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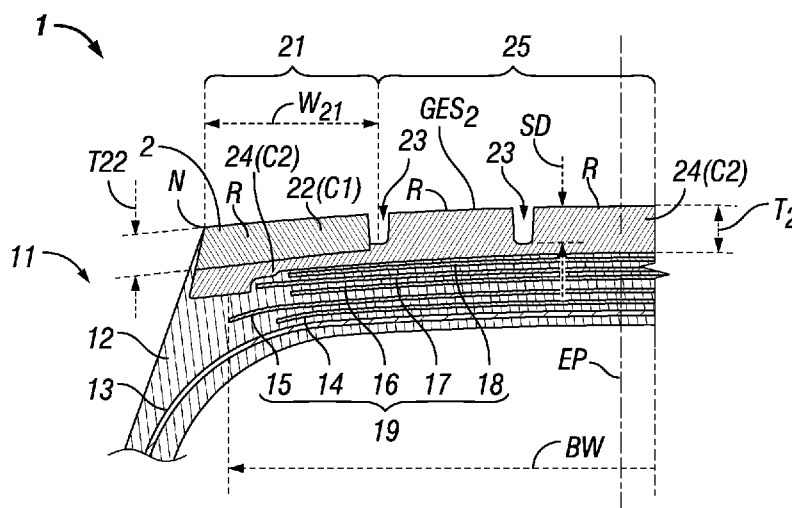


FIG. 4

(57) **Abstract:** Particular embodiments of the disclosure provide a tire tread having a width parsed at least into a pair of shoulder zones and a central zone. Each shoulder zone of the pair of shoulder zones is arranged adjacent to each shoulder edge of the pair of shoulder edges forms 15% to 40% of the rolling width. The central zone is arranged between the pair of shoulder zones and includes a plurality of sipes being spaced apart by an average distance to provide an average sipe density that is greater than an average sipe density for at least one shoulder zone. The shoulder zone is formed of at least partially of a first tread compound and the central zone is at least partially formed of a second tread compound along a common wear layer, the second compound being characterized as having lower wear resistance than the first compound.

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IMPROVED TREAD WEAR PROFILE WITH SIPED CENTER REGION

Field

[0001] Embodiments of this disclosure relate generally to tire tread and tires employing said treads.

BACKGROUND

[0002] It is known in the industry that tire designers must often compromise on certain characteristics of the tires they are designing. Changing a tire design to improve one characteristic of the tire will often result in a compromise; i.e., an offsetting decline in another tire characteristic. One such compromise exists between the use of sipes and tread wear rates.

[0003] It is often desirable to provide a tire that over time, wears generally evenly across the tread width. It is also often desirable to provide a greater density of sipes to the central region of a tire tread relative to the shoulder regions. Because the use of sipes can reduce the tread wear rate, providing a greater density of sipes in the central region reduces the wear rate of the central region relative to the shoulder regions, resulting in a difference in wear rates between the shoulder and central regions, the shoulder regions wearing at a faster rate relative to the central region.

[0004] Improved wear performance for faster wearing portions, such as the shoulder regions, can be improved by using a tread rubber compound having improved wear resistance properties or by providing a thicker tread. Employing a more wear resistant tread compound may result in lower traction or increased operating temperature and rolling resistance, which may not be desirable. Thickening the tread in each shoulder region typically results in an increase in operating temperature and rolling resistance, which may be undesirable. Improvements in wear performance for faster wearing shoulder regions may also be improved by lamellization, that is, by the addition of sipes, but this may lead to irregular wear in the shoulder, which is certainly undesirable.

[0005] Accordingly, there is a desire to provide a more uniform tread wear profile, that is, a more constant wear resistance across the width of the tire tread, when employing a greater density of sipes within a central region of a tire tread relative to a pair of opposing shoulder regions.

SUMMARY

[0006] Embodiments of the present disclosure include a tire tread comprising a length and a rolling width extending perpendicular to the length, the rolling width extending between a pair of opposing shoulder edges. The tire tread also includes a thickness extending perpendicular to both the length and width, the thickness extending depthwise from an outer, ground-engaging side to a bottom side configured for attachment to a tire, the length being greater than both the width and thickness, the width being greater than the thickness. The tread width includes a pair of shoulder zones, each shoulder zone of the pair of shoulder zones: (1) extends annularly around the tread; (2) is arranged adjacent to each shoulder edge of the pair of shoulder edges; and (3) forms 15% to 40% of the rolling width. The tread width further includes a central zone arranged between the pair of shoulder zones, the central zone extending annularly around the tread and including a plurality of sipes. Each sipe has a length, a height extending in a direction of the tread thickness, and a width extending between opposing side walls of the sipe, the width being sized such that the side walls come in and out of contact during tire operation. The plurality of sipes are spaced apart by an average distance to provide an average sipe density that is greater than an average sipe density for at least one shoulder zone. At least one shoulder zone is at least partially formed of a first tread compound and the central zone is at least partially formed of a second tread compound along a common wear layer, the second compound being characterized as having lower wear resistance than the first compound, each of the first and second compound forming an elastomeric material. Each of the first and second compound form an elastomeric material, where each of the first and second compounds are arranged in the respective zones along a common wear layer. Other embodiments include a tire comprising the tread arranged in an annular configuration and affixed to the tire, where the tread thickness extends in a radial direction of the tire and where the length extends annularly and perpendicular to the tread thickness.

[0007] The foregoing and other objects, features, and advantages will be apparent from the following more detailed descriptions of particular embodiments, as illustrated in the accompanying drawings wherein like reference numbers represent like parts of particular embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a partial perspective view of a tire;

[0009] FIG. 2 is a partial sectional view of a tire taken along a plane extending axially and radially relative to the tire, the partial section showing the tire tread, belt, and the associated portion of the tire carcass;

[0010] FIG. 3 is a top view of an exemplary tire tread having a pair of shoulder zones with a central zone arranged there between, the central zone including a plurality of sipes, whereby the central zone has a greater sipe density than either shoulder zone, in accordance with an exemplary embodiment;

[0011] FIG. 4 is a partially enlarged portion of FIG. 3 showing the presence of different tread compounds (also referred to as "elastomeric materials") in central and shoulder zones of the tire;

[0012] FIG. 5 is a partially enlarged portion of a tire showing the presence of different tread compounds in central and shoulder zones of the tire in accordance with an alternative embodiment relative to FIG. 4;

[0013] FIG. 6 is a partially enlarged portion of a tire showing the presence of different tread compounds in central and shoulder regions of the tire in accordance with an alternative embodiment relative to FIGS. 4 and 5; and,

[0014] FIG. 7 is a table showing particular parameters describing each of the shoulder and central compounds in accordance with an exemplary embodiment.

DEFINITIONS

[0015] As used herein, the "radial" direction is any direction in any plane that contains the axis of rotation of the tire.

[0016] As used herein, the "lateral", "transverse" or "axial" direction extends along the tire width and is parallel to the axis of rotation of the tire.

[0017] As used herein, the "circumferential" or "longitudinal" direction is perpendicular to both the radial and axial directions, and extends parallel to an equatorial plane of a tire.

