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(54) **Title:** TIRE TREADS HAVING INCREASING BLOCK LENGTHS FROM SHOULDER TO CENTER OF TREAD

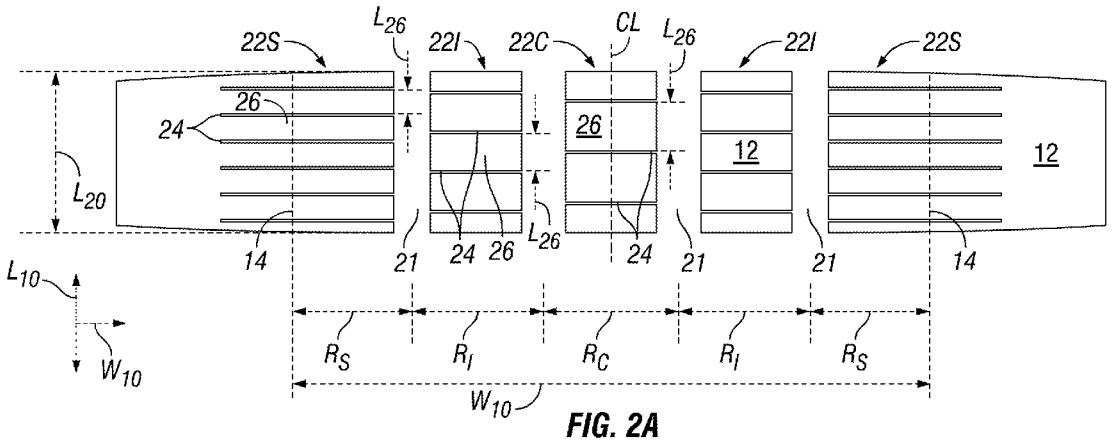


FIG. 2A

(57) **Abstract:** Particular embodiments provide a tire tread having a plurality of tread elements and a plurality of lateral discontinuities arranged along the tread width and tread length, each of the plurality of tread elements being spaced apart by one of the plurality of lateral discontinuities, where the tread width is divided into a plurality of regions, the plurality of regions including: a pair of outermost regions, each outermost region being arranged closest to one of the pair of opposing lateral sides of the tread, and at least one centermost region is arranged closest to the longitudinal centerline of the tread. At least one of the tread elements arranged in the at least one centermost region has a length greater than a length of at least one of tread elements arranged in the pair of outermost regions.

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TIRE TREADS HAVING INCREASING BLOCK LENGTHS FROM SHOULDER TO CENTER OF TREAD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to, and the benefit of, U.S. Provisional Patent Application No. 62/428,299, filed November 30, 2016 with the U.S. Patent Office, and which is hereby incorporated by reference.

BACKGROUND

Field

[0002] This disclosure relates generally to tire treads, and more particularly, to tire treads having a plurality of tread elements (blocks) with lateral discontinuities arranged there between.

Description of the Related Art

[0003] Tire treads, including directional tire tread designs, are prone to irregular wear, and notably heel and toe wear. Heel and toe wear occurs at the trailing edge of a tread block, and may appear to have rounded the trailing edge or form a saw tooth shape along the surface of the tread blocks as viewed from a lateral side of the tire. Stated differently, heel and toe wear appears as a step change in tread height (thickness) from the trailing edge of one block to the leading edge of the next block length.

[0004] This heel and toe wear is a result of natural wear mechanisms operating on the tread blocks during tire operation. The leading edge of the block may be defined as the first block edge coming into contact with the ground as the tire rotates in the forward direction. The trailing edge is then the edge of the block that is last to come in contact. As the block exits contact at the end of the contact patch, the trailing edge is the last to leave contact. As downward pressure is released from the block, the trailing edge slides. As a result, the trailing edge tends to wear more than the leading edge. This uneven wear leads to the heel and toe shape of the block. Excessive heel and toe wear (greater than 1 mm) is visually unappealing and can lead to increased noise from the tire. It is appreciated that a trailing edge may be associated with any lateral discontinuity separating adjacent tread blocks, such as a lateral groove or sipe.

[0005] The heel and toe wear problem is usually solved by a combination of a sculpture design (tread design) and tire profile shape in the equatorial plane of the tire (that is,

along the plane bisecting the tire through the widthwise centerline of the tread). By altering these aspects of the design, the relative sliding between ribs (that is, the differences in wear rate between different ribs) can be altered to minimize the development of heel and toe wear.

[0006] The shoulder ribs tend to experience more braking solicitations than the center and intermediate ribs of the tire. Heel and toe wear is more prone to occur under braking solicitations relative to driving solicitations (constant speed or acceleration). Therefore, when heel and toe wear develops it is usually most prominent on the shoulder ribs. The shoulder rib is also the most visible from the exterior of the vehicle, and therefore the most noticeable to an observer. Therefore, it is desirable to limit the development of heel and toe wear in the shoulders.

SUMMARY

[0007] Particular embodiments provide a tire tread comprising a tread length extending in a longitudinal direction, a tread width extending in a lateral direction, a tread thickness extending in a depthwise direction from an outer, ground-engaging side of the tread, each of the longitudinal direction, the lateral direction, and the depthwise direction being perpendicular to one another. The tread width extends between a pair of opposing sides of the tread each arranged at a widthwise extent of the outer, ground-engaging side, and a longitudinal centerline extending in the tread length in the longitudinal direction midway across the tread width. The tire tread further includes a plurality of tread elements and a plurality of lateral discontinuities arranged along the tread width and tread length, each of the plurality of tread elements being spaced apart by one of the plurality of lateral discontinuities. The tread width is divided into a plurality of regions including: (1) a pair of outermost regions, each outermost region being arranged closest to one of the pair of opposing lateral sides of the tread, and (2) at least one centermost region is arranged closest to the longitudinal centerline of the tread. At least one of the tread elements arranged in the at least one centermost region has a length greater than a length of at least one of tread elements arranged in the pair of outermost regions.

[0008] 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 drawing wherein like reference numbers represent like parts of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a top view of a prior art tire tread, and a segment of the tire tread, where the length of the tread elements (blocks) become shorter when moving from shoulder ribs to a center rib.

[0010] FIG. **2A** is a top view of a tire tread, and a segment of the tire tread, where the length of the tread elements (blocks) become longer when moving from shoulder ribs to a center rib.

[0011] FIG. **2B** is a sectional view of the tread shown in FIG. **2A**, showing the tread width and thickness.

[0012] FIG. **3** is a side view of lateral discontinuities in FIG. **2A**.

[0013] FIG. **4** is a sectional side view of an alternative embodiment of the tire tread shown in FIG. **3**, showing lateral discontinuities extending into the tread depth biased to the direction of the tread thickness.

[0014] FIG. **5** is a sectional side view of an alternative embodiment of the tire tread shown in FIG. **3**, showing lateral discontinuities extending into the tread depth along non-linear paths.

[0015] FIG. **6** is a top view of a tire tread, showing a tread element having a variable width, where the leading and trailing edges extend lengthwise along linear paths.

[0016] FIG. **7** is a top view of a tire tread, showing a tread element having a variable width, where the leading and trailing edges extend lengthwise along non-linear paths.

[0017] FIG. **8** is a top view of an alternative embodiment to the tread shown in FIG. **2A**, where a pair of central ribs are provided.

