US 20140174626A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2014/0174626 A1
(43) Pub. Date: Jun. 26, 2014
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(54) AIR MAINTENANCE TIRE

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(21) Appl. No.: **13/777,330**

(22) Filed: **Feb. 26, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/740,470, filed on Dec. 21, 2012.

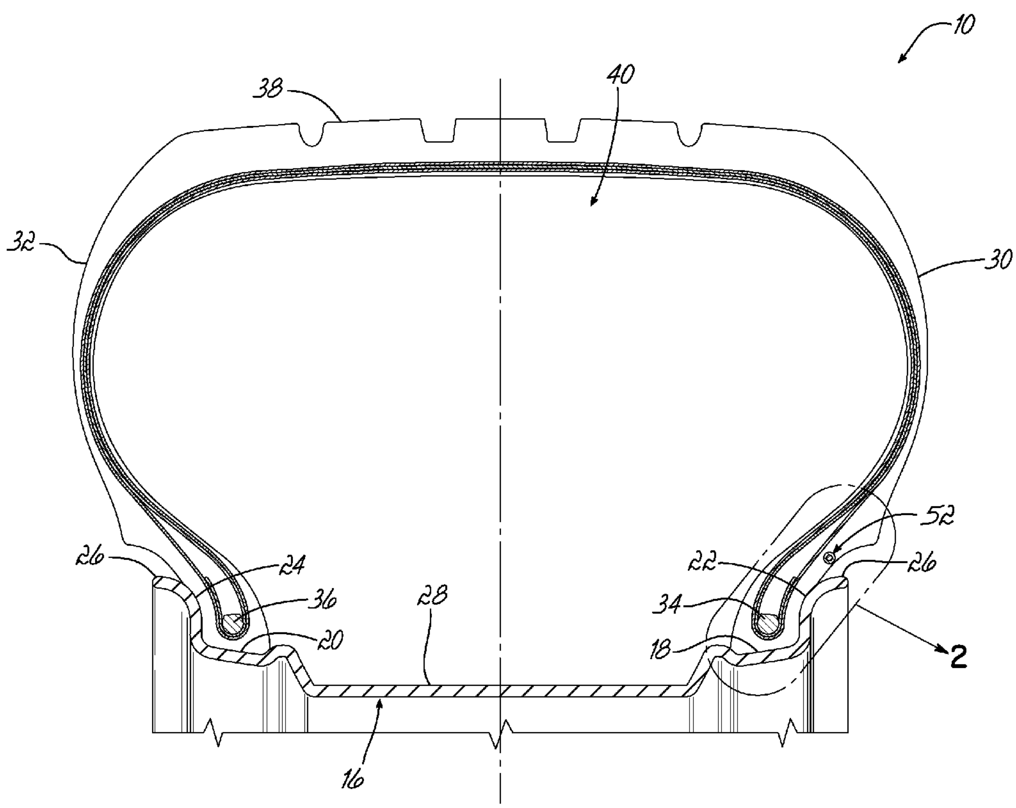
Publication Classification

(51) **Int. Cl.**
B60C 19/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B60C 19/00*** (2013.01)
USPC **152/539**; 152/450; 264/138

(57) **ABSTRACT**

A green pneumatic tire comprising a tire cavity; first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region; and a cable embedded into a rubber material of the green tire for allowing a creation of an air passageway in the tire after curing the green tire in a tire mold is disclosed. The cable comprises a core of a first material and a shell of a second material, wherein the shell surrounds the core. Also, a method of manufacturing a pneumatic tire comprising an air passageway is disclosed. The method comprises the steps of: providing a green pneumatic tire comprising a tire cavity, first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region, and a cable embedded in a rubber material of the green tire, the cable comprising a core of a first material and a shell of a second material, wherein the shell surrounds the core; curing the green tire together with the cable in a tire mold; and extracting the core of the cable from the cured tire thereby providing an air passageway in the tire.



