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### PNEUMATIC TIRE

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#### Abstract

A pneumatic tire includes a bead core including end portions in a width direction formed as a vertical line along a radial direction, the vertical line has a length of 31% to 45% of a core height, in two adjacent bead core layers of first, second and third layers of the bead core, the number of bead wires in the radially outer layer is larger by two or more than the number of bead wires in the radially inner layer, and a misalignment amount between bead wires located at an end portion on one side in the width direction is one-half of the bead wire, and a side on which the one-half misalignment amount between the bead wires in the first and second layers is opposite in the width direction to a side of the one-half misalignment amount between the second and third layer bead wires.

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## Background/Summary

### TECHNICAL FIELD

[0001] The present technology relates to a pneumatic tire.

### BACKGROUND ART

[0002] A pneumatic tire is mounted on a rim wheel by fitting a bead portion, which includes a bead core that is an annular member formed by bundling a plurality of bead wires, onto a rim of the rim wheel. The bead portion, which is a portion that is actually mounted on the rim wheel in mounting the pneumatic tire on the rim wheel, is an important portion for ensuring the performance of the pneumatic tire, and some known pneumatic tires achieve their desired performance by making various types of modifications to the bead portion.

[0003] For example, in a pneumatic tire described in Japan Unexamined Patent Publication No. 2018-34784 A, a bead core includes a substantially flat bead surface bonded to rounded end portions on both sides, thereby reducing wear in a bead region. In a heavy duty pneumatic tire described in Japan Unexamined Patent Publication No. H09-240223 A, inner and outer contours of a bead core in a radial direction are formed by a lower bottom side and an upper bottom side that extend in a tire axial direction, an outer contour in a tire axial direction is formed by a pair of upper and lower outer oblique sides each extending at an incline from outer ends of the lower bottom side and the upper bottom side in the tire axial direction toward an outer side in the tire axial direction, and an inner contour in the tire axial direction of the bead core is formed by an inner side connecting inner ends of the lower bottom side and the upper bottom side in the tire axial direction, thus improving durability performance of a bead portion.

[0004] In a bead core described in Japan Unexamined Patent Publication No. 2005-88793 A, a cross-sectional shape on a radially inner side from a cross-sectional center of the bead core is formed by a bottom side parallel to an axial direction of the bead core, both left and right intermediate sides orthogonal to the axial direction of the bead core, and oblique sides composed of two sides meeting at an obtuse angle, connecting inner ends of the left and right intermediate sides to both sides of the bottom side, thereby reducing a breakage failure due to fretting of carcass cords and a tire failure due to an air pocket. In a pneumatic tire described in Japan Patent No. 4243091 B, in manufacturing a bead core having an annular shape as a whole and composed of wires arranged in a plurality of rows and a plurality of stages without a gap, a wire on the outermost side in a width direction of each wire row from the innermost circumferential side to the maximum width position is positioned on an outer side in the width direction with respect to each wire on the outermost side in the width direction of a wire row on the inner circumferential side of each wire row, and a misalignment amount thereof is reduced as a tendency from the innermost circumferential side toward the maximum width position, thus preventing breakage of a carcass and generation of corrugation to a turned-up end portion of the carcass in, for example, manufacturing of the tire.

[0005] Here, although a bead core typically has a polygonal shape in a tire meridian cross-section, some ultra-large pneumatic tires include a nylon cover wound around a bead core to avoid stress concentration on a carcass due to a corner of the bead core. However, a sufficient distance between the corner of the bead core and the carcass is not ensured only with the nylon cover, and thus a portion near the corner of the bead core and the carcass are likely to rub against each other while being subjected to large force when large tension acts on the carcass. In this case, the corner of the bead core and the carcass rub against each other, and thus the carcass cord may break. In particular, in a pneumatic tire mounted on a vehicle, such as a loader or a scraper for which traction

performance is required, a bead core having a relatively flat shape in a tire meridian cross-section is often used, and a corner of the bead core and the carcass are likely to rub against each other, so the carcass cord is prone to breakage. Therefore, for the pneumatic tires of the related art, there is room for improvement in terms of the durability of the bead portion.

## SUMMARY

[0006] The present technology has been made in view of the description above, and the present technology provides a pneumatic tire that can provide improved durability of a bead portion.

[0007] A pneumatic tire according to an embodiment of the present technology includes: a pair of bead portions disposed on both respective sides of a tire equatorial plane in a tire width direction; a bead core disposed in each of the pair of bead portions, formed by winding a bead wire into a ring shape, and having a polygonal cross-sectional shape in a tire meridian cross-section; and a carcass including a carcass body portion disposed extending between the pair of bead portions and a turned-up portion that is formed continuously from the carcass body portion and is folded back from an inner side in the tire width direction to an outer side in the tire width direction of the bead core, the carcass being formed by coating a carcass cord with a coating rubber. The bead core has a portion located on an innermost side in the tire width direction and a portion located on an outermost side in the tire width direction in a contour in the tire meridian cross-section each formed as a vertical line extending along a tire radial direction. The vertical line has a length within a range of 31% or more and 45% or less with respect to a core height that is a height of the bead core in the tire radial direction. The vertical line has a distance in the tire radial direction from a bead core bottom surface that is an inner circumferential surface of the bead core to an inner end portion in the tire radial direction of the vertical line within a range of 20% or more and 35% or less with respect to the core height. In the bead core, a plurality of circumferential portions of the bead wire wound in a ring shape are aligned in the tire width direction to form a layer, and a plurality of the layers are layered in the tire radial direction. For a first layer that is the layer located on an innermost circumference in the tire radial direction, a second layer that is the layer layered adjacent to an outer side of the first layer in the tire radial direction, and a third layer that is the layer layered adjacent to an outer side of the second layer in the tire radial direction of the plurality of the layers, in two of the layers adjacent to each other in the tire radial direction, the number of the bead wires in the layer located relatively on the outer side in the tire radial direction is larger by two or more than the number of the bead wires in the layer located on an inner side in the tire radial direction, and a misalignment amount in the tire width direction between the bead wires located at an end portion on one side in the tire width direction is one-half of the bead wire. A side on which the misalignment amount between the bead wires in the first layer and the second layer is one-half of the bead wire is opposite in the tire width direction to a side on which the misalignment amount between the bead wires in the second layer and the third layer is one-half of the bead wire.

[0008] In addition, in the pneumatic tire described above, the bead core preferably has a width of the bead core bottom surface in the tire meridian cross-section within a range of 45% or more and 70% or less with respect to a maximum width of the bead core.

[0009] In addition, in the pneumatic tire described above, the bead core preferably has a distance in the tire width direction between an end portion on an inner side in the tire width direction on a bead core top surface that is an outer circumferential surface in the tire meridian cross-section and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to a maximum width of the bead core, has a distance in the tire width direction between an end portion on the inner side in the tire width direction on the bead core bottom surface and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to the maximum width of the bead core, and has the maximum width of the bead core within a range of 0.9 times or more and 1.4 times or less as large as the core height.

[0010] In addition, in the pneumatic tire described above, the carcass preferably has the number of ends of the carcass cords at a position on the inner side in the tire width direction of the bead core

within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less.

[0011] The pneumatic tire according to an embodiment of the present technology has an effect capable of providing improved durability of the bead portion.

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## Description

### BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. 1 is a meridian cross-sectional view illustrating a main portion of a pneumatic tire according to an embodiment.

[0013] FIG. 2 is a detailed view of portion A in FIG. 1.

[0014] FIG. 3 is a detailed view of a bead core illustrated in FIG. 2.

[0015] FIG. 4 is a detailed view of portion B in FIG. 3.

[0016] FIG. 5 is a detailed view of the bead core of a modified example of the pneumatic tire according to the embodiment, in which bead wires are layered in a different form from the embodiment illustrated in FIG. 3.

[0017] FIGS. 6A-6F are tables indicating results of performance evaluation tests of pneumatic tires.

### DETAILED DESCRIPTION

[0018] Pneumatic tires according to embodiments of the present technology are described in detail below with reference to the drawings. However, the technology is not limited to the embodiments. In addition, constituents of the following embodiments include elements that can be substituted and easily conceived of by a person skilled in the art or that are substantially identical.

#### Embodiments

[0019] In the following description, the term “tire radial direction” refers to a direction orthogonal to the tire rotation axis (not illustrated) which is a rotation axis of a pneumatic tire 1, the term “inner side in the tire radial direction” refers to a side toward the tire rotation axis in the tire radial direction, and the term “outer side in the tire radial direction” refers to a side away from the tire rotation axis in the tire radial direction. In addition, the term “tire circumferential direction” refers to a circumferential direction with the tire rotation axis as a center axis. Additionally, the term “tire width direction” refers to a direction parallel with the tire rotation axis, the term “inner side in the tire width direction” refers to a side toward a tire equatorial plane (tire equator line) CL in the tire width direction, and the term “outer side in the tire width direction” refers to a side away from the tire equatorial plane CL in the tire width direction. The term “tire equatorial plane CL” refers to a plane orthogonal to the tire rotation axis and running through the center of the tire width of the pneumatic tire 1. The tire equatorial plane CL aligns, in a position in the tire width direction, with a center line in the tire width direction corresponding to a center position of the pneumatic tire 1 in the tire width direction. The tire width is a width in the tire width direction between portions located on the outermost sides in the tire width direction, in other words, a distance between the portions that are the most distant from the tire equatorial plane CL in the tire width direction. The term “tire equator line” refers to a line in the tire circumferential direction of the pneumatic tire 1 that lies on the tire equatorial plane CL. Further, in the description below, “tire meridian cross-section” refers to a cross-section of the tire taken along a plane including the tire rotation axis.