[0018] FIG. **9** is a top view of an alternative embodiment to the tread shown in FIG. **2A**, where the tread is free of any ribs.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0019] In many conventional tread sculptures (designs), the shortest block length is used in center ribs while the longest block length is used in shoulder ribs. However, this has the disadvantage that the large shoulder blocks will exhibit the largest step change in sculpture height when there is heel and toe wear as previously described. Now, contrary to

conventional practice, to combat heel and toe wear, the opposite strategy will be employed, where longer tread block lengths will be used along the center regions or ribs, and shorter tread block lengths will be used along the shoulder regions or ribs. This concept can be applied to any tread sculpture.

[0020] For a number of tire performances, a certain amount of longitudinal rigidity of the sculpture may be desired, which can be reflected in maintaining a certain average block length for the design. In such instances, there is some freedom in adjusting the block lengths used in each region or rib across the width of the tire tread. This may be used as a design mechanism to improve heel and toe wear performance while maintaining any desired average block length for the tire tread.

[0021] To improve heel and toe wear, contrary to the common practice of maintaining longer tread blocks in shoulder ribs, the inventors now intend to reduce or minimize the block length in the shoulder ribs.

[0022] A tire tread, as generally discussed herein, includes a tread length extending in a longitudinal direction, a tread width extending in a lateral direction, a tread thickness extending in a depthwise direction, each of the longitudinal direction, the lateral direction, and the depthwise direction being perpendicular to one another. The tread width extends between a pair of opposing sides of the tread. Each of the pair of sides are also referred to as a lateral side of the tread. Each of the pair of opposing sides is arranged at the widthwise extent of the outer, ground-engaging side of the tread, which extends along a lateral profile to each of opposing widthwise extents until reaching a portion of the tread that begins to extend down each opposing sidewall of the tire. Therefore, when referencing the width of the tread herein, unless specifically noted otherwise, the width of the tread means the widthwise extent of the outer, ground-engaging side and not the full widthwise extend of the tread material, which extends beyond the lateral profile of the outer, ground-engaging side and down the sidewalls of the tire. The tire tread also includes a widthwise centerline extending in the direction of the tread length, or, in other words, in the longitudinal direction of the tire tread, midway across the tread width between the pair of opposing sides.

[0023] The tire tread also includes a plurality of tread elements, which are also referred to as tread blocks. These tread elements are separated by a plurality of discontinuities, which may form any combination of grooves and sipes. Stated differently, each tread element is defined by any combination of one or more discontinuities and any

lateral side edge of the tire tread. For example, an interior tread element spaced lateral inward from a lateral side of the tread may be bounded by four (4) discontinuities, such as a pair of spaced apart longitudinal grooves each extending in the longitudinal direction of the tread length and a pair of spaced apart lateral discontinuities extending at least partially in a direction of the tread width. By further example, a tread element arranged along a lateral side of the tire tread, which is referred to as a shoulder tread element, may be bounded by a lateral side edge of the tread, a longitudinal groove, and a pair of spaced apart lateral discontinuities. A lateral discontinuity, for any tread, may form a groove or sipe, where a sipe is a narrow groove or laceration.

[0024] It is appreciated that tread elements may be arranged in any manner along the tread, and may be submerged below the outer, ground-engaging side of the tread when at least partially formed by submerged discontinuities. In certain instances, the tread elements are arranged without using any longitudinal grooves extending in the longitudinal direction (that is, the direction of the tread length), such that plurality of tread elements are not arranged adjacently (side-by-side) in a longitudinal direction of the tread to form one or more ribs. In certain other instances, a plurality of tread elements are arranged adjacently (side-by-side) in a longitudinal direction of the tread to form one or more ribs and which are bounded by a longitudinal groove. Adjacent tread elements (of the plurality of adjacent tread elements) are separated by a lateral discontinuity. The plurality of tread elements forming a rib may be described as forming an array of tread elements along the length of the corresponding rib. A rib commonly extends a full length of the tread, but could, in certain instances, extend less than the full length of the tire tread. While one or more ribs may be provided, in particular instances, the tire tread includes a plurality of ribs extending in the longitudinal direction of the tire tread.

[0025] In any tire tread, whether or not having any ribs, a lateral discontinuity has a length extending at least partially in the lateral direction of the tire tread. When extending partially in the lateral direction, the length also extends partially in the longitudinal direction of the tread, whereby the length can be described as being biased relative to the lateral direction. When not extending partially in the lateral direction, the lateral discontinuity length extends in the lateral direction of the tread. The lateral discontinuity also has a depthwise extension extending into the tread thickness at least partially in the direction of the tread thickness away from the outer, ground-engaging side. The depthwise extension extends perpendicular to the lateral discontinuity length. When this depthwise extension extends

partially in the direction of the tread thickness, the depthwise extension also extends partially in the longitudinal direction of the tread, where the depthwise extension can be described as being biased relative to the direction of the tread thickness. When not extending partially in the direction of the tread thickness, the depthwise extension of the lateral discontinuity extends in the direction of the tread thickness.

[0026] It is also noted that each lateral discontinuity has a thickness (also referred to as a width). The thickness extends in a direction perpendicular to the length and depthwise extension of the lateral discontinuity. In certain instances, a lateral discontinuity has a zero thickness, that is, when the lateral discontinuity forms a sipe comprising a laceration. Otherwise, when the lateral discontinuity has a non-zero thickness, it is either a sipe that forms a narrow groove or a lateral groove having a thickness greater than the width of the narrow groove otherwise forming a sipe. In certain instances, the sipe has a width such that the sipe is configured to articulate between an open configuration and a closed configuration as the tire rotates during tire operation. A sipe can be described as having a width equal to or less than 1.4 mm or equal to or less than 1.0 mm, and as low as zero (0).

[0027] It is appreciated that the length of any lateral discontinuity may extend along any linear or non-linear path. Likewise, the depthwise extension for any lateral discontinuity may extend along any linear or non-linear path. Further, the thickness for any of the lateral discontinuity has a thickness extending perpendicular to both the depthwise extension and length of the lateral discontinuity. The thickness may be constant, or variable, as each lateral discontinuity extends along the depthwise extension and along the length of the lateral discontinuity.

[0028] It is appreciated that when the tire tread is in an unworn state, the lateral discontinuities may extend into the tread thickness from the outer, ground-engaging side of the tread or, when the lateral discontinuity is a submerged lateral discontinuity, extends into the tread thickness from below the outer, ground-engaging side of the tread. When submerged, the lateral discontinuity becomes exposed to the outer, ground-engaging side after a thickness of the tread arranged between the outer, ground-engaging side and the submerged lateral discontinuity is removed, such as due to wear, for example.