[0018] As used herein, a "groove" is any elongate void or channel arranged within the tread having a pair of opposing side walls extending depthwise into the tread thickness and which

are commonly spaced apart by at least 2.0 mm or otherwise by an average distance as measured between the side walls for the entire depth of the groove by 2.0 mm or more. A groove is designed to have a width, based upon the depth of the groove, to remain open as the tread rolls into, through, and out of a contact patch. A “lateral groove” is a groove that extends in a direction oblique to the longitudinal direction (the circumferential direction). A “longitudinal groove” is a groove that extends substantially in the longitudinal direction. A “circumferential groove” is synonymous with a longitudinal groove, each of which extends annularly around the tire. A groove extends depthwise within a direction of the tread thickness greater than 0.5 mm in height.

[0019] As used herein, a “sipe” is any elongate void or incision arranged within the tread having a pair of opposing side walls extending depthwise into the tread thickness and which are commonly spaced apart by less than 2.0 mm or otherwise by an average distance as measured between the sidewalls for the entire depth of the groove that is less than 2.0 mm. The side walls of the sipe come into contact from time to time as the tread rolls in and out of the contact patch of the tire as the tire rolls on the ground. By lateral sipe, it is meant a sipe that extends in a direction that is oblique to the longitudinal direction. A sipe extends depthwise within a direction of the tread thickness greater than 0.5 mm in height.

[0020] As used herein, a “tread element” is a portion of the tread defined by one or more grooves and/or sipes arranged along the outer, ground-engaging side of the tread. Examples of tread elements include tread blocks and ribs.

[0021] As used herein, a “tread block” is a tread element having a perimeter that is defined by one or more grooves with or without a lateral side of the tread, thereby creating an isolated structure in the tread. A sipe does not define any portion of a tread block perimeter.

[0022] As used herein, a “rib” is a tread element that runs substantially in the longitudinal direction of the tire and that is bounded by a pair of longitudinal grooves or by a longitudinal groove and any of the pair of lateral sides defining a width of the tread. A rib may include any lateral features, which includes any lateral grooves and lateral sipes, as well as any arrangement of tread blocks. A solid rib may include sipes and lateral grooves, but is not interrupted by any lateral groove extending fully across a width of the rib in a substantially lateral direction or any other grooves oblique thereto

[0023] As used herein, “elastomeric material,” “elastomer,” and “rubber” are synonymous terms used herein to reference a polymer exhibiting rubber-like elasticity, such as a material comprising rubber, whether natural, synthetic, or a blend of both natural and synthetic rubbers.

[0024] The loss factor " $\tan(\delta)$ " is a dynamic property of the rubber compound. It is measured on a viscosity analyzer (Metravib VA4000) according to Standard ASTM D5992- 96. The response of a test specimen consisting of two cylindrical pellets each 2 mm thick and one centimeter in diameter is recorded (the test specimen is made from samples taken from a tire mid-way up the height of the layer concerned as close as possible to the region of the equatorial plane in a region that is thick enough to be able to form the test specimen), the specimen being subjected to simple alternating sinusoidal shear loadings at a frequency of 10 Hz, at a temperature of 60° C. The sweep covers amplitude of deformation from 0.1% to 50% peak to peak (on the outbound cycle) then from 50% to 1% peak to peak (on the return cycle). The results that are used here are the loss factor $\tan(\delta)$ and the complex dynamic shear modulus. The complex dynamic shear modulus is denoted "G*50" in reference to the 50% strain applied during the test. During the outbound cycle, the maximum value of $\tan(\delta)$ that is observed is denoted "max $\tan(\delta)$ ".

[0025] Dynamic properties “Tg” and “G*” for the rubber compositions were measured on a Metravib Model VA400 ViscoAnalyzer Test System in accordance with ASTM D5992-96. The response of a sample of vulcanized material (double shear geometry with each of the two 10 mm diameter cylindrical samples being 2 mm thick) was recorded as it was being subjected to an alternating single sinusoidal shearing stress of a constant 0.7 MPa and at a frequency of 10 Hz over a temperature sweep from – 60° C to 100° C. with the temperature increasing at a rate of 1.5° C/min. The dynamic shear modulus G* at 60° C. was captured and the temperature at which the max tan delta occurred was recorded as the glass transition temperature, Tg.

[0026] As used herein, "phr" is "parts per hundred parts of rubber by weight" and is a common measurement in the art wherein components of a rubber composition are measured relative to the total weight of rubber in the composition, i.e., parts by weight of the component per 100 parts by weight of the total rubber(s) in the composition.

[0027] As used herein, "based upon" is a term recognizing that embodiments of the present invention are made of vulcanized or cured rubber compositions that were, at the time of their

assembly, uncured. The cured rubber composition is therefore "based upon" the uncured rubber composition. In other words, the cross-linked rubber composition is based upon or comprises the constituents of the cross-linkable rubber composition.

[0028] Tread compound wear resistance testing, that is, testing the elastomeric material used to form portions of a tire tread described herein to determine the wear resistance characterizing each such tread compound for comparison purposes by determining corresponding wear performance data using the following testing standards: DIN 53516, DIN ISO 4649 (which replaced DIN 53516), and ASTM D 5963. Abrasion testing using DIN ISO 4649/ DIN 53516 measures the abrasion resistance of the tread compound by moving a test piece across the surface of an abrasive sheet mounted to a revolving drum, and is expressed as volume loss in cubic millimeters or abrasion resistance index in percent. For volume loss, a smaller number indicates better abrasion resistance, while for the abrasion resistance index, a smaller number denotes poorer abrasion resistance.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0029] The present disclosure concerns tire treads and tires to which said tire treads are affixed. These tire treads may be provided with new, original tires or may be provided separately, such as for retreading tires. These treads may also be used on pneumatic or non-pneumatic tires. It is appreciated that the tire may be used on any vehicle. In certain instances, the tire is a heavy truck tire used for tractor and trailers, and designed to endure for at least 100,000 to 200,000 miles, for example.

[0030] By way of example, FIGS. 1 and 2 show a pneumatic tire 1 having a crown portion 11 connected by respective sidewalls 12, 12' to bead portions. One or more body plies 13 extend radially from a bead core in a bead portion to an opposite bead core in an opposite bead portion. Beads, body ply(s) and sidewalls are generally referred together as the tire sub-casing or carcass.

[0031] In the crown portion 11 of the tire, radially inward tire tread 2 and radially outward the sub-casing and body ply(s) 13 is a belt 19 comprised of belt plies 14, 15, 16, 17 and 18. While any quantity of belt plies may be employed, in particular instances at least two belts are provided. In the embodiment shown, belt 19 includes a plurality of belt plies comprising a breaker ply 14, working plies 15 and 17 (so called because they provide reinforcements at angle to one another and at angle to the body ply reinforcements. Belt ply 16 may be a

helicoid winding of circumferential reinforcements (often called "zero degree reinforcements" because they run at an angle close to zero degree relative to the circumferential direction of the tire). Belt ply **18** may be a protector ply.