[0020] FIG. 1 is a meridian cross-sectional view illustrating a main portion of the pneumatic tire 1 according to the embodiment. The pneumatic tire 1 according to the embodiment is a radial tire for a construction vehicle referred to as an off the road tire (OR tire). The pneumatic tire 1 illustrated in FIG. 1 as the present embodiment includes a tread portion 2 disposed on an outermost side in the tire radial direction as viewed in the tire meridian cross-section, and the tread portion 2 is composed of a tread rubber 2a that is a rubber composition. The surface of the tread portion 2, that is, a portion that comes into contact with a road surface during traveling of a vehicle (not illustrated) mounted with the pneumatic tire 1, is formed as a tread contact surface 3.

[0021] A plurality of grooves, such as circumferential grooves **15** extending in the tire circumferential direction and lug grooves extending in the tire width direction, (not illustrated) are formed in the tread contact surface **3** of the tread portion **2**, and a plurality of land portions **10** are defined and formed in the tread portion **2** by the grooves.

[0022] Both ends of the tread portion **2** in the tire width direction are formed as shoulder portions **4**. Sidewall portions **5** are disposed from the shoulder portions **4** to predetermined positions on an inner side in the tire radial direction. In other words, the sidewall portions **5** are disposed at two positions on both sides of the pneumatic tire **1** in the tire width direction. The sidewall portion **5** is composed of a sidewall rubber **5a**, which is a rubber composition. Additionally, a rim check line **9** is formed at a position closer to the inner side in the tire radial direction in each of the sidewall portions **5** on both sides in the tire width direction. The rim check line **9** projects from a surface of the sidewall portion **5** and is formed all around the circumference in the tire circumferential direction.

[0023] Furthermore, a bead portion **20** is located on an inner side of each sidewall portion **5** in the tire radial direction, and similar to the sidewall portions **5**, the bead portions **20** are disposed at two positions on both sides of the tire equatorial plane CL. In other words, a pair of the bead portions **20** are disposed on both sides of the tire equatorial plane CL in the tire width direction. A bead core **21** is disposed in each of the pair of bead portions **20**, and a bead filler **50** is disposed on an outer side of each bead core **21** in the tire radial direction. The bead core **21** is formed by winding a bead wire **30** (see FIG. 3), which is a steel wire, into a ring shape. The bead filler **50** is a rubber material disposed in a space formed by an end portion in the tire width direction of a carcass **6** described below being folded back to the outer side in the tire width direction at the position of the bead core **21**. In addition, the bead filler **50** includes a lower filler **51** disposed in contact with an outer circumferential surface of the bead core **21**, and an upper filler **52** disposed at a position closer to the outer side in the tire radial direction than the lower filler **51**.

[0024] The bead portion **20** is configured to be mountable on a rim wheel including a 5°-tapered specified rim R. Specifically, the pneumatic tire **1** according to the present embodiment can be mounted on the specified rim R including a portion fitted to the bead portion **20** and inclined in a direction toward an outer side in the tire radial direction as the portion extends from an inner side toward an outer side in the tire width direction at an inclination angle of 5°±1° with respect to the rotation axis of the rim wheel. Note that “specified rim R” refers to an “applicable rim” defined by the JATMA (Japan Automobile Tyre Manufacturers Association, Inc.), a “Design Rim” defined by the TRA (Tire and Rim Association, Inc.), or a “Measuring Rim” defined by the ETRTO (European Tyre and Rim Technical Organisation).

[0025] A belt layer **7** is provided on an inner side of the tread portion **2** in the tire radial direction. The belt layer **7** has a multilayer structure in which three or more belt plies are layered, and in a typical OR tire, four to eight belt plies are layered. In the present embodiment, the belt layer **7** has six belt plies **7a**, **7b**, **7c**, **7d**, **7e**, and **7f**, layered. The belt plies **7a**, **7b**, **7c**, **7d**, **7e**, and **7f** constituting the belt layer **7** in this way are formed by coating a plurality of belt cords made from steel or an organic fiber material with coating rubber, followed by rolling processing. The six belt plies **7a**, **7b**, **7c**, **7d**, **7e**, and **7f** include, for example, cross belt layers **7a**, **7b**, **7c**, and **7d** and protective belt layers **7e** and **7f**. Additionally, the belt plies **7a**, **7b**, **7c**, **7d**, **7e**, and **7f** have mutually different inclination angles of the belt cords in the tire width direction with respect to the tire circumferential direction, are layered such that the inclination directions of the cross belt layers and protective belt layers intersect with one another in the layers, and are thus configured into a so-called crossply structure.

[0026] The carcass **6**, which includes a code of a radial ply, is provided in a continuous manner on an inner side of the belt layer **7** in the tire radial direction and on the tire equatorial plane CL side of the sidewall portion **5**. The carcass **6** has a single layer structure made of one carcass ply or a multilayer structure made of a plurality of layered carcass plies, and extends between the bead

cores **21** disposed on both sides in the tire width direction in a toroidal shape, forming a backbone of the tire. Specifically, the carcass **6** extends between the pair of bead portions **20**, and is disposed extending from one bead portion **20** to the other bead portion **20** of the pair of bead portions **20** located on both sides in the tire width direction. In addition, the carcass **6** is folded back from the inner side of the bead core **21** in the tire width direction to the outer side in the tire width direction in the bead portion **20** through the inner side of the bead core **21** in the tire radial direction while wrapping the bead core **21** and the bead filler **50**. In other words, the carcass **6** is folded back around the bead core **21** from the inner side of the bead core **21** in the tire width direction to the outer side of the bead core **21** in the tire width direction in the bead portion **20**.

[0027] Thus, the carcass **6** includes a carcass body portion **6a** disposed between the pair of bead portions **20** and a turned-up portion **6b** formed continuously from the carcass body portion **6a** and folded back from the inner side in the tire width direction to the outer side in the tire width direction of the bead core **21**. The carcass body portion **6a** referred to herein is a portion formed between the inner sides of the pair of bead cores **21** in the tire width direction in the carcass **6**, and the turned-up portion **6b** is a portion formed continuously from the carcass body portion **6a** on the inner side of the bead core **21** in the tire width direction, running through the inner side of the bead core **21** in the tire radial direction, and folded back to the outer side in the tire width direction. The bead filler **50** is disposed on the inner side of the turned-up portion **6b** in the tire width direction, which is a portion folded back to the outer side of the bead core **21** in the tire width direction in this manner, and on the outer side of the bead core **21** in the tire radial direction.

[0028] The carcass ply of the carcass **6** disposed in this manner is formed by coating a plurality of carcass cords **6c** (see FIG. 2) as cord members made of steel or an organic fiber material, such as aramid, nylon, polyester, or rayon, with a coating rubber **6d** (see FIG. 2), which is a rubber member, followed by rolling processing. Additionally, the carcass **6** has a carcass angle of 85° or more and 95° or less, the carcass angle being the inclination angle of the carcass cords **6c** with respect to the tire circumferential direction.

[0029] Additionally, an innerliner **8** is formed along the carcass **6** on the inner side of the carcass **6** or on the inner side of the carcass **6** in the pneumatic tire **1**.

[0030] FIG. 2 is a detailed view of portion A in FIG. 1. FIG. 3 is a detailed view of the bead core **21** illustrated in FIG. 2. The bead core **21** is formed to have a polygonal cross-sectional shape when viewed in the tire meridian cross-section. In the present embodiment, the bead core **21** is formed to have a cross-sectional shape close to an octagon. Specifically, the bead core **21** is formed such that a bead core bottom surface **23** corresponding to an inner circumferential surface of the bead core **21** and a bead core top surface **22** corresponding to the outer circumferential surface of the bead core **21** in the overall view of the bead core **21** are substantially parallel to each other. In addition, the bead core **21** has a portion located on the innermost side in the tire width direction and a portion located on the outermost side in the tire width direction in a contour in the tire meridian cross-section each formed as a vertical line **25** extending along the tire radial direction.

[0031] In addition, in the contour of the bead core **21** in the tire meridian cross-section, an inner portion in the tire radial direction of the vertical line **25** on the inner side in the tire width direction and an end portion on the inner side in the tire width direction of the bead core bottom surface **23** are connected in a side shape, and an outer portion in the tire radial direction of the vertical line **25** on the inner side in the tire width direction and an end portion on the inner side in the tire width direction of the bead core top surface **22** are connected in a side shape. Also, in the contour of the bead core **21** in the tire meridian cross-section, an inner portion in the tire radial direction of the vertical line **25** on the outer side in the tire width direction and an end portion on the outer side in the tire width direction of the bead core bottom surface **23** are connected in a side shape, and an outer portion in the tire radial direction of the vertical line **25** on the outer side in the tire width direction and an end portion on the outer side in the tire width direction of the bead core top surface **22** are connected in a side shape. This forms the bead core **21** in a substantially octagonal shape in

the tire meridian cross-section.