[0029] The tread width can be described as being divided into different widthwise regions. For example, in certain instances, the tread is parsed into having at least a pair of shoulder regions and a center region. Each of these regions extend across a portion of the

tread width and along the length of the tread, that is, the full length of the tread. In certain instances, the width of these regions can be associated to the tread width by percentage. For example, in certain instances, each of the center and shoulder regions form 1/3rd of the tread width. In other instances, the width of the center region is 15% to 30% of the tread width, while the width of each shoulder region is 35% to 42.5% of the tread width. In still other instances, the width of the shoulder region is 20% to 35% of the tread width, and the width of the center region is 30% to 60% the tread width. Optionally, an intermediate region may be arranged between any shoulder region and the center region, with the understanding that if an intermediate region is located between the center region and any shoulder region, a second intermediate region may or may not be arranged between the center region and the other shoulder region. It is appreciated that the width of any intermediate region can be equal to any percentage of the tread width, but in certain instances, could be equal to 2% to 5% of the of the tread width or 20% to 70% of the tread width, where these percentages contemplate the tire tread having one or two intermediate regions. It is also contemplated that in any of the prior instances, or in other instances, the shoulder region is 30% greater than the center region and/or each of the shoulder and center regions are equal to or greater than 20 mm.

[0030] When a tire tread includes a plurality of ribs, the plurality of ribs are spaced apart laterally, that is, in the direction of the tread width, where a longitudinal groove is arranged between adjacent ribs. A longitudinal groove extends primarily in the direction of the tread length, and may extend along a path that extends continuously in the direction of the tread length or may also extend partially in the lateral direction at any location along the longitudinal groove length as desired. The plurality of ribs includes a pair of outermost ribs, each rib of the pair of outermost ribs being arranged closest to one of the pair of opposing lateral sides of the tread of the plurality of ribs. These outermost ribs are each referred to as a shoulder rib. The plurality of ribs also includes at least one centermost rib being arranged closest to the longitudinal centerline of the tread of the plurality of ribs. It is appreciated that the tire tread may have a single central rib (centermost rib) or a plurality of central ribs (centermost ribs). For example, in certain instances, the at least one centermost rib forms a single central rib arranged closest to the widthwise centerline. This single central rib may be arranged along the centerline. This single central rib may be arranged in any relation to the centerline, such as being centered or offset from the centerline, for example. By further example, the at least one centermost rib may form a pair of central ribs arranged on laterally opposing sides of the centerline. It is appreciated that for the pair, one may be arranged along

(coincident with) the centerline and the other spaced apart from the centerline by a short distance to remain close or near the centerline. In other instances, each of the pair is spaced apart from the centerline. Optionally, between one or each of the pair of outermost ribs and the one or more centermost rib is arranged one or more intermediate ribs.

[0031] As it is apparent from the foregoing that various ribs that may be present, it is appreciated that, for any combination of ribs contemplated above, the plurality of ribs arranged along a tire tread include at least three ribs (a pair of shoulder ribs and a center rib) and may include any additional quantity of ribs. Regardless as to whether the quantity of ribs is odd or even in number, it is appreciated that the arrangement of ribs may be symmetrical or asymmetrical about the widthwise centerline. It is appreciated that each rib may have any desired width, although in certain instances, the width of each rib is at least 20 mm and/or each shoulder rib is between 20 and 40% greater than the corresponding center rib. It is also appreciated that, in certain embodiments, the pair of shoulder ribs, the center rib, and any optional intermediate ribs are arranged within a corresponding region discussed above, where any shoulder rib is arranged within the shoulder region, any center rib is arranged within the center region, and any intermediate rib present is arranged within an intermediate region. It is appreciated that any intermediate region may include one or more intermediate ribs, any center region may include one or more center ribs, and any shoulder region may include one or more shoulder ribs.

[0032] With reference again to the various regions arranged across the tread width, the length of at least one tread element in each shoulder region is less than the length of at least one tread element located in any central region, and when any intermediate region is optionally present, the length of at least one tread element within any intermediate region is less than the length of the at least one tread element in the central region and greater than the length of the at least one tread element in each shoulder region. In particular instances, with regard to ribs, the length of at least one tread element in each of the shoulder ribs is less than the length of at least one tread element located in each central rib, and when any intermediate ribs are optionally present, the length of at least one tread element within any intermediate rib is less than the length of the at least one tread element in any central rib and greater than the length of the at least one tread element in each shoulder rib. These distinctions or relative associations between lengths may be made by comparing at least one or each tread element in each of the regions or ribs, meaning, at least one or each tread element in each region or rib has any relative lengths characterized as noted previously, or the length associations are made

with regard to an average tread element length determined for each region or rib, or any lengthwise portion of each, whether or not the prior tread element length characterizations are made with regard to these determined average lengths. While any tread element lengths may be used, so long as the tread element length associations between regions and/or ribs are provided in a tread, in certain exemplary instances, tread element lengths of 12 millimeter (mm), 9 mm and 6 mm were used for the center, intermediate, and shoulder region or rib tread element lengths, respectively. More generally, in certain exemplary instances, the tread element lengths in the shoulder regions and/or ribs range from 4 to 15 mm while greater tread element lengths in the center region and/or ribs range from 8 to 30 mm. In these exemplary instances, or in other instances, when an intermediate region/rib is present, the tread element lengths in an intermediate region and/or rib is 6 to 22 mm. Certainly, different tread lengths may be present in any other variation for any intermediate region and/or rib may be employed, so it length is between corresponding tread element lengths in corresponding shoulder and center regions and/or ribs.

[0033] Determining the length of each tread element may be accomplished in a variety of ways. Using any manner, the length of any tread element is measured between the opposing pairs of lateral discontinuities and the faces of the tread element associated with each of the lateral discontinuity of the pair, the faces forming a leading and a trailing face of the tread element. In measuring the length of the tread element in the longitudinal direction, the length extends from a leading edge to a trailing edge of the tread element. Each of the leading and trailing edges are arranged at a top edge of one of a pair of opposing faces extending into the tread thickness from the outer, ground-engaging side. Each one of the pair of opposing faces are associated with one of the lateral discontinuities forming the length of the tread element. The face associated with leading edge is referred to as the leading face, while the face associated with the trailing edge is referred to as the trailing face. It is appreciated that, for any tread element, the length of the tread element may remain constant or vary across the width of the tread element. It can be said that the length measurement may be made in the same plane or direction as a longitudinal centerline extending lengthwise along the tread element and located midway across a width of the tread element. Stated differently, the length is measured from a mirrored opposite relative a lateral centerline extending across the width midway between the pair of opposing faces, where the lengthwise measurement extends the shortest straight-line distance between the opposing faces – stressing that the length is not measured from any void arranged along any lateral

discontinuity. Particularly, the tread element length is measured from each such face and not any other void arranged along the lateral discontinuity, where the void has a thickness (width) greater than the thickness of the lateral discontinuity. In other words, the length is measured from each face at a location along each associated discontinuity, and not along any void arranged along the lateral discontinuity.

[0034] In comparing between the tread element lengths arranged in a shoulder region (outermost region), in a center region (centermost region), and, when present, in an intermediate region, it is appreciated that any such length may form any length measured along the depthwise extension of the tread element and taken at any location across the width of the tread element, or the length may be an average thickness determined for each such tread element. In other instances, an average tread element length may be determined for each region, and the relative average tread element lengths provided amongst the shoulder and center regions, and if present, each intermediate region.

