

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2014282221 B2**

(54) Title
Pneumatic tire

(51) International Patent Classification(s)
B60C 9/18 (2006.01) **B60C 9/20** (2006.01)

(21) Application No: **2014282221** (22) Date of Filing: **2014.06.17**

(87) WIPO No: **WO14/203908**

(30) Priority Data

(31) Number	(32) Date	(33) Country
2013-130921	2013.06.21	JP

(43) Publication Date: **2014.12.24**

(44) Accepted Journal Date: **2016.12.15**

(71) Applicant(s)
The Yokohama Rubber Co., Ltd.

(72) Inventor(s)
Yamaguchi, Yukihiro; Isobe, Satoru

(74) Agent / Attorney
Davies Collison Cave Pty Ltd, Level 15 1 Nicholson Street, MELBOURNE, VIC, 3000

(56) Related Art
JP 2007-062428 A
US 5318643 A
JP 03-279432 A

(12) 特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2014 年 12 月 24 日(24.12.2014)



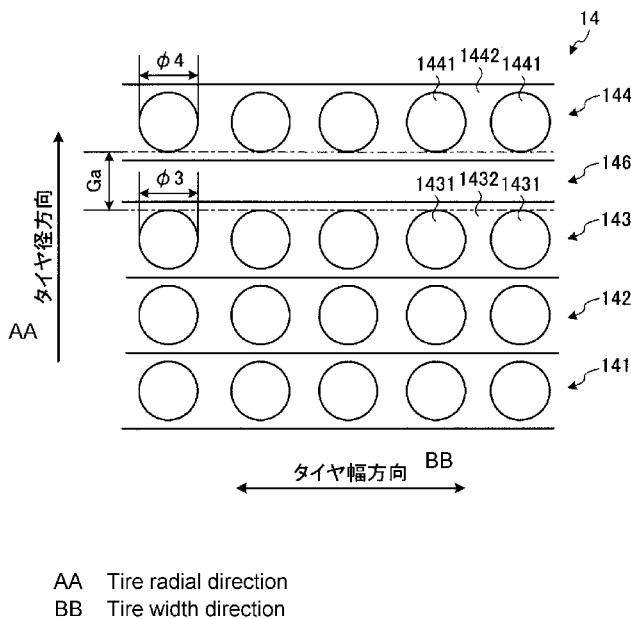
(10) 国際公開番号
WO 2014/203908 A1

- (51) 国際特許分類:
B60C 9/18 (2006.01) *B60C 9/20* (2006.01)
- (21) 国際出願番号: PCT/JP2014/066066
- (22) 国際出願日: 2014 年 6 月 17 日(17.06.2014)
- (25) 国際出願の言語: 日本語
- (26) 国際公開の言語: 日本語
- (30) 優先権データ:
特願 2013-130921 2013 年 6 月 21 日(21.06.2013) JP
- (71) 出願人: 横浜ゴム株式会社 (THE YOKOHAMA RUBBER CO., LTD.) [JP/JP]; 〒1058685 東京都港区新橋 5 丁目 3 番 1 号 Tokyo (JP).
- (72) 発明者: 山口 晋均 (YAMAGUCHI, Yukihito); 〒2548601 神奈川県平塚市追分 2 番 1 号 横浜ゴム株式会社 平塚製造所内 Kanagawa (JP). 磯部 哲 (ISOBE, Satoru); 〒2548601 神奈川県平塚市追分 2 番 1 号 横浜ゴム株式会社 平塚製造所内 Kanagawa (JP).
- (74) 代理人: 酒井 宏明, 外 (SAKAI, Hiroaki et al.); 〒1006020 東京都千代田区霞が関三丁目 2 番 5 号 霞が関ビルディング 酒井国際特許事務所 Tokyo (JP).
- (81) 指定国 (表示のない限り、全ての種類の国内保護が可能): 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, 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) 指定国 (表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, RU, TJ, TM), ヨーロッパ (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).
- 添付公開書類:
— 国際調査報告 (条約第 21 条(3))

(54) Title: PNEUMATIC TIRE

(54) 発明の名称: 空気入りタイヤ

[図4]



(57) Abstract: This pneumatic tire (1) is provided with: a pair of bead cores (11, 11); a carcass layer (13) extending between the pair of bead cores (11, 11); and a belt layer (14) including a laminate of at least four belt plies (141 to 144) comprising steel belt cords covered with coating rubber, the belt layer being disposed on the outside in a tire radial direction of the carcass layer (13). An inter-cord distance (G_a) between the outer-most layer belt ply (fourth belt (144)) and an adjacent belt ply (third belt (143)) has the relationship $0.80 \leq G_a/\phi_{\max} \leq 1.80$ with respect to a maximum value ($\phi_{\max}$) of outer diameters (ϕ_4 , ϕ_3) of the belt cords (1441, 1431) in the outer-most layer belt ply (144) and the adjacent belt ply (143).

(57) 要約: この空気入りタイヤ 1 は、一対のビードコア 11、11 と、一対のビードコア 11、11 間に架け渡されるカーカス層 13 と、スチール製のベルトコードをコートゴムで被覆して成る少なくとも 4 枚のベルトプリー 141 ~ 144 を積層して構成されると共にカーカス層 13 のタイヤ径方向外側に配置されるベルト層 14 とを備える。また、最外層ベルトプリー (4 番ベルト 144) と隣接ベルトプリー (3 番ベルト 143) との間のコード間距離 G_a が、最外層ベルトプリー 144 および隣接ベルトプリー 143 におけるベルトコード 1441、1431 の外径 ϕ

4、 ϕ_3 の最大値 $\phi_{\max}$ に対して、 $0.80 \leq G_a/\phi_{\max} \leq 1.80$ の関係を有する。

2014282221 07 Nov 2016

PNEUMATIC TIRE

[0001]

5 The present invention relates to a pneumatic tire, and in particular to a pneumatic tire with improved durability performance.

[0002]

10 Radial tires for construction vehicles are generally used for an extended period of time under heavy load and poor road conditions, and thus require high durability performance. In particular, suppressing the occurrence of separation (belt-edge separation) of an edge portion of a belt ply is in high demand.

[0003]

15 The technology described in Japanese Patent No. 3064108B is known as a conventional radial tire for construction vehicles.

[0005]

20 Preferred embodiments of the present invention seek to provide a pneumatic tire with improved durability performance.

[0006]

25 According to an aspect of the present invention, there is provided a pneumatic tire comprising: a pair of bead cores; a carcass layer extending between the pair of bead cores; and a belt layer including a laminate of at least four belt plies having steel belt cords covered with coating rubber, the belt layer being disposed on an outer side in a tire radial direction of the carcass layer; when the belt ply disposed on an outermost side in the tire radial direction is designated as an outermost layer belt ply and the belt ply disposed on an inner side in the tire radial direction of the outermost layer belt ply is designated as an adjacent belt ply, an inter-cord distance G_a between the outermost layer belt ply and the adjacent belt ply having a relationship such that $0.80 \leq G_a/\phi_{\max} \leq 1.80$ with respect to a maximum value $\phi_{\max}$ of outer diameters of the belt cords in the outermost layer belt ply and the adjacent belt ply; a ratio between the inter-cord distance between another set of adjacent belt plies and the maximum value of the outer diameters of the belt cords of the pair of belt plies that form this inter-cord distance is in a range of not less than 0.3 and not greater than 0.7, and a ratio between the inter-cord distance between

30

35

2014282221 07 Nov 2016

adjacent belt plies and the maximum value of the outer diameters of the belt cords is set largest between the outermost layer belt ply and the adjacent belt ply.

