



(51) International Patent Classification:

B60C 9/20 (2006.01) *B60C 9/18* (2006.01)
B60C 9/22 (2006.01)

(21) International Application Number:

PCT/US2016/069371

(22) International Filing Date:

30 December 2016 (30.12.2016)

(25) Filing Language:

English

(26) Publication Language:

English

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(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, DJ, 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, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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.

(54) Title: IMPROVED TIRE BELT CONSTRUCTION

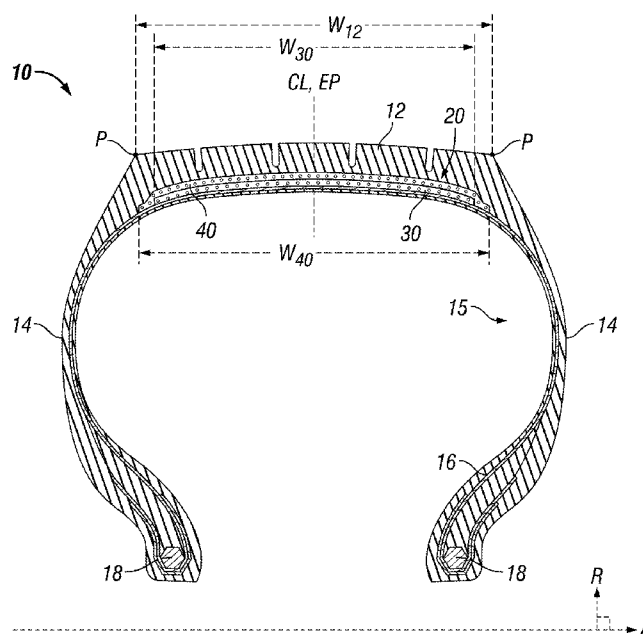


FIG. 1

(57) Abstract: In embodiments, a pneumatic tire includes a tire carcass (16) having a body layer extending between a pair of beads (18). The tire further includes a belt (20) arranged along the tire carcass between the pair of beads. The belt has at least a single primary reinforcement layer (30), where the length of each elongate metal reinforcement in the single primary reinforcement layer extends in a direction biased from an equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value. The belt also has an annular belt cap layer (40), where the length of each elongate non-metal reinforcement in the annular belt cap layer extends in a direction biased from an equatorial plane of the tire by an angle of 0 to 10 degrees in absolute value.

(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, ST, 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).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

IMPROVED TIRE BELT CONSTRUCTION

BACKGROUND

Field

[0001] Embodiments relate generally to pneumatic tires, and more specifically, to tires having a belt construction.

Description of the Related Art

[0002] Pneumatic tires generally include a tire carcass and a belt arranged around the tire carcass. Commonly, the belt is formed of multiple stacked belt layers, each of which being a reinforcement layer including a plurality of spaced-apart, elongate metal reinforcements. As a result, the summit of a tire having multiple stacked metal belt layers is heavy and inflexible. Also, because the elongate metal reinforcements extend substantially in a circumferential direction of the belt or tire (that is, approximately 0 degrees relative to the circumferential direction of the tire), to provide the necessary circumferential or hoop strength of the belt and tire, this greatly prevents the belt from stretching or expanding during tire construction operations. For example, this reduced ability to expand can make molding operations difficult. Additionally, because the belt does not substantially expand, the belt is commonly assembled separate from the tire carcass, and later, after belt assembly, applied to the tire carcass to form an assembled, uncured tire. Accordingly, there is a need to overcome these issues.

SUMMARY

[0003] Embodiments include a pneumatic tire. Particular embodiments include a cured pneumatic tire with a tire carcass having one or more body ply reinforcement layers. The one or more body ply reinforcement layers extend along each of a pair of sidewalls and between a pair of beads where the beads are spaced apart in an axial direction of a tire. An annular belt extends around a radial extent of the tire carcass. The annular belt has a width and a single primary reinforcement layer extending around the tire and across the width of the belt. The annular belt also has an annular belt cap layer. The annular belt cap layer extends around a radial outer extent of the primary reinforcement layer. The annular belt cap layer has a width which extends at least across the width of the belt and includes one or more cap reinforcement layers. Each of the one or more cap reinforcement layers extend around the tire.

[0004] The single primary reinforcement layer includes a plurality of elongate metal reinforcements. The elongate metal reinforcements are spaced apart at least partially along a length of the annular belt and have a metal reinforcement length extending at least partially in a direction of the annular belt width where the metal reinforcement length for each of the elongate metal reinforcements extends in a direction biased from an equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value.

[0005] Each of the one or more cap reinforcement layers include a plurality of elongate non-metal reinforcements. The elongate non-metal reinforcements are spaced apart at least partially along the length of the annular belt and have a non-metal reinforcement length extending at least partially in the direction of the annular belt width and where the non-metal reinforcements extend in the direction biased from the equatorial plane of the tire by an angle of 0 degrees to 10 degrees in absolute value.

[0006] Various embodiments may have an elastomeric separation layer positioned between the single primary reinforcement layer and the annular belt cap layer. In some of these embodiments, the elastomeric separation layer may have a thickness of up to 3 mm.

[0007] Some embodiments also include an intermediate reinforcement layer arranged between the single primary reinforcement layer and the annular belt cap layer. The intermediate reinforcement layer includes a plurality of elongate reinforcements spaced apart at least partially along the length of the annular belt and each have a reinforcement length extending at least partially in the direction of the annular belt width where the reinforcement length for each of the elongate reinforcements extends in the direction biased from the equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value. The intermediate reinforcement layer has a width extending partially across the width of the single primary reinforcement layer.

[0008] Additional embodiments are described below.

DETAILED DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a front sectional view of a tire, in accordance with a particular embodiment.

[0010] FIG. 2 is an exploded view of a belt of the tire of FIG. 1.

[0011] FIG. 3 is a partial top view of the belt of the tire of FIG. 2.

[0012] FIG. 4 is an exploded view of a belt of a tire, in accordance with another

embodiment.

[0013] FIG. 5 is an exploded view of a belt of a tire, in accordance with a further embodiment.