[0035] For example, in certain instances, the tread element length taken at any location along the depthwise extension thereof in a shoulder region is less than the tread element length taken at any location along the depthwise extension thereof in a center region, and when present, the tread element length taken at any location along the depthwise extension thereof in an intermediate region is less than the tread element length in the center region and greater than the tread element length in the shoulder region. It is appreciated that the relative association between tread elements in different regions and the lengths thereof may be made by relating tread elements located at the same or different longitudinal locations around the tire. In certain instances, the tread elements in different regions whose lengths are being related are located at the same longitudinal location of the tire tread, where at the longitudinal location, which extends across the tread width, a corresponding lateral discontinuity located in a shoulder and central region, and when present, in an intermediate region, are associated and characterized as having the relative length associations described herein. In lieu of requiring association based upon a specific longitudinal location, association between tread element lengths within the different regions may occur within a specific range of longitudinal locations. In particular instances, this is accomplished within a segment of the tire tread. A segment of the tread can be described as a portion of the tire tread that extends for a specified length less than the full length of the tread, and while each segment may form a partial length of the tread, each segment extends the full width of the tread. Often, the tread pattern, that is, the arrangement of voids along the outer, ground-

engaging side, repeats, where each segment forms a repeating portion of the tread pattern or more generally of the tread, although minor variations may occur between segments, such as to slightly increase or decrease the size of certain features to improve noise performance. As such, the tread is comprised of multiple segments that may or may not be the same. While any quantity of segments may be arranged adjacently in the lengthwise direction of the tire to form the tire tread, by example, a tire tread may be formed of 20 to upwards of 80 segments. In certain other instances in associating between tread element lengths within the different regions within a specific range of longitudinal locations, in certain instances, the tread elements related by the different lengths are concurrently arranged within a tire footprint during tire operation. A tire footprint is the area of contact between a tire, and more specifically, the tire tread and a ground surface. It is the outer, ground-engaging side of the tire tread that contacts the ground. In certain instances, the related tread elements are located in the direction of the tread length 0 to 20% of the footprint length, where the footprint length is measured in the direction of the tread length.

[0036] In comparing between each of the length of a shoulder tread element, that is, a tread element arranged in a shoulder rib, the length of a center tread element, that is, a tread element arranged in a centermost rib, and, when present, the length of any intermediate tread element, that is, a tread element arranged in an intermediate rib, it is appreciated that any such length may form any length measured along the width of a corresponding tread element or it may be an average length determined for each such tread element that is utilized for relative comparison. In other instances, an average tread element length is determined for each rib, and the average tread element lengths are compared between shoulder, intermediate, and center ribs.

[0037] For example, in certain instances, a measured length of a shoulder tread element taken at any location along the width of the shoulder tread element is less than a measured length of a center tread element taken at any location along the width of the center tread element, and when present, a measured length of an intermediate tread element taken at any location along the width of the intermediate tread element is less than the measured length of the center tread element and greater than the measured length of the shoulder tread element. It appreciated that the relative association between tread elements in different ribs and their lengths may be made by relating tread elements located at the same or different longitudinal locations around the tire. In certain instances, the tread elements in different ribs whose lengths are related are located at the same longitudinal location of the tire tread, where

at the longitudinal location, which extends across the tread width, a corresponding shoulder and central tread element, and when present, an intermediate tread element, are associated and characterized as having the relative length associations described herein. In lieu of requiring association based upon a specific longitudinal location, association between tread elements within the different ribs may occur within a specific range of longitudinal locations, which can be described as occurring within a segment of the tire tread, which was described above.

[0038] When relating the lengths of different tread elements, this is done at a particular tread depth of the tread thickness. Accordingly, this depth may be located at a zero depth, that is, at the outer, ground engaging side of the tread, or at any depth below the outer, ground-engaging side.

[0039] In determining an average length for any tread element, the average length is an average length as determined at any particular depth of the tread thickness, where the average length is determined across the width of a subject tread element, from leading edge to trailing edge. In doing so, the average may be arrived at according to any desired method. For example, in particular instances, when either or both the leading and trailing edges extend lengthwise along non-linear paths, such that the respective edge has a non-linear length, linear regression may be employed to convert the edge having a non-linear length to having an associated linear length. When doing so, the average length for any non-linear length is determined using the associated linear length. Of course, other techniques may be employed within any leading or trailing edge has a non-linear length, such as using differential equations or other known techniques, including use of any modeling or analytical software program.

[0040] In other instances, when determining an average length for any tread element, the average length is not quantified as an average taken at a particular depth of the tread thickness, but rather an average taken for over the full depth of the tread element, which means, more specifically, the full depth of the shortest face between the pair of opposing faces forming the respective leading and trailing edges of a respective tread element. This may be accomplished using any of a variety of known techniques.

[0041] As noted previously, normally, in the prior art, the tread elements in the shoulder are longer and therefore larger than the other ribs, as this can help maintain a more consistent or uniform wear rate between different ribs in those cases. A longer element may

result in a more rigid tread element, and vice versa. Reducing the tread element length in the shoulder typically will reduce rigidity and cause more wear between ribs. In this case, when employing shorter tread element lengths in the shoulder ribs, to better maintain tread element rigidness in the shoulders, use of lateral discontinuities in the shoulder ribs comprising sipes that are thinner than the lateral discontinuities used in other ribs by prove beneficial. Alternatively or additionally, using a more rigid tread material in the shoulder rib relative to the tread material used to form the other ribs may also prove beneficial.

[0042] Exemplary embodiments of the tire treads discussed above will now be described in association with the figures.

[0043] With reference to FIG. **1**, a segment **120** of a prior art tread **110** is shown, the segment **120** forming a portion of the tread where the segment extends longitudinally for only a portion of the tread length $\mathbf{L_{110}}$ and across tread width $\mathbf{W_{110}}$, which is the width of the tread associated with the outer, ground-engaging side **12**, and not necessarily the full tread width, which may or may not extend down towards the tire sidewall. The tread **110**, as well as the tread segment **120**, includes a plurality of ribs, including a pair of shoulder ribs **122S**, a center rib **122C**, and intermediate ribs **122I**. The ribs are separated by longitudinal grooves **121**. Each rib includes a plurality of lateral discontinuities **124** spaced apart in the longitudinal direction of the tread (direction of tread length $\mathbf{L_{110}}$) to define a tread element (tread block) **126**. As can be seen, the length $\mathbf{L_{126}}$ of the each tread element **126** in each shoulder rib **122S** is longer than the length $\mathbf{L_{126}}$ of tread elements **126** in each of the center rib **122C** and the intermediate ribs **122I**. It is also evident that the length $\mathbf{L_{126}}$ of the tread elements **126** in the intermediate rib **122I** are longer than those in the center rib **122C**.