5 [0007]

In the pneumatic tire according to preferred embodiments of the present invention, the inter-cord distance G_a between the outermost layer belt ply and the adjacent belt ply is appropriately adjusted, thereby decreasing a strain that occurs between these belt plies during a tire rolling motion. This results in the advantage that the occurrence of separation is suppressed and tire durability performance is improved.

[0008]

15 The invention is described, by way of non-limiting example only, with reference to the accompanying drawings, which are briefly described as follows.

FIG. 1 is a cross-sectional view in a tire meridian direction illustrating a pneumatic tire according to an embodiment of the present invention.

FIG. 2 is an explanatory view illustrating a belt layer of the pneumatic tire illustrated in FIG. 1.

20 FIG. 3 is an explanatory view illustrating the belt layer of the pneumatic tire illustrated in FIG. 1.

FIG. 4 is an explanatory view illustrating the belt layer of the pneumatic tire illustrated in FIG. 1.

25 FIG. 5 is an explanatory view illustrating a modified example of the pneumatic tire illustrated in FIG. 1.

FIG. 6 is an explanatory view illustrating the modified example of the pneumatic tire illustrated in FIG. 1.

FIG. 7 is a table showing results of performance testing of pneumatic tires according to the embodiment of the present invention.

30

[0009]

Hereinafter, the present invention will be described in detail with reference to the drawings. It should be noted that the present invention is not limited to the following embodiment. In addition, the constituents of the embodiment include those replaceable and obviously replaced while maintaining the identity of the invention. Moreover, a plurality of modified examples described in the embodiment may be combined together as desired as far as they are obvious for those skilled in the art.

2014282221 07 Nov 2016

[0010]

[Pneumatic Tire]

FIG. 1 is a cross-sectional view in a tire meridian direction illustrating a pneumatic tire according to an embodiment of the present invention. FIG. 1 illustrates a one-sided region of the cross-sectional view in a tire radial direction. Further, FIG. 1 illustrates a radial tire for construction vehicles called an off-the-road (OR) tire as an example of the pneumatic tire.

[0011]

It should be noted that, in FIG. 1, a cross section in the tire meridian direction refers to a cross section when the tire is cut along a plane that includes a tire rotational axis (not illustrated). Further, a symbol CL corresponds to a tire equatorial plane and refers to a plane orthogonal to a tire radial direction that passes through a center point of the tire in the tire rotational axis direction. Further, a tire width direction refers to a direction parallel to the tire rotational axis, and the tire radial direction refers to a direction orthogonal to the tire rotational axis.

[0012]

A pneumatic tire 1 includes a pair of bead cores 11, 11 having annular structures that center around a tire rotational axis, a pair of bead fillers 12, 12, a carcass layer 13, a belt layer 14, a tread rubber 15, a pair of side wall rubbers 16, 16, and a pair of rim cushion rubbers 17, 17 (refer to FIG. 1). It should be noted that boundaries between the bead fillers 12, the tread rubber 15, the sidewall rubbers 16, and the rim cushion rubbers 17 are not illustrated.

[0013]

The pair of bead cores 11, 11 are annular members formed by bundling a plurality of bead wires, and constitute cores of left and right bead portions. The pair of bead fillers 12, 12 are disposed on outer peripheries in the tire radial direction of the pair of bead cores 11, 11 so as to reinforce the bead portions.

[0014]

The carcass layer 13 extends between the left and right bead cores 11, 11 in toroidal form, forming a framework for the tire. Additionally, both edge portions of the carcass layer 13 are folded from an inner side toward an outer side in the tire width direction so as to envelop the bead cores 11 and the bead fillers 12, and fixed. Further, the carcass layer 13 is constituted by a plurality of carcass cords formed of steel, covered by coating rubber, and subjected to a rolling process. The carcass layer 13 has a carcass angle (an angle of inclination of the direction of the fibers of the carcass cord with respect to a

2014282221 07 Nov 2016

tire circumferential direction), as an absolute value, of not less than 85 deg and not greater than 95 deg.

[0015]

The belt layer 14 includes a laminate of at least four belt plies 141 to 144, and is disposed so as to extend over an outer periphery of the carcass layer 13. Generally, in an OR tire, four to eight belt plies are laminated to form the belt layer 14 (not illustrated). The structure of the belt layer 14 will be described later.

[0016]

The tread rubber 15 is disposed on the outer periphery in the tire radial direction of the carcass layer 13 and the belt layer 14, and forms a tread portion of the tire. The pair of side wall rubbers 16, 16 are disposed on each outer side in the tire width direction of the carcass layer 13 so as to form left and right side wall portions. The pair of rim cushion rubbers 17, 17 are disposed on each inner side in the tire radial direction of the folded portion of the left and right bead cores 11, 11 and the carcass layer 13 so as to form a contact surface of the left and right bead portions with respect to a rim flange.

[0017]

[Belt Layer]

FIGS. 2 and 3 are explanatory views illustrating the belt layer of the pneumatic tire depicted in FIG. 1. In these figures, FIG. 2 illustrates an enlarged view of an edge region of the belt layer 14, and FIG. 3 illustrates a laminated structure of the belt layer 14. In FIG. 3, the hatching depicted in each of the belt plies 141 to 144 schematically illustrates the disposition structure of the belt cords.

[0018]

In the configuration in FIG. 1, as illustrated in FIGS. 2 and 3, the belt layer 14 is formed of the four laminated belt plies 141 to 144, and is disposed so as to extend over the outer periphery of the carcass layer 13. Here, these belt plies 141 to 144 are referred to as a first belt 141, a second belt 142, a third belt 143, and a fourth belt 144, in the order from the inner side in the tire radial direction.

[0019]

Further, the belt ply disposed on the outermost side in the tire radial direction is referred to as the outermost layer belt ply, and the adjacent belt ply disposed on the inner side in the tire radial direction with respect to the outermost layer belt ply is referred to as the adjacent belt ply. In the

2014282221 07 Nov 2016

configuration in FIG. 1, the fourth belt 144 is the outermost layer belt ply, and the third belt 143 is the adjacent belt ply.

[0020]

Each of the belt plies 141 to 144 is a member formed by steel cords
5 being covered with coating rubber and subjected to a rolling process (refer to FIG. 3).

[0021]

A belt angle of the outermost layer belt ply 144 is preferably smallest
10 among all of the belt angles of the belt plies 141 to 144. At this time, the belt angle of the outermost layer belt ply 144 and the belt angle of any one of the other belt plies may be the same. Further, the belt angle, as an absolute value, of the outermost layer belt ply 144 is preferably in a range of not less than 16 deg and not greater than 20 deg.

[0022]

15 Further, a difference between absolute values of the belt angle of the outermost layer belt ply 144 and the belt angle of the adjacent belt ply 143 is preferably not less than 3 deg. As illustrated in FIG. 3, each of the belt plies 141 to 144 has a belt angle of a different sign with respect to the adjacent belt ply. The belt plies are laminated so that the inclination directions of the belt
20 cords are horizontally inverted in an alternate manner. Accordingly, a crossply structure is formed, increasing the structural strength of the belt layer 14.