[0014] FIG. 6 is a partial top view of a belt of the tire of FIG. 5.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0015] Embodiments described herein include pneumatic tires having a belt with a single primary reinforcement layer extending around the tire. The single primary reinforcement layer extends across a width of the belt and includes a plurality of spaced-apart elongate metal reinforcements. This single primary reinforcement layer may also be referred to as a single, metal-reinforced belt layer. The elongate metal reinforcements in this single primary reinforcement layer are biased by an angle of ± 70 degrees to ± 90 degrees, or 70 to 90 degrees, in absolute value, relative to the circumferential direction of the tire, or, stated differently, relative to an equatorial plane of the belt or tire. The belt also includes a cap layer, the cap layer being a reinforcement layer formed of non-metal elongate reinforcements and extending substantially across the width of the belt. In some embodiments the cap layer may extend across the full width of the belt. The non-metal elongate reinforcements extend lengthwise in a direction biased by an angle of 0 degrees to ± 10 degrees from the circumferential direction of the tire or belt or from an equatorial plane of the belt or tire. Additional details and other variations are described herein.

[0016] Commonly, tires have a plurality of belt layers each formed of elongate metal reinforcements, where each of these metal-reinforced belt layers extend the substantial width of the belt or the substantial effective rolling width of the tire tread. As noted previously, when multiple metal-reinforced belt layers are used, and especially when the metal reinforcements in each layer extend in the circumferential direction of the belt or tire (that is, unbiased to an equatorial plane of the belt or tire), the belt is restricted from stretching or expanding during tire construction and molding operations. And while the metal-reinforced belt layers are provided at the summit to provide sufficient strength to resist breaking energy, use of multiple metal-reinforced belt layers greatly increase the weight of a tire and reduce the flexibility of the tire. Accordingly, embodiments described herein, incorporating a single primary reinforcement layer, provide various benefits, including significantly reducing the mass and weight of the tire and the overall rolling resistance. As a result, these belts may be employed by lightweight vehicles.

[0017] A tire as described herein is a pneumatic tire, and includes a tire carcass having one or more body ply reinforcement layers extending along each of a pair of side walls and between a pair of beads spaced apart in an axial direction of a tire. It is appreciated that the tire carcass may comprise any tire carcass formed of any construction as desired by one of ordinary skill in the art.

[0018] The tire also includes an annular belt having a length extending circumferentially around a radial extent of the tire carcass, and a width extending laterally generally in an axial direction of the tire. As noted previously, the belt includes the single primary reinforcement layer having a plurality of spaced-apart metal elongate reinforcements. The single primary reinforcement layer extends around the tire and across the width of the belt. The elongate metal reinforcements are spaced apart, and each has a length, also referred to as a “metal reinforcement length,” extending at least partially in the direction of the annular belt width. In particular embodiments, the length for each elongate metal reinforcement extends in a direction biased from the circumferential direction of the tire, or, stated differently, from an equatorial plane of the tire, by an angle of ± 70 degrees to ± 90 degrees, or, in other words, 70 to 90 degrees, in absolute value.

[0019] The belt also includes an annular belt cap layer extending circumferentially around a radial extent of the tire carcass. The annular belt cap layer has a width extending across a width of the belt. The annular belt cap layer is formed of one or more cap reinforcement layers, each of the one or more cap reinforcement layers extending circumferentially around the tire. Each of the one or more cap reinforcement layers includes a plurality of elongate non-metal reinforcements. The plurality of elongate non-metal reinforcements are spaced apart in a direction generally perpendicular to a length of each metal reinforcement. The length of each elongate non-metal reinforcement, which is also referred to as a “non-metal reinforcement length,” extends at least partially in the circumferential direction of the tire. In certain embodiments, the length of each of elongate non-metal reinforcement extends in a direction biased from the circumferential direction, or from an equatorial plane of the tire, by an angle of 0 degrees to ± 10 degrees, or, in other words, 0 to 10 degrees in absolute value. In particular embodiments, the annular belt cap layer is formed of a single cap reinforcement layer extending at least substantially across the width of the belt. At least substantially across the width of the belt means that the cap reinforcement layer extends at least 90% of the belt width, but may extend the full belt width or may even extend beyond the full belt width. In other variations, the annular belt cap layer

is formed of a plurality of cap reinforcement layers, which are stacked in a radial direction of the tire. It is appreciated that each of the plurality of cap reinforcement layers may extend partially or at least substantially across the width of the belt.

[0020] It is appreciated that any reinforcement layer discussed herein may be provided in any form known to one of ordinary skill. For example, any reinforcement layer may be provided having the plurality of elongate reinforcements (whether metal or non-metal) arranged within an elastomeric polymer matrix. The elastomeric polymer may form any desired natural or synthetic rubber. Metal reinforcements are constructed from chords most commonly formed of steel, but may be formed of any metal. Non-metal reinforcements are constructed from chords formed of any fabric or textile, such as polyester, rayon, nylon, aramid, silk, or fiberglass. The chords may be formed of a plurality of the wire (metal) or yarn/filaments (non-metal, arranged lengthwise and twisted along their lengths, as desired). In one particular embodiment, the non-metal reinforcements within the annular belt cap layer are aramid. In another particular embodiment, the non-metal reinforcements within the annular belt cap layer are silk. In yet another embodiment, multiple annular belt cap layers having non-metal reinforcements may be provided, including the same or different materials in each respective layer to reach a sufficient strength and to maintain the desired mass. It is appreciated embodiments may comprise any combination of materials forming the chords.

[0021] Optionally, in certain embodiments, one or more intermediate elastomeric layers of a desired thickness may be arranged between the single primary reinforcement layer and the annular belt cap layer. The one or more intermediate elastomeric layers form an elastomeric separating layer between the single primary reinforcement layer and the annular belt cap layer. In particular embodiments, one of the one or more intermediate elastomeric layers has a thickness of up to 3 mm. It is appreciated that each of the intermediate elastomeric layers may be formed of any elastomeric material, including any desired natural or synthetic rubber.

[0022] Embodiments may also include an intermediate reinforcement layer. The intermediate reinforcement layer is arranged between the single primary reinforcement layer and the annular belt cap layer and extends annularly around the tire. The intermediate reinforcement layer includes a plurality of spaced apart elongate reinforcements, each elongate reinforcement having a length (a “reinforcement length”) extending in a direction biased from the circumferential direction of the tire, or, in other words, from the equatorial plane of the tire, by an angle of +/- 70 degrees to +/- 90 degrees (that is, 70 to 90 degrees in

absolute value). The intermediate reinforcement layer also has a width extending partially across the width of the single belt reinforcement layer. In certain instances, the width of the intermediate reinforcement layer is equal to 10 percent (10%) to 20 percent (20%) of the belt width or of the single primary reinforcement layer width. It is also appreciated that the width of the intermediate reinforcement layer is arranged to extend along the widthwise centerline of the belt or tire, whether or not the intermediate reinforcement layer is centered across the belt or tire width. It is also appreciated that the plurality of reinforcements arranged within the intermediate reinforcement layer may comprise any metal or non-metal reinforcement, or a combination thereof. In a particular embodiment, the intermediate reinforcement layer is formed of aramid. In another particular embodiment, the intermediate reinforcement layer is formed of metal. It is understood that more than one intermediate reinforcement layer may be provided.