[0032] As used herein, the term "ply" or "plies" refers to a reinforcement layer of the tire and is not limited to a particular method of manufacturing the tire or of manufacturing the ply itself. The assembly of those circumferential (annular) belt plies is generally referred to as a belt or belt package **19**. This reinforced structure may comprise a lower or greater number of plies or a different arrangement of them depending upon the exact tire type and upon its manufacturing process but this principle is widely known and used in heavy truck tires. A belt width **BW** is defined as the greatest axial distance between remote belt edges of any belt ply in the belt **19**. The assembly of the sub-casing and the belt is generally referred as the casing. Equatorial plane **EP** bisects tire **1** into opposing halves of substantially the same construction.

[0033] A tire tread **2** is attached annularly around the above described reinforced structure. The tread includes an outer, ground-engaging side **GES₂** that is configured to contact the ground when the tire is rolling. This area of contact is referred to as a contact patch. The tread thickness **T₂** extends from the outer, ground-engaging side **GES₂** and to a bottom side configured to attach the tread to the tire. When arranged along a tire, the tread thickness extend radially (in a radial direction), where the length extends annularly and perpendicular to the tread thickness. A rolling tread width **RTW** is defined as the distance from a first edge **N** to an opposite second edge **N'** of the tread, and is commonly narrower than the bottom side. The tread edges **N**, **N'** are defined as the maximum axial locations where the tread of the tire no longer comes in contact with the ground under standard, straight rolling conditions (75% of the TRA load at standard pressure for the tire). These locations do not account for tread that may intermittently come in contact (such as is the case for a sacrificial rib). It is appreciated that any tread contemplated herein may comprise any number of void features, including grooves **23** extending in any shape or form, to provide grip over different surfaces and to evacuate water from a contact patch when rolling on a wet surface. In a new tread, the maximum depth of those grooves is generally referred to as the skid depth **SD**.

[0034] With reference to FIGS. **2** and **3**, each tire tread **2** is shown to include an outer, ground-engaging side **GES₂** together with other void features. In embodiment shown, the lateral width of the tire tread **2** is divided into zones comprising a pair of shoulder zones **21**

with a central zone **25** arranged there between. Each zone is characterized as having different tread compounds arranged along a common tread wear layer, where along said wear layer the central zone is formed of one or more tread compounds each characterized as having a wear rate that is greater than any tread compound used to form at least one or both of the shoulder zones along the common wear layer. The tread compounds are discussed more fully elsewhere herein. Each shoulder zone **21** is arranged at one of the pair of tread edges **N**, **N'**. The central zone **25** is arranged between shoulder zones **21**. It is appreciated that in different embodiments, the central zone may extend from one shoulder zone to the other shoulder zone, or may form one zone of multiple zones arranged between the pair of shoulder zones, where the other zones arranged between the central zone and the shoulder zones may be referred to as intermediate zones (not shown). In any such embodiment, such as is exemplary shown in FIG. 2, the central zone **25** may be arranged such as to include the widthwise centerline of the tread, which is arranged within equatorial plane **EP** of the tire.

[0035] While not necessary, in particular embodiments, any one or more zones are formed of one or more tread ribs. For example, with reference to FIG. 3, each zone **21**, **25** is formed of one or more ribs **R**. In the embodiment shown, each shoulder zone **21** forms a solid rib free of any sipes or grooves extending across the full width of any such rib. The solid ribs **R** shown, however, include ornamental, non-functional surface void features **30** extending across each shoulder rib width and into the tread thickness by 0.5 mm or less from the outer, ground-engaging side **GES₂** of the tread in a new condition. These surface void features **30** are not typically included in any assessment or quantification of functional void content, such as in the determination of surface or volumetric void ratios.

[0036] With reference to the central zone, a plurality of sipes **32** are arranged therein and spaced apart in the longitudinal direction **D_{Long}**, which is parallel to the equatorial plane **EP**. The sipes extend across the full width of each corresponding central rib **R** along a non-linear path.

[0037] It is appreciated that the tire tread may employ any sipe of any type, style, or configuration. For example, any sipe employed may extend along any linear or non-linear path in the depthwise and/or lengthwise directions, and may extend partially or fully across the width of a tread element, whether a rib or tread block. It is further appreciated that the sipe may be a tear drop sipe, where a void, such as a groove, is arranged at or near a bottom of the sipe, thereby providing a submerged void.

[0038] It is further appreciated that for the central zone, the average sipe-to-sipe spacing may be any distance as desired, so long as there is a smaller sipe-to-sipe spacing in the central zone than an average sipe-to-sipe spacing for any shoulder zone, should any shoulder zone include any sipes. With reference to FIG. 3, this average sipe-to-sipe spacing is obtained by measuring the distance S between adjacent sipes **32** in the longitudinal direction D_{LONG} of the tread, and averaging all such spacing measurements for the corresponding zone. The average sipe-to-sipe spacing is referred to as sipe density. The smaller the average sipe-to-sipe spacing, the greater the sipe density. The sipe-to-sipe spacing may be measured from a sipe widthwise centerline to a sipe widthwise centerline or by measuring the space between adjacent sipes (sidewall-to-sidewall), where such measurements are averaged for the length of each sipe, where the sipe length may be linear or non-linear. It is also appreciated that the length and/or depth of any sipe may extend along any linear or non-linear path. Any manner known by one of ordinary skill may be employed to measure sipe density for any corresponding tire tread. In the tread shown in FIG. 3, because sipes **32** are included in the central zone **25** while no sipes are shown in either shoulder zone **21**, the average sipe density in the central zone **25** is necessarily greater than the average sipe density in each shoulder zone. It is noted that the sipes shown have lengths extending across each rib R , the lengths being non-linear, that is, lengths extending along non-linear paths. In other variations, it is contemplated the sipe density of the central zone may be greater than the sipe density of only one shoulder zone of the pair of shoulder zones. When the average sipe density of the central zone is greater than the average sipe density of any one or both shoulder zones, it is appreciated that any such shoulder zone may or may not include sipes. It is also contemplated that sipes may be included in any one or both shoulder zones, where the arrangement of sipes along any one or both shoulder zones may provide a sipe density that is less than the average sipe density of the central zone.

[0039] As stated previously, each widthwise tread zone is characterized as having different tread compounds arranged along a common tread wear layer, where along said wear layer the central zone is formed of one or more tread compounds each characterized as having a wear rate that is greater than any tread compound used to form at least one or both of the shoulder zones along the common wear layer. A wear layer is an anticipated depthwise location of the outer, ground-engaging side during the worn life of the tread, the wear layer forming the initial wear layer, namely, the original outer, ground-engaging side of the tread or a subsequent location of the outer, ground-engaging side after a depth of the tread thickness is

worn away. For purposes herein, any subsequent wear layer is spaced a uniform distance (depth) into the tread thickness from the original outer, ground-engaging side, when the tread is in a new, unworn condition. It is appreciated that typically, the anticipated worn life of the tread life extends to the skid depth, that is, to the bottom of the deepest groove arranged in the tread.

