intersect the equatorial plane at a second angle.

6. The tire of claim 5, wherein the first angle is greater than the second angle and both the first and second angles are between 45 and 74 degrees.

7. The tire of claim 6, wherein the first angle is between 60 and 74 degrees and the second angle is between 60 and 74 degrees.

8. The tire of claim 1, wherein the body ply has body ply cords that intersect an equatorial plane of the tire at a substantially right angle.

9. The tire of claim 1, wherein the body ply has body ply cords that intersect an equatorial plane of the tire at an acute angle.

10. The tire of claim 9, wherein the acute angle is between 1 and 10 degrees.

11. The tire of claim 9, wherein the acute angle is about 2 degrees.

12. A tire comprising:

a carcass ply;

at least one annular structure associated with the carcass ply;

a metal-free circumferential belt region, the metal-free circumferential belt region further comprising a first metal-free belt ply and a second metal-free belt ply;

a metal-free cap ply, the metal-free cap ply disposed radially outward of the first metal-free belt ply and the second metal-free belt ply;

a metal-free circumferential tread, the metal-free circumferential tread being a portion of the tire that contacts a road; and

a pair of sidewalls associated with at least one annular structure and the metal-free circumferential tread.

13. The tire of claim 12, wherein the sidewalls are metal-free sidewalls.

14. The tire of claim 12, wherein the first metal-free belt ply contains high-density, metal-free fibers and the second metal-free belt ply also contains high-density, metal-free fibers.

15. The tire of claim 12, wherein the tire is configured to operate at an inflation pressure between 15 and 45 psi.

16. A tire comprising:

a pair of annular beads configured to secure the tire to a vehicle wheel;

a non-metallic body ply associated with the annular beads, wherein the non-metallic body ply forms a radially inner portion of the tire;

a non-metallic annular belt disposed radially outward of the non-metallic body ply, wherein the non-metallic annular belt forms a radially intermediate portion of the tire;

a first non-metallic reinforcement, wherein the first non-metallic reinforcement further forms a radially intermediate portion of the tire;

a second non-metallic reinforcement, wherein the second non-metallic reinforcement further forms a radially intermediate portion of the tire;

a tread disposed radially outward of the first and second non-metallic reinforcements, wherein the tread forms a radially outer portion of the tire; and

a pair of sidewalls, wherein the sidewalls form axially outer portions of the tire.

17. The tire of claim 16, wherein the first non-metallic reinforcement is made from a material selected from the group consisting of nylon, rayon, aramid, para-aramid, polyester, PEN, PET, PVA, PBO, POK, carbon fiber, and fiberglass.

18. The tire of claim 16, wherein the second non-metallic reinforcement is made of a different material than the first non-metallic reinforcement.

19. The tire of claim 16, wherein the first non-metallic reinforcement and the second non-metallic reinforcement are disposed at different angles.

20. The tire of claim 16, wherein the tire is configured for use on a vehicle selected from the group consisting of motorcycles, tractors, agricultural vehicles, lawnmowers, golf carts, scooters, airplanes, military vehicles, passenger vehicles, hybrid vehicles, high-performance vehicles, sport-utility vehicles, light trucks, heavy trucks, heavy-duty vehicles, and buses.