[0023] In particular embodiments, the reinforcement length for each of the elongate reinforcements in the intermediate reinforcement layer extends at an angle of -70 degrees to -90 degrees and the reinforcement length for each of the elongate reinforcements in the single belt reinforcement layer extends at an angle of 70 degrees to 90 degrees in the direction bias the equatorial plane of the tire, or vice versa. In other words, the reinforcement length of the elongate reinforcements of the intermediate reinforcement layer cross the reinforcement length for each of the elongate reinforcements in the single belt reinforcement layer, at an equatorial plane of the tire. Thereby, a mesh configuration is formed between the two layers.

[0024] When a tire includes the optional elastomeric separation layer together with the optional one or more intermediate reinforcement layers, any one or all of the one or more intermediate reinforcement layers may be separated from either the annular belt cap and/or the single primary reinforcement layer (or more generally the belt) by the elastomeric separation layer or by any of the one or more intermediate polymer layers.

[0025] In particular embodiments, the single primary reinforcement layer, the belt cap layer, and any intermediate reinforcement layer are arranged along a central portion of the tire carcass between the pair of beads. The single primary reinforcement layer, the belt cap layer, and any intermediate reinforcement layer, if included, are stacked in a radial direction. In one particular embodiment, the single primary reinforcement layer is stacked radially inward or below the belt cap layer. In yet another embodiment, the single primary reinforcement layer is stacked radially inward or below the annular belt cap layer with an intermediate reinforcement layer between the single primary reinforcement layer and the belt cap layer.

[0026] The single belt reinforcement layer, the belt cap layer, and the intermediate reinforcement layer each have a width formed relative a rolling tread width. The rolling tread width is the width of the tire tread that is available for engagement with a ground surface during tire operation. In particular embodiments, the single belt layer width is 80 percent (80%) to 90 percent (90%) of the rolling tread width and, when present, the intermediate reinforcement layer width is 8 percent (8%) to 18 percent (18%) of the rolling tread width. It is appreciated that the widths of the different layers may be defined with reference to one another. For example, in certain embodiments, the intermediate reinforcement layer width is 10 percent (10%) to 20 percent (20%) of the width of the single belt layer. In combination with the corresponding width, each respective width may be further defined by a minimum dimension. For example, in particular embodiments, the intermediate reinforcement layer width is 10 percent (10%) to 20 percent (20%) of the width of the single belt layer and a minimum of 25 mm.

[0027] It is appreciated that in certain embodiments, the single belt reinforcement layer width, the belt cap layer width, and the intermediate reinforcement layer width, when present, are symmetrical about the an equatorial plane of the tire (that is, the widthwise centerline of the tire). However, in other embodiments, one or more layer widths may be offset relative the equatorial plane of the tire. This may include offsetting one or more layers, or a combination of layers, in a balanced or unbalanced configuration.

[0028] The embodiments of the tires discussed above will now be discussed below in association with particular embodiments shown in the figures.

[0029] With reference to FIG. 1, a cross-sectional view of a cured, pneumatic tire **10** is shown in accordance with a particular embodiment. It is noted that tire **10** includes a rotational axis **A** defining an axial direction of the tire. A radial direction **R** is also identified, which extends perpendicular to rotational axis **A** and the axial direction. Tire **10** includes a tread **12** arranged overtop a belt **20** comprising a single primary reinforcement layer **30** and an annular belt cap layer **40**, all of which are bonded to a tire carcass **15**. In this particular embodiment, the annular belt cap layer **40** is radially outward of the single primary reinforcement layer **30**. In other words, the single primary reinforcement layer **30** is radially inward of the annular belt cap layer **40**. Tire **10**, and carcass **15**, include a pair of sidewalls **14** spaced apart in the axial direction **A** of the tire, one or more body ply reinforcement layers **16** extending along each of the sidewalls and between a pair of beads **18** spaced apart in the axial direction **A** of the tire. The axial direction also identifies a direction of the tire width, as

well as a direction of the belt width, the primary reinforcement layer width W_{30} , and the cap width W_{40} . A widthwise centerline **CL** is shown defining an equator extending around a perimeter of the tire **10**. An equatorial plane **EP** extends through the tire **10** along the centerline **CL**. FIG. 2 is a close-up view of the tire shown in FIG. 1.

[0030] FIG. 3 is a top cutaway view of the belt **20** of FIGs. 1-2, showing the single primary reinforcement layer **30** and the annular belt cap layer **40**. Each layer forms a sheet and includes a plurality of elongate reinforcements formed within an elastomeric polymer matrix **22**. The single primary reinforcement layer **30** includes elongate metal reinforcements **32** and the annular belt cap layer **40** includes elongate non-metal reinforcements **42**. The elongate metal reinforcements **32** of the single primary reinforcement layer **30** extend lengthwise in a direction biased by an angle θ_1 from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative to the equatorial plane **EP**. The angle θ_1 is +/- 70 degrees to +/- 90 degrees from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative to the equatorial plane **EP**. The elongate non-metal reinforcements **42** of the annular belt cap layer **40** extend lengthwise in a direction biased by an angle θ_2 from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative the equatorial plane **EP**. The angle θ_2 is 0 degrees to +/- 10 degrees from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative to the equatorial plane **EP**.

[0031] With reference to FIGs. 1-3, the widths of the single primary reinforcement layer **30** and/or the annular belt cap layer **40** may each be expressed as a percentage in a direction of a full belt width or a rolling tread width W_{12} . In particular embodiments, the rolling tread width W_{12} can be effectively referred to as a width or a tread arc which engages the operating surface (not shown). The rolling tread width W_{12} is defined to extend between locations **P** arranged on opposing sides of centerline **CL** along the tread width. In particular embodiments, the single primary reinforcement layer width W_{30} may be a portion of the rolling tread width W_{12} . By example, the single primary reinforcement layer may be equal to or less than 85 percent (85%) of the rolling tread width W_{12} .