[0032] Note that, the bead core bottom surface **23** of the bead core **21** in this case refers to, in the tire meridian cross-section, a surface indicated by an imaginary straight line in contact with a portion, which is exposed on the surface side of the bead core **21**, of a plurality of the bead wires **30** aligned in a row at a position on the inner side of the bead core **21** in the tire radial direction to form the surface of the bead core **21**. Similarly, the bead core top surface **22** of the bead core **21** refers to, when the pneumatic tire **1** is viewed in the tire meridian cross-section, a surface indicated by an imaginary straight line in contact with a portion, which is exposed on the surface side of the bead core **21**, of a plurality of the bead wires **30** disposed in a row at a position on the outer side of the bead core **21** in the tire radial direction to form the surface of the bead core **21**.

[0033] In addition, the vertical line **25** of the bead core **21** refers to, when the tire width direction is the width direction of the bead core **21** in the tire meridian cross-section, an imaginary straight line in contact with a portion, which is exposed on the outer side of the bead core **21** in the width direction, of a plurality of the bead wires **30** located on the outermost side of the bead core **21** in the width direction. Specifically, the vertical line **25** is formed to extend along the tire radial direction in a state where a spacing in the tire width direction between the pair of bead portions **20** located on the both sides in the tire width direction with respect to the tire equatorial plane CL is a spacing when the pneumatic tire **1** is mounted on the specified rim R (see FIG. 1).

[0034] In other words, the bead wires **30** are disposed in the bead core **21** such that an imaginary straight line in contact with the plurality of bead wires **30** located on the outermost side in the width direction of the bead core **21** extends along the tire radial direction in a state where a spacing in the tire width direction between the pair of bead portions **20** located on the both sides in the tire width direction with respect to the tire equatorial plane CL is a spacing when the pneumatic tire **1** is mounted on the specified rim R.

[0035] In the present embodiment, the vertical line **25** on the inner side of the bead core **21** in the tire width direction in the tire meridian cross-section is located on the innermost side of the bead wires **30** in the tire width direction and is a tangent line in contact with the bead wires **30** at three positions aligned with spacing in the tire radial direction. In addition, the vertical line **25** on the outer side of the bead core **21** in the tire width direction in the tire meridian cross-section is located on the outermost side of the bead wires **30** in the tire width direction and is a tangent line in contact with the bead wires **30** at three positions aligned with spacing in the tire radial direction.

[0036] Note that, the shape around the bead portion **20** is hereinafter described in the same manner as the description of the vertical line **25**, and a spacing in the tire width direction of the pair of bead portions **20** located on the both sides in the tire width direction with respect to the tire equatorial plane CL is a spacing when the pneumatic tire **1** is mounted on the specified rim R. In addition, the vertical line **25** of the bead core **21** need not strictly extend in the tire radial direction. The vertical line **25** may be formed within a range of 0° or more and 15° or less with respect to the tire radial direction.

[0037] As described above, the vertical line **25** located on each of both sides in the width direction of the bead core **21** has a length CV within a range of 31% or more and 45% or less with respect to a core height CH that is a height in the tire radial direction of the bead core **21**. In other words, the vertical line **25** has a ratio CV/CH of the length CV to the core height CH within the range of 31% or more and 45% or less. The length CV of the vertical line **25** in this case is a distance between an end portion on the outer side in the tire radial direction of the bead wire **30** located on the outermost side in the tire radial direction and an end portion on the inner side in the tire radial direction of the bead wire **30** located on the innermost side in the tire radial direction among the plurality of bead wires **30** constituting the vertical line **25**. In addition, the core height CH in this case is a distance between the bead core top surface **22** and the bead core bottom surface **23**.

[0038] Further, the vertical line **25** has a distance Va in the tire radial direction from the bead core bottom surface **23** to an inner end portion **25a** in the tire radial direction of the vertical line **25**

within a range of 20% or more and 35% or less of the core height CH. In this case, the inner end portion **25a** of the vertical line **25** in the tire radial direction is an end portion on the inner side in the tire radial direction of the bead wire **30** located on the innermost side in the tire radial direction among the plurality of bead wires **30** constituting the vertical line **25**.

[0039] Specifically, the bead core **21** has the vertical lines **25** on the both sides in the width direction of the bead core **21**, and each of the vertical lines **25** located on the both sides in the width direction of the bead core **21** has the distance Va in the tire radial direction from the bead core bottom surface **23** to the inner end portion **25a** in the tire radial direction of the vertical line **25** within the range of 20% or more and 35% or less of the core height CH. In other words, any of the vertical lines **25** located on the both sides in the width direction of the bead core **21** has a ratio  $Va/CH$  of the distance Va in the tire radial direction from the bead core bottom surface **23** to the inner end portion **25a** of the vertical line **25** to the core height CH within the range of 20% or more and 35% or less.

[0040] In addition, the bead core **21** has, in the tire meridian cross-section, a distance Vb in the tire width direction between an end portion **22** in on the inner side in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction of the vertical lines **25** on the both sides of the bead core **21** in the tire width direction within a range of 10% or more and 25% or less with respect to a maximum width CW of the bead core **21**. In other words, the bead core **21** has a ratio  $Vb/CW$  of the distance Vb in the tire width direction between the end portion **22** in on the inner side in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction to the maximum width CW of the bead core **21** within the range of 10% or more and 25% or less. The maximum width CW of the bead core **21** in this case is a distance between the vertical lines **25** located on the both sides in the width direction of the bead core **21**. In addition, the end portion **22** in on the inner side in the tire width direction of the bead core top surface **22** in this case is an end portion on the inner side in the tire width direction of the bead wire **30** located on the innermost side in the tire width direction among the plurality of bead wires **30** constituting the bead core top surface **22**.

[0041] Similarly, the bead core **21** has a distance Vc in the tire width direction between an end portion **23** in on the inner side in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to the maximum width CW of the bead core **21**. In other words, the bead core **21** has a ratio  $Vc/CW$  of the distance Vc in the tire width direction between the end portion **23** in on the inner side in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction to the maximum width CW of the bead core **21** within the range of 10% or more and 25% or less. The end portion **23** in on the inner side in the tire width direction of the bead core bottom surface **23** in this case is an end portion on the inner side in the tire width direction of the bead wire **30** located on the innermost side in the tire width direction among the plurality of bead wires **30** constituting the bead core bottom surface **23**.

[0042] Additionally, the bead core **21** has, in the tire meridian cross-section, the maximum width CW of the bead core **21** within a range of 0.9 times or more and 1.4 times or less as large as the core height CH. Moreover, the bead core **21** has a width CBW of the bead core bottom surface **23** in the tire meridian cross-section within a range of 45% or more and 70% or less with respect to the maximum width CW of the bead core **21**. In other words, the bead core **21** has a ratio  $CW/CH$  of the maximum width CW of the bead core **21** to the core height CH within the range of 0.9 times or more and 1.4 times or less and a ratio  $CBW/CW$  of the width CBW of the bead core bottom surface **23** to the maximum width CW of the bead core **21** within the range of 45% or more and 70% or less.

[0043] FIG. 4 is a detailed view of portion B in FIG. 3. The bead core **21** is formed by winding the bead wire **30** in a ring shape. Specifically, a plurality of circumferential portions of the bead wire **30** wound in a ring shape are aligned in the tire width direction to form one layer **31**, and a plurality



of the layers **31** are layered in the tire radial direction. In this case, in the layers **31** adjacent to each other in the tire radial direction, the bead wires **30** forming the respective layers **31** are disposed misaligned in the tire width direction by one-half of a thickness of the bead wire **30**.

[0044] For a first layer **31a**, a second layer **31b**, and a third layer **31c** counted from the inner side in the tire radial direction of the plurality of layers **31** included in the bead core **21**, in two of the layers **31** adjacent to each other in the tire radial direction, the number of bead wires **30** in the layer **31** located relatively on the outer side in the tire radial direction is larger by two or more than the number of bead wires **30** in the layer **31** located on the inner side in the tire radial direction. The first layer **31a** in this case is the layer **31** located on the innermost circumference in the tire radial direction among the plurality of layers **31** included in the bead core **21**. In addition, the second layer **31b** is the layer **31** layered adjacent to the outer side of the first layer **31a** in the tire radial direction, and the third layer **31c** is the layer **31** layered adjacent to the outer side of the second layer **31b** in the tire radial direction. In the present embodiment, the number of bead wires **30** in the second layer **31b** is larger by two than that in the first layer **31a**, and the number of bead wires **30** in the third layer **31c** is larger by two than that in the second layer **31b**.

[0045] In addition, for the first layer **31a**, the second layer **31b**, and the third layer **31c** of the bead core **21**, in two of the layers **31** adjacent to each other in the tire radial direction, a misalignment amount in the tire width direction of the bead wires **30** each located at an end portion on one side in the tire width direction is one-half of the thickness of the bead wire **30**. Further, in the first layer **31a**, the second layer **31b**, and the third layer **31c**, a side on which the misalignment amount between the bead wires **30** located in the end portions in the tire width direction of the first layer **31a** and the second layer **31b** is one-half of the bead wire **30** is located opposite in the tire width direction to a side on which the misalignment amount between the bead wires **30** located in the end portions in the tire width direction of the second layer **31b** and the third layer **31c** is one-half of the bead wire **30**.