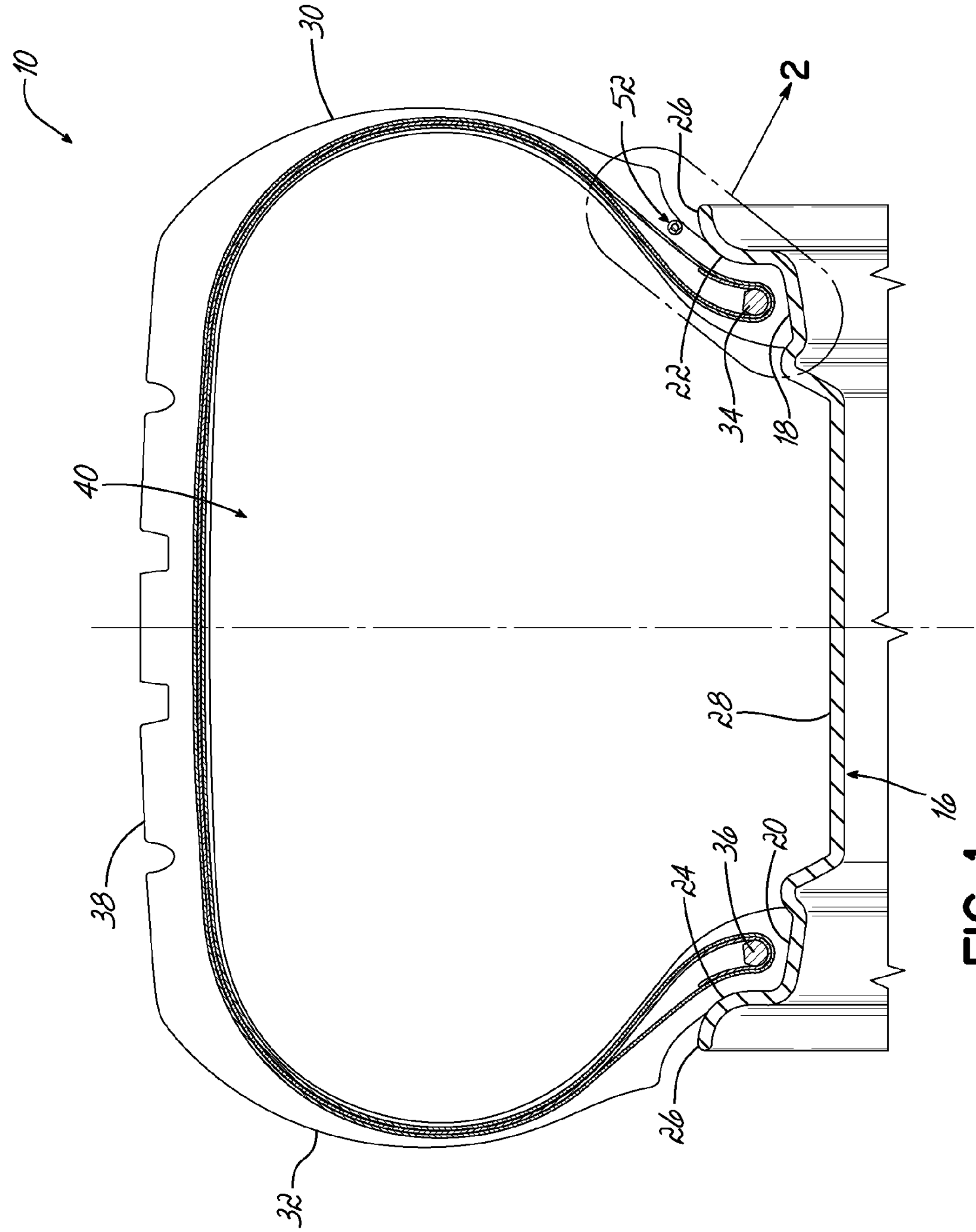


FIG. 1

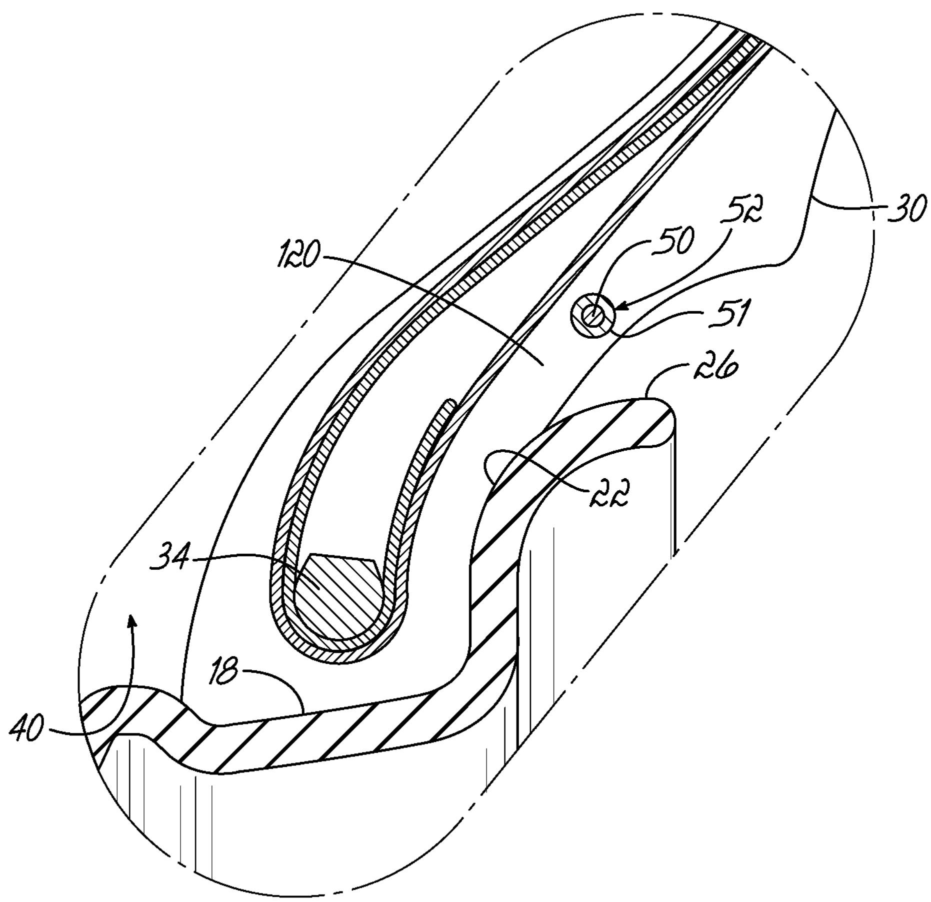


FIG. 2

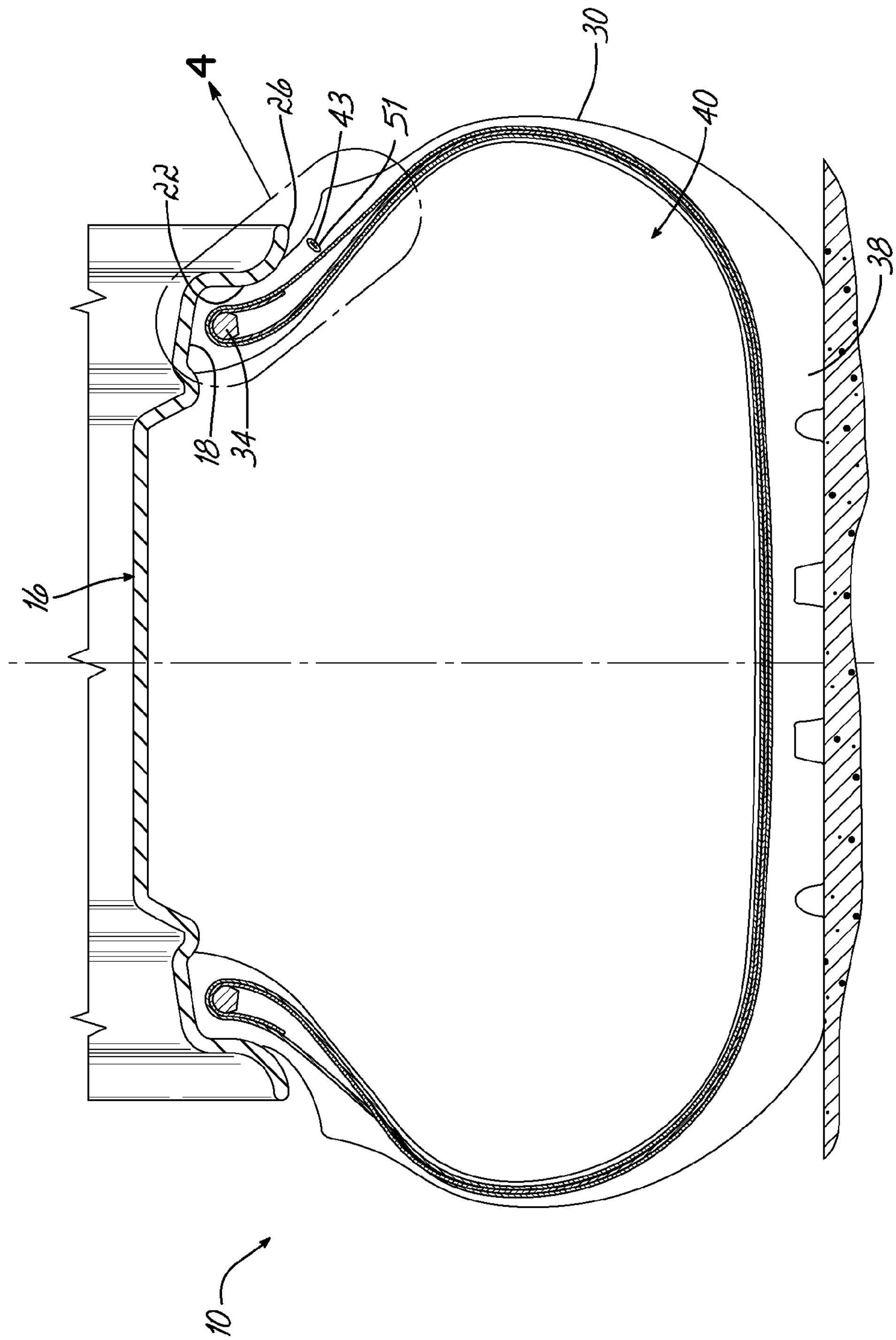


FIG. 3

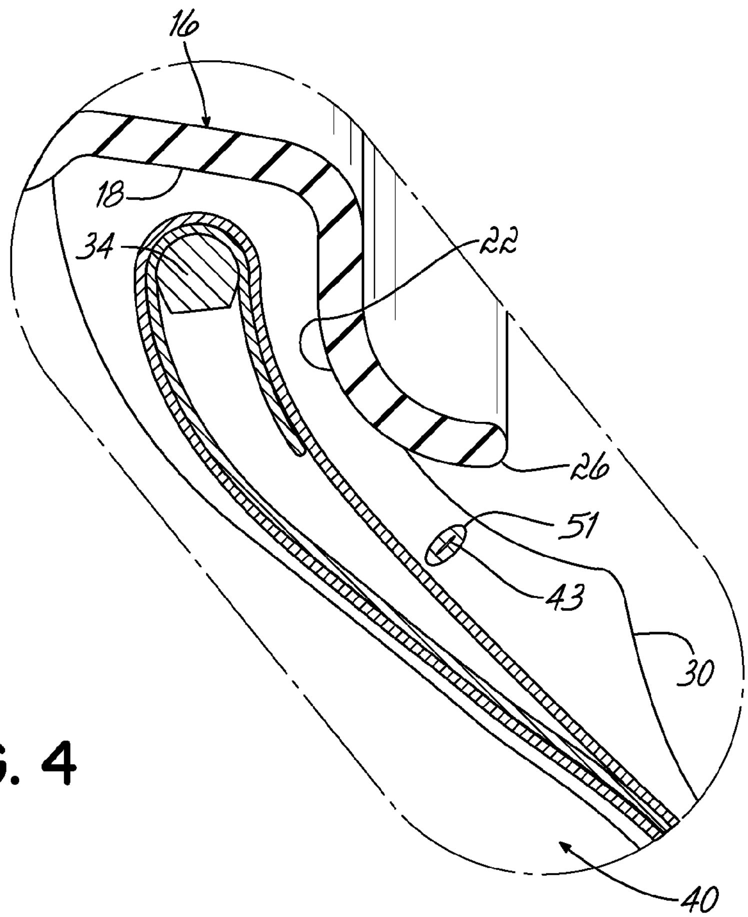


FIG. 4

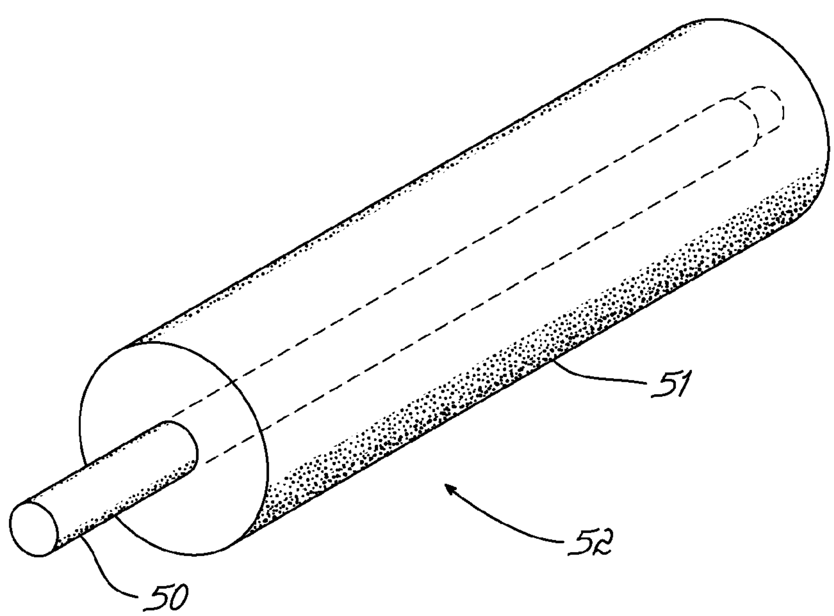


FIG. 5

AIR MAINTENANCE TIRE

FIELD OF THE INVENTION

[0001] The invention relates generally to pneumatic tires and in particular to self-inflating tires and to a method of manufacturing a pneumatic tire.

BACKGROUND OF THE INVENTION

[0002] Normal air diffusion reduces tire pressure over time. The natural state of tires is under inflated. Accordingly, drivers must repeatedly act to maintain tire pressures or they will see reduced fuel economy, tire life and reduced vehicle braking and handling performance. Tire Pressure Monitoring Systems have been proposed to warn drivers when tire pressure is significantly low. Such systems, however, remain dependant upon the driver taking remedial action when warned to re-inflate a tire to recommended pressure. It is a desirable, therefore, to incorporate a self-inflating feature within a tire that will self-inflate the tire in order to compensate for any reduction in tire pressure over time without the need for driver intervention.