[0032] With reference to FIG. 4, an exploded view of another embodiment of a belt **20** is illustrated. In this embodiment, the belt **20** includes an elastomeric separation layer **60**. The elastomeric separation layer **60** is positioned between a single primary reinforcement layer **30** and an annular belt cap layer **40**. The elastomeric separation layer **60** may be formed

separately in the elastomeric polymer matrix **22**. In one particular embodiment, the elastomeric separation layer **60** is 3 mm.

[0033] With reference to FIG. 5, yet another embodiment of a belt **20** is provided. In this embodiment, the belt **20** includes an intermediate reinforcement layer **50**. The intermediate reinforcement layer **50** is arranged between a single primary reinforcement layer **30** and an annular belt cap layer **40**. The intermediate reinforcement layer **50** has an intermediate reinforcement layer width W_{50} and comprises elongate reinforcement **52**.

[0034] FIG. 6 is a top cutaway view of the belt **20** of FIG. 5, showing the single primary reinforcement layer **30**, the intermediate reinforcement layer **50**, and the annular belt cap layer **40**. Each belt layer forms a sheet and includes a plurality of the respective reinforcements formed within an elastomeric polymer matrix **22**. The single belt reinforcement layer **30** includes elongate metal reinforcements **32** and the annular belt cap layer **40** includes elongate non-metal reinforcements **42**. The intermediate reinforcement layer **50** may comprise elongate metal reinforcements and/or elongate non-metal reinforcements. The elongate reinforcements **52** of the intermediate reinforcement layer **50** extend lengthwise in a direction biased by an angle θ_3 from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative to the equatorial plane **EP**. The angle θ_3 is +/- 70 degrees to +/- 90 degrees from the circumferential direction of the tire or belt or from the widthwise centerline **CL** of the tire or belt or relative to the equatorial plane **EP**. In this particular embodiment, the elongate reinforcements **52** in the intermediate reinforcement layer **50** extend lengthwise in a direction biased by an angle θ_3 that is -70 degrees to -90 degrees and the elongate reinforcements **42** in the single belt reinforcement layer **30** extend lengthwise in a direction biased by an angle θ_1 that is 70 degrees to 90 degrees. In yet another embodiment, the elongate reinforcements in the intermediate reinforcement layer and the elongate reinforcements in the single belt reinforcement layer may be oriented vice versa. In contrast, the angle θ_2 of the elongate reinforcements **42** of the annular belt cap layer **40** extend lengthwise in a direction biased by an angle of 0 degrees to +/- 10 degrees.

[0035] To the extent used, the terms “comprising,” “including,” and “having,” or any variation thereof, as used in the claims and/or specification herein, shall be considered as indicating an open group that may include other elements not specified. The terms “a,” “an,” and the singular forms of words shall be taken to include the plural form of the same words, such that the terms mean that one or more of something is provided. The terms “at least one”

and “one or more” are used interchangeably. The term “single” shall be used to indicate that one and only one of something is intended. Similarly, other specific integer values, such as “two,” are used when a specific number of things is intended. The terms “preferably,” “preferred,” “prefer,” “optionally,” “may,” and similar terms are used to indicate that an item, condition or step being referred to is an optional (i.e., not required) feature of the embodiments. Ranges that are described as being “between a and b” are inclusive of the values for “a” and “b” unless otherwise specified.

[0036] While various improvements have been described herein with reference to particular embodiments thereof, it shall be understood that such description is by way of illustration only and should not be construed as limiting the scope of any claimed invention. Accordingly, the scope and content of any claimed invention is to be defined only by the terms of the following claims, in the present form or as amended during prosecution or pursued in any continuation application. Furthermore, it is understood that the features of any specific embodiment discussed herein may be combined with one or more features of any one or more embodiments otherwise discussed or contemplated herein unless otherwise stated.

CLAIMS

What is claimed is:

1. A cured pneumatic tire comprising:

a tire carcass having one or more body ply reinforcement layers extending along each of a pair of sidewalls and between a pair of beads spaced apart in an axial direction of a tire;

an annular belt extending around a radial extent of the tire carcass, the annular belt having a width and a single primary reinforcement layer extending around the tire and across the width of the belt;

the annular belt having annular belt cap layer extending around a radial outer extent of the primary reinforcement layer, the annular belt cap layer having a width extending at least across the width of the belt and including one or more cap reinforcement layers, each of the one or more cap reinforcement layers extending around the tire;

where the single primary reinforcement layer includes a plurality of elongate metal reinforcements spaced apart at least partially along a length of the annular belt and having a metal reinforcement length extending at least partially in a direction of the annular belt width where the metal reinforcement length for each of the elongate metal reinforcements extends in a direction biased from an equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value;

where each of the one or more cap reinforcement layers include a plurality of elongate non-metal reinforcements spaced apart at least partially along the length of the annular belt and having a non-metal reinforcement length extending at least partially in the direction of the annular belt width where the non-metal reinforcement length for each of the elongate non-metal reinforcements extends in the direction biased from the equatorial plane of the tire by an angle of 0 degrees to 10 degrees in absolute value.

2. The tire of claim 1, where the non-metal reinforcements are each formed of aramid.
3. The tire of claim 1, where the non-metal reinforcements are each formed of silk.
4. The tire of any one of claims 1 to 3 further comprising:

an elastomeric separation layer positioned between the single primary reinforcement layer and the annular belt cap layer.

5. The tire of claim 4, where the elastomeric separation layer has a thickness of up to 3 mm.
6. The tire of any one of claims 1 to 5, where an intermediate reinforcement layer is arranged between the single primary reinforcement layer and the annular belt cap layer, where the intermediate reinforcement layer includes a plurality of elongate reinforcements spaced apart at least partially along the length of the annular belt and each having a reinforcement length extending at least partially in the direction of the annular belt width where the reinforcement length for each of the elongate reinforcements extends in the direction biased from the equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value, the intermediate reinforcement layer having a width extending partially across the width of the single primary reinforcement layer.
7. The tire of claim 6, where the plurality of elongate reinforcements for one of the single primary reinforcement layer and the intermediate reinforcement layer extends at an angle of -70 degrees to -90 degrees and the other extends at an angle of 70 degrees to 90 degrees in the direction biased from the equatorial plane of the tire.
8. The tire of any one of claims 6 to 7, where the single primary reinforcement layer width is 80% to 90% of a rolling tread width and the intermediate reinforcement layer width is 8% to 18% of the rolling tread width.
9. The tire of any one of claims 6 to 7, where the single primary reinforcement layer width is 80% to 90% of a rolling tread width and the intermediate reinforcement layer width is 10% to 20% of the single primary reinforcement layer width and a minimum of 25 mm.
10. The tire of any one of claims 6 to 9, where the plurality of elongate reinforcements of the intermediate layer are each formed of aramid.
11. The tire of any one of claims 6 to 9, where the plurality of elongate reinforcements of the intermediate layer are each formed of metal.
12. The tire of any one of claims 1 to 11, where the annular belt cap layer is radially outward of the single primary reinforcement layer.