[0044] In an exemplary embodiment shown in FIG. **2A**, improvements over prior art tire treads are shown, where in the exemplary tread **10**, the length $\mathbf{L_{26}}$ of the tread elements in the shoulder ribs **22S** are now shorter than those in the center **22C** and intermediate ribs **22I**. Further, the length $\mathbf{L_{26}}$ of the tread elements in the intermediate ribs **22I** are shorter than those in the center rib **22C** but longer than the length $\mathbf{L_{26}}$ of tread elements in the shoulder ribs **22S**. More generally, in the exemplary embodiments, a segment **20** of the exemplary tread **10** is shown, the segment **20** forming a portion of the tread where the segment extends longitudinally for only a portion of the tread length $\mathbf{L_{10}}$ and across tread width $\mathbf{W_{10}}$, which is the width of the tread associated with the outer, ground-engaging side **12**. The tread **10**, as well as the tread segment **20**, includes a plurality of widthwise regions of the tread, namely, a pair of shoulder regions $\mathbf{R_S}$ arranged at the outermost extend of tread

width $\mathbf{W_{10}}$, a center region $\mathbf{R_C}$ arranged closest to the tread centerline **CL**, and intermediate regions $\mathbf{R_I}$ each arranged between the center region $\mathbf{R_C}$ and one of the shoulder regions $\mathbf{R_S}$. Each region $\mathbf{R_S}$, $\mathbf{R_C}$, $\mathbf{R_I}$ includes a portion of the plurality tread elements **26** and a portion of the plurality of lateral discontinuities **24**. In the embodiment shown, each partition between adjacent regions is arranged along longitudinal grooves **21**, but it is appreciated that in other instances, it is not necessary to align these partitions at or within longitudinal grooves as the partitions may be arranged at any desired location across the tread width. The tread **10**, as well as the tread segment **20**, also include a plurality of ribs **22S**, **22I**, **22C**, as noted previously, separated by longitudinal grooves **21**. Each rib includes a plurality of lateral discontinuities **24** spaced apart in the longitudinal direction of the tread (direction of tread length $\mathbf{L_{10}}$) to define the tread elements (tread block) **26** in each rib. In this instance, each shoulder rib **22S** is arranged in one of the shoulder regions $\mathbf{R_S}$, center rib **22C** is arranged in center region $\mathbf{R_C}$, and each intermediate rib $\mathbf{22_I}$ is arranged in one of the intermediate regions $\mathbf{R_I}$.

[0045] With reference to the view shown in FIG. **2B**, the lateral profile of the tire tread of FIG. **2A** is shown, where the tread width $\mathbf{W_{10}}$ extends between the pair of opposing lateral sides **14** of the tread **10**, the width forming a widthwise extent of the outer, ground-engaging side **12** of the tread **10**. Tread width $\mathbf{W_{10}}$ extends along the outer, ground-engaging side of the tread and its lateral profile until reaching each lateral side **14**, at which point the tread **10** begins to extend down towards each opposing sidewall of the tire. Therefore, when referencing the tread width $\mathbf{W_{10}}$, as noted previously, unless specifically noted otherwise, the tread width $\mathbf{W_{10}}$ references the widthwise extent of the outer, ground-engaging side **12** and not necessarily the full widthwise extend of the tread material, which may or may not extend beyond the lateral profile of the outer, ground-engaging side and down the sidewalls of the tire.

[0046] With reference to FIG. **3**, a sectional view of the tread in FIG. **2A** shows the depthwise extension of particular lateral discontinuities **24** and tread elements **26**, where each extends into the tread thickness $\mathbf{T_{10}}$ from an outer, ground-engaging side **12** of the tread. Each lateral discontinuity **24** is associated with a pair of opposing faces **28** of the tread, the faces extend depthwise into the tread (in the direction of the tread thickness $\mathbf{T_{10}}$) to a terminal end $\mathbf{28_E}$ located within the tread thickness. Each face **28** also partially defines a tread element **26**. The lengthwise extent of each tread element is defined by a pair of opposing faces **28** associated with different lateral discontinuities. At the junction where each face **28**

intersects the outer, ground-engaging side **12** is an edge. With regard to the pair of faces **28** defining the length $\mathbf{L_{26}}$ of the tread element, the face **28** located upstream the other face **28** in the direction of intended tire rotation **R**, the edge $\mathbf{28_{LE}}$ formed long the outer, ground-engaging side along this upstream face **28** is referred to the leading edge, which enters contact with the ground before the edge $\mathbf{28_{TE}}$ formed by the other face **28**, which is referred to as a trailing edge.

[0047] In the embodiment shown in each of FIGS. **2A** and **3**, each lateral discontinuity **24** has a linear length and a linear depthwise extension. With reference to FIG. **2A**, as for the length of each lateral discontinuity, the length extends in the lateral direction of the tread (which is the widthwise direction and which extends perpendicular to the longitudinal direction of the tread). Also, with reference to FIG. **3**, the depthwise extension of each lateral discontinuity extends in the direction of the tread thickness (which is perpendicular to both the longitudinal direction of the tread and the widthwise direction of the tread). As a result, the tread elements generally form cuboids or rectangular prisms. Of course, other variations are contemplated, meaning that any of the opposing faces and lateral discontinuity partially forming any tread element may be shaped differently to provide a differently shaped tread element. Likewise, as previously noted, any lateral discontinuity may extend along any linear or non-linear path that may extend at any desired angle relative to the directions of the tread width, thickness, and length, and each leading and trailing edge may be of the same or different length. Of final note, as previously discussed, different quantities and arrangements of ribs are also contemplated.

[0048] With reference now to another exemplary embodiment in FIG. **4**, the lateral discontinuities **24** extend depthwise into the tread along linear paths, but biased to the direction of the tread thickness. Specifically, the lateral discontinuities **24** each extend into the tread thickness biased to the direction of the tread thickness by a corresponding angle ϕ_1, ϕ_2. In this embodiment, angles ϕ_1, ϕ_2 are different, which means that the length $\mathbf{L_{26}}$ of tread element **26** varies through the height $\mathbf{H_{26}}$ of the tread element **26** (which is also referred to as the tread element thickness). In this embodiment, the tread element length $\mathbf{L_{26}}$ narrows or shortens as the tread element wears to lower heights $\mathbf{H_{26}}$.

[0049] It has been appreciated above that each lateral discontinuity may extend lengthwise and depthwise not only along any linear path, but also along any non-linear path. In a further exemplary embodiment shown in FIG. **5**, lateral discontinuities **24** are shown to extend depthwise along non-linear paths. Because the non-linear paths are different from one

another, the length $\mathbf{L_{26}}$ of tread element **26** varies between different depths within the tread element height $\mathbf{H_{26}}$. It is noted that the tread element height $\mathbf{H_{26}}$ only extends to the terminal end $\mathbf{28_E}$ of the shortest lateral discontinuity **24**. In measuring the length $\mathbf{L_{26}}$ of tread element **26**, the length $\mathbf{L_{26}}$ extends from the leading edge $\mathbf{28_{LE}}$ to the trailing edge $\mathbf{28_{TE}}$. This lengthwise measurement $\mathbf{L_{26}}$ is taken between opposing faces **28** at any height location throughout the tread element height $\mathbf{H_{26}}$. In certain instances, the length $\mathbf{L_{26}}$ of any tread element **26** taken at a particular height within height $\mathbf{H_{26}}$ is compared to the lengths of the other tread elements contained in the other ribs at the same height, to arrive at the length characterizations across the different ribs as described herein. It is appreciated that an average length may be determined for each tread element over the tread element height $\mathbf{H_{26}}$. It is possible to arrive at an average length for the tread element height using linear regression to transform any non-linear face to a line. For example, in the current embodiment, the non-linear path along which each face **28** extends in the depthwise direction is transformed to a linear representation **28'** using linear regression, or any other technique. From this line, an average length $\mathbf{L'_{26}}$ may be determined for the height $\mathbf{H_{26}}$ at a particular location across the width of the tread element. Of course, this average length may be further averaged across the width of the tread element to arrive at an average length for the tread element.