[0046] Specifically, in the first layer **31a** and the second layer **31b**, the misalignment amount in the tire width direction between the bead wires **30** located in the end portions on the inner side in the tire width direction is one-half of the thickness of the bead wire **30**. In contrast, in the second layer **31b** and the third layer **31c**, the misalignment amount in the tire width direction between the bead wires **30** located in the end portions on the outer side in the tire width direction is one-half of the thickness of the bead wire **30**.

[0047] In addition, in the present embodiment, the bead core **21** is configured such that the number of the bead wires **30** in the layer **31** decreases by one toward the outer side in the tire radial direction on the further outer side in the tire radial direction than the layer **31** including the bead wires **30** forming the end portion on the outer side in the tire radial direction of the vertical line **25** (see FIG. 3) located on both sides in the width direction of the bead core **21** in the plurality of layers **31** layered in the tire radial direction.

[0048] The carcass **6** is disposed by being folded back around the bead core **21** from the inner side in the tire width direction to the outer side in the tire width direction of the bead core **21** formed as described above, and is configured by covering the plurality of carcass cords **6c** with the coating rubber **6d**, followed by rolling processing. In the carcass **6** including the plurality of carcass cords **6c**, the number of ends of the carcass cords **6c** at a position on an inner side of the bead core **21** in the tire width direction is within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less. In this case, the position on the inner side of the bead core **21** in the tire width direction is a position where the range in the tire radial direction at the position on the inner side in the tire width direction with respect to the bead core **21** is the same range as the range in the tire radial direction in which the bead core **21** is disposed. That is, the position on the inner side of the bead core **21** in the tire width direction in this case is a position within the same range as the range in the tire radial direction in which the bead core **21** is disposed in the carcass body portion **6a**.

[0049] In the carcass **6**, the number of ends per 50 mm in the direction, in which the carcass cords

**6c** are aligned, at the position on the inner side of the bead core **21** in the tire width direction defined as described above, that is, the cord count of the carcass cords **6c** is within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less.

[0050] The bead filler **50** including the lower filler **51** and the upper filler **52** is disposed on the outer side of the bead core **21** in the tire radial direction. Of these fillers, the lower filler **51** is disposed between the carcass body portion **6a** and the turned-up portion **6b** included in the carcass **6**. In addition, a width in the tire width direction of the lower filler **51** is approximately the same as that of the bead core **21** in a location near the bead core **21** in the tire meridian cross-section, and the width decreases toward the outer side in the tire radial direction.

[0051] On the other hand, the upper filler **52** is disposed from the position where the lower filler **51** is disposed in the tire radial direction to the position on the outer side of the lower filler **51** in the tire radial direction, and an inner end portion of the upper filler **52** in the tire radial direction is located near the bead core **21**. Specifically, within a range in which the lower filler **51** is disposed in the tire radial direction, the upper filler **52** is located on the outer side of the lower filler **51** in the tire width direction and disposed between the turned-up portion **6b** of the carcass **6** and the lower filler **51**, and on the outer side of the lower filler **51** in the tire radial direction, the upper filler **52** is disposed between the carcass body portion **6a** and the turned-up portion **6b** of the carcass **6** (see FIG. 1).

[0052] The lower filler **51** and the upper filler **52** included in the bead filler **50** are rubber compositions having physical properties different from each other.

[0053] In addition, the bead portion **20** includes a rim cushion rubber **46** on the inner side of the bead core **21** in the tire radial direction. The rim cushion rubber **46** also forms a bead base portion **40** that is the inner circumferential surface of the bead portion **20** and is a rubber composition that is brought into contact with the rim wheel while being elastically deformed when fitted to the rim wheel.

[0054] The bead base portion **40** referred to herein is an inner circumferential surface of the bead portion **20**, and is a portion of the bead portion **20**, which is brought into contact with the rim wheel and fitted to the rim wheel. The bead base portion **40** includes a bead toe **41** at an inner end in the tire width direction and a bead heel **42** at an outer end in the tire width direction and is formed in a tapered shape in which a diameter increases from the bead toe **41** side toward the bead heel **42** side.

[0055] In the bead portion **20**, a reinforcing layer **60** reinforcing the carcass **6** is disposed in a portion of the carcass **6** folded back around the bead core **21**. The reinforcing layer **60** is disposed along the carcass **6** at least on the inner side of the carcass body portion **6a** in the tire width direction. In the present embodiment, three reinforcing layers **60** are disposed, and these three reinforcing layers **60** are disposed such that positions of end portions in the tire radial direction in the tire meridian cross-section are different from each other.

[0056] Specifically, in the case where the three reinforcing layers **60** are referred to as a first reinforcing layer **61**, a second reinforcing layer **62**, and a third reinforcing layer **63** from the carcass **6** side toward the direction away from the carcass **6** in the thickness direction of the carcass **6** or the reinforcing layer **60**, the first reinforcing layer **61** is disposed folded back along the carcass **6** from the inner side in the tire width direction to the outer side in the tire width direction of the bead core **21**. In contrast, the second reinforcing layer **62** and the third reinforcing layer **63** are not disposed on the outer side of the bead core **21** in the tire width direction. In other words, the second reinforcing layer **62** and the third reinforcing layer **63** are not disposed on the turned-up portion **6b** side but are disposed along the carcass **6** only within a range where the carcass body portion **6a** is located.

[0057] In the second reinforcing layer **62** and the third reinforcing layer **63** disposed as described above, the end portion on the inner side in the tire radial direction in the tire meridian cross-section is located on the further inner side in the tire radial direction in the second reinforcing layer **62** than in the third reinforcing layer **63**. In addition, in the second reinforcing layer **62** and the third

reinforcing layer **63**, the end portion on the outer side in the tire radial direction in the tire meridian cross-section is located on the further outer side in the tire radial direction in the third reinforcing layer **63** than in the second reinforcing layer **62**.

[0058] The plurality of reinforcing layers **60** disposed as described above are each configured by coating a plurality of cords with a coating rubber, followed by rolling processing. Of these reinforcing layers **60**, in the first reinforcing layer **61**, the cords are made of steel cords. On the other hand, in the second reinforcing layer **62**, the cords are made of organic fiber cords. Similarly, in the third reinforcing layer **63**, cords are made of organic fiber cords.

[0059] The first reinforcing layer **61** is disposed folded back along the carcass **6** from the inner side in the tire width direction to the outer side in the tire width direction of the bead core **21**. In addition, the first reinforcing layer **61** has an end portion located on the inner side of the bead core **21** in the tire width direction and an end portion located on the outer side of the bead core **21** in the tire width direction in the first reinforcing layer **61**, both the end portions being located on the further outer side in the tire radial direction than the bead core top surface **22** of the bead core **21**.

[0060] In addition, in the plurality of reinforcing layers **60** disposed by being overlapped along the carcass **6** in the bead portion **20**, the reinforcing layers **60** adjacent to each other have the inclination directions of the cords of the respective reinforcing layers **60** in the tire circumferential direction with respect to the tire radial direction opposite to each other.

#### Method of Manufacturing Pneumatic Tire

[0061] Next, a method of manufacturing the pneumatic tire **1** according to the embodiment will be described. In manufacturing the pneumatic tire **1**, first, processing is performed on each of the members constituting the pneumatic tire **1**, and the processed members are assembled. In other words, the rubber members such as the tread rubber **2a** and each of the members such as the carcass **6**, the belt layer **7**, and the bead core **21** are processed, and the processed members are assembled.

[0062] For example, the bead core **21** is formed by winding the bead wire **30** into a ring shape. At this time, the bead core **21** is formed such that a portion located on the innermost side in the tire width direction and a portion located on the outermost side in the tire width direction in the contour in the tire meridian cross-section form the vertical lines **25** each extending along the tire radial direction. Further, the bead core **21** is made to have the length CV of the vertical line **25** within a range of 31% or more and 45% or less with respect to the core height CH of the bead core **21**, and the vertical line **25** is made to have the distance Va in the tire radial direction from the bead core bottom surface **23** to the inner end portion **25a** in the tire radial direction of the vertical line **25** within a range of 20% or more and 35% or less with respect to the core height CH.

[0063] In addition, the bead core **21** is formed by aligning a plurality of circumferential portions of the bead wire **30** in the tire width direction to form one layer **31** and layering a plurality of the layers **31** in the tire radial direction. At this time, for the three layers **31** of the first layer **31a**, the second layer **31b**, and the third layer **31c** counted from the innermost circumference of the bead core **21** in the tire radial direction, in two of the layers **31** adjacent to each other in the tire radial direction, the number of bead wires **30** in the layer **31** located relatively on the outer side in the tire radial direction is made larger by two or more than the number of bead wires **30** in the layer **31** located on the inner side in the tire radial direction, and the misalignment amount in the tire width direction between the bead wires **30** each located at the end portion on one side in the tire width direction is made to be one-half of the thickness of the bead wire **30**. In addition, in the three layers **31**, the side on which the misalignment amount between the bead wires **30** in the first layer **31a** and the second layer **31b** is made to be one-half of the thickness of the bead wire **30** is made opposite in the tire width direction to the side on which the misalignment amount between the bead wires **30** in the second layer **31b** and the third layer **31c** is made to be one-half of the thickness of the bead wire **30**.