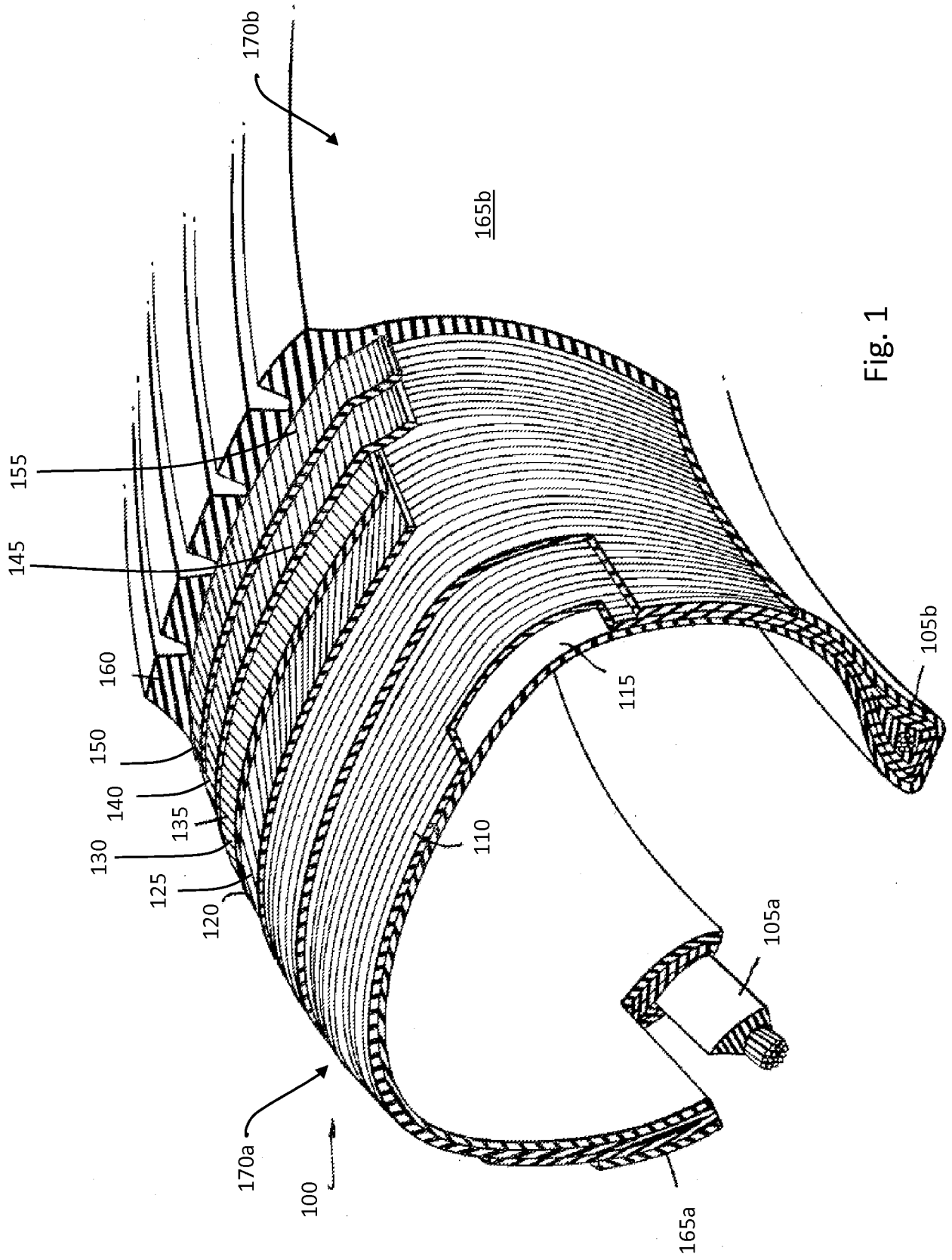


Fig. 1