13. The tire of any one of claims 1 to 12, where the annular belt cap layer is formed of a single cap reinforcement layer extending at least substantially across the width of the belt.

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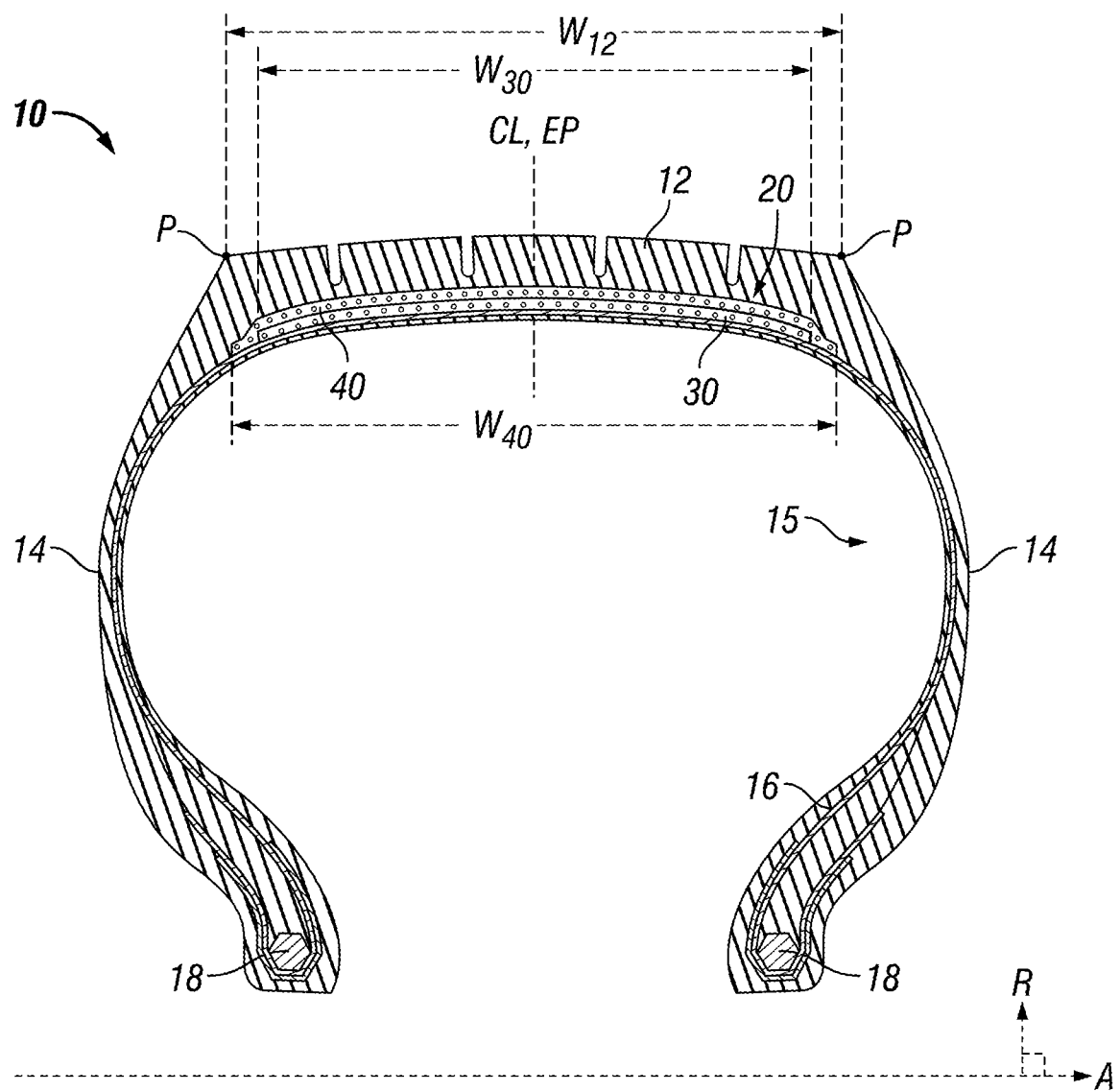