[0003] EP-A2-2 343 200 describes a self-inflating tire having an annular tube connected to the tire and defining an annular air passageway wherein the tube is composed of a flexible material. The tube is integrated into the tire in the tire bead area but not fully enclosed by tire rubber material. This has the disadvantage the tube can become damaged due to chafing or due to impact from the rim or objects sliding along the tire sidewall.

[0004] EP-B1-1 648 721 describes the forming of an air passageway in the bead area of a tire wherein the air passageway is enclosed by rubber material and is manufactured applying the principle of a "lost mold" known from casting technology or by embedding a wire in the bead area of a green tire and extracting the wire after vulcanization.

SUMMARY OF THE INVENTION

[0005] In one aspect of the invention, a green pneumatic tire is disclosed, the tire comprising a tire cavity; first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region; and a cable embedded into a rubber material of the green tire for allowing a creation of an air passageway in the tire after curing the green tire in a tire mold, the cable comprising a core of a first material and a shell of a second, different material, wherein the shell surrounds the core.

[0006] In a further aspect of the invention, after curing the tire, the static friction coefficient at room temperature of the second material with respect to the rubber material may be larger than the static friction coefficient at room temperature of the first material with respect to the second material.

[0007] In yet a further aspect of the invention, after curing the tire, the static friction coefficient at room temperature of the second material with respect to the rubber material may be smaller than the static friction coefficient at room temperature of the rubber material with respect to itself.

[0008] In yet a further aspect of the invention, the air passageway in the cured tire may be operative to allow a portion of the air passageway near a tire footprint to at least substantially close when the cured tire is mounted to vehicle, inflated and rolling under load in accordance with the tire's specification.

[0009] In one aspect of the invention, the air passageway in the cured tire may be enclosed by cured rubber material.