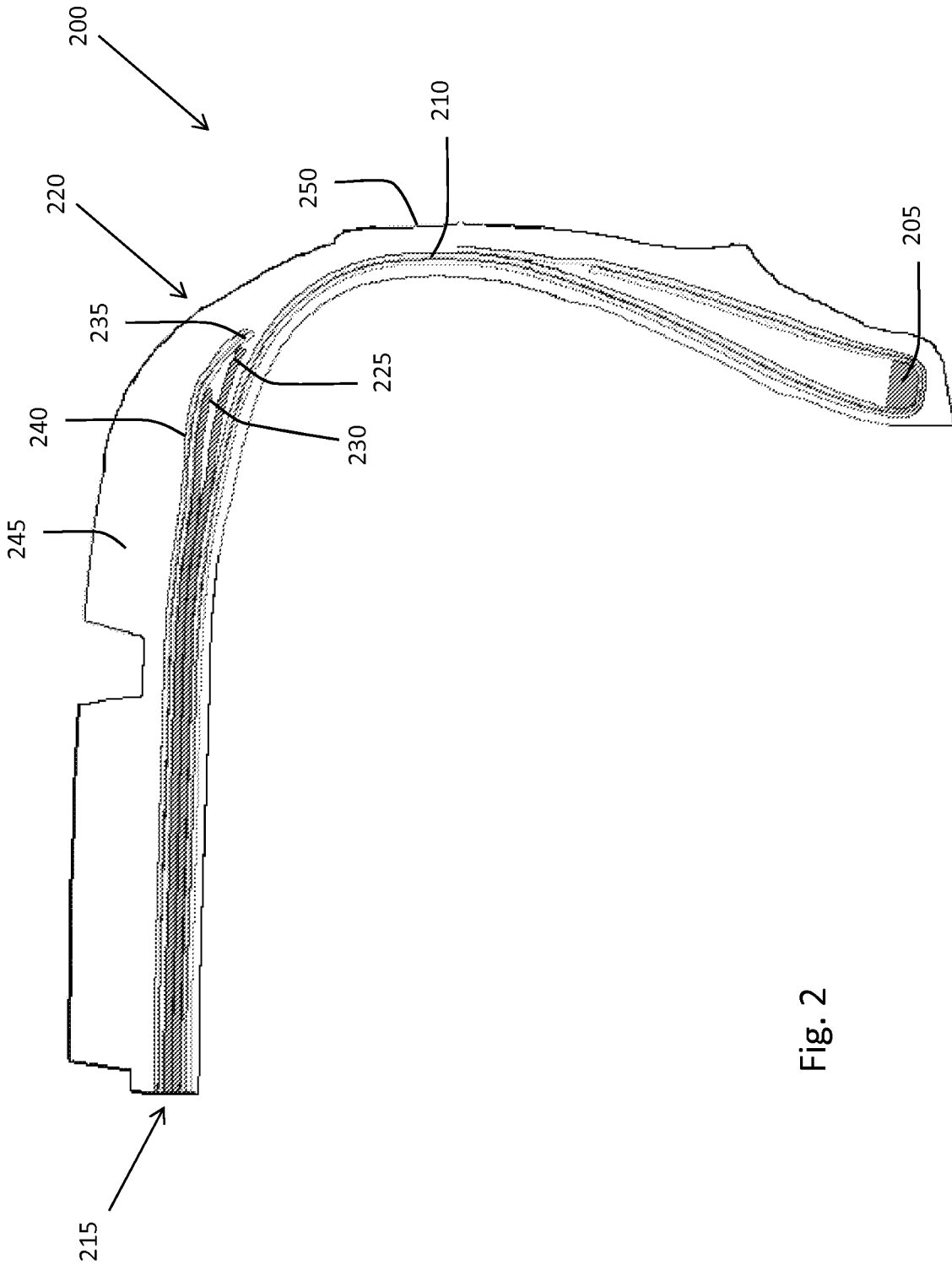


Fig. 2