FIG. 1

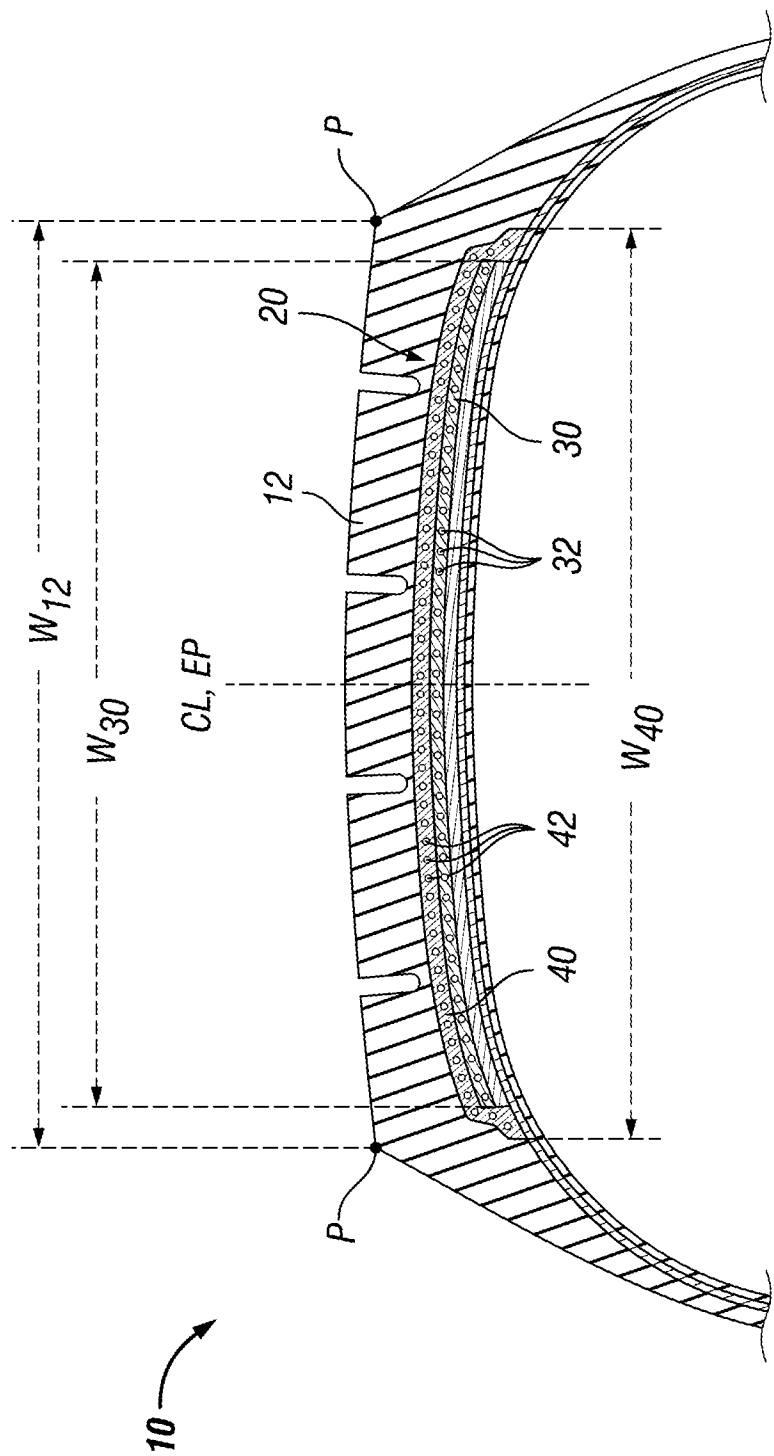


FIG. 2

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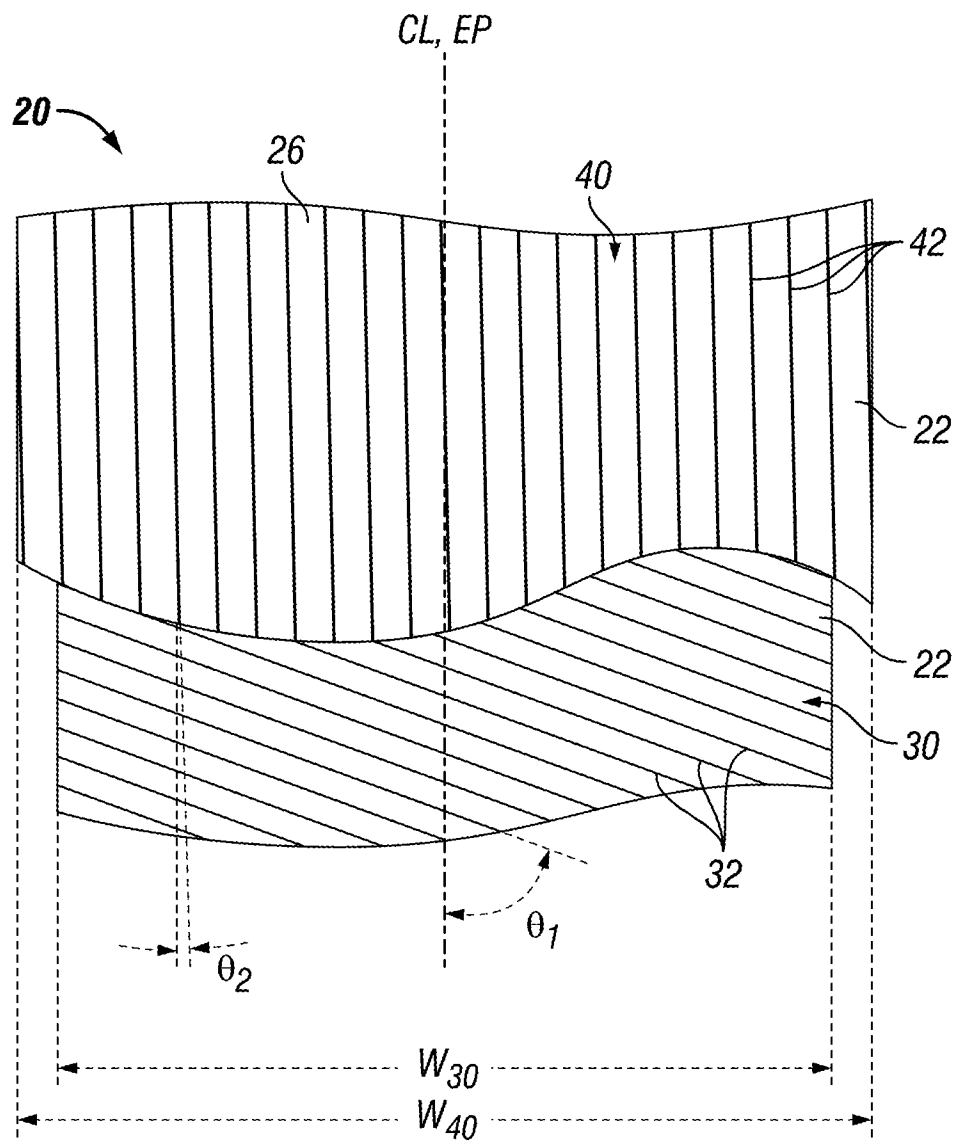