[0010] In yet a further aspect of the invention, the static friction coefficient at room temperature of the second material with respect to the rubber material may be at least 0.1 smaller, alternatively at least 0.3 or at least 0.5 smaller, than the static friction coefficient at room temperature of the rubber material with respect to itself.

[0011] In yet a further aspect of the invention, the static friction coefficient at room temperature of the second material with respect to the rubber material may be at least 0.1 larger, alternatively at least 0.3 or at least 0.5 larger, than the static friction coefficient at room temperature of the first material with respect to the second material.

[0012] In yet a further aspect of the invention, the Young's modulus at room temperature of the first material may be higher, alternatively at least **10** times higher or at least 50 times higher, than the Young's modulus at room temperature of the second material.

[0013] In yet a further aspect of the invention, the first material may be selected from the group consisting of steel, brass, copper, zinc, nickel, tin, titanium, aramid, silicone, a rubber material, a duroplastic material, a reinforced Teflon material or any combination thereof. In one embodiment, steel is used.

[0014] In yet a further aspect of the invention, the second material may be selected from the group consisting of Teflon, a plastic material, a rubber material, graphite, silicone, or any combination thereof. In one embodiment, Teflon is used.

[0015] In yet a further aspect of the invention, the tire may have at least one of the following features:

[0016] (i) the second material has a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 10 times higher, than the thermal expansion coefficient of the rubber material; or

[0017] (ii) the first material has a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 10 times higher, than the thermal expansion coefficient of the rubber material.

[0018] In yet a further aspect of the invention, the first material may have a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 4 times higher, than the thermal expansion coefficient of the second material.

[0019] In yet a further aspect of the invention, the cable may be located in the bead region of the tire and embedded in a chafer of the tire or in a bead apex of the tire.

[0020] Preferably, the cable extends annularly within the green tire.

[0021] In yet a further aspect of the invention, the cable may be located in the bead region of the tire radially above a radially outermost rim surface when the tire is mounted to a rim and inflated in accordance with the tire specification but unloaded. Preferably, it is embedded in the chafer axially outside of the axially outermost tire ply or tire ply turn-up and radially above, more preferably at least 5 mm radially above the radially outermost location of the tire which is in contact with the rim when the tire is mounted to a rim in accordance with the tire specification. Alternatively, the cable may be located in the bead region of the tire radially inside a radially outermost rim surface when the tire is mounted to a rim and inflated in accordance with the tire specification but unloaded. In this case, the cable is preferably embedded in the chafer or in a bead apex.

[0022] In yet a further aspect of the invention, the core may be a wire or may comprise a plurality of twisted for untwisted filaments or wires, or may comprise one of more central, preferably untwisted filaments or wires and one or more twisted sheath filaments or wires surrounding the center of the core. The shell may be a bushing having the wire received therein or may comprise a preferably helically wound strip surrounding the core. In one aspect of the invention, the core may have only one wire. In an other aspect of the invention, the core may comprise three wires of preferably the same size lying adjacent next to each other in a row, or may comprise three wires of preferably the same size lying adjacent next to each other in a first row and three wires of preferably the same size lying adjacent next to each in a second row on top of and adjacent to the first row. In yet a further aspect of the invention, the core may comprise of from 1 to 10 (such as 1, 3, 6 or 7) twisted or untwisted wires either arranged in a single row, or in a bundle preferably having a round, rectangular, pentagonal, or hexagonal configuration.

[0023] In one aspect of the invention, the overall cross section of the core may be round, lens-shaped, elliptical, star-shaped, or may have the shape of a polygon with n edges, n being an integer in the range of from 3 to 12 such as 4, 5, 6 or 8. Preferably, it is round, elliptical or lens-shaped. Similarly, the overall cross section of the cable (or the external cross section of the shell) may be round, lens-shaped, elliptical, star-shaped, or may have the shape of a polygon with n edges, n being an integer in the range of from 3 to 12 such as 4, 5, 6 or 8. Preferably, it is round, elliptical or lens-shaped. Although the cross section of the core and of the external cross section of the shell or the cable overall respectively may be different and independently selected, they are preferably they same or at least about the same.

[0024] In one aspect of the invention, the diameter of the wire or the overall diameter of the plurality of wires may at least substantially correspond to the inside diameter of the bushing.

[0025] In yet a further aspect of the invention, at least one of a lubricant may be provided between the core and the shell and/or at least one lubricant may be provided between the shell and the rubber material. The lubricant may be an oil, talcum powder, graphite powder or Teflon powder for instance.

[0026] In yet a further aspect of the invention, a method of manufacturing a pneumatic tire comprising an air passageway is disclosed. The method comprises the steps of:

[0027] providing a green pneumatic tire comprising a tire cavity, first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region, and a cable embedded in a rubber material of the green tire, the cable comprising a core of a first material and a shell of a second material, wherein the shell surrounds the core;

[0028] curing the green tire together with the cable in a tire mold; and

[0029] extracting the core of the cable from the cured tire thereby providing an air passageway in the tire.

[0030] In one aspect of the invention, the method may further comprise extracting the shell of the cable from the cured tire after extracting the core of the cable from the cured tire. In another aspect of the invention, the shell of the cable may be extracted from the cured tire together with extracting the core of the cable from the cured tire.