[0064] In this manner, the bead wire **30** to be wound into a ring shape when forming the bead core

**21** starts to be wound from the end portion on the outer side in the tire width direction of the first layer **31a** when manufacturing the pneumatic tire **1**. In other words, when the bead wire **30** is wound into a ring shape to form the bead core **21**, the bead wire **30** is wound such that the end portion of the bead wire **30** located on the bead core bottom surface **23** is located at the end portion on the outer side in the tire width direction of the bead core bottom surface **23**.

[0065] The bead wire **30** starting to be wound from the end portion on the outer side in the tire width direction of the bead core bottom surface **23** is spirally wound by a predetermined number of turns determined for each layer **31** to be aligned in the tire width direction, thereby forming the layer **31**. When the number of times of winding the bead wire **30** reaches a predetermined number of turns determined for each layer **31**, the bead wire **30** is folded back to the upper side in the tire radial direction and spirally wound by the number of turns determined as the number of turns of the layer **31** adjacent on the outer side in the tire radial direction, thereby forming the layer **31**.

[0066] In other words, the bead wire **30** starts to be wound from the end portion on the outer side in the tire width direction in the first layer **31a**, and when winding of the first layer **31a** is completed, the second layer **31b** adjacent to the first layer **31a** on the outer side in the tire radial direction starts to be wound. As a result, the side on which the misalignment amount between the bead wires **30** in the first layer **31a** and the second layer **31b** is made to be one-half of the thickness of the bead wire **30** is inevitably located on the end portion side on the inner side in the tire width direction in the first layer **31a** and the second layer **31b**. By repeating such winding, the layers **31** formed by aligning a plurality of circumferential portions of the bead wire **30** in the tire width direction are layered in the tire radial direction, and thus the bead core **21** is formed to have a polygonal cross-sectional shape in the tire meridian cross-section.

[0067] In the bead portion **20** in which the bead core **21** formed in this manner is disposed, the carcass **6** is disposed folded back from the inner side in the tire width direction to the outer side in the tire width direction of the bead core **21**. For the carcass **6**, a carcass ply is used in which the number of ends of the carcass cords **6c** at a position on the inner side of the bead core **21** in the tire width direction is within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less. The manufacturing of the pneumatic tire **1** is performed in this manner, and thus the pneumatic tire **1** according to the present embodiment is manufactured.

#### Functions and Effects

[0068] When mounting the pneumatic tire **1** according to the present embodiment on a vehicle, the bead base portion **40** is first fitted to the specified rim R of the rim wheel to mount the pneumatic tire **1** on the specified rim R, and the pneumatic tire **1** is mounted on the rim wheel. Once mounted on the rim, the pneumatic tire **1** is inflated, and the pneumatic tire **1** inflated is mounted on the vehicle. The pneumatic tire **1** according to the present embodiment is mounted on a vehicle, such as a loader and a scraper for which traction performance is required, for example, and is used under a large load condition.

[0069] When the vehicle on which the pneumatic tires **1** are mounted travels, the pneumatic tire **1** rotates while the tread contact surface **3** located at the lower side in the tread contact surface **3** comes into contact with the road surface. The vehicle travels by transferring a driving force or a braking force to the road surface, using the friction force between the tread contact surface **3** and the road surface, or by generating a turning force.

[0070] During traveling of the vehicle having the pneumatic tires **1** mounted thereon, although the vehicle can travel with the aid of a friction force generated between the tread contact surface **3** of the pneumatic tire **1** and the road surface in this way, loads in various directions act on each portion of the pneumatic tire **1** during traveling of the vehicle. The load acting on the pneumatic tire **1** is received by the pressure of the air filled inside the pneumatic tire **1**, the carcass **6** provided as the framework of the pneumatic tire **1**, and the like.

[0071] For example, due to the weight of the vehicle and the recesses and protrusions of the road surface, the load acting in the tire radial direction between the tread portion **2** and the bead portion

**20** is mainly received by the pressure of the air filled inside the pneumatic tire **1** or deflection of the sidewall portion **5** or the like. In particular, since the pneumatic tire **1** according to the present embodiment is mounted on a large vehicle and used under a large load condition, the sidewall portions **5** and the carcass **6** receive a very large load. Therefore, a large tension acts on the carcass **6**.

[0072] The carcass **6** is folded back around the bead core **21** in the bead portion **20** and thus held by the bead portion **20**. Therefore, when a large tension acts on the carcass **6**, the tension of the carcass **6** is transmitted to the bead core **21**, and a large force acts between the carcass **6** and the bead core **21**. In other words, since the carcass **6** is folded back around the bead core **21** and thus held by the bead portion **20**, when the tension acts on the carcass **6**, a tension in a direction from the bead portion **20** side toward the outer side in the tire radial direction acts on the carcass body portion **6a**. Therefore, a large force also acts between the bead core **21** and the carcass **6** as well.

[0073] Here, the sidewall portion **5** is inclined with respect to the tire radial direction in a direction from the position of the bead portion **20** toward the outer side in the tire width direction as it is directed toward the outer side in the tire radial direction. Therefore, when a large tension acts on the carcass body portion **6a**, while the carcass body portion **6a** is pulled in the tire radial direction, the carcass body portion **6a** generates a force in a direction toward the outer side in the tire width direction in the vicinity of the bead portion **20**.

[0074] On the other hand, in a pneumatic tire mounted on a large vehicle and used under a large load condition, a bead core formed to have a substantially hexagonal cross-sectional shape in a tire meridian cross-section is often used, and in this case, the bead core has a corner portion projecting toward the inner side in the tire width direction. Accordingly, when a large tension acts on a carcass and a carcass body portion is about to move in the tire radial direction due to the tension while generating a force toward the outer side in the tire width direction at a location near a bead portion, the carcass body portion rubs against the corner portion projecting toward the inner side in the tire width direction in the bead core while applying a large load to the corner portion. This causes, in the carcass body portion, the coating rubber to be worn and the carcass cord to be directly rubbed, and a failure such as breakage of the carcass cord may occur.

[0075] In addition, the carcass is folded back around the bead core, and thus, when a large tension acts on the carcass, rubbing occurs between the carcass and the bead core even at a position other than the corner portion projecting toward the inner side in the tire width direction in the bead core, and a failure such as breakage of the carcass cord may occur in the carcass due to such rubbing.

[0076] In contrast, in the pneumatic tire **1** according to the present embodiment, the bead core **21** has a portion located on the innermost side in the tire width direction and a portion located on the outermost side in the tire width direction in the contour in the tire meridian cross-section each formed as the vertical line **25** extending along the tire radial direction. In other words, since the bead core **21** is formed in a shape forming the vertical line **25** extending along the tire radial direction at a position of the maximum width of the bead core **21** in the tire width direction, the bead core **21** is formed without a corner portion projecting with respect to the tire width direction. This allows, even when a large force acts between the carcass **6** and the bead core **21** due to the large tension acting on the carcass **6**, the occurrence of stress concentration to be reduced and the stress acting between the carcass **6** and the bead core **21** to be dispersed. Accordingly, the wear of the coating rubber **6d** of the carcass body portion **6a** due to the stress concentration occurring between the carcass **6** and the bead core **21** can be suppressed, and the occurrence of a failure such as breakage of the carcass cord **6c** due to direct rubbing of the carcass cord **6c** caused by the wear of the coating rubber **6d** can be reduced.

[0077] In addition, the length CV of the vertical lines **25** located on the both sides of the bead core **21** in the tire width direction is within the range of 31% or more and 45% or less with respect to the core height CH, and thus the stress generated between the carcass **6** and the bead core **21** can be more reliably dispersed. In other words, when the length CV of the vertical line **25** is less than 31%

with respect to the core height CH, the length CV of the vertical line 25 is too short, and thus even forming the vertical lines 25 on the both sides of the bead core 21 in the tire width direction may make it difficult to effectively reduce the stress concentration occurring between the carcass 6 and the bead core 21. In addition, when the length CV of the vertical line 25 is larger than 45% with respect to the core height CH, the length CV of the vertical line 25 is too long, and thus even forming the vertical lines 25 on the both sides of the bead core 21 in the tire width direction may cause stress concentration to occur between the carcass 6 and the bead core 21 at both end positions in the length direction of the vertical line 25.

[0078] In contrast, when the length CV of the vertical line 25 is within the range of 31% or more and 45% or less with respect to the core height CH, the stress generated between the carcass 6 and the bead core 21 can be more reliably dispersed by the vertical lines 25 formed on the both sides of the bead core 21 in the tire width direction. This can more reliably reduce the occurrence of a failure such as breakage of the carcass cord 6c due to the stress concentration occurring between the carcass 6 and the bead core 21.