FIG. 3

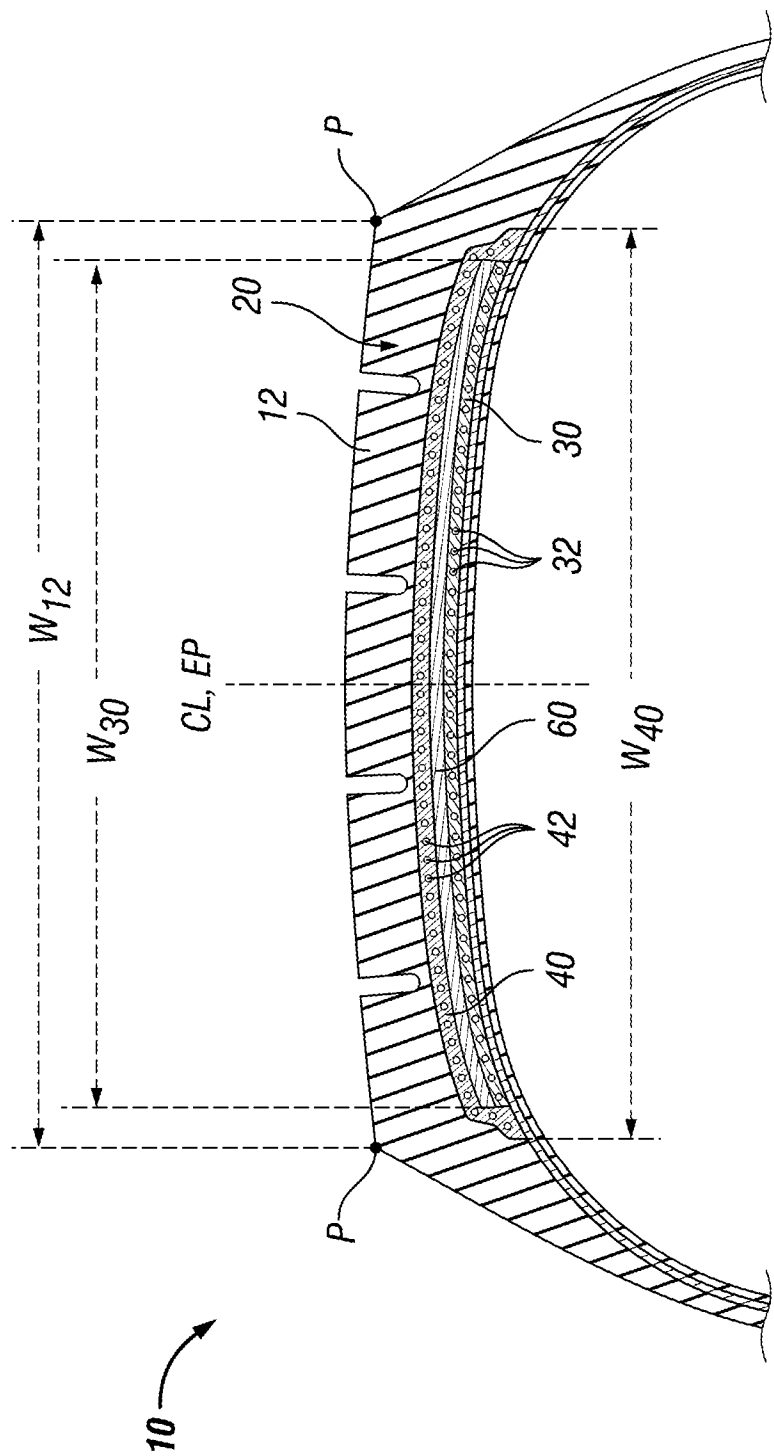


FIG. 4

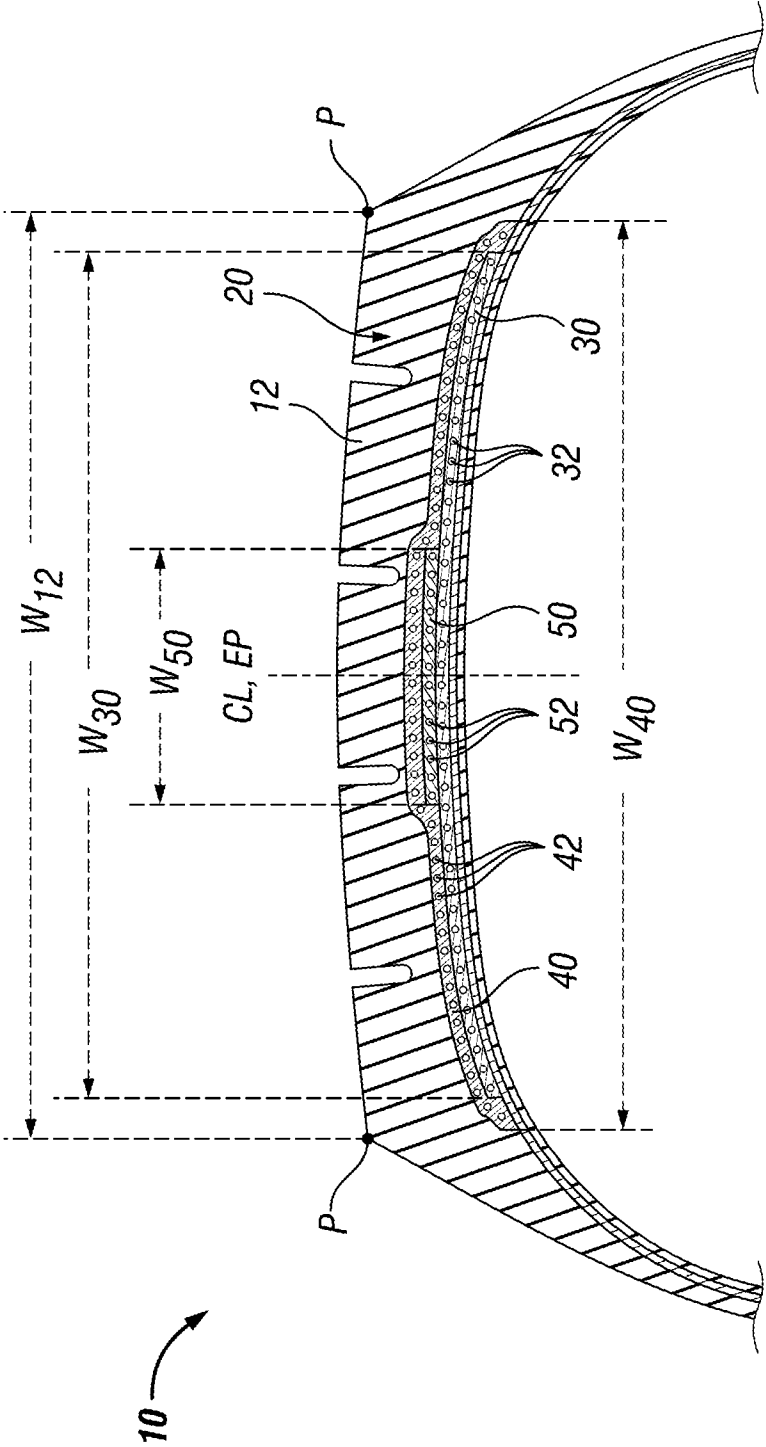


FIG. 5

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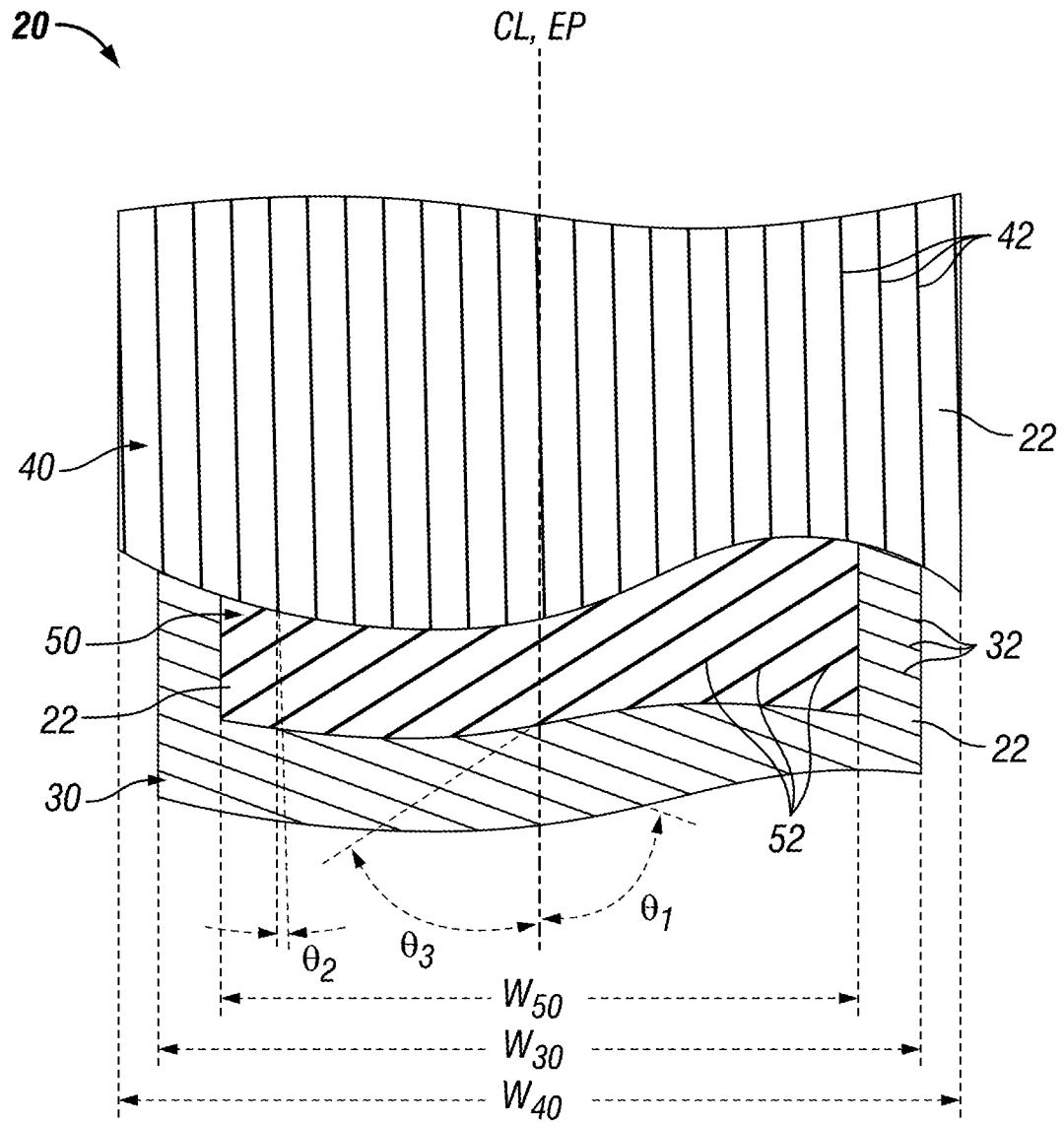


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/069371

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60C9/20 B60C9/22 B60C9/18
ADD.

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

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009 101719 A (SUMITOMO RUBBER IND) 14 May 2009 (2009-05-14)	1,2,12, 13
Y	paragraphs [0020] - [0027], [0030];	4,5
A	claims 1-3; figures 1,2 -----	3,6-11
X	EP 3 064 376 A1 (BRIDGESTONE CORP [JP]) 7 September 2016 (2016-09-07)	1,2,12, 13
A	paragraphs [0009], [0049], [0050], [0052]; claims 1-4; figures 1,2 -----	3-11
X	US 2011/303340 A1 (BORDOZ FRANCIS [FR] ET AL) 15 December 2011 (2011-12-15)	1,6,7, 10-13
A	paragraphs [0017], [0041], [0053], [0066], [0067], [0076], [0083]; claims 1,9; figures 1,3 ----- -/--	2-5,8,9



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)

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"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

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Date of the actual completion of the international search

22 November 2017

Date of mailing of the international search report

07/12/2017

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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/069371

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 770 673 A (DUNLOP RUBBER CO) 20 March 1957 (1957-03-20) page 1, lines 41-62; figure 1 -----	3