[0050] Referring now to another exemplary embodiment in FIG. **6**, a partial top view of an outer, ground-engaging side **12** of a tire tread **10** is shown. Particularly, an intermediate tread element **26** is shown arranged within an intermediate rib **22I**, where the intermediate tread element **26** has a variable length $\mathbf{L_{26}}$, which decreases from right to left across the tread width. Intermediate tread element **26** is arranged lengthwise between a pair of lateral discontinuities **24** extending lengthwise along linear paths, albeit different paths so to create the variable length $\mathbf{L_{26}}$ of the intermediate tread element **26**. Each of the intermediate rib **22S** and intermediate tread element **26** are arranged between an alternating longitudinal groove **21** on the left and a straight longitudinal groove **21** on the right. The straight longitudinal groove is curvilinear when the tread is arranged along an annular tire, although the annular, curvilinear path extends within a plane – unlike the path of the alternating longitudinal groove.

[0051] It has been appreciated above that each lateral discontinuity may extend lengthwise not only along any linear path, but also along any non-linear path. In a further exemplary embodiment shown in FIG. **7**, lateral discontinuities **24** are shown to extend lengthwise along non-linear paths. Because the non-linear paths are different from one

another, the length $\mathbf{L_{26}}$ of tread element **26** varies across the width $\mathbf{W_{26}}$ of the tread element **26**. In measuring the length $\mathbf{L_{26}}$ of tread element **26**, the length $\mathbf{L_{26}}$ extends from the leading edge $\mathbf{28_{LE}}$ to the trailing edge $\mathbf{28_{TE}}$. This lengthwise measurement $\mathbf{L_{26}}$ is taken at any location across tread element width $\mathbf{W_{26}}$. In certain instances, the length $\mathbf{L_{26}}$ of any tread element **26** taken at a particular location across width $\mathbf{W_{26}}$ is compared to the lengths of the other tread elements contained in the other ribs, to arrive at the length characterizations across the different ribs as described herein. It is appreciated that an average length may be determined for each tread element across the tread element width $\mathbf{W_{26}}$. It is possible to arrive at an average length for the tread element width using linear regression to transform any non-linear face to a line. For example, in the current embodiment, the non-linear path along which each of the leading and trailing edges $\mathbf{28_{LE}}$, $\mathbf{28_{TE}}$ extends is transformed to a linear representation $\mathbf{28'_{LE}}$, $\mathbf{28'_{TE}}$ using linear regression, or any other technique. From this line, an average length $\mathbf{L'_{26}}$ may be determined for the width $\mathbf{W_{26}}$ at a particular location throughout the height of the tread element. Of course, this average length may be further averaged across the height of the tread element to arrive at an average length for the tread element.

[0052] As noted previously, a tread may include any number of ribs, but at least a pair of shoulder ribs and a center rib. With reference to another exemplary tire tread in FIG. **8**, a variation of the tread **10** of FIG. **2A** is shown. In FIG. **8**, a tire tread **10** having six (6) ribs is shown, which include shoulder ribs **22S** and intermediate ribs **22I**, but unlike the tread of FIG. **2A**, which has a single center rib **22C**, the tire tread **10** of FIG. **8** has a pair of center ribs **22C** spaced apart by a longitudinal groove **21**, each center rib **22C** located on opposite sides of the centerline **CL** and spaced apart from the centerline **CL** It is appreciated that each center rib **22C** may be spaced apart from the centerline **CL** by the same distance (such as is exemplarily shown) or by different distances, which would render the tire tread asymmetrical about centerline **CL**.

[0053] As noted previously, a tread may include a plurality of tread elements that are not arranged in a rib. In an exemplary embodiment shown in FIG. **9**, a plurality of tread elements **26** are arranged along a segment **20** of a tread **10**. The tread elements **26** are separated by lateral discontinuities **24** and longitudinal grooves **21'** that do not extend the full length $\mathbf{L_{10}}$ of the tread and/or does not extend in the direction of the tread length along any linear or non-linear path. Therefore, each array of tread elements **26** arranged adjacent each longitudinal groove **21'** do not form a rib since the array of tread elements **26** does not extend the full length $\mathbf{L_{10}}$ of the tread due to each corresponding longitudinal groove **21'** extending

at an angle biased to the longitudinal direction $\mathbf{L_{10}}$ of the tread. In this embodiment, instead of arranging tread elements **26** of different lengths $\mathbf{L_{26}}$ as otherwise described herein between ribs, different tread element lengths $\mathbf{L_{26}}$ are arranged between shoulder regions $\mathbf{R_S}$, a center region $\mathbf{R_C}$, and intermediate regions $\mathbf{R_I}$. Of course, in other variations, one or more ribs may be included in any tread while other tread elements outside any of the one or more ribs may be associated with a shoulder or center region, or, if present, an intermediate region. It is important to note that in situations such as this, where each array of tread elements does not form a rib (where a rib is bordered by a longitudinal groove that extends in the direction of the tread length, along any linear or non-linear path, and/or extends the full length of the tread), the tread element length is measured between opposing lateral discontinuities, which may or may not be entirely in the direction of the tread length, where the length extends from a leading face and to a trailing face of the tread element in association with the pair of opposing lateral discontinuities. Otherwise, measuring the length of any tread element may be accomplished in any manner contemplated therein. It is stressed, however, consistent with the measuring of any tread element length as described herein, the tread element length is measured from each such face associated with the lateral discontinuity and not any other void arranged along the lateral discontinuity, where the void has a thickness (width) greater than the thickness of the lateral discontinuity.

[0054] 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.

[0055] While various improvements have been described herein with reference to particular embodiments thereof, it shall be understood that such description is by way of illustration only and should not be construed as limiting the scope of any claimed invention.

Accordingly, the scope and content of any claimed invention is to be defined only by the terms of the following claims, in the present form or as amended during prosecution or pursued in any continuation application. Furthermore, it is understood that the features of any specific embodiment discussed herein may be combined with one or more features of any one or more embodiments otherwise discussed or contemplated herein unless otherwise stated.

CLAIMS

What is claimed is:

1. A tire tread comprising:

a tread length extending in a longitudinal direction, a tread width extending in a lateral direction, a tread thickness extending in a depthwise direction from an outer, ground-engaging side of the tread, each of the longitudinal direction, the lateral direction, and the depthwise direction being perpendicular to one another,

the tread width extending between a pair of opposing sides of the tread each arranged at a widthwise extent of the outer, ground-engaging side, and a longitudinal centerline extending in the tread length in the longitudinal direction midway across the tread width;

a plurality of tread elements and a plurality of lateral discontinuities arranged along the tread width and tread length, each of the plurality of tread elements being spaced apart by one of the plurality of lateral discontinuities;

where the tread width is divided into a plurality of regions,

the plurality of regions including: (1) a pair of outermost regions, each outermost region being arranged closest to one of the pair of opposing lateral sides of the tread,

and (2) at least one centermost region is arranged closest to the longitudinal centerline of the tread,

where at least one of the tread elements arranged in the at least one centermost region has a length greater than a length of at least one of tread elements arranged in the pair of outermost regions.