[0079] In addition, the vertical line 25 of the bead core 21 has the distance Va in the tire radial direction from the bead core bottom surface 23 to the inner end portion 25a in the tire radial direction of the vertical line 25 within the range of 20% or more and 35% or less with respect to the core height CH, allowing the occurrence of stress concentration generated between the carcass 6 and the bead core 21 to be more reliably reduced. In other words, when the distance Va in the tire radial direction from the bead core bottom surface 23 to the inner end portion 25a in the tire radial direction of the vertical line 25 is less than 20% with respect to the core height CH, the position of the vertical line 25 may be too close to the inner side in the tire radial direction.

[0080] In addition, when the distance Va in the tire radial direction from the bead core bottom surface 23 to the inner end portion 25a in the tire radial direction of the vertical line 25 is larger than 35% with respect to the core height CH, the position of the vertical line 25 may be too close to the outer side in the tire radial direction. In these cases, the shape of the bead core 21 in which the vertical lines 25 are formed on the both sides in the tire width direction may be unlikely to be a shape along the shape of the carcass 6 folded back at the bead portion 20. This causes stress concentration between the carcass 6 and the bead core 21, and a failure such as breakage of the carcass cord 6c may easily occur.

[0081] In contrast, when the distance Va in the tire radial direction from the bead core bottom surface 23 to the inner end portion 25a in the tire radial direction of the vertical line 25 is within the range of 20% or more and 35% or less with respect to the core height CH, the shape of the bead core 21 in which the vertical lines 25 are formed on the both sides in the tire width direction can be brought close to a shape along the shape of the carcass 6 folded back at the bead portion 20. This can more reliably reduce the occurrence of stress concentration between the carcass 6 and the bead core 21 and the occurrence of a failure such as breakage of the carcass cord 6c due to the stress concentration occurring between the carcass 6 and the bead core 21.

[0082] In addition, for the first layer 31a, the second layer 31b, and the third layer 31c counted from the innermost circumference side in the tire radial direction of the plurality of layers 31 formed by the bead wire 30 in the bead core 21, in two of the layers 31 adjacent to each other in the tire radial direction, the number of bead wires 30 in the layer 31 located relatively on the outer side in the tire radial direction is larger by two or more than the number of bead wires 30 in the layer 31 located on the inner side in the tire radial direction. This can make the contour shape of the bead core 21 from the first layer 31a to the third layer 31c in the tire meridian cross-section a shape having a small inclination angle in the tire radial direction with respect to the tire width direction. Accordingly, the cross-sectional shape of the bead core 21 at a position close to the bead core bottom surface 23 can be brought closer to a shape along the shape of the carcass 6 folded back at the bead portion 20.

[0083] In addition, for the first layer 31a, the second layer 31b, and the third layer 31c of the

plurality of layers **31** formed by the bead wire **30**, in two of the layers **31** adjacent to each other in the tire radial direction, the misalignment amount in the tire width direction between the bead wires **30** each located at an end portion on one side in the tire width direction is one-half of the thickness of the bead wire **30**. This can suppress the excessively increasing misalignment amount in the tire width direction between the bead wires **30** at a portion straddling two of the layers **31** adjacent to each other in the tire radial direction and can suppress the loss of shape of the bead core **21** due to the excessively increasing misalignment amount between the bead wires **30** at the portion straddling two of the layers **31** adjacent to each other in the tire radial direction.

[0084] In addition, the side on which the misalignment amount between the bead wires **30** in the first layer **31a** and the second layer **31b** is one-half of the thickness of the bead wire **30** is located opposite in the tire width direction to the side on which the misalignment amount between the bead wires **30** located in the second layer **31b** and the third layer **31c** is one-half of the thickness of the bead wire **30**. This can bring the contour shape of the bead core **21** in the tire meridian cross-section close to a shape along the shape of the carcass **6** folded back at the bead portion **20** in a well-balanced manner on the both sides in the tire width direction. Accordingly, the stress generated between the carcass **6** and the bead cores **21** can be more reliably dispersed, and the occurrence of a failure such as breakage of the carcass cord **6c** due to the stress concentration occurring between the carcass **6** and the bead cores **21** can be more reliably reduced. As a result, the durability of the bead portion **20** can be improved.

[0085] In addition, the bead core **21** is formed in a shape in which the vertical line **25** is formed on the outer side in the tire width direction, allowing contact pressure between the rim wheel and a bead portion outer surface **45** (see FIG. 2), which is a surface on the outer side of the bead portion **20** in the tire width direction, to be made nearly uniform compared to a bead core having a substantially hexagonal cross-sectional shape. In other words, when the bead core has a substantially hexagonal cross-sectional shape, the bead core is formed having a portion on the outer side in the tire width direction having a corner portion projecting toward the outer side in the tire width direction, and thus the contact pressure between the rim wheel and the bead portion outer surface is high at the corner portion, whereas the contact pressure between the rim wheel and the bead portion outer surface is likely to be low at portions other than the corner portion. In this case, it may be difficult to secure air-sealing properties at a portion between the rim wheel and the bead portion outer surface when mounting the pneumatic tire on the rim wheel and inflating the pneumatic tire.

[0086] In contrast, in the present embodiment, the bead core **21** is formed in a shape in which the vertical line **25** is formed on the outer side in the tire width direction, allowing a change in the distance between the bead core **21** and the bead portion outer surface **45** to be reduced. In other words, an area of a portion where contact pressure on the rim wheel from the bead core **21** can be increased can be made larger. This allows for substantially uniform contact pressure between the rim wheel and the bead portion outer surface **45**. As a result, air-sealing properties at the bead portion **20** can be improved.

[0087] In addition, the width CBW of the bead core bottom surface **23** in the tire meridian cross-section is within the range of 45% or more and 70% or less with respect to the maximum width CW of the bead core **21**, allowing the occurrence of stress concentration between the bead core bottom surface **23** and the carcass **6** to be reduced. In other words, when the width CBW of the bead core bottom surface **23** is less than 45% with respect to the maximum width CW of the bead core **21**, the width CBW of the bead core bottom surface **23** is too small, and thus the shape of the bead core **21** in the tire meridian cross-section may excessively project toward the lower side in the tire radial direction. In this case, stress concentration may be likely to occur between the carcass **6** and the bead core **21** at a location near the bead core bottom surface **23** of the bead core **21**. In addition, when the width CBW of the bead core bottom surface **23** is larger than 70% with respect

to the maximum width CW of the bead core **21**, the width CBW of the bead core bottom surface **23** is too large, and thus stress concentration may be likely to occur between the carcass **6** and the bead core **21** at both end positions of the bead core bottom surface **23** in the width direction.

[0088] In contrast, when the width CBW of the bead core bottom surface **23** is within the range of 45% or more and 70% or less with respect to the maximum width CW of the bead core **21**, the occurrence of stress concentration between the bead core bottom surface **23** and the carcass **6** can be effectively reduced. This can more reliably reduce the occurrence of a failure such as breakage of the carcass cord **6c** due to the stress concentration occurring between the carcass **6** and the bead core **21**. As a result, the durability of the bead portion **20** can be more reliably improved.

[0089] In addition, the bead core **21** has the distance Vb in the tire width direction between the end portion **22** in on the inner side in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction within the range of 10% or more and 25% or less with respect to the maximum width CW of the bead core **21** and the distance Vc in the tire width direction between the end portion **23** in on the inner side in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction within the range of 10% or more and 25% or less with respect to the maximum width CW of the bead core **21**, allowing the stress concentration occurring between the carcass **6** and the bead core **21** to be more reliably reduced. In other words, when the distance Vb between the inner end portion **22** in in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction or the distance Vc between the inner end portion **23** in in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction is less than 10% with respect to the maximum width CW of the bead core **21**, the projection amount of the bead core **21** from the position of the bead core top surface **22** or the bead core bottom surface **23** toward the inner side in the tire width direction may excessively decrease. In this case, the shape of a surface located on the inner side in the tire width direction of the bead core **21** in the tire meridian cross-section is less likely to be a shape along the curved shape of a portion located on the inner side in the tire width direction of the bead core **21** in the carcass **6**, and this may cause stress concentration to easily occur between the carcass **6** and the bead core **21**.

[0090] In addition, when the distance Vb between the inner end portion **22** in in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction or the distance Vc between the inner end portion **23** in in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction is larger than 25% with respect to the maximum width CW of the bead core **21**, the projection amount of the bead core **21** from the position of the bead core top surface **22** or the bead core bottom surface **23** toward the inner side in the tire width direction may excessively increase. Also in this case, the shape of the surface located on the inner side in the tire width direction of the bead core **21** in the tire meridian cross-section is less likely to be a shape along the curved shape of a portion located on the inner side in the tire width direction of the bead core **21** in the carcass **6**, and thus stress concentration may be likely to occur between the carcass **6** and the bead core **21**.