[0040] With reference to FIG. 4, according to an embodiment, tire **1** has a tread with a central zone **25** and a shoulder zone **21** defined by the use of different compounds. For the useful thickness of the tire tread **2**, that is, for the thickness of the tread extending depthwise to the skid depth **SD**, the shoulder zone **21** is formed of a first compound **C1**, that is, a first elastomeric material, while the central zone is formed of a second compound **C2**, that is, a second elastomeric material, the second elastomeric material being characterized as having a higher wear rate (that is, lower wear resistance) than the first elastomeric material. Accordingly, it can be said that the first and second compounds **C1**, **C2**, and the relational difference in wear resistance is provided at all wear layers (worn stages) of tread **2** since each compound **C1**, **C2** extends fully from the outer, ground-engaging side **GES₂** and to the skid depth **SD**. It is appreciated that these compounds may continue through the full tread thickness **T₂** to a bottom of the tread facing the belt **19**. It is appreciated, in other variations that any zone may include one or more tread compounds at different tread depths while still providing a wear layer including the first and second compounds **C1**, **C2** and the relational difference in wear resistance. These additional compounds may be arranged within the usable tread thickness (that is, the thickness of the tread extending from the outer, ground-engaging side **GES₂** to the skid depth **SD**), whether extending partially or fully within the usable tread thickness and/or may be arranged below the skid depth **SD**. When arranged partially within the usable tread thickness, where any such tread includes multiple layers (that is, 2 or more layers) within the usable tread thickness of any zone, it is appreciated that compounds **C1** and **C2** may each form an initial, radially outer layer arranged along the outer, ground-engaging side of a new tire tread or may be arranged below any initial, radially outer layer in a submerged layer spaced apart from the outer, ground-engaging side in a new tire tread condition. The submerged layer is exposed when a sufficient amount of tread thickness is worn away, such that at least a portion of the submerged layer forms at least a portion of the outer, ground-engaging side.

[0041] For example, in FIG. 4, while each of the first and second compounds **C1**, **C2** could extend the full tread depth, shoulder zone **21** optionally includes another compound by virtue of providing two different layers: a radially outer shoulder layer **22** and a radially lower shoulder layer **24**. The outer shoulder layer **22** is intended to come into contact with the ground when the tire is rolling and the inner shoulder layer **24** is interposed between the outer shoulder layer **22** and the belt **19**. The shoulder zone **21** and outer shoulder layer **22** extends axially from edge **N** inward to the first groove **23** over a distance W_{21} , defining a width of the shoulder zone **21**. In this embodiment, the outer shoulder layer **22** has a thickness T_{22} that is optionally equal to about 110% of the skid depth **SD** over the full zone width W_{21} . The width W_{21} of shoulder zone **21**, in this embodiment, represents 18% of the rolling tread width **RTW**. The thickness of the lower shoulder layer **24** is greater than 4 mm over the portion of the shoulder zone which covers the belt **19**. It is appreciated that shoulder zone width W_{21} may be greater or less than 18% of the rolling tread width **RTW** in other variations.

[0042] In the embodiment shown in FIG. 4, the first compound **C1** is arranged in the radially outer shoulder layer **22** while a different compound is arranged in radially inner shoulder layer **24**, the radially outer shoulder tread compound **C1** having higher wear resistance characteristics (properties) relative to the central tread compound **C2**, which also forms the compound used to form the lower shoulder tread layer **24**. Accordingly, central compound **C2** extends the full tread thickness T_2 . This second compound **C2** may optionally have better rolling resistance characteristics than the first compound. In other variations, in lieu of the central compound **C2** extending below a radially outer shoulder layer **22**, the shoulder zone may be formed of a single compound extending the full tread thickness T_2 and extend into the central zone as a radially inner central layer, which would be arranged radially inward one or more radially outer central layers. Of course, more than two compounds may be arranged at different tread depths to form different wear layers within the tread thickness for any zone.

[0043] FIG. 5 shows another embodiment providing a shoulder zone **21** and a central zone **25**, where each zone is of variable width and depth. In particular, at an early wear layer, the shoulder zone **21** has a width W_{21} including two ribs (and thereby extends beyond the first shoulder groove **23**), where in a later wear layer the shoulder zone **21** is narrower in width as it only includes a single rib. Accordingly, the central zone **25** is narrower in the early wear layer than in the later wear layer. The shoulder zone **21** is again formed of multiple tread compound layers, namely, radially outer and radially inner shoulder layers **22**, **24**, which are

formed of compounds **C1** and **Cx** respectively. **Cx** is a compound different from **C1** and **C2**. In this embodiment, the central zone **25** also is formed of multiple tread compounds (**C2** and **Cx**). Specifically, while central zone **25** includes compound **C2** arranged in a radially outer central layer, inner shoulder layer **24** of compound **Cx** extends across the full tread width to also form a radially inner central layer, which is also arranged below the skid depth of the tread. The shoulder zone width W_{21} at its maximum in the early wear layer is about 25% of the rolling tread width **RTW**, which is wider than the shoulder zone width W_{21} shown in FIG. 4. While the variable width of the shoulder and central zones **21**, **25** tapered with increasing and decreasing tread depths, in other variations, an abrupt change in width may occur with no tapering with increasing and decreasing tread depths.

[0044] FIG. 6 shows another embodiment, also a variation of the embodiment of FIG. 4. While the embodiment of FIG. 6 also provides a shoulder zone **21** having multiple tread compound layers, namely, radially outer and radially inner shoulder layers **22**, **24** formed of tread layers, namely, radially outer shoulder layer **22** and radially inner shoulder layer **24**, where the radially outer and inner shoulder layers **22**, **24** are formed of different compounds **C1** and **Cx**, respectively. The central zone **25** also has multiple tread layers, the multiple layers being arranged within the useful thickness of the tread, that is, within a thickness of the tread extending depthwise to the skid depth **SD**. The multiple central tread layers comprise radially outer central layer **26** and radially inner central layer **28**. It is appreciated that compounds used in each of the outer and inner central layers **26**, **28** are different, and are shown as compounds **C2** and **Cy** respectively. It can be said that inner shoulder layer **24** also forms a second radially inner layer of central zone **25**. In the embodiment shown, compound **C2** forms the outer central layer **26** while compound **C1** forms the outer shoulder layer **22**, where each of the radially outer shoulder and central layers **22**, **26** formed of compounds **C1** and **C2**, respectively, are arranged along a common wear layer. In other variations, compound **C2** forms the inner central layer **28** while **C1** continues to form outer shoulder layer **22**, where each **C1** and **C2** are arranged along a common wear layer. It is appreciated that just as usable tread thickness of the central zone **25** is parsed into multiple layers, so can shoulder zone **21** – additionally or in the alternative. The compound used to form the radially inner central layer may be formed of compound **C1** or any other compound having desired characteristics. Likewise, the compound used to form inner shoulder layer **24** may be formed of any compound having desired characteristics, which could be compound **C2** or the other compound forming the other central layer.

[0045] In each of the embodiments shown in FIGS. 4 to 6, it is appreciated that in certain embodiments, when another tread compound is employed and arranged below any of first and second compounds **C1**, **C2**, and any third compound when present in the opposing shoulder zone, in certain variations the other tread compound has a lower or equivalent complex dynamic shear modulus relative to the first, second, and third tread compounds and/or has a lower or equivalent maximum tan delta relative to the first, second, and third tread compounds.