[0031] In yet a further aspect of the invention, the method may further comprise retaining the shell of the cable in the cured tire after having extracted the core of the cable thereby providing a hose-like structure enclosed in the tire.

[0032] In yet a further aspect of the invention, the cable may be embedded in the bead region in a chafer or in a bead apex of the tire.

[0033] In yet a further aspect of the invention, the cable may be embedded in the sidewall of the tire in a sidewall rubber or in a sidewall rubber insert of the tire, or the cable may be embedded in a tire shoulder or in a tire tread.

[0034] In a preferred aspect of the invention, the cured tire may be a self-inflating tire with a portion of the air passageway near a tire footprint at least substantially closing when the cured tire is mounted to vehicle, inflated and rolling under load in accordance with the tire specification.

[0035] In the tire in accordance with the invention, the air passageway created for instance in the bead area of the tire is fully embedded in said tire bead area and thereby protected from being damaged during tire operation.

[0036] The method in accordance with the invention allows an efficient and reliable manufacturing of such an air passageway in the tire wherein the air passageway is fully integrated into the tire and thereby protected from being damaged during tire operation. Furthermore, such an air passageway is less prone to crack creation and crack propagation in the tire.

DEFINITIONS

[0037] "Axial" and "axially" means lines or directions that are parallel to the axis of rotation of the tire.

[0038] "Chafer" is a strip of material placed around the outside of a tire bead to protect the cord plies from wearing and cutting against the rim and distribute the flexing above the rim.

[0039] "Circumferential" means lines or directions extending along the perimeter of the surface of the annular tread perpendicular to the axial direction.

[0040] "Footprint" means the contact patch or area of contact of the tire tread with a flat surface at zero speed and under normal load and pressure.

[0041] "Lateral" means an axial direction.

[0042] "Peristaltic" means operating by means of wave-like contractions that propel contained matter, such as air, along tubular pathways.

[0043] "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

BRIEF DESCRIPTION OF THE DRAWINGS

[0044] The invention will be described by way of example and with reference to the accompanying drawings in which:

[0045] FIG. **1** shows a cross-section of an inflated tire mounted to a rim but without compression.

[0046] FIG. **2** is an enlarged view of the bead area of the tire of FIG. **1**.

[0047] FIG. **3** shows a cross-section of an inflated tire under compression and mounted to a rim.

[0048] FIG. **4** is an enlarged view of the bead area of the tire of FIG. **3**.

[0049] FIG. **5** is a view of a cable for embedding into a green tire prior to tire vulcanization.

DETAILED DESCRIPTION OF THE INVENTION

[0050] FIGS. **1** shows a tire **10** mounted to a tire rim **16**. The tire **10** includes a peristaltic pump assembly in accordance with the principles of such a pump assembly as described in

EP-A2-2 343 200, fully incorporated by reference herein in its entirety, allowing a self-inflation of the tire when operated on a vehicle. The tire **10** mounts in a conventional fashion to a pair of rim mounting surfaces **18**, **20** located adjacent outer rim flanges **22**, **24**. The outer rim flanges **22**, **24** have an outer rim surface **26**. An annular rim body **28** joins the rim flanges **22**, **24** and supports the tire assembly as shown. The tire has a pair of sidewalls **30**, **32** extending from opposite bead areas **34**, **36** to a crown or tire tread region **38**. The tire **10** and rim **16** enclose a tire cavity **40**.

[0051] The peristaltic pump assembly preferably includes a first and second pump that are mounted in an air passageway **43** located in the sidewall area of the tire near the bead region. Other than in EP-A2-2 343 200, the air passageway **43** is however embedded in the tire and enclosed by rubber material or rubber and ply material.

[0052] As shown in FIG. **2**, the air passageway **43** is preferably circular or elliptical in cross section and located between the tire chafer **120** and the axially outermost carcass ply of the tire **10** or it is embedded in the tire chafer material.

[0053] The air passageway **43** is established by first embedding a cable **52** comprising a core **50** and a shell **51** into the green tire in such a way that the cable **52** is fully enclosed within the tire and removing at least the core **50** of the cable **52** or, in an alternative embodiment, the core **50** and the shell **51** of the cable **52**, after curing the tire. The air passageway **43** thereby forms a tube formed of a resilient, flexible material such as plastic, polymer, elastomer or a rubber compound, and is capable of withstanding repeated deformation cycles when the tube is deformed into a flattened condition subject to external force and, upon removal of such force, returns to an original condition generally circular in cross-section. The tube is preferably of a diameter sufficient to operatively pass a volume of air sufficient for the purposes described herein and allowing a positioning of the tube in an operable location within the tire assembly as will be described. Preferably, the tube has a circular cross-sectional shape, although other shapes such as elliptical or lens-shaped may be utilized.

[0054] As explained in EP-A2-2 343 200, the inlet device and the outlet device of the peristaltic pump assembly are preferably spaced apart approximately 180 degrees at respective locations forming two 180 degree pumps. The inlet and outlet device may be located adjacent each other, thus forming a single 360 degree pump. Other variations may be utilized, such as 270 degrees, etc. The inlet device and the outlet device are in fluid communication with the circular air passageway **43** and positioned generally 180 degrees apart. As the tire rotates in a direction of rotation, a footprint is formed against a ground surface. A compressive force is directed into the tire from the footprint and acts to flatten a segment of the air passageway **43**.