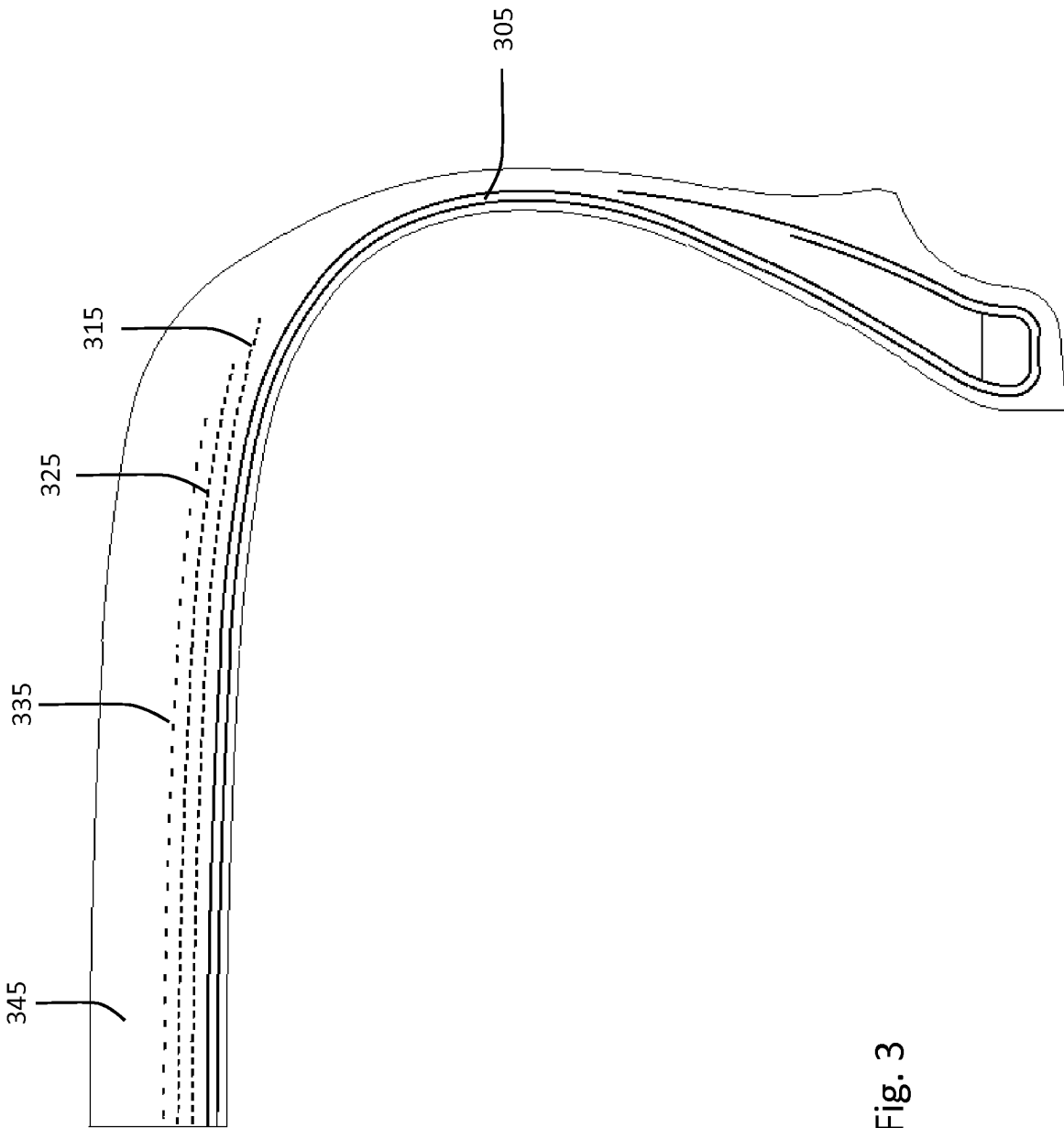


Fig. 3

Fig. 4

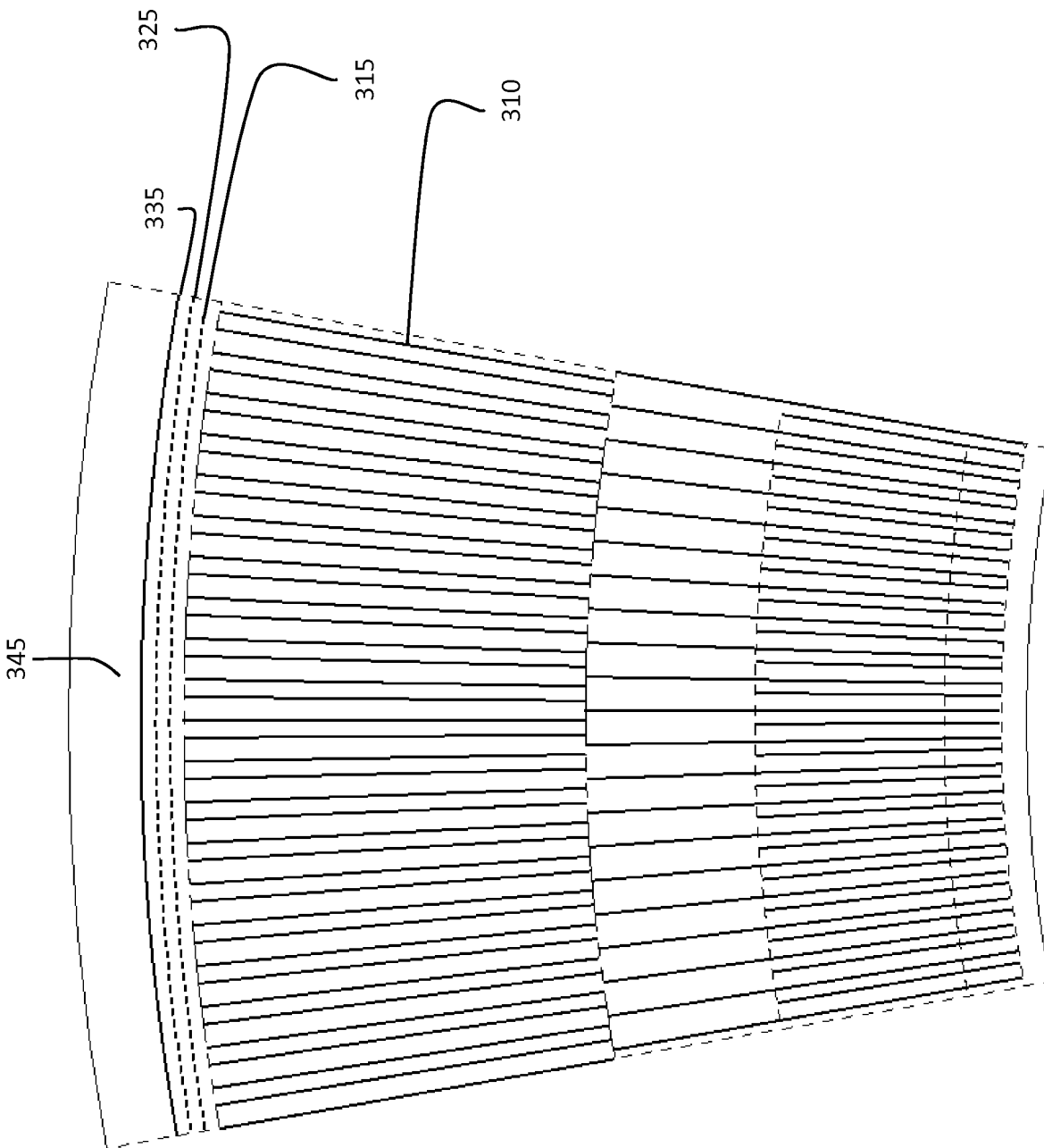