[0023]

It should be noted that, in a radial tire for construction vehicles, an outer
25 diameter ϕ of the belt cords of the belt plies 141 to 144 is in a range of $1.50 \text{ mm} \leq \phi \leq 6.00 \text{ mm}$. At this time, the belt cords of each of the belt plies 141 to 144 may have the same outer diameters ϕ or outer diameters ϕ that differ from each other.

[0024]

30 When the belt cord is formed of a plurality of cords twisted together, the outer diameter of the belt cord is measured as the diameter of a circle that circumscribes the belt cord in a cross-sectional view in the radial direction.

[0025]

Further, in the radial tire for construction vehicles, a breaking elongation
35 E of the belt cords of the belt plies 141 to 144 is in a range of $270\% \leq E \leq 410\%$.

[0026]

2014282221 07 Nov 2016

The breaking elongation is measured by performing a tensile test conforming to JIS-K7161 using a tensile tester (INSTRON 5585H manufactured by Instron Corp.) at a pulling speed of 2 mm/min.

[0027]

5 Further, in the radial tire for construction vehicles, a modulus M_b at 100% elongation of the coating rubber of the belt plies 141 to 144 is in a range of $3.0 \text{ MPa} \leq M_b \leq 4.5 \text{ MPa}$.

[0028]

10 The modulus is measured by a tensile test at room temperature in accordance with JIS-K6251 (using No. 3 dumbbells).

[0029]

15 Further, in the configuration in FIG. 3, the second belt 142 has the widest structure, and the fourth belt 144 that is the outermost layer belt ply has the narrowest structure. Therefore, the first belt 141 has a structure that is narrower than that of the second belt 142. Further, the third belt 143 has a structure that is narrower than that of the second belt 142 and wider than that of the fourth belt 144.

[0030]

20 Further, belt edge cushions 19, 19 are respectively inserted between the left and right edge portions of the first belt 141 and the second belt 142, and the left and right edge portions of the third belt 143 and the second belt 142. Accordingly, the edge portion of the first belt 141 and the edge portion of the third belt 143 are disposed so as to be separated from the second belt 142. Further, a modulus M_c of the belt edge cushion 19 preferably has a relationship such that $M_c \leq M_b$ and, more preferably, $M_c < M_b$ with respect to the modulus M_b of the coating rubber of the adjacent belt ply. Accordingly, a stress concentration on the edge portion of the belt ply is alleviated and the occurrence of the separation is suppressed.

[0031]

30 [Inter-cord Distance of Belt Plies]

FIG. 4 is an explanatory view illustrating the belt layer of the pneumatic tire depicted in FIG. 1. FIG. 4 schematically illustrates the disposition structure of the belt cords and coating rubber that constitute each of the belt plies 141 to 144.

35 [0032]

Radial tires for construction vehicles are generally used for an extended period of time under heavy load and poor road conditions, and thus require high durability performance. In particular, suppressing the occurrence of

07 Nov 2016
2014282221

separation (belt-edge-separation) of an edge portion of a belt ply is in high demand.

[0033]

Hence, this pneumatic tire 1 includes the following bead structure to improve durability performance (refer to FIG. 4.).

[0034]

First, in the configuration in FIG. 4, an inter-cord distance G_a between the fourth belt 144, which is the outermost layer belt ply, and the third belt 143, which is the adjacent belt ply, is defined.

[0035]

The inter-cord distance is a thickness of a rubber material between belt cords of adjacent belt plies, and is measured with the tire mounted on a specified rim and inflated to the specified internal pressure under no load. Specifically, the tire itself is applied and fixed with tape or the like to an imaginary line of the tire profile measured by a laser profiler, for example. Next, for the adjacent belt plies to be measured, the distance in the tire radial direction between an upper edge position of the belt cord of the belt ply located on the inner side in the tire radial direction and a lower edge position of the belt cord of the belt ply located on the outer side in the tire radial direction is measured using a caliper or the like, and the value is taken to be the inter-cord distance. The laser profiler used here is a tire profile measuring device (manufactured by Matsuo Co., Ltd.).

[0036]

The specified rim refers to an "applicable rim" defined by the Japan Automobile Tyre Manufacturers Association (JATMA), a "design rim" defined by the Tire and Rim Association (TRA), or a "measuring rim" defined by the European Tyre and Rim Technical Organisation (ETRTO). The specified internal pressure refers to a "maximum air pressure" defined by JATMA, a maximum value in "tire load limits at various cold inflation pressures" defined by TRA, or "inflation pressures" defined by ETRTO. A specified load refers to a "maximum load capacity" defined by JATMA, a maximum value in "tire load limits at various cold inflation pressures" defined by TRA, or a "load capacity" defined by ETRTO. However, with JATMA, in the case of passenger car tires, the specified internal pressure is an air pressure of 180 kPa, and the specified load is 88% of the maximum load capacity.

[0037]

Further, the maximum value $\phi_{\max}$ of the outer diameters of the belt cords of the outermost layer belt ply and the adjacent belt ply is defined.

2014282221 07 Nov 2016

Accordingly, in the configuration in FIG. 4, an outer diameter $\phi 4$ of a belt cord 1441 of the fourth belt 144 and an outer diameter $\phi 3$ of a belt cord 1431 of the third belt 143 are compared, and the larger of the two is selected as the maximum value $\phi_{\max}$.

5 [0038]

At this time, the inter-cord distance G_a between the outermost layer belt ply 144 and the adjacent belt ply 143 and the maximum value $\phi_{\max}$ of the outer diameters of the belt cords has the relationship such that $0.80 \leq G_a/\phi_{\max} \leq 1.80$. Further the ratio $G_a/\phi_{\max}$ is in a range of $1.30 \leq G_a/\phi_{\max} \leq 1.80$.

10 [0039]

Further, the ratio between the inter-cord distance (not illustrated) between another set of adjacent belt plies 141, 142 (142, 143) and the maximum value of the outer diameters of the belt cords of the pair of belt plies 141, 142 (142, 143) that form this inter-cord distance is preferably in a range of not less than 0.3 and not greater than 0.7. Accordingly, the ratio between the inter-cord distance between adjacent belt plies and the maximum value of the outer diameters of the belt cords is set largest between the outermost layer belt ply 144 and the adjacent belt ply 143.

[0040]

20 In the above-described configuration, the inter-cord distance G_a between the outermost layer belt ply 144 and the adjacent belt ply 143 is appropriately adjusted, thereby decreasing the strain that occurs between these belt plies during a tire rolling motion. As a result, the occurrence of separation is suppressed.

25 [0041]

It should be noted that, in the configuration in FIG. 1, as illustrated in FIG. 2 and FIG. 4, the inter-cord distance G_a between the outermost layer belt ply 144 and the adjacent belt ply 143 is substantially constant in the disposed region of the outermost layer belt ply 144. Therefore, in the overall disposed region of the outermost layer belt ply 144, the ratio $G_a/\phi_{\max}$ is set to the above-described range.

30 [0042]

However, the inter-cord distance G_a between the outermost layer belt ply 144 and the adjacent belt ply 143 and the ratio $G_a/\phi_{\max}$ are not limited to the above, and may be set to the above described ranges at at least both edge portions of the outermost layer belt ply 144. Accordingly, separation of the edge portion of the outermost layer belt ply 144, which is particularly susceptible to separation, can be effectively suppressed.