[0046] It is appreciated that any aspect or feature of the embodiments discussed above in association with FIGS. 4-6, including all variations thereof, may be separated and combined with other such features to arrive at any different combination of features not shown to arrive at any desired tread design, where one or more wear layers provide a first compound in the shoulder zone and a second compound in the central zone, where the first compound has higher wear resistance than the second compound. It is appreciated that along any common wear layer, in each zone, one or more additional compounds may or may not be present. In certain instances when any additional compounds are present along a common wear layer, any additional compound in a shoulder zone has higher wear resistance than any compound within the central zone. In certain instances when any additional compounds are present along a common wear layer, any additional compound in a central zone has lower wear resistance than any compound within at least one shoulder zone or both shoulder zones. It is also appreciated that the tire shown in FIGS. 4-6 may or may not be symmetrical relative to equatorial plane **EP**.

[0047] It is contemplated that the shoulder zone width W_{21} may form any width, which may be constant or variable along the length of the tread, although in certain embodiments, shoulder zone width W_{21} is 15% to 40% of the rolling tread width **RTW**.

[0048] In particular embodiments, any tread compound arranged in at least one or both shoulder zones along a common wear layer has a higher complex dynamic shear modulus (G^*) than a tread compound arranged in the central zone along a common wear layer. In the same or different embodiments, any tread compound used in at least one or both shoulder zones along a common wear layer has a higher maximum tan delta than a tread compound arranged in the central zone along a common wear layer. In certain instances, the maximum tan delta of the tread compound arranged in at least one of both shoulder zones is at least 0.02 greater than the maximum tan delta of the central zone tread compound.

[0049] In achieving a tread compound for the central zone that has a lower wear resistance than any tread compound arranged in either or both shoulder zones along a common wear layer, the oil content in the shoulder zone tread compound(s) is/are lower than the central zone tread compound. Additionally or separately, in achieving a tread compound for the central zone that has a lower wear resistance than any tread compound arranged in either or both shoulder zones along a common wear layer, the shoulder zone tread compound(s) includes/include more reinforcing filler, such as carbon black, silica, mica, etc., than the central zone tread compound.

[0050] Tires according to the invention demonstrate a break in the compromise of performances described in the preamble of this specification.

[0051] The rubber compounds used for the central zone and for the lower shoulder layer may be based upon natural rubber or upon synthetic polyisoprene with a majority of cis- 1,4 chains and possibly on at least one other diene elastomer and of a reinforcing filler consisting:

- (i) either of a white filler of the silica and/or alumina type having SiOH and/or AlOH surface functions, selected from the group formed by precipitated or pyrogenic silicas, aluminas or aluminosilicates, with a specific surface area in the range between 120 and 200 m²/g, used in a loading between 0 phr and 70 phr,
- (ii) or of a blend of carbon black having a CTAB specific surface area of between 20 and 120 m²/g in a loading greater than or equal to 0 phr and less than or equal to 25 phr and of a white filler described in (i), in which the overall content of filler is between 40 phr and 70 phr.

[0052] The CTAB specific surface area is determined according to AFNOR Standard NFT 45-007 (November 1987, method B).

[0053] If a clear filler or white filler is used, a coupling and/or coating agent, chosen from agents known to those skilled in the art, must be used. Examples of preferred coupling agents that may be mentioned are sulphurized alkoxysilanes of the bis-(3-trialkoxysilylpropyl) polysulphide type, and of these, notably, the bis(3-triethoxysilylpropyl) tetrasulphide marketed by Degussa under the trade names Si69 for the pure liquid product and X50S for the solid product (blended 50/50 by weight with N330 black). Examples of coating agents that may be mentioned are fatty alcohol, alkylalkoxysilane such as hexadecyltrimethoxy or

triethoxy silane marketed by Degussa under the trade names Si 116 and Si216 respectively, diphenylguanidine, polyethylene glycol, and silicone oil, modified by means of the OH or alkoxy functions if required. The coating and/or coupling agent is used in a proportion of between 1/100 and 20/100 by weight to the filler, and preferably in the range from 2/100 to 15/100 if the clear filler forms the whole of the reinforcing filler and in the range from 1/100 to 20/100 if the reinforcing filler is formed by a blend of carbon black and clear filler.

[0054] Other examples of reinforcing fillers, having the morphology and SiOH and/or AIOH surface functions of the materials of the silica and/or alumina type described above and suitable for use according to the invention in total or partial replacement of these, that may be mentioned include carbon blacks modified either during synthesis by the addition of a silicon and/or aluminum compound to the oil supplied to the furnace, or after synthesis by the addition of an acid to an aqueous suspension of carbon black in a sodium silicate and/or aluminate solution so as to coat at least part of the surface of the carbon black with SiOH and/or AIOH functions. Some non-limiting examples of this type of carbonated filler with SiOH and/or AIOH surface functions that may be mentioned are the CSDP fillers described at Conference No. 24 of the ACS Meeting, Rubber Division, Anaheim, Calif., 6-9 May 1997, and those mentioned in patent application EP-A-0 799 854.

[0055] If a clear filler is used as the sole reinforcing filler, the properties of hysteresis and cohesion are obtained by using a precipitated or pyrogenic silica or a precipitated alumina or an aluminosilicate with a CTAB specific surface area in the range from 120 to 180 m²/g. Some non-limiting examples of this type of filler that may be mentioned are the silicas: KS404, marketed by Akzo, Ultrasil VN2 or VN3 and BV3370GR marketed by Degussa, Zeopol 8745 marketed by Huber, Zeosil 175MP or Zeosil 11 65M marketed by Rhodia, HI-SIL 2000 marketed by PPG, etc.

[0056] Among the diene elastomers that may be used in a blend with natural rubber or a synthetic polyisoprene with a majority of cis-1,4 chains, mention may be made of polybutadiene (BR), preferably with a majority of cis-1,4 chains, styrene-butadiene copolymer (SBR) solution or emulsion, butadiene-isoprene copolymer (BIR), or even styrene-butadiene-isoprene terpolymer (SBIR). These elastomers may be elastomers modified during polymerization or after polymerization by means of branching agents such as divinylbenzene or star forming agents such as carbonates, tin halogens and silicon halogens, or alternatively by means of functionalizing agents causing oxygenated carbonyl, carboxyl functions or an

amine function to be grafted on to the chain or at the end of the chain, by the action of dimethyl- or diethylamino-benzophenone for example. In the case of blends of natural rubber or synthetic polyisoprene with a majority of cis-1,4 chains with one or more diene elastomers, mentioned above, the natural rubber or synthetic polyisoprene is preferably used in a majority proportion and more preferably in a proportion of more than 70 phr.

[0057] For example, in the configurations where the tread includes a common wear layer in which a tread compound for the central zone that has a lower wear resistance than a tread compound arranged in either or both shoulder zones along the common wear layer, those compounds may be as described in the table shown in FIG. 7.

[0058] It should be understood from the foregoing description that various modifications and changes may be made to the embodiments of the present invention without departing from its true spirit. For example, due to the lack of electrical conduction of some rubber compounds, it is well known that tire treads may include provisions to conduct static electricity between the ground and the tire rim. Those provisions can include specific compounds or layer profiles being inserted in the tread for this specific purpose. It is understood that such limited variations are not in contradiction to the spirit of the invention and should not influence the way the invention is perceived from the above description or the appended claims.