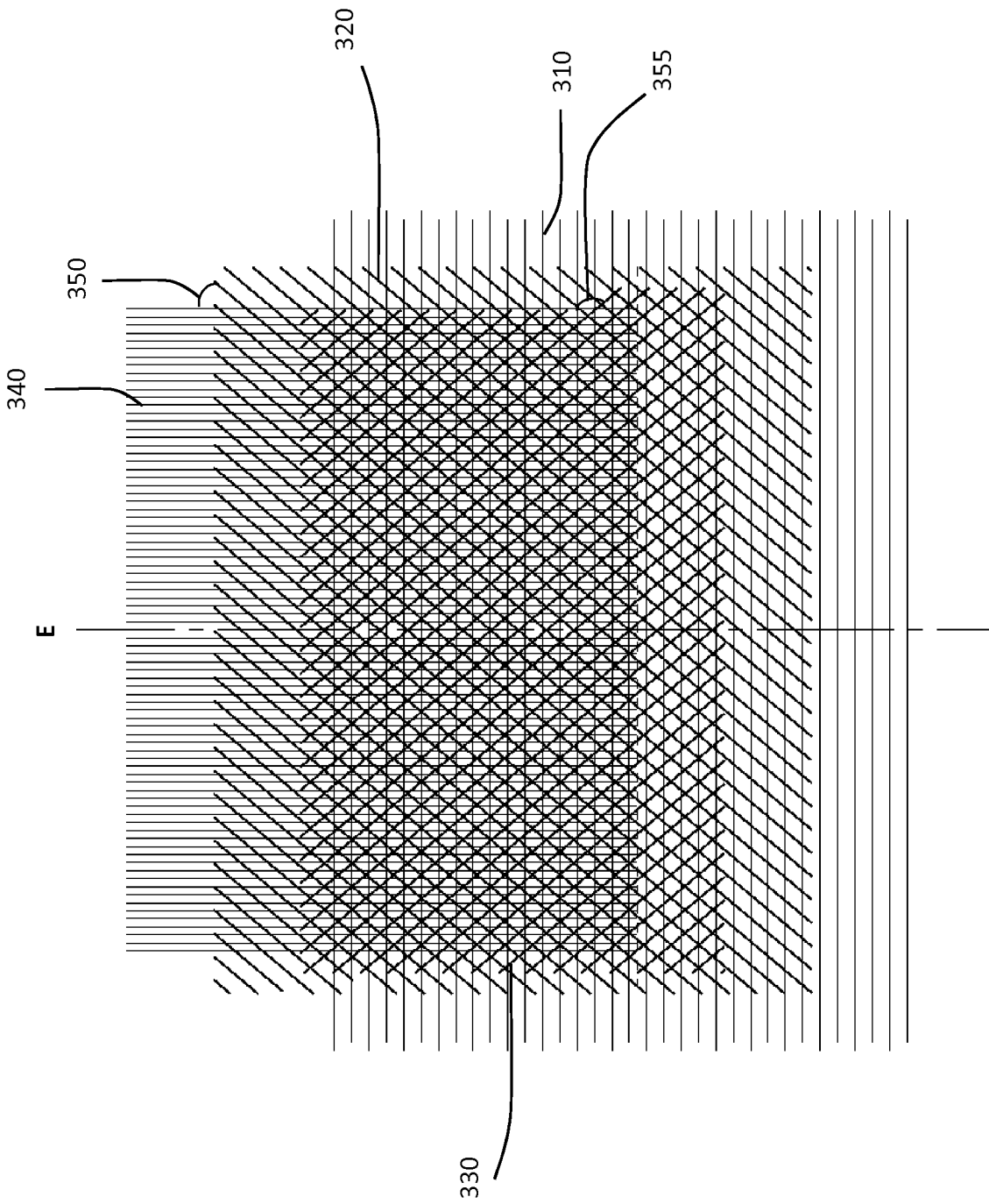