[0055] The location of the peristaltic pump assembly and in particular the air passageway **43** will be understood from FIGS. **2** and **4**. In one embodiment, the peristaltic pump assembly is positioned in the tire sidewall, radially outward of the rim flange surface **26** in the chafer **120**. So positioned, the air passageway **43** is radially inward from the tire footprint and is thus positioned to be flattened by forces directed from the tire footprint. The segment of the air passageway that is opposite the footprint will flatten from the compressive force from the footprint pressing the chafer **120** and thereby also the air passageway segment against the rim flange surface **26**. Although the positioning of the air passageway **43** is specifically shown as between a chafer **120** of the tire at the bead region **34** and the rim surface **26**, it is not limited to same, and may be located at any region of the tire such as anywhere in the sidewall or tread.

[0056] From the forgoing, it will be appreciated that the subject invention provides a peristaltic pump for a self-inflating tire in which an air passageway **43** flattens segment by segment and closes in the tire footprint.

[0057] FIG. **1** shows a cured tire comprising the air passageway **43** which has been created by first embedding the cable **52** in the green tire, curing the green tire and then removing the core material **51** of the cable **52** so that the shell material **51** of the cable forms the surrounding wall of the air passageway **43**. Hence, to arrive a the tire **10** as shown in FIG. **1**, a green tire is build with the cable **52** as shown in FIG. **5** embedded for instance in the bead area of the tire at the location where the air passageway **43** is to be created. Afterwards, the tire **10** is cured in a tire mold as usual and, after curing, the cable **52** is accessed through a respective opening left during the molding process or created after the molding process in the bead area of the tire, i.e. through an access to the cable **52** molded into the green tire for instance. Through this access, the core material **50** may be extracted from the cured tire so that only the shell material **51** is left in the cured tire and the air passageway is formed inside the shell material **51** or is defined by the shell material **51**. The diameter of the core **50** in the form of a wire embedded into the shell material **51** acting as a bushing is typically in the rage of from 0.5 to 3 mm, preferably 1 to 2 mm. The external diameter of the shell material **51** forming the bushing as shown in FIG. **5** is typically in a range of from 2 to 6 mm, preferably 3 to 5 mm.

[0058] Instead of leaving the shell material **51** inside the cured tire and extracting only the core material **50** as shown in FIG. **1**, the shell material **51** may also be extracted from the cured tire either together with the core material **50** or, preferably, thereafter. To facilitate a removal of the core material **50** and/or a removal of the shell material **51**, a lubricant may be used and applied between core material **50** and shell material **51**, i.e. inside the bushing, and/or on the outer surface of the bushing at the interface between the shell material **51** and the surrounding rubber material of the tire. Such a lubricant may, for instance, be talcum powder.

[0059] FIG. **2** shows a detail of FIG. **1** prior to the core material **50** has been extracted from the tire, i.e. prior to the air passageway **43** is established.

[0060] FIG. **3** shows the tire of FIG. **1** when mounted on a vehicle, inflated with air in accordance with the tire specification, mounted to a rim and under load while the air passageway **43** goes through the footprint of the tire. Thereby at least a segment of the air passageway **43** is closed thereby providing a peristaltic pumping effect.

[0061] FIG. **4** shows an enlarged detail of FIG. **3** with the air passageway **43** closed after the core material **50** has been removed and with only the shell material **51** left.

[0062] As explained above, and in an alternative embodiment, also the shell material **51** may be extracted from the tire so that only a hollow body is created in the bead area of the tire forming the air passageway **43**.

[0063] To allow an efficient and reliable extraction of the core **50**, the material of the core **50** preferably has a Young's modulus at room temperature significantly higher than the Young's modulus at room temperature of the shell material **51**.

[0064] The core material may be steel for instance and the shell material may be Teflon for instance.

[0065] In an alternative embodiment, the core material may be steel, and the shell material may be plastic.

[0066] In yet a further embodiment, the core material may be aramid and the shell material may be Teflon or plastic.

[0067] To further facilitate an extraction of the shell material **51** from the tire **10**, it is advantageous if the shell material has a static friction coefficient at room temperature with respect to the material surrounding the shell, i.e. preferably rubber, of less than the static friction coefficient at room temperature of the surrounding material with respect to itself, i.e. tire chafer rubber to tire chafer rubber. Preferably, this difference in static friction coefficient is at least 0.1, more preferably at least 0.2.

[0068] The extraction of the shell material **51** from the tire after curing the tire can also be facilitated by using a shell material having a thermal expansion coefficient higher than the thermal expansion coefficient of the material surrounding the shell at its radially outer side, i.e. than tire chafer rubber. With such a higher expansion coefficient, the shell material **51** expands more than the surrounding rubber material when the tire is cured in a tire mold, i.e. typically at a temperature at a range of from 100-200° C., and after cooling the tire after cure thereby a small gap or space may be created between the shell material **51** and the surrounding tire chafer rubber. In other words, the shell material **51** may thereby create a clearance between the shell material and the surrounding tire chafer rubber after the tire is cooled down again. This allows an easier extraction of the shell material **51** from the tire. A use of a shell material **51** having a higher formal expansion coefficient than the surrounding rubber material is particularly beneficial in case one wishes to extract also the shell material **51** from the cured tire and not only the core material **50**. Accordingly, in case it is wished to keep the shell material **51** within the cured tire and to only extract only the core material **50**, it is rather preferable to use a shell material **51** with a formal expansion coefficient not different or even smaller than the expansion coefficient of the surrounding tire chafer rubber.