[0059] To the extent used, the terms “comprising,” “including,” and “having,” or any variation thereof, as used in the claims and/or specification herein, shall be considered as indicating an open group that may include other elements not specified. The terms “a,” “an,” and the singular forms of words shall be taken to include the plural form of the same words, such that the terms mean that one or more of something is provided. The terms “at least one” and “one or more” are used interchangeably. The term “single” shall be used to indicate that one and only one of something is intended. Similarly, other specific integer values, such as “two,” are used when a specific number of things is intended. The terms “preferably,” “preferred,” “prefer,” “optionally,” “may,” and similar terms are used to indicate that an item, condition or step being referred to is an optional (i.e., not required) feature of the embodiments. Ranges that are described as being “between a and b” are inclusive of the values for “a” and “b” unless otherwise specified.

CLAIMS

What is claimed is:

1. A tire tread comprising:

a length and a rolling width extending perpendicular to the length, the rolling width extending between a pair of opposing shoulder edges,

a thickness extending perpendicular to both the length and width, the thickness extending depthwise from an outer, ground-engaging side to a bottom side configured for attachment to a tire, the length being greater than both the width and thickness, the width being greater than the thickness,

where the tread width includes a pair of shoulder zones, each shoulder zone of the pair of shoulder zones: (1) extends annularly around the tread; (2) is arranged adjacent to each shoulder edge of the pair of shoulder edges; and (3) forms 15% to 40% of the rolling width,

the tread width further includes a central zone arranged between the pair of shoulder zones, the central zone extending annularly around the tread and including a plurality of sipes, each sipe having a length, a height extending in a direction of the tread thickness, and a width extending between opposing side walls of the sipe, the width being sized such that the side walls come in and out of contact during tire operation, the plurality of sipes being spaced apart by an average distance to provide an average sipe density that is greater than an average sipe density for at least one shoulder zone,

where at least one shoulder zone is at least partially formed of a first tread compound and the central zone is at least partially formed of a second tread compound along a common wear layer, the second compound being characterized as having lower wear resistance than the first compound, each of the first and second compound forming an elastomeric material.

2. The tire tread of claim 1, where the average sipe density of at least one shoulder zone is zero.
3. The tire tread of any one of claims 1 and 2, where the plurality of sipes in the central zone are spaced apart by an average distance to provide an average sipe density that is greater than an average sipe density characterizing each of the pair of shoulders.

4. The tire tread of any one of claims 1 to 3, where the first tread compound has a higher complex dynamic shear modulus than the second tread compound.
5. The tire tread of any one of claims 1 to 4, where the first tread compound has a higher maximum tan delta than the second tread compound.
6. The tire tread of claim 5, where the maximum tan delta of the first tread compound is at least 0.02 greater than the maximum tan delta of the second tread compound.
7. The tire tread of any one of claims 1 to 6, where the first tread compound has an oil content lower than an oil content in the second tread compound.
8. The tire tread of any one of claims 1 to 7, where the first tread compound includes more reinforcing filler than the second tread compound.
9. The tire tread of any one of claims 1 to 8, where both shoulder zones are at least partially formed of the first elastomeric material.
10. The tire tread of any one of claims 1 to 8, where the other shoulder zone of the pair of shoulder zones is formed of a third tread compound different from the first and second tread compounds, the third tread compound forming an elastomeric material and being characterized as having higher wear resistance than the second tread compound, where each of the first, second, and third compounds are arranged in the respective zones along a common wear layer.
11. The tire tread of claim 10, where the second tread compound has a lower complex dynamic shear modulus than the first and third tread compounds.
12. The tire tread of any one of claims 10 and 11, where the second tread compound has a lower maximum tan delta than the first and third tread compounds.
13. The tire tread of claim 12, where the maximum tan delta of each of the first and third tread compounds is at least 0.02 greater than the maximum tan delta of the second tread compound.
14. The tire tread of any one of claims 10 to 13, where each of the first and third tread compounds has an oil content lower than an oil content in the second tread compound.
15. The tire tread of any one of claims 10 to 14, where each of the first and third tread compounds includes more reinforcing filler than the second tread compound.

16. The tire tread of any one of claims 1 to 15, where each shoulder zone also includes a plurality of sipes spaced apart by an average distance, the average distance by which the plurality of sipes are spaced apart in each shoulder zone is greater than an average distance by which the plurality of sipes in the central zone.
17. The tire tread of any of claims 1 to 9, where there is at least one other tread compound forming an elastomeric material located radially inward from the first and/or second tread compound in the respective zones.
18. The tire tread of claim 17, where the at least one other tread compound has a lower or equivalent complex dynamic shear modulus relative to the first and second tread compounds.
19. The tire tread of any one of claims 17 and 18, where the at least one other tread compound has a lower or equivalent maximum tan delta relative to the first and second tread compounds.
20. The tire tread of any of claims 10 to 15, where there is at least one other tread compound forming an elastomeric material located radially inward from the first, second, and/or third tread compound in the respective zones.
21. The tire tread of claim 20, where the at least one other tread compound has a lower or equivalent complex dynamic shear modulus relative to the first, second, and third tread compounds.
22. The tire tread of any one of claims 20 and 21, where the at least one other tread compound has a lower or equivalent maximum tan delta relative to the first, second, and third tread compounds.
23. A tire comprising:
the tread according to any one of claims 1 to 22, the tread arranged in an annular configuration and affixed to the tire, where the tread thickness extends in a radial direction of the tire and where the length extends annularly and perpendicular to the tread thickness.
24. The tire of claim 23, where the tire is a heavy truck pneumatic tire.