Fig. 5



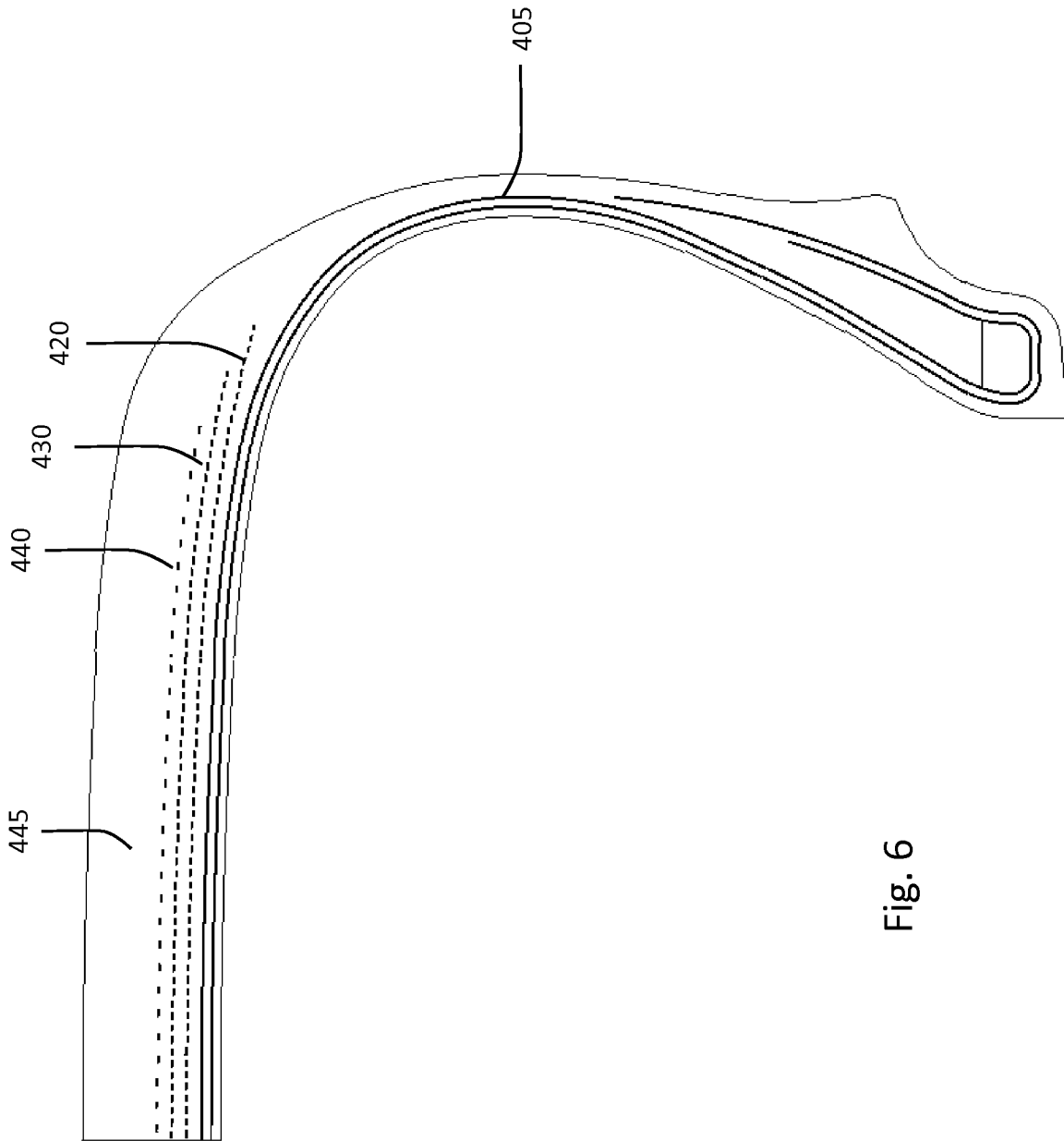


Fig. 6

Fig. 7