2014282221 07 Nov 2016

[0043]

[Shock Absorbing Rubber]

In this pneumatic tire 1, as illustrated in FIGS. 2 to 4, the belt layer 14 includes a shock absorbing rubber 146. This shock absorbing rubber 146 is a member that is disposed between the outermost layer belt ply 144 and the adjacent belt ply 143 and adjusts the inter-cord distance G_a .

[0044]

Further, in the above-described configuration, a modulus M_d of the shock absorbing rubber 146 preferably has a relationship such that $M_d \leq M_b$ and, more preferably, $M_d < M_b$ with respect to the modulus M_b of a coating rubber 1442 of the outermost layer belt ply 144. Further, the modulus M_d of the shock absorbing rubber 146 is preferably in a range of $3.0 \text{ MPa} \leq M_d \leq 4.0 \text{ MPa}$.

[0045]

Further a gauge G_a' (not illustrated) of the shock absorbing rubber 146 preferably has a relationship such that $0.45 \leq G_a'/\phi_{\max} \leq 1.00$ with respect to the maximum value $\phi_{\max}$ of the outer diameters of the belt cords of the outermost layer belt ply 144 and the adjacent belt ply 143.

[0046]

For example, in the configuration in FIGS. 2 to 4, the shock absorbing rubber 146 is wider than the outermost layer belt ply 144 and narrower than the adjacent belt ply 143, and is disposed across the entire region of the outermost layer belt ply 144. Further, the shock absorbing rubber 146 has a single structure and has a uniform gauge G_a' .

[0047]

[Modified Example]

FIGS. 5 and 6 are explanatory views illustrating a modified example of the pneumatic tire depicted in FIG. 1. FIG. 5 illustrates an enlarged view of the edge region of the belt layer 14. FIG. 6 schematically illustrates the disposition structure of the belt cords and coating rubber that constitute each of the belt plies 141 to 144.

[0048]

In this pneumatic tire 1, as illustrated in FIG. 5, the belt layer 14 may have a protective layer 147.

[0049]

This protective layer 147 is disposed so as to cover the outer side in the tire radial direction of the outermost layer belt ply 144, and protects the other belt plies 141 to 144. Further, the protective layer 147 is formed by steel

2014282221 07 Nov 2016

cords being covered by a coating rubber and subjected to a rolling process. The protective layer 147, as illustrated in FIG. 5, is disposed so as to cover the entire region of the belt widths of the other belt plies 141 to 144 that constitute a strengthening member. Further, the protective layer 147, compared to the other belt plies 141 to 144, differs in that the protective layer 147 is a belt ply made of steel cords having a breaking elongation of no less than 3%.

[0050]

Further, in the configuration in FIGS. 2 to 4, as described above, the belt layer 14 includes the shock absorbing rubber 146 that is disposed between the outermost layer belt ply 144 and the adjacent belt ply 143 and adjusts the inter-cord distance G_a . Such a configuration allows the inter-cord distance G_a to be easily adjustable, and is therefore preferred.

[0051]

However, the present invention is not limited to the above, allowing the shock absorbing rubber 146 to be omitted and the inter-cord distance G_a to be adjusted by increasing the gauge of the coating rubbers 1442, 1432 of the belt plies 144, 143, as illustrated in FIG. 6.

[0052]

[Effect]

As described above, the pneumatic tire 1 includes the pair of bead cores 11, 11, the carcass layer 13 extending between the pair of bead cores 11, 11, and the belt layer 14 including a laminate of at least four belt plies 141 to 144 having steel belt cords covered with coating rubber, the belt layer 14 being disposed on the outer side in the tire radial direction of the carcass layer 13 (refer to FIGS. 1 to 3). Further, the inter-cord distance G_a between the outermost layer belt ply (the fourth belt 144) and the adjacent belt ply (the third belt 143) has the relationship such that $0.80 \leq G_a/\phi_{\max} \leq 1.80$ with respect to the maximum value $\phi_{\max}$ of the outer diameters ϕ_3 , ϕ_4 of the belt cords 1431, 1441 in the outermost layer belt ply 144 and the adjacent belt ply 143 (refer to FIG. 4).

[0053]

In such a configuration, the inter-cord distance G_a between the outermost layer belt ply 144 and the adjacent belt ply 143 is appropriately adjusted, thereby decreasing the strain that occurs between these belt plies 144, 143 during a tire rolling motion. As a result, the advantage of suppressing the occurrence of separation and improving tire durability performance is achieved. That is, because of the relationship such that $0.80 \leq G_a/\phi_{\max}$, the inter-cord distance G_a in the outermost layer belt ply 144 is suitably maintained.

2014282221 07 Nov 2016

Further, because of the relationship such that $Ga/\phi_{\max} \leq 1.80$, a hoop effect by the outermost layer belt ply 144 is suitably maintained and the strain between the other belt plies 141 to 143 is suppressed. Accordingly, the occurrence of separation is effectively suppressed.

5 [0054]

Further, according to the pneumatic tire 1, the maximum value $\phi_{\max}$ of the outer diameters ϕ_4 , ϕ_3 of the belt cords 1441, 1431 is preferably in the range of $1.50 \text{ mm} \leq \phi_{\max} \leq 6.00$, and more preferably in a range of $1.55 \text{ mm} \leq \phi_{\max} \leq \phi_{5.00} \text{ mm}$ (refer to FIG. 4). Accordingly, there is the advantage that the outer diameters ϕ_4 , ϕ_3 of the belt cords 1441, 1431 are appropriately adjusted.

10

[0055]

Further, according to the pneumatic tire 1, the modulus M_b at 100% elongation of the coating rubber 1442 of the outermost layer belt ply 144 is preferably in the range of $3.0 \text{ MPa} \leq M_b \leq 4.5 \text{ MPa}$, and more preferably in a range of $3.3 \text{ MPa} \leq M_b \leq 4.3 \text{ MPa}$. Accordingly, there is the advantage that the modulus M_b of the coating rubber 1442 is appropriately adjusted.

15

[0056]

Further, according to the pneumatic tire 1, the breaking elongation E of the belt cord 1441 of the outermost layer belt ply 144 is preferably in the range of $270\% \leq E \leq 410\%$, and more preferably in a range of $290\% \leq E \leq 390\%$. Accordingly, there is the advantage that the breaking elongation E of the belt cord 1441 is appropriately adjusted.

20

[0057]

Further, according to the pneumatic tire 1, a belt angle α_4 (not illustrated) of the outermost layer belt ply 144 among all belt angles α of the belt plies 141 to 144 is solely smallest. Therefore, the outermost layer belt has the lowest angle, and there is no belt having the same angle. Accordingly, there is the advantage that the hoop effect by the outermost layer belt ply 144 is effectively achieved.

25

30

[0058]

Further, according to the pneumatic tire 1, the belt angle α_4 , as an absolute value, of the outermost layer belt ply 144, is in the range of not less than 16 deg and not greater than 20 deg. Accordingly, there is the advantage that the belt angle α_4 of the outermost layer belt ply 144 is appropriately adjusted. That is, because the belt angle α_4 is no greater than 20 deg, the strength of the outermost layer belt ply 144 is suitably maintained.

35

[0059]

07 Nov 2016

2014282221

Further, according to the pneumatic tire 1, the outermost layer belt ply 144 and the adjacent belt ply 143 have the belt angles α_4 and α_3 (not illustrated) having mutually different signs (refer to FIG. 3). Accordingly, a crossply structure is formed, resulting in the advantage that the strength of the belt layer 14 is improved.