X	EP 2 082 901 A1 (BRIDGESTONE CORP [JP]) 29 July 2009 (2009-07-29)	1,2,6,7, 10-13
Y	paragraphs [0011], [0012], [0018]; claim	4,5
A	1; figure 1 -----	3,8,9
Y	JP H02 147408 A (SUMITOMO RUBBER IND) 6 June 1990 (1990-06-06) abstract; claim 1; figures 1,2 -----	4,5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/069371

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of Item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 12, 13

A tire wherein the cap reinforcement layers comprise non-metal reinforcements each formed of silk.

2. claims: 4, 5

A tire comprising an elastomeric separation layer positioned between the single primary reinforcement layer and the annular belt cap layer.

3. claims: 6-11

A tire wherein an intermediate reinforcement layer is arranged between the single primary reinforcement layer and the annular belt cap layer, where the intermediate reinforcement layer includes a plurality of elongate reinforcements spaced apart at least partially along the length of the annular belt and each having a reinforcement length extending at least partially in the direction of the annular belt width where the reinforcement length for each of the elongate reinforcements extends in the direction biased from the equatorial plane of the tire by an angle of 70 degrees to 90 degrees in absolute value, the intermediate reinforcement layer having a width extending partially across the width of the single primary reinforcement layer.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/069371

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