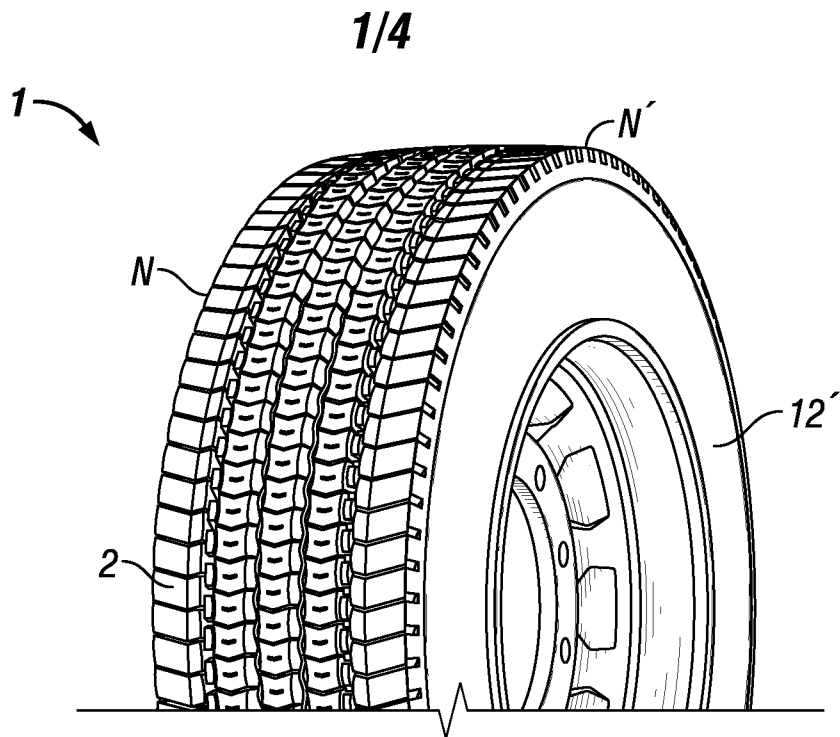


FIG. 1

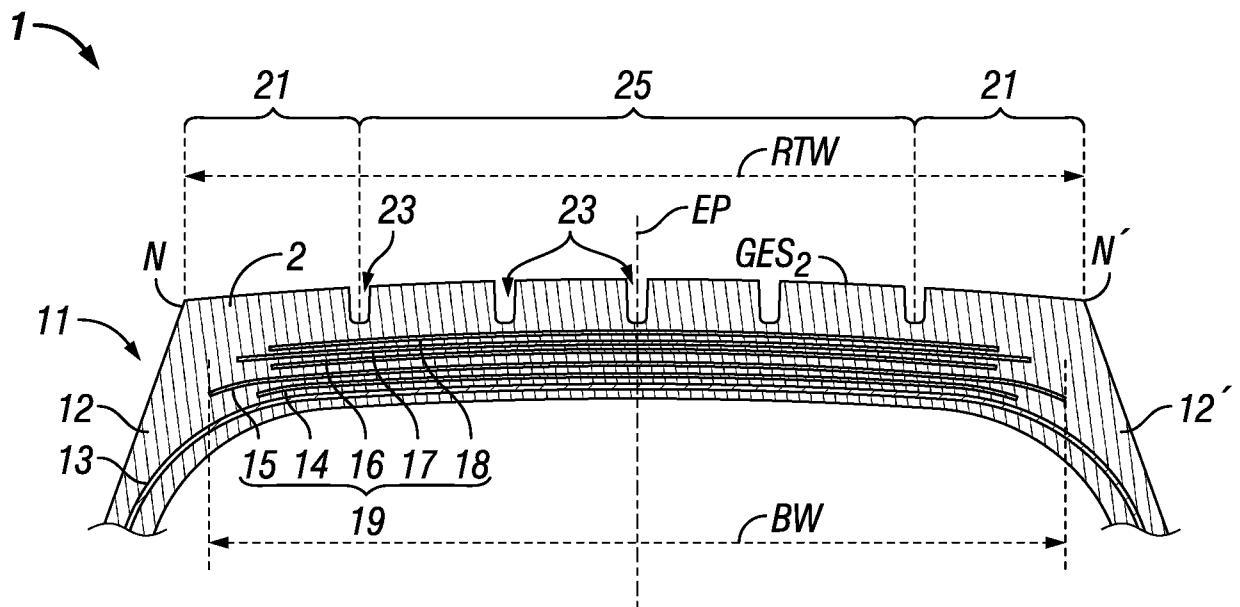


FIG. 2

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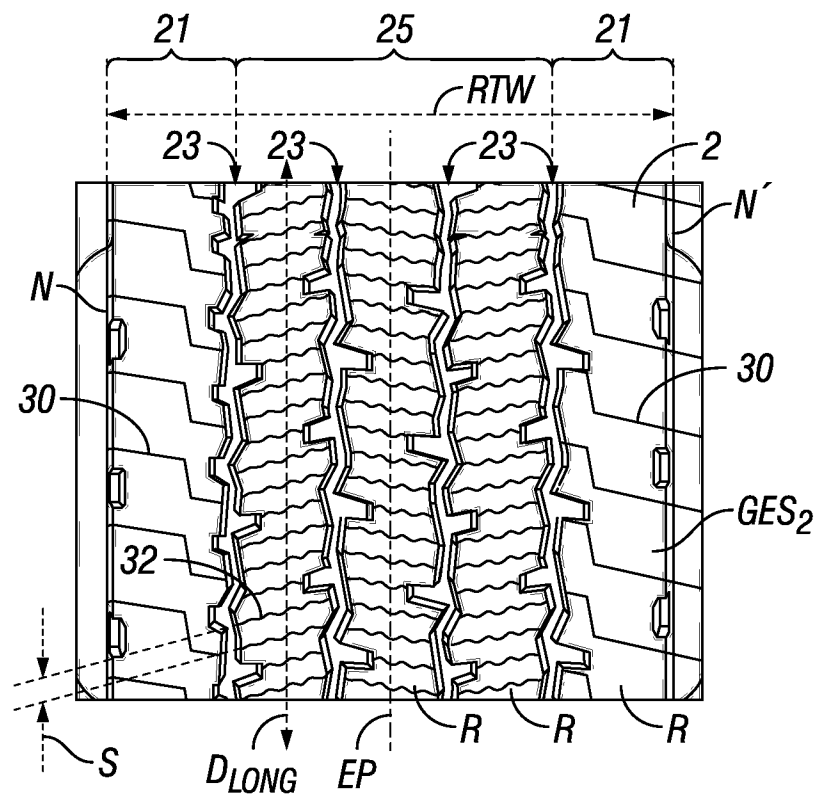