[0060]

Further, the pneumatic tire 1 further includes the shock absorbing rubber 146 that is disposed between the outermost layer belt ply 144 and the adjacent belt ply 143 and adjusts the inter-cord distance G_a (refer to FIGS. 2 to 4).

Accordingly, there is the advantage that the inter-cord distance G_a can be easily adjusted.

[0061]

Further, according to the pneumatic tire 1, the modulus M_d at 100% elongation of the shock absorbing rubber 146 has the relationship such that $M_d < M_b$ with respect to the modulus M_b at 100% elongation of the coating rubber 1442 of the outermost layer belt ply 144. Accordingly, there is the advantage that the strain acting between the outermost layer belt ply 144 and the adjacent belt ply 143 is effectively reduced.

[0062]

Further, according to the pneumatic tire 1, the gauge G_a' of the shock absorbing rubber 146 has the relationship such that $0.45 \leq G_a'/\phi_{\max} \leq 1.00$ with respect to the maximum value $\phi_{\max}$ of the outer diameters ϕ_4 , ϕ_3 of the belt cords 1441, 1431 of the outermost layer belt ply 144 and the adjacent belt ply 143. Accordingly, there is the advantage that the gauge G_a' of the shock absorbing rubber 146 is appropriately adjusted.

[0063]

Further, according to the pneumatic tire 1, the difference between the absolute values of the belt angle α_4 of the outermost layer belt ply 144 and the belt angle α_3 of the adjacent belt ply 143 is no less than 3 deg. Accordingly, there is the advantage that the relationship between the belt angle α_4 of the outermost layer belt ply 144 and the belt angle α_3 of the adjacent belt ply 143 is appropriately adjusted.

[0064]

Further, according to the pneumatic tire 1, the absolute value $|\alpha|$ of the belt angles α of all belt plies 141 to 144 is in a range of $16 \text{ deg} \leq |\alpha| \leq 38 \text{ deg}$. Accordingly, there is the advantage that the belt angles α of the belt plies 141 to 144 are appropriately adjusted.

[0065]

2014282221 07 Nov 2016

Further, the pneumatic tire 1 further includes the protective layer 147 disposed on the outer side in the tire radial direction of the outermost layer belt ply 144 (refer to FIG. 5). Accordingly, there is the advantage that the belt layer 14 is protected.

5 [0066]

[Target of Application]

The pneumatic tire 1 is preferably used for a radial tire for construction vehicles. The radial tire for construction vehicles, which is a tire mounted to a construction vehicle that travels on an uneven ground of, for example, a civil engineering construction site, is mounted to a construction vehicle such as a large dump truck, a tire roller, a scraper, a grader, a crane, or a wheel loader.

10 [0067]

However, the present invention is not limited to the above, and the pneumatic tire 1 may be used as a radial tire for heavy loads that is mounted to a truck, a bus, or the like (not illustrated).

15

EXAMPLES

[0068]

FIG. 7 is a table showing results of performance testing of pneumatic tires according to the embodiment of the present invention.

20

[0069]

In these performance tests, evaluation was carried out on a plurality of different test tires for durability performance. The test tires having a tire size of 3300R51 E*2 were each assembled on a TRA specified rim, and a TRA specified air pressure and TRA specified load were applied to the test tires.

25 Further, the test tires were mounted on all wheels of a dump truck test vehicle having a maximum loading capacity of 150 t.

[0070]

In the evaluation of durability performance, after the test vehicle had traveled 7000 h at an average speed of 15 km/h on a predetermined off-road course, the test tires were disassembled and examined for the separation that occurred between the outermost layer belt ply and the adjacent belt ply. Then, evaluations were performed by indexing the examination results with the conventional example as the standard score (100). In these evaluations,

30 higher scores are preferable, and a score of 110 or greater is considered as having a sufficiently superior effect.

35

[0071]

2014282221 07 Nov 2016

The test tire from Working Example 1 had the structure illustrated in FIGS. 1 to 4. Further, the belt angle of the first belt 141 was 22 deg, the belt angle of the second belt 142 was 24 deg, the belt angle α_3 of the third belt 143 was 22 deg, and the belt angle α_4 of the fourth belt 144 was 18 deg. Further, as illustrated in FIG. 3, the belt plies 141 to 144 were laminated so that the inclination directions (the signs of the belt angles) of the belt cords are horizontally inverted in an alternate manner. Further, the outer diameters ϕ of the belt cords of each of the belt plies 141 to 144 were all the same, and were 3.8 mm ($= \phi_3 = \phi_4 = \phi_{\max}$). The modulus M_b at 100% elongation of the coating rubber 1442 of the outermost layer belt ply 144 was 4.0 MPa, and the breaking elongation E of the belt cord 1441 was 330%.
[0072]

The test tires from Working Examples 2 through 5 were modified examples of Working Example 1.

In the Conventional Example, the belt layer 14 in the structure illustrated in FIGS. 1 to 4 does not include the shock absorbing rubber 146. For this reason, the ratio $G_a/\phi_{\max}$ is small.
[0074]

As shown in the test results, it can be seen that the durability performance is improved in the test tires of the Working Examples 1 to 5.

Reference Number

[0075]

1 Pneumatic tire

11 Bead core

12 Bead filler

13 Carcass layer

14 Belt layer

15 Tread rubber

16 Side wall rubber

17 Rim cushion rubber

19 Belt edge cushion

141 First belt

142 Second belt

143 Third belt (adjacent belt ply)

1431 Belt cord

1432 Coating rubber

07 Nov 2016

2014282221

144 Fourth belt (outermost layer belt ply)

1441 Belt cord

1442 Coating rubber

146 Shock absorbing rubber

5 147 Protective layer

[0076]

10 The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

[0077]

15 Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

20 [0078]

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

25

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A pneumatic tire comprising:
 - a pair of bead cores;
 - 5 a carcass layer extending between the pair of bead cores; and
 - a belt layer including a laminate of at least four belt plies having steel belt cords covered with coating rubber, the belt layer being disposed on an outer side in a tire radial direction of the carcass layer;
 - when the belt ply disposed on an outermost side in the tire radial direction is designated as an outermost layer belt ply and the belt ply disposed on an inner side in the tire radial direction of the outermost layer belt ply is designated as an adjacent belt ply,
 - 10 an inter-cord distance G_a between the outermost layer belt ply and the adjacent belt ply having a relationship such that $0.80 \leq G_a/\phi_{\max} \leq 1.80$ with respect to a maximum value $\phi_{\max}$ of outer diameters of the belt cords in the outermost layer belt ply and the adjacent belt ply;
 - a ratio between the inter-cord distance between another set of adjacent belt plies and the maximum value of the outer diameters of the belt cords of the pair of belt plies that form this inter-cord distance is in a range of not less than 0.3 and not
 - 20 greater than 0.7, and
 - a ratio between the inter-cord distance between adjacent belt plies and the maximum value of the outer diameters of the belt cords is set largest between the outermost layer belt ply and the adjacent belt ply.
- 25 2. The pneumatic tire according to claim 1, wherein the maximum value $\phi_{\max}$ of the outer diameters of the belt cords is in a range of $1.50 \text{ mm} \leq \phi_{\max} \leq 6.00 \text{ mm}$.
3. The pneumatic tire according to either claim 1 or claim 2, wherein a modulus M_b at 100% elongation of the coating rubber of the outermost layer belt ply is in a
- 30 range of $3.0 \text{ MPa} \leq M_b \leq 4.5 \text{ MPa}$.
4. The pneumatic tire according to any one of claims 1 to 3, wherein a breaking elongation E of the belt cords of the outermost layer belt ply is in a range of $270\% \leq E \leq 410\%$.