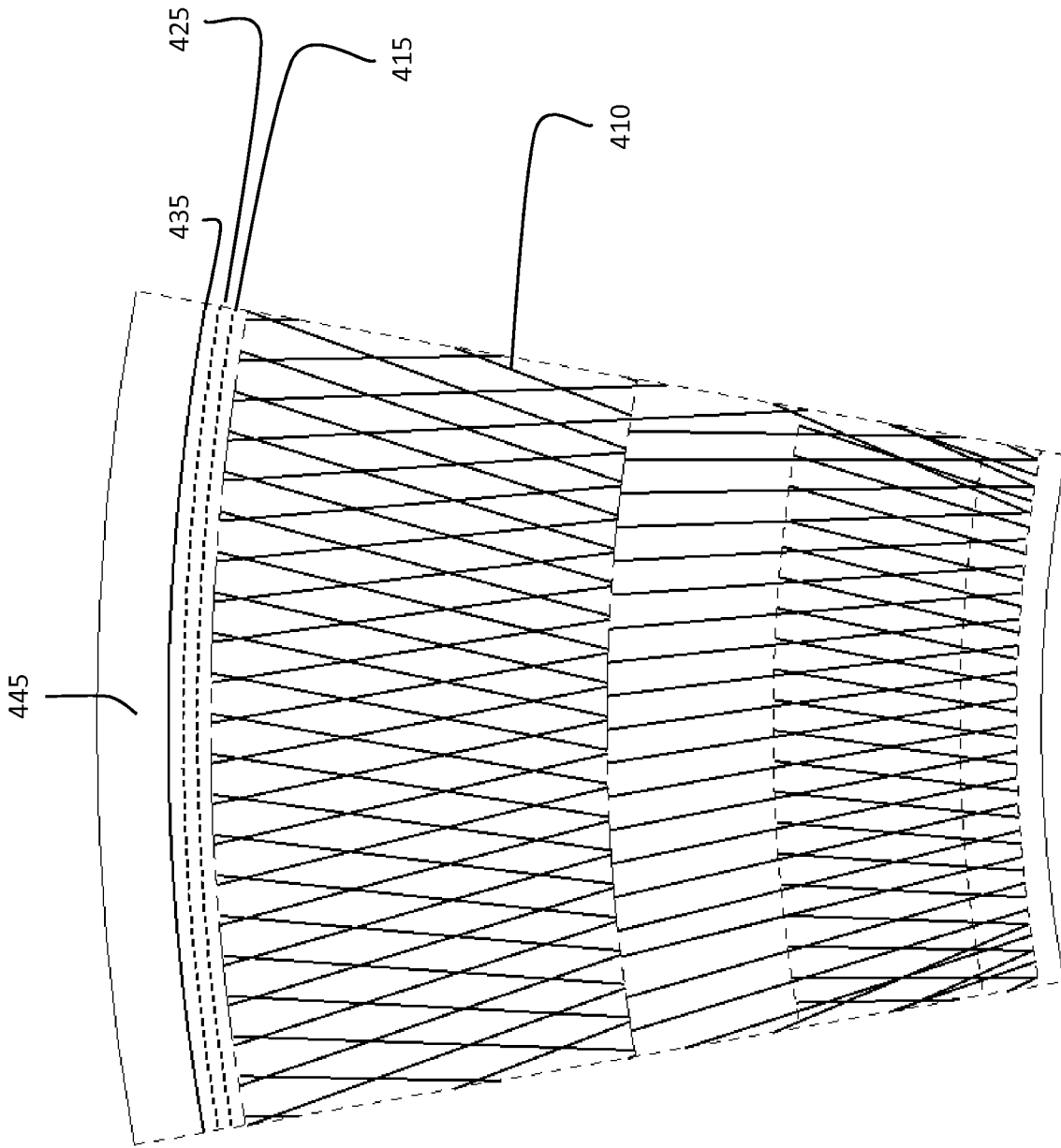
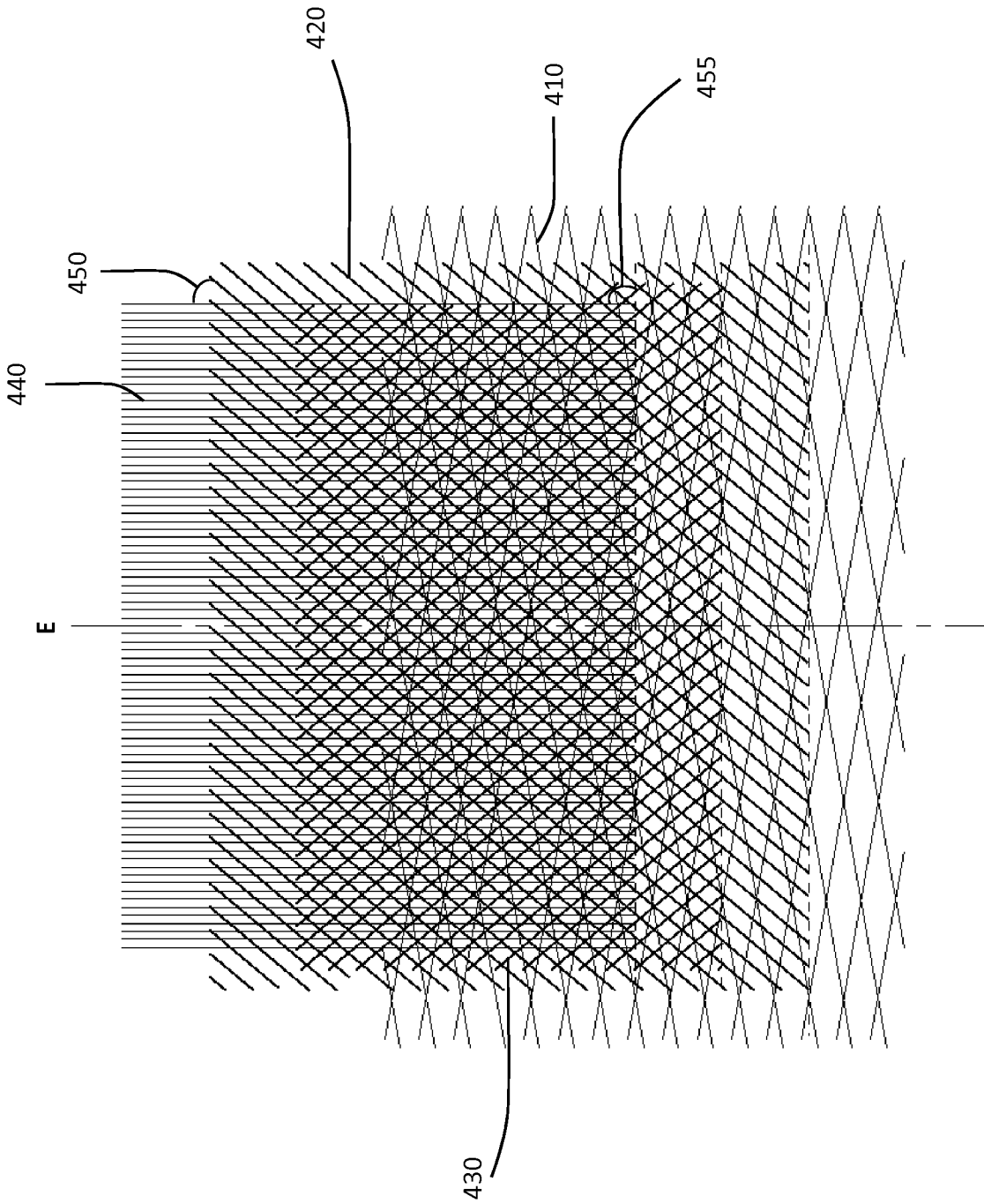