2. The tire tread of claim 1, where the tire tread includes a plurality of ribs extending in the longitudinal direction of the tire tread, where a portion of the plurality of tread elements are arranged side-by-side in the longitudinal direction of the tread in each rib of the plurality of ribs,

where the plurality of ribs includes a pair of outermost ribs, each rib of the pair of outermost ribs arranged closest to one of the pair of opposing lateral sides of the tread of the plurality of ribs, and at least one centermost rib arranged closest to the longitudinal centerline of the tread of the plurality of ribs,

where one rib of the pair of outermost ribs is arranged in one of the pair of outermost regions and the other rib of the pair of outermost ribs is arranged in the

other of the pair of outermost ribs, and where the center rib is arranged in the center region.

3. The tire tread of any one of claims 1 and 2 further comprising:

an intermediate region arranged between the centermost region and at least one of the pair of outermost regions, at least one of the tread elements in each intermediate region having a length greater than at least one of the tread elements arranged in the pair of outermost regions and smaller than at least one of the tread elements arranged in the centermost region.

4. The tire tread of claim 3 further comprising:

one or more intermediate ribs arranged between the at least one centermost rib and the pair of outermost ribs, each of the one or more intermediate ribs being arranged in the intermediate rib.

5. The tire tread of any one of claims 1 to 4, where each of the lateral discontinuities forms a sipe or a groove.

6. The tire tread of any one of claims 1 to 4, where each of the plurality of lateral discontinuities forms a sipe.

7. The tire tread of claim 6, where each the sipe thickness for each sipe is configured to articulate between an open configuration and a closed configuration as the tire rotates during tire operation.

8. The tire tread of any one of claims 1 to 7, where each of the lateral discontinuities extend into the tread from the outer, ground-engaging side of the tread.

9. The tire tread of any one of claims 1 to 8, where the at least one of the tread elements arranged in the at least one centermost region has a length greater than a length of at least one of tread elements arranged in the pair of outermost regions is arranged within a segment of the tread, the segment of the tread extending the width of the tread and partially in the longitudinal direction of the tread.

10. The tire tread of any one of claims 1 to 8, where the at least one of the tread elements arranged in the at least one centermost region having a length greater than a length of at least one of tread elements arranged in the pair of outermost regions is arranged to be within a tire footprint concurrently during tire operation.

11. The tire tread of any one of claims 1 to 10, where the at least one of the tread elements arranged in the at least one centermost region having a length greater than a length of at least one of tread elements arranged in the pair of outermost regions is arranged at the same lengthwise location along the tread length.

12. The tire tread of any one of claims 1 to 11, where an average length of the tread elements arranged in each of the pair of outermost regions is smaller than an average length of the tread elements arranged in the centermost region.

13. The tire tread of claim 12, where the average length of the tread elements arranged in the pair of outermost regions is smaller than an average length of the tread elements arranged in the one or more intermediate regions, and where the average length of the tread elements in the one or more intermediate regions is smaller than the average length of the tread elements arranged in each of the at least one centermost region.

14. The tire tread of any one of claims 1 to 13, where an average length of the tread elements arranged in the pair of outermost ribs is smaller than an average length of the tread elements arranged in the at least one centermost rib.

15. The tire tread of claim 14, where the average length of the tread elements arranged in the pair of outermost ribs is smaller than an average length of the tread elements arranged in each of the one or more intermediate ribs, and where the average length of the tread elements in the one or more intermediate ribs is smaller than the average length of the tread elements arranged in each of the at least one centermost rib.

16. The tire tread of any one of claims 1 to 15, where the length for each of the lateral discontinuities extends along a linear or non-linear path.

17. The tire tread of any one of claims 1 to 16, where the depthwise extension for each of the lateral discontinuities extends along a linear or non-linear path.

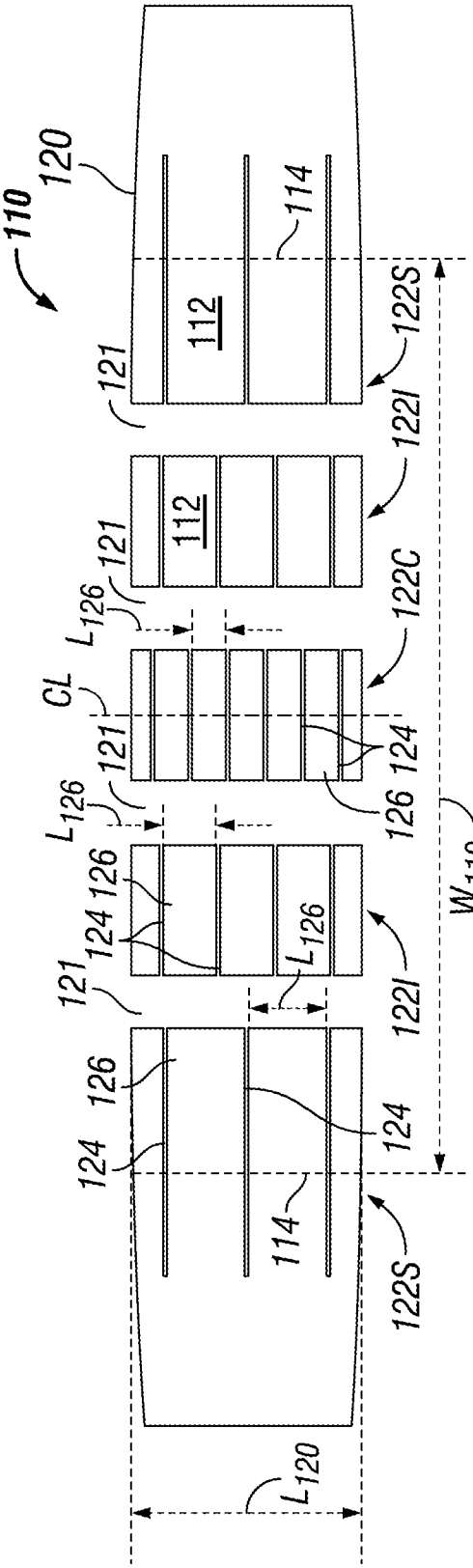


FIG. 1
(Prior Art)