35

2014282221 07 Nov 2016

5. The pneumatic tire according to any one of claims 1 to 4, wherein a belt angle of the outermost layer belt ply among belt angles of all of the belt plies is solely smallest.
- 5 6. The pneumatic tire according to claim 5, wherein the belt angle, as an absolute value, of the outermost layer belt ply is not less than 16 deg and not greater than 20 deg.
7. The pneumatic tire according to any one of claims 1 to 6, wherein the
10 outermost layer belt ply and the adjacent belt ply have belt angles having mutually different signs.
8. The pneumatic tire according to any one of claims 1 to 7, further comprising a shock absorbing rubber that is disposed between the outermost layer belt ply and
15 the adjacent belt ply and adjusts an inter-cord distance G_a .
9. The pneumatic tire according to claim 8, wherein a modulus M_d at 100% elongation of the shock absorbing rubber has a relationship such that $M_d < M_b$ with respect to the modulus M_b at 100% elongation of the coating rubber of the
20 outermost layer belt ply.
10. The pneumatic tire according to claim 8 or 9, wherein a gauge G_a' of the shock absorbing rubber has a relationship such that $0.45 \leq G_a'/\phi_{\max} \leq 1.00$ with respect to the maximum value $\phi_{\max}$ of the outer diameters of the belt cords in the
25 outermost layer belt ply and the adjacent belt ply.
11. The pneumatic tire according to any one of claims 1 to 10, wherein a difference between absolute values of a belt angle of the outermost layer belt ply and a belt angle of the adjacent belt ply is not less than 3 deg.
30
12. The pneumatic tire according to any one of claims 1 to 11, further comprising a protective layer disposed on an outer side in the tire radial direction of the outermost layer belt ply.
13. The pneumatic tire according to any one of claims 1 to 12, wherein an absolute value of belt angles α of all of the belt plies is in a range of $16 \text{ deg} \leq |\alpha| \leq 28 \text{ deg}$.
35

14. The pneumatic tire according to any one of claims 1 to 13, wherein a radial tire for construction vehicles is a target of application