Fig. 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/043332**A. CLASSIFICATION OF SUBJECT MATTER****B60C 13/00(2006.01)i, B60C 13/04(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60C 13/00; B60C 9/20; B60C 9/22; B32B 5/12; B60C 9/00; B60C 9/02; B60C 9/04; B60C 9/18; B60C 13/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: tire, reinforcement ply, belt, metal and cornering coefficient

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004-0221938 A1 (OCHIAI, KIYOSHI) 11 November 2004 See paragraphs [0024]-[0030],[0035]-[0048] and figures 1-3.	1-20
Y	US 6668889 B1 (LOSEY et al.) 30 December 2003 See column 2, lines 2-7, column 3, lines 18-45, column 5, line 39-column 6, line 21 and figures 1-5.	1-20
A	US 6851463 B1 (SOCCI et al.) 08 February 2005 See column 8, line 24-column 10, line 18 and figures 1-5.	1-20
A	US 2012-0222792 A1 (KRIER et al.) 06 September 2012 See paragraphs [0046]-[0058] and figures 1-2.	1-20
A	US 5490551 A (PRAKASH et al.) 13 February 1996 See column 1, line 47-column 4, line 22 and figures 1-2.	1-20

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 October 2014 (21.10.2014)

Date of mailing of the international search report

22 October 2014 (22.10.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

BAE, Geun Tae

Telephone No. +82-42-481-5580



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/043332

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004-0221938 A1	11/11/2004	CN 1550359 A DE 602004008826 D1 DE 602004008826 T2 EP 1475249 A1 EP 1475249 B1 JP 2004-352226 A JP 4481709 B2 US 7201198 B2	01/12/2004 25/10/2007 12/06/2008 10/11/2004 12/09/2007 16/12/2004 16/06/2010 10/04/2007
US 6668889 B1	30/12/2003	EP 1242252 A1 JP 2003-517963 A JP 4451586 B2 WO 01-45966 A1	25/09/2002 03/06/2003 14/04/2010 28/06/2001
US 6851463 B1	08/02/2005	None	
US 2012-0222792 A1	06/09/2012	EP 2495112 A1 EP 2495112 B1 US 8578990 B2	05/09/2012 28/05/2014 12/11/2013
US 5490551 A	13/02/1996	JP 2598134 Y2 KR 10-1994-0006811 A	03/08/1999 25/04/1994