[0091] In contrast, the distance Vb between the inner end portion **22** in in the tire width direction of the bead core top surface **22** and the vertical line **25** on the inner side in the tire width direction or the distance Vc between the inner end portion **23** in in the tire width direction of the bead core bottom surface **23** and the vertical line **25** on the inner side in the tire width direction is within the range of 10% or more and 25% or less with respect to the maximum width CW of the bead core **21**. Accordingly, the shape of the surface located on the inner side in the tire width direction of the bead core **21** in the tire meridian cross-section can be easily made to be a shape along a curved shape of a portion located on the inner side in the tire width direction of the bead core **21** in the carcass **6**. This can more reliably reduce the occurrence of stress concentration between the carcass **6** and the bead core **21**. As a result, the durability of the bead portion **20** can be more reliably



improved.

[0092] In addition, the bead core **21** has the maximum width CW of the bead core **21** within the range of 0.9 times or more and 1.4 times or less as large as the core height CH, and thus the occurrence of stress concentration between the carcass **6** and the bead core **21** can be more reliably reduced. In other words, when the maximum width CW of the bead core **21** is less than 0.9 times as large as the core height CH, the maximum width CW of the bead core **21** is too small. Accordingly, it is difficult to bring the shape of the bead core **21** in the tire meridian cross-section into a shape along the shape of the carcass **6** folded back around the bead core **21**, and thus stress concentration may be likely to occur between the carcass **6** and the bead core **21**. Specifically, when the maximum width CW of the bead core **21** is too small, stress concentration may be likely to occur between the bead core **21** and a portion located near the bead core bottom surface **23** in the carcass **6** folded back around the bead core **21**.

[0093] In addition, when the maximum width CW of the bead core **21** is 1.4 times larger than the core height CH, the maximum width CW of the bead core **21** is too large, also in this case, it is difficult to bring the shape of the bead core **21** in the tire meridian cross-section into a shape along the shape of the carcass **6**, and thus stress concentration may be likely to occur between the carcass **6** and the bead core **21**. Specifically, the maximum width CW of the bead core **21** is too large, and thus stress concentration may be likely to occur between the bead core **21** and a portion located near either side in the tire width direction of the bead core **21** in the carcass **6** folded back around the bead core **21**.

[0094] In contrast, when the maximum width CW of the bead core **21** is within the range of 0.9 times or more and 1.4 times or less as large as the core height CH, the shape of the bead core **21** in the tire meridian cross-section can be brought close to a shape along the shape of the carcass **6** folded back around the bead core **21**. This can more reliably reduce the occurrence of stress concentration between the carcass **6** and the bead core **21**. As a result, the durability of the bead portion **20** can be more reliably improved.

[0095] Further, in the carcass **6**, the number of ends of the carcass cords **6c** at a position on the inner side of the bead core **21** in the tire width direction is within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less. Therefore, failure of the carcass **6** at the position of the bead portion **20** can be more reliably reduced. That is, when the number of ends of the carcass cords **6c** at the position on the inner side of the bead core **21** in the tire width direction is less than 10 cords per 50 mm, the number of ends of the carcass cords **6c** is too small. Therefore, when a large tension acts on the carcass **6**, the tension borne by each carcass cord **6c** may excessively increase. In this case, in a portion of the carcass **6** disposed in the bead portion **20**, stress per one carcass cord **6c** excessively increases, and the carcass cord **6c** may be likely to be broken. Further, when the number of ends of the carcass cords **6c** at a position on the inner side of the bead core **21** in the tire width direction is more than 20 cords per 50 mm, the number of ends of the carcass cords **6c** is too large. Therefore, the intervals between the carcass cords **6c** decrease, and the volume of the coating rubber **6d** positioned between the adjacent carcass cords **6c** may excessively decrease. In this case, since it is difficult to hold the carcass cord **6c** by the coating rubber **6d** and the carcass cord **6c** is likely to be peeled off from the coating rubber **6d**, it may be difficult to manufacture the carcass **6** with appropriate durability.

[0096] In contrast, when the number of ends of the carcass cords **6c** at the position on the inner side of the bead core **21** in the tire width direction is within the range of 10 cords per 50 mm or more and 20 cords per 50 mm or less, the volume of the coating rubber **6d** positioned between the adjacent carcass cords **6c** can be suppressed from excessively decreasing, and the force borne by the carcass cords **6c** can be dispersed to more carcass cords **6c**. As a result, the peeling off of the carcass cord **6c** from the coating rubber **6d** is reduced, and when a large tension acts on the carcass **6** at the position of the bead portion **20**, the tension borne by each carcass cord **6c** can be reduced, allowing an easy breakage of the carcass cord **6c** due to an excessively large stress of each carcass

cord **6c** to be reduced. Therefore, the durability of the carcass **6** can be ensured, and the failure of the carcass **6** at the position of the bead portion **20** can be more reliably reduced. As a result, the durability of the bead portion **20** can be more reliably improved.

[0097] In a method of manufacturing the pneumatic tire **1** according to the embodiment, the bead core **21** is formed such that a portion located on the innermost side in the tire width direction and a portion located on the outermost side in the tire width direction of the bead core **21** are the vertical lines **25**, allowing, even when a large force acts between the carcass **6** and the bead core **21** due to a large tension acting on the carcass **6**, the occurrence of stress concentration to be reduced. As a result, the occurrence of a failure such as breakage of the carcass cord **6c** due to the stress concentration occurring between the carcass **6** and the bead core **21** can be reduced.

[0098] In addition, in the method of manufacturing the pneumatic tire **1** according to the embodiment, the length CV of the vertical line **25** is made to fall within the range of 31% or more and 45% or less with respect to the core height CH, allowing the stress generated between the carcass **6** and the bead core **21** to be more reliably dispersed by the vertical lines **25** formed on the both sides of the bead core **21** in the tire width direction. This can more reliably reduce the occurrence of a failure such as breakage of the carcass cord **6c** due to the stress concentration occurring between the carcass **6** and the bead core **21**.

[0099] In addition, in the method of manufacturing the pneumatic tire **1** according to the embodiment, the distance Va in the tire radial direction from the bead core bottom surface **23** to the inner end portion **25a** in the tire radial direction of the vertical line **25** is made to fall within the range of 20% or more and 35% or less with respect to the core height CH, allowing the shape of the bead core **21** to be brought close to a shape along the shape of the carcass **6** folded back at the bead portion **20**. This can more reliably reduce the occurrence of stress concentration between the carcass **6** and the bead core **21**.

[0100] In the method of manufacturing the pneumatic tire **1** according to the embodiment, for the first layer **31a**, the second layer **31b**, and the third layer **31c** of the plurality of layers **31** formed by the bead wire **30**, in two of the layers **31** adjacent to each other, the misalignment amount in the tire width direction between the bead wires **30** each located at the end portion on one side in the tire width direction is made to be one-half of the thickness of the bead wire **30**. This can reduce the excessively increasing misalignment amount in the tire width direction between the bead wires **30** at a portion straddling the two layers **31** adjacent to each other in the tire radial direction and can reduce the loss of shape of the bead core **21**.

[0101] In the method of manufacturing the pneumatic tire **1** according to the embodiment, the side on which the misalignment amount between the bead wires **30** in the first layer **31a** and the second layer **31b** is made to be one-half of the thickness of the bead wire **30** is made opposite in the tire width direction to the side on which the misalignment amount between the bead wires **30** in the second layer **31b** and the third layer **31c** is made to be one-half of the thickness of the bead wire **30**. This can bring the shape of the bead core **21** in the tire meridian cross-section close to a shape along the shape of the carcass **6** in a well-balanced manner on the both sides in the tire width direction, can reduce the generation of stress concentration between the carcass **6** and the bead core **21**, and thus can more reliably reduce the occurrence of a failure such as breakage of the carcass cord **6c**. As a result, the durability of the bead portion **20** can be improved.

[0102] In addition, in the method of manufacturing the pneumatic tire **1** according to the embodiment, the bead wire **30** starts to be wound from the end portion on the outer side in the tire width direction in the first layer **31a**, and thus the durability of the bead core **21** can be ensured. In other words, when the pneumatic tire **1** is inflated, the bead core **21** is required to have the highest strength at the position of the end portion **23** in on the inner side in the tire width direction on the bead core bottom surface **23**. Thus, the end portion of the bead wire **30** located at the position of the end portion **23** in on the inner side in the tire width direction on the bead core bottom surface **23** decreases the durability of the bead core **21**, and the bead core **21** may be likely to lose its shape.

[0103] In contrast, when the bead wire **30** starts to be wound from the end portion on the outer side in the tire width direction in the first layer **31a**, the strength at the position of the end portion **23** in on the inner side in the tire width direction on the bead core bottom surface **23** where the highest strength is required can be ensured, allowing the likelihood of loss of shape of the bead core **21** to be reduced. As a result, the durability of the bead core **21** can be ensured.

#### MODIFIED EXAMPLES

[0104] Note that in the pneumatic tire **1** according to the embodiment described above, in the bead core **21**, the number of the bead wires **30** in the layer **31** decreases by one toward the outer side in the tire radial direction on the further outer side in the tire radial direction than the layer **31** including the bead wire **30** forming the end portion on the outer side in the tire radial direction of the vertical line **25**. However, the bead core **21** may be formed in a form other than this.