5

2014282221 07 Nov 2016

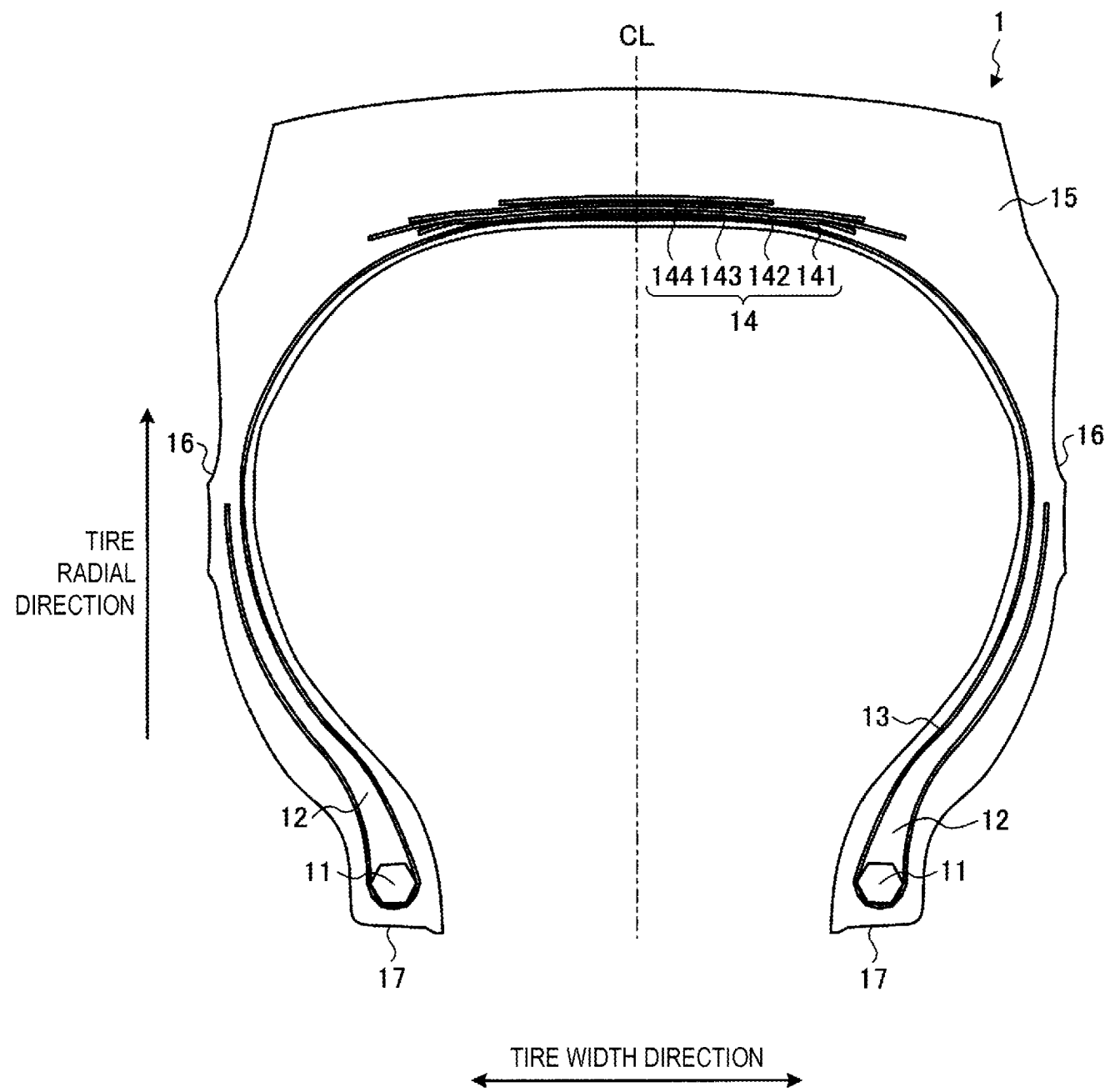


FIG. 1

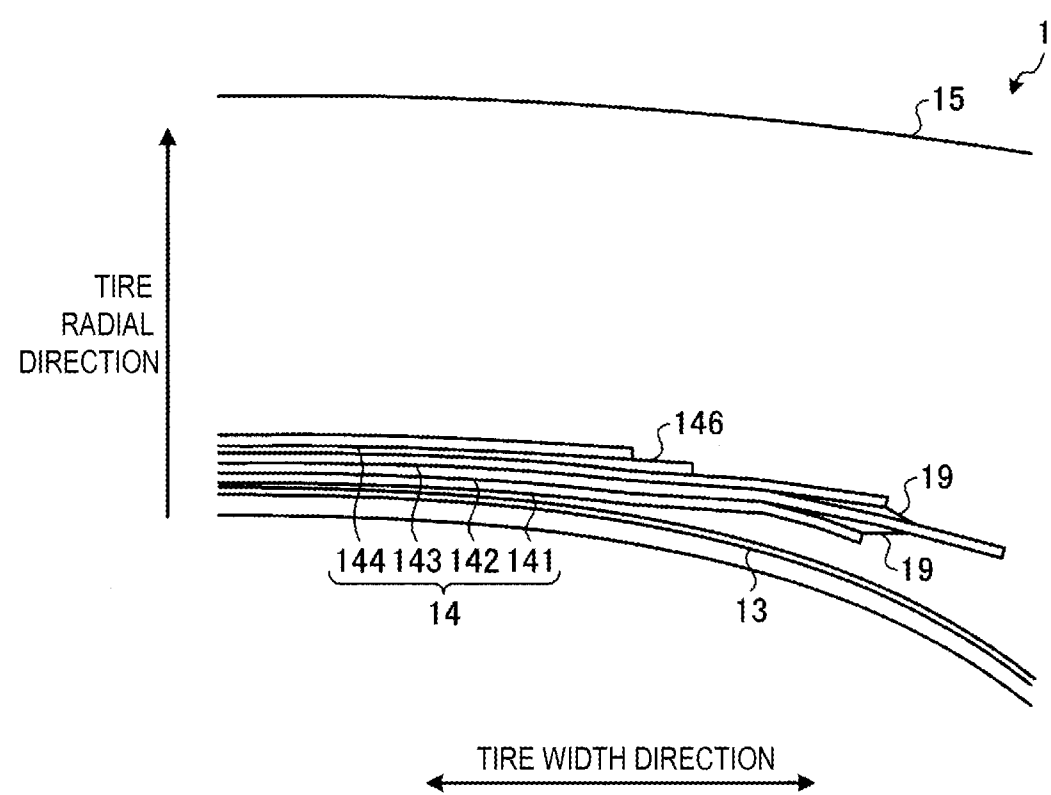


FIG. 2

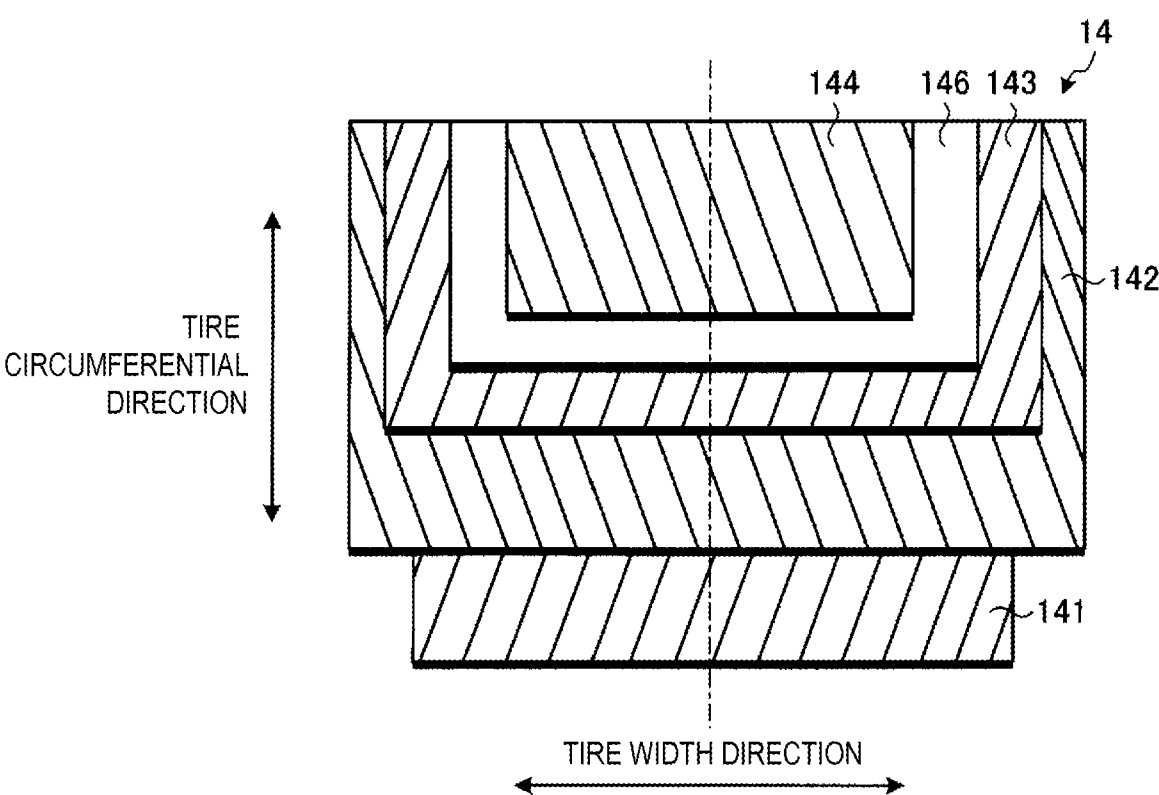


FIG. 3

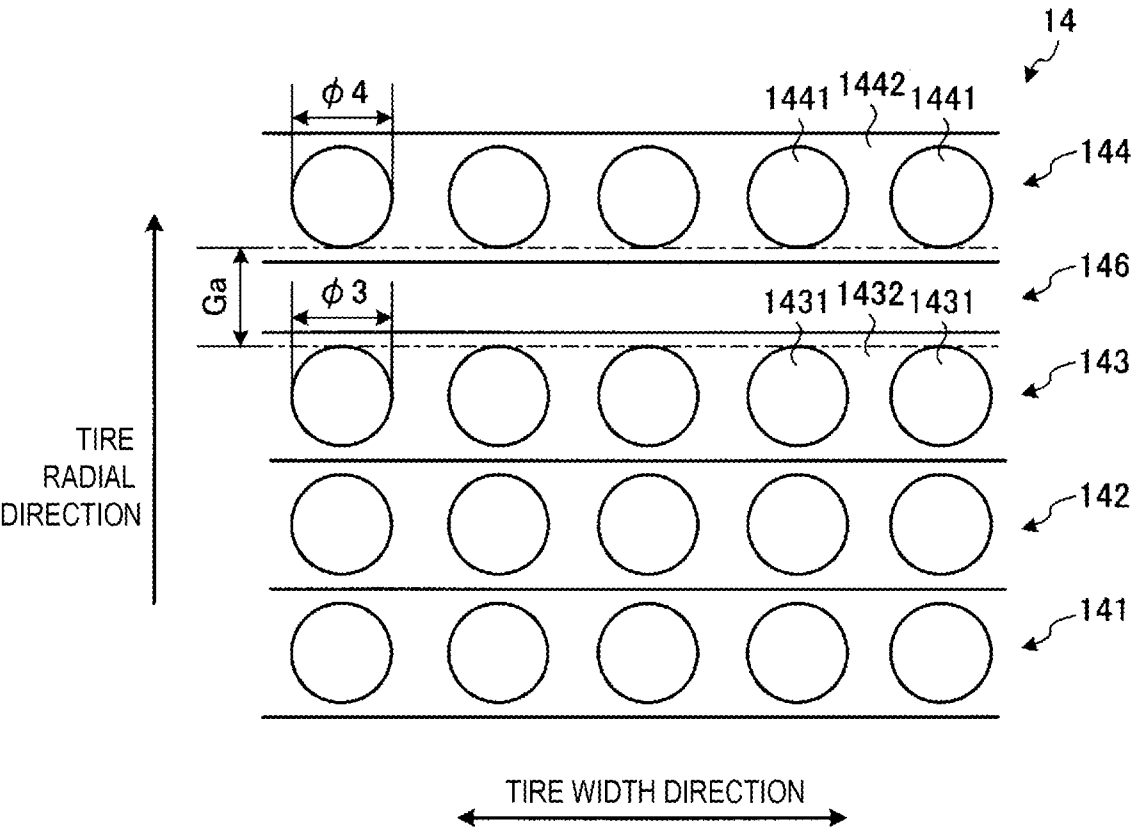


FIG. 4

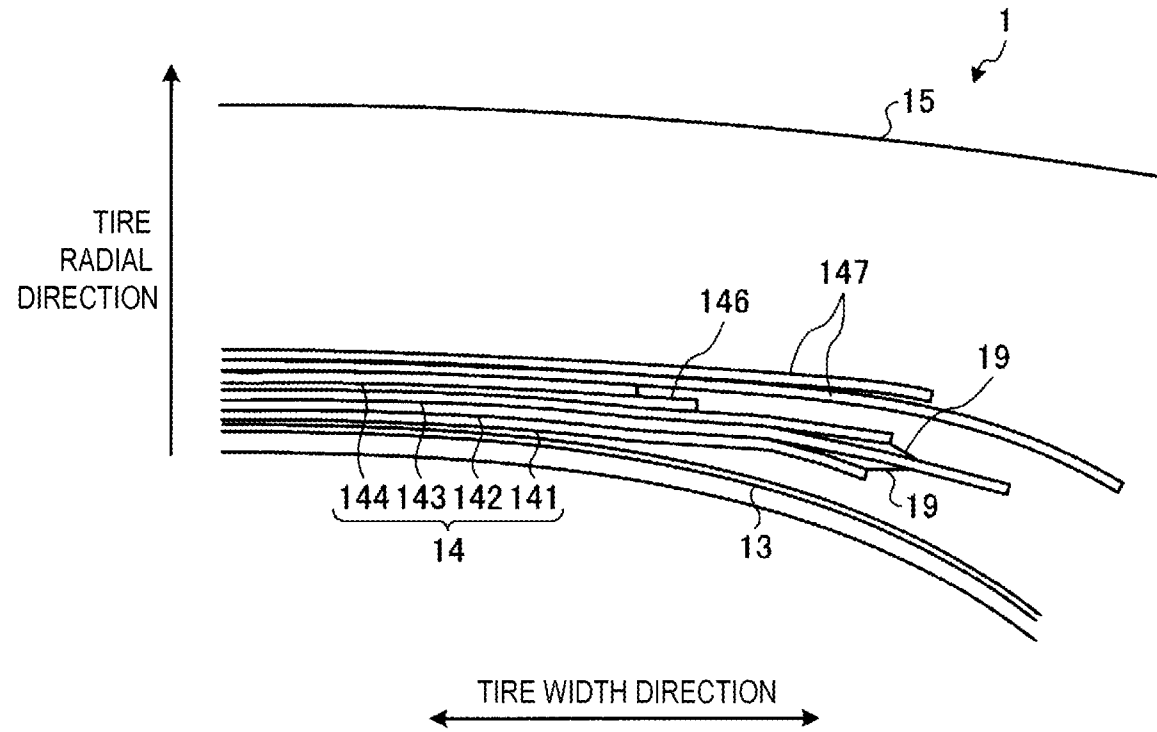


FIG. 5

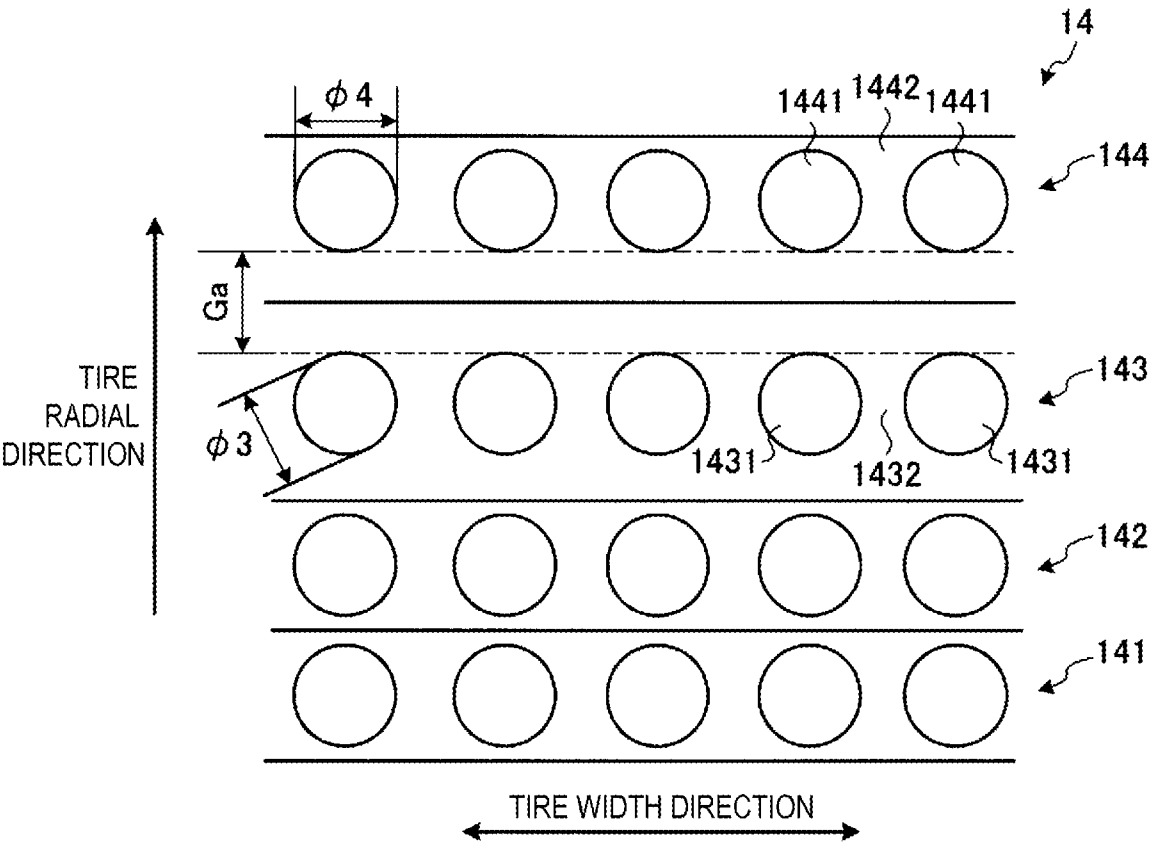


FIG. 6

	CONVENTIONAL EXAMPLE	COMPARATIVE EXAMPLE	WORKING EXAMPLE 1	WORKING EXAMPLE 2	WORKING EXAMPLE 3	WORKING EXAMPLE 4	WORKING EXAMPLE 5
Ga/ϕ_{max}	0.40	1.85	1.00	1.30	1.70	1.30	1.30
SHOCK ABSORBING RUBBER	No	Yes	Yes	Yes	Yes	Yes	Yes
RELATIONSHIP BETWEEN MODULI MD, MB OF SHOCK ABSORBING RUBBER AND FOURTH BELT	—	Md = Mb	Md = Mb	Md = Mb	Md = Mb	Md < Mb	Md < Mb
BELT ANGLE DIFFERENCE BETWEEN FOURTH BELT AND THIRD BELT [deg]	0	0	0	0	0	0	3
DURABILITY PERFORMANCE	100	102	110	115	113	120	125

FIG. 7