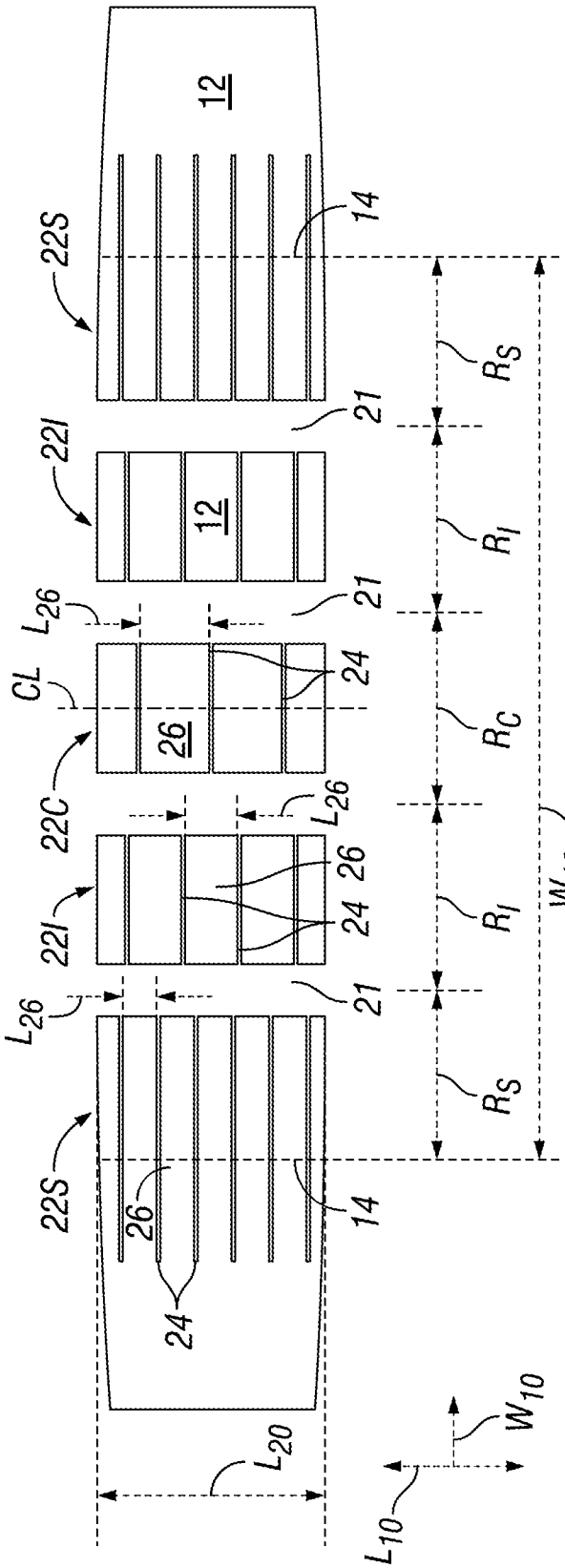


FIG. 2A

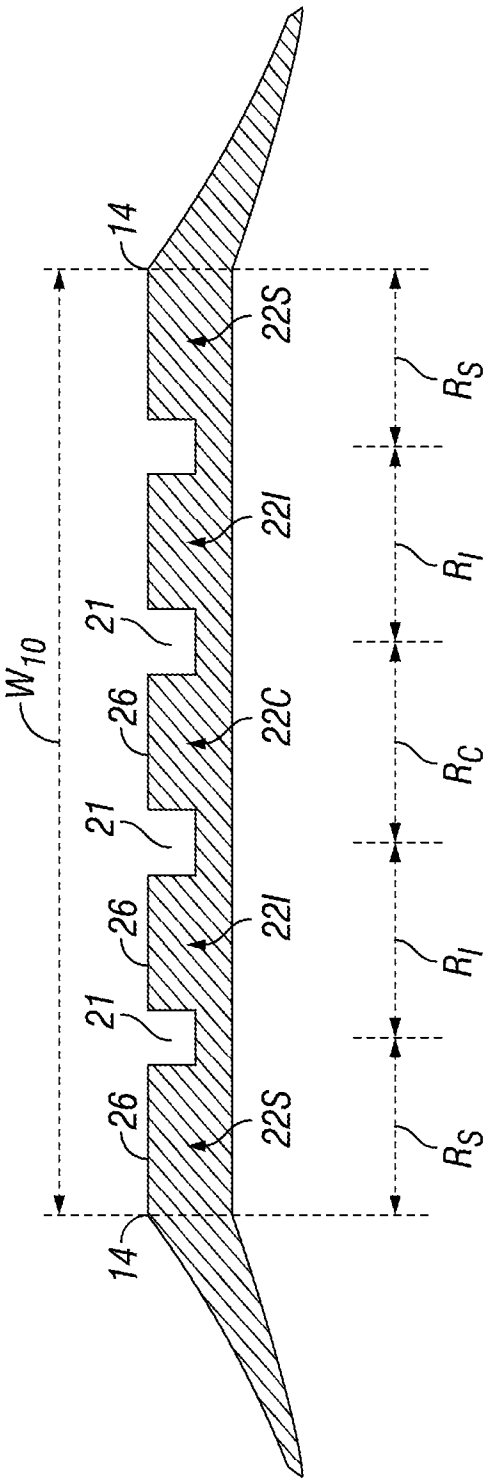


FIG. 2B

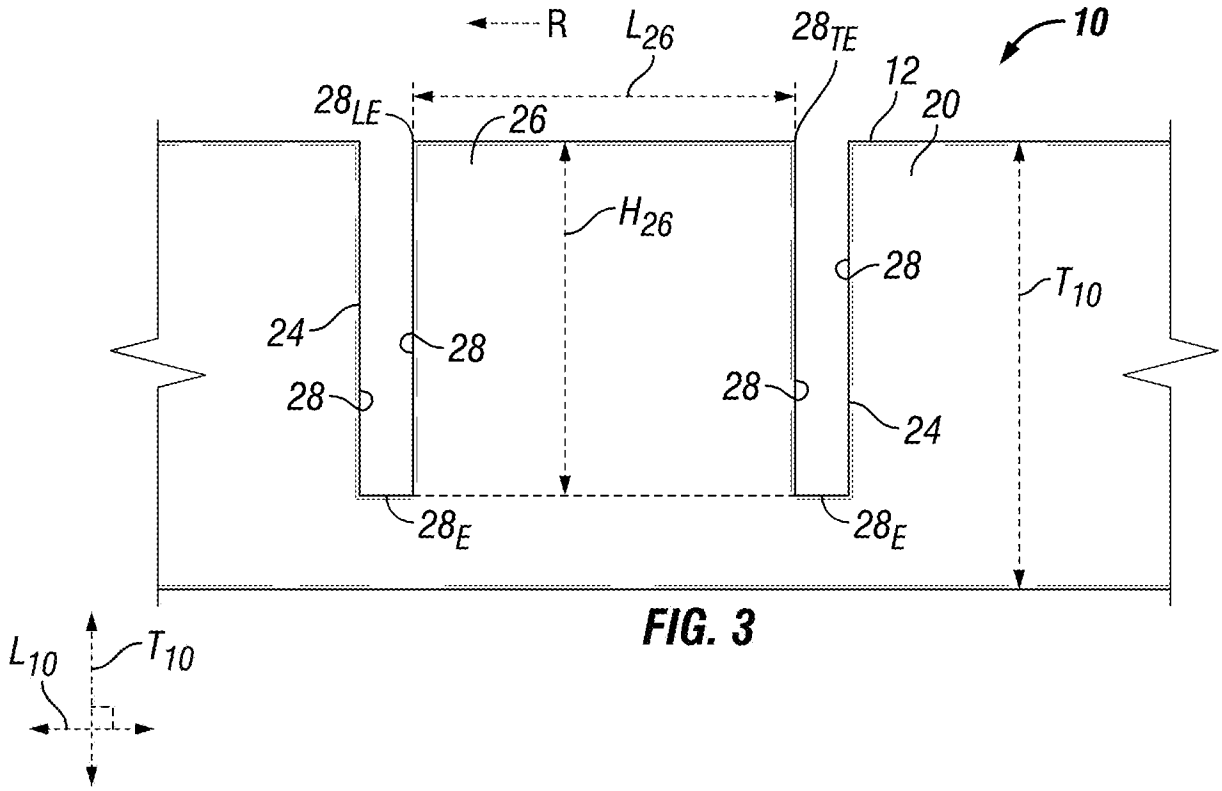

R
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28_{TE}
10
12
20
28_{LE}
26
H_{26}
28
T_{10}
24
28
28
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L_{10}
T_{10}

FIG. 3