[0105] FIG. **5** is a detailed view of the bead core **21** of a modified example of the pneumatic tire **1** according to the embodiment, in which the bead wires **30** are layered in a different form from the embodiment described above. For example, as illustrated in FIG. **5**, in two of the layers **31** adjacent to each other in the tire radial direction on the further outer side in the tire radial direction than the vertical line **25**, the bead core **21** may have a portion where the number of bead wires **30** in the layer **31** located relatively on the outer side in the tire radial direction is smaller by two than the number of bead wires **30** in the layer **31** located on the inner side in the tire radial direction. The form of the portion on the further outer side in the tire radial direction than the vertical line **25** is not limited, as long as the bead core **21** is formed to have a cross-sectional shape close to an octagon when viewed in a tire meridian cross-section, and the first layer **31a**, the second layer **31b**, and the third layer **31c** counted from the innermost circumference in the tire radial direction among the plurality of layers **31** formed by the bead wire **30** are formed as in the embodiment described above.

[0106] In addition, in the pneumatic tire **1** according to the embodiment described above, three reinforcing layers **60** are disposed; however, the reinforcing layers **60** with the number of layers other than three may be disposed. The number of the reinforcing layers **60** and the range in which the reinforcing layers **60** are disposed in the tire meridian cross-section may be different from the number and the range of the reinforcing layers **60** in the embodiment described above.

#### EXAMPLES

[0107] FIGS. **6A-6F** are tables indicating results of performance evaluation tests of pneumatic tires. Hereinafter, performance evaluation tests conducted on a pneumatic tire of Conventional Example and pneumatic tires **1** according to the embodiments of the present technology will be described. In the performance evaluation tests, durability tests for evaluating the durability of the pneumatic tire **1** were conducted.

[0108] In the performance evaluation tests, the pneumatic tire **1** having a tire nominal size of 37.25R35 was used as a test tire. The test tire was mounted on a rim wheel conforming to the TRA standard, the air pressure was adjusted to an air pressure defined in the TRA standard, and the tests were conducted with the tire subjected to a load specified by the TRA standard.

[0109] In the evaluation method for durability, a running test was conducted using an indoor drum testing machine with a load set to 120% of the maximum load specified by the TRA and a speed set to 10 km/h, and the durability was evaluated by expressing the breakage rate of the strand wires of the carcass cord in the bead portion when the pneumatic tire was run for 300 hours by an index with the conventional example described below being 100. With respect to the breakage rate of the strand wire, 40 carcass cords in the bead portion at the end of running were sampled at arbitrary positions, all the sampled carcass cords were observed, and the average value of (the number of broken strand wires in each carcass cord/the total number of strand wires in each carcass cord) was defined as the breakage rate.

[0110] The performance evaluation test was conducted on 24 types of pneumatic tires, in other words, the pneumatic tires of Conventional Example, which was an example of a known pneumatic

tire, and Examples 1 to 23, which were the pneumatic tires **1** according to the embodiment of the present technology. Of these pneumatic tires, the pneumatic tire of Conventional Example has a substantially hexagonal cross-sectional shape of the bead core in the tire meridian cross-section, and the bead core does not have vertical lines on the innermost side and the outermost side in the tire width direction.

[0111] In contrast, in all of Examples 1 to 23 corresponding to examples of the pneumatic tires **1** according to the embodiment of the present technology, the bead core **21** has the vertical lines **25** on the innermost side and the outermost side in the tire width direction, the length CV of the vertical line **25** of the bead core **21** is within the range of 31% or more and 45% or less with respect to the core height CH of the bead core **21**, and the distance Va from the bead core bottom surface **23** to the inner end portion **25a** of the vertical line **25** is within the range of 20% or more and 35% or less with respect to the core height CH. In addition, in the pneumatic tires **1** according to Examples 1 to 23, the ratio (CBW/CW) of the width CBW of the bead core bottom surface **23** to the maximum width CW of the bead core **21**, the ratio (Vb/CW) of the distance Vb between the vertical line **25** on the inner side in the tire width direction and the end portion **22** in of the bead core top surface **22** to the maximum width CW of the bead core **21**, the ratio (Vc/CW) of the distance Vc between the vertical line **25** on the inner side in the tire width direction and the end portion **23** in of the bead core bottom surface **23** to the maximum width CW of the bead core **21**, the ratio (CW/CH) of the maximum width CW of the bead core to the core height CH, and the number of ends of the carcass cords **6c** at the position on the inner side of the bead core **21** in the tire width direction are different from each other, respectively.

[0112] As a result of the performance evaluation tests using the pneumatic tires **1**, as illustrated in FIGS. **6A-6F**, it has been found that the pneumatic tires **1** according to Examples 1 to 23 have better breakage rates of the strand wires of the carcass cords **6c** of the bead portions **20** compared to the Conventional Example, and also breakages of the carcass cords **6c** in the bead portions **20** are less likely to occur. In other words, the pneumatic tires **1** according to Examples 1 to 23 can provide improved durability of the bead portion **20**.

## Claims

1. A pneumatic tire, comprising: a pair of bead portions disposed on both respective sides of a tire equatorial plane in a tire width direction; a bead core disposed in each of the pair of bead portions, formed by winding a bead wire into a ring shape, and having a polygonal cross-sectional shape in a tire meridian cross-section; and a carcass comprising a carcass body portion disposed extending between the pair of bead portions and a turned-up portion that is formed continuously from the carcass body portion and is folded back from an inner side in the tire width direction to an outer side in the tire width direction of the bead core, the carcass being formed by coating a carcass cord with a coating rubber; the bead core having a portion located on an innermost side in the tire width direction and a portion located on an outermost side in the tire width direction in a contour in the tire meridian cross-section each formed as a vertical line extending along a tire radial direction, the vertical line having a length within a range of 31% or more and 45% or less with respect to a core height that is a height of the bead core in the tire radial direction, the vertical line having a distance in the tire radial direction from a bead core bottom surface that is an inner circumferential surface of the bead core to an inner end portion in the tire radial direction of the vertical line within a range of 20% or more and 35% or less with respect to the core height, in the bead core, a plurality of circumferential portions of the bead wire wound in a ring shape being aligned in the tire width direction to form a layer, and a plurality of the layers being layered in the tire radial direction, and a number of the bead wires in the layer decreases by one toward the outer side in the tire radial direction on the further outer side in the tire radial direction than the layer including the bead wires forming an end portion on an outer side in the tire radial direction of the vertical line in the

plurality of layers, in the layer located on the inner side in the tire radial direction than the layer including the bead wire forming the inner end of the vertical line, in two of the layers adjacent to each other in the tire radial direction, the number of the bead wires in the layer located relatively on the outer side in the tire radial direction being larger by two or more than the number of the bead wires in the layer located on an inner side in the tire radial direction, and a misalignment amount in the tire width direction between the bead wires located at an end portion on one side in the tire width direction being one-half of the bead wire, and for a first layer that is the layer located on an innermost circumference in the tire radial direction, a second layer that is the layer layered adjacent to an outer side of the first layer in the tire radial direction, and a third layer that is the layer layered adjacent to an outer side of the second layer in the tire radial direction of the plurality of the layers, a side on which the misalignment amount between the bead wires in the first layer and the second layer is one-half of the bead wire being opposite in the tire width direction to a side on which the misalignment amount between the bead wires in the second layer and the third layer is one-half of the bead wire.

2. The pneumatic tire according to claim 1, wherein the bead core has a width of the bead core bottom surface in the tire meridian cross-section within a range of 45% or more and 70% or less with respect to a maximum width of the bead core.

3. The pneumatic tire according to claim 1, wherein the bead core has a distance in the tire width direction between an end portion on an inner side in the tire width direction on a bead core top surface that is an outer circumferential surface in the tire meridian cross-section and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to a maximum width of the bead core, has a distance in the tire width direction between an end portion on the inner side in the tire width direction on the bead core bottom surface and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to the maximum width of the bead core, and has the maximum width of the bead core within a range of 0.9 times or more and 1.4 times or less as large as the core height.

4. The pneumatic tire according to claim 1, wherein the carcass has the number of ends of the carcass cords at a position on the inner side in the tire width direction of the bead core within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less.

5. The pneumatic tire according to claim 2, wherein the bead core has a distance in the tire width direction between an end portion on an inner side in the tire width direction on a bead core top surface that is an outer circumferential surface in the tire meridian cross-section and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to a maximum width of the bead core, has a distance in the tire width direction between an end portion on the inner side in the tire width direction on the bead core bottom surface and the vertical line on the inner side in the tire width direction within a range of 10% or more and 25% or less with respect to the maximum width of the bead core, and has the maximum width of the bead core within a range of 0.9 times or more and 1.4 times or less as large as the core height.

6. The pneumatic tire according to claim 5, wherein the carcass has the number of ends of the carcass cords at a position on the inner side in the tire width direction of the bead core within a range of 10 cords per 50 mm or more and 20 cords per 50 mm or less.

7. The pneumatic tire according to claim 1, wherein a reinforcing layer is disposed in the pair of bead portions along the carcass at least inside the carcass body portion in the tire width direction, in the reinforcing layer, a plurality of reinforcing layers each having a plurality of cords are arranged in a stacked manner, In the plurality of reinforcing layers, inclination directions of the plurality of cords in the tire circumferential direction with respect to the tire radial direction are opposite to each other between adjacent reinforcing layers.

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