[0069] Other than shown in the embodiment of FIGS. **1** to **4**, the cable **52** may also be located within a bead apex of the tire or even in the tire sidewall, the tire shoulder or under a tread of the tire to there create hidden grooves for instance for applications other than self-inflating tires.

[0070] Variations in the present invention are possible in light of the description of it provided herein. While certain representative embodiments and details have been shown for the purpose of illustrating the subject invention, it will be apparent to those skilled in this art that various changes and modifications can be made therein without departing from the scope of the subject invention. It is, therefore, to be understood that changes can be made in the particular embodiments described which will be within the full intended scope of the invention as defined by the following appended claims.

1. A green pneumatic tire comprising a tire cavity; first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region; and a cable embedded into a rubber material of the green tire for allowing a creation of an air passageway in the tire after curing the green tire in a tire mold, the cable comprising a core of a first material and a shell of a second material, wherein the shell surrounds the core.

2. The green tire of claim **1** wherein, after curing the tire, the static friction coefficient at room temperature of the second material with respect to the rubber material is larger than the static friction coefficient at room temperature of the first material with respect to the second material.

3. The green tire of claim **1** wherein, after curing the tire, the static friction coefficient at room temperature of the second material with respect to the rubber material is smaller than the static friction coefficient at room temperature of the rubber material with respect to itself.

4. The green tire of claim **1** wherein the air passageway in the cured tire is operative to allow a portion of the air passageway near a tire footprint to at least substantially close when the cured tire is mounted to vehicle, inflated and rolling under load in accordance with the tire's specification.

5. The green tire of claim **3** wherein the static friction coefficient at room temperature of the second material with respect to the rubber material is at least 0.1 smaller, alternatively at least 0.3 or at least 0.5 smaller, than the static friction coefficient at room temperature of the rubber material with respect to itself.

6. The green tire of claim **2** wherein the static friction coefficient at room temperature of the second material with respect to the rubber material is at least 0.1 larger, alternatively at least 0.3 or at least 0.5 larger, than the static friction coefficient at room temperature of the first material with respect to the second material.

7. The green tire of claim **1** wherein the Young's modulus at room temperature of the first material is higher, alternatively at least 10 times higher or at least 50 times higher, than the Young's modulus at room temperature of the second material.

8. The green tire of claim **1** wherein the first material is selected from the group consisting of steel, brass, copper, zinc, nickel, tin, titanium, aramid, silicone, a rubber material, a duroplastic material, a reinforced Teflon material or any combination thereof.

9. The green tire of claim **1** wherein the second material is selected from the group consisting of Teflon, a plastic material, a rubber material, graphite, silicone, or any combination thereof.

10. The green tire of claim **1** wherein the tire has at least one of the following features:

(i) the second material has a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 10 times higher, than the thermal expansion coefficient of the rubber material; or

(ii) the first material has a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 10 times higher, than the thermal expansion coefficient of the rubber material.

11. The green tire of claim **10** wherein the first material has a thermal expansion coefficient higher, alternatively at least 2 times or at least 2 to 4 times higher, than the thermal expansion coefficient of the second material.

12. The green tire of claim **1** wherein the cable is located in the bead region of the tire and embedded in a chafer of the tire or in a bead apex of the tire, and wherein the cable extends annularly within the green tire.

13. The green tire of claim **1** wherein the cable is located in the bead region of the tire radially above a radially outermost rim surface when the tire is mounted to a rim and inflated in accordance with the tire specification but unloaded.

14. The green tire of claim **1** wherein the core is a wire or comprises a plurality of twisted filaments, and wherein the shell is a bushing having the wire received therein or comprises a helically would strip surrounding the core.

15. The green tire of claim **1** further comprising at least one of a lubricant between the core and the shell and/or comprising a lubricant between the shell and the rubber material.

16. A method of manufacturing a pneumatic tire comprising an air passageway, the method comprising the steps of:

providing a green pneumatic tire comprising a tire cavity, first and second sidewalls extending respectively from first and second tire bead regions to a tire tread region, and a cable embedded in a rubber material of the green tire, the cable comprising a core of a first material and a shell of a second material, wherein the shell surrounds the core;

curing the green tire together with the cable in a tire mold; and

extracting the core of the cable from the cured tire thereby providing an air passageway in the tire.

17. The method of claim **16** further comprising extracting the shell of the cable from the cured tire after extracting the core of the cable from the cured tire, or further comprising extracting the shell of the cable from the cured tire together with extracting the core of the cable from the cured tire.

18. The method of claim **16** further comprising retaining the shell of the cable in the cured tire after having extracted the core of the cable.

19. The method of claim **16** wherein the cable is embedded in the bead region in a chafer or in a bead apex of the tire.

20. The method of claim **16** wherein the cable is embedded in the sidewall of the tire in a sidewall rubber or in a sidewall rubber insert of the tire, or wherein the cable is embedded in a tire shoulder or in a tire tread.

* * * * *