FIG. 3

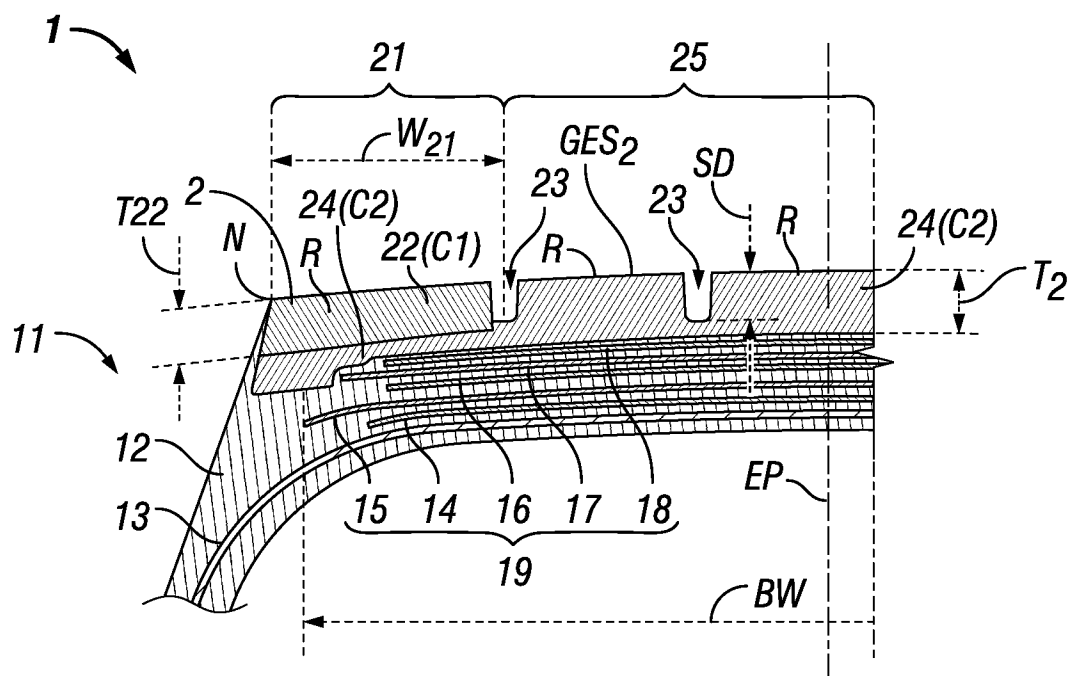


FIG. 4

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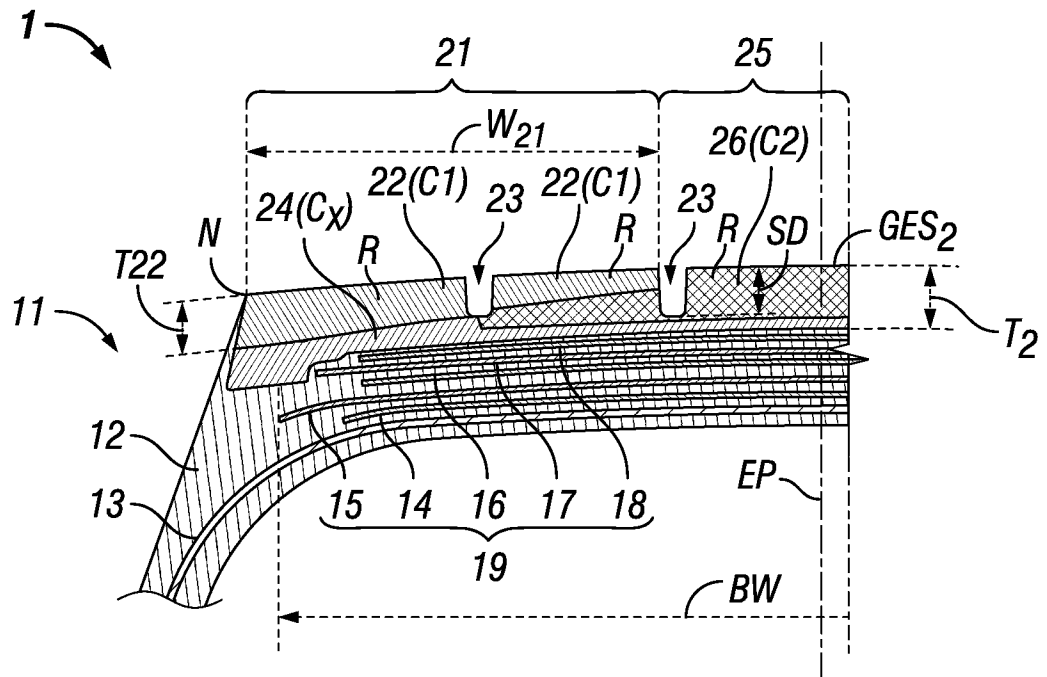


FIG. 5

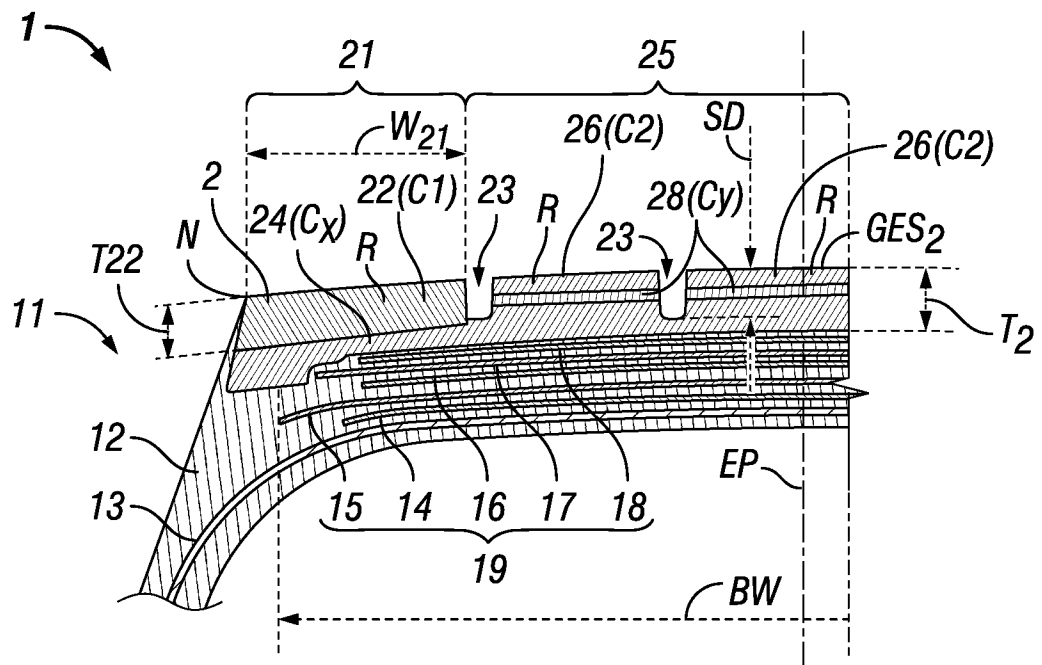


FIG. 6

4/4

	SHOULDER COMPOUND	CENTER COMPOUND
NR (PHR)	80	100
BR (PHR)	20	
N234 (PHR)	49	5.7
SILICA (160 m ² /g) (PHR)		38
N330/COUPLING AGENT (PHR)		3.8/3.8
ANTI DEGRADANTS (SUCH AS PARAFFIN, ANTI-OXIDANT) (PHR)	4	2.5
CURE PACKAGE (SUCH AS STEARIC ACID, ZnO, SULPHUR, ACCELERATOR) (PHR)	6.58	8.64
COVERING AGENT (PHR)		0.33
G* 50% CC/60°C (MPA)	1.6	1.4
MAX TAN (δ)	0.13	0.06

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/040361

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60C11/00 B60C11/12
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2017/116834 A1 (MICHELIN & CIE [FR]; MICHELIN RECH TECH [CH]; TROWBRIDGE JEREMY [US];) 6 July 2017 (2017-07-06) abstract; figures 1, 5, 9 paragraph [0038] - paragraph [0039] paragraph [0046] - paragraph [0051] paragraph [0059] - paragraph [0067] paragraph [0073] - paragraph [0074] -----	1-24
Y	JP H03 125606 A (TOYO TIRE & RUBBER CO) 29 May 1991 (1991-05-29) abstract; figures 1-3, 5 paragraph [0001] - paragraph [0008] -----	1-24
Y	US 5 833 779 A (VAN DER MEER ALEX [DE] ET AL) 10 November 1998 (1998-11-10) abstract; figures 1-3 column 1, line 12 - line 34 ----- -/-	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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Date of the actual completion of the international search

18 September 2018

Date of mailing of the international search report

19/10/2018

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Ozdemir, Anil

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/040361

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/039249 A1 (TAKAHASHI SOUICHI [JP]) 11 February 2016 (2016-02-11) abstract; figures 2, 3; table 1 paragraph [0004] - paragraph [0007] paragraph [0012] - paragraph [0022] -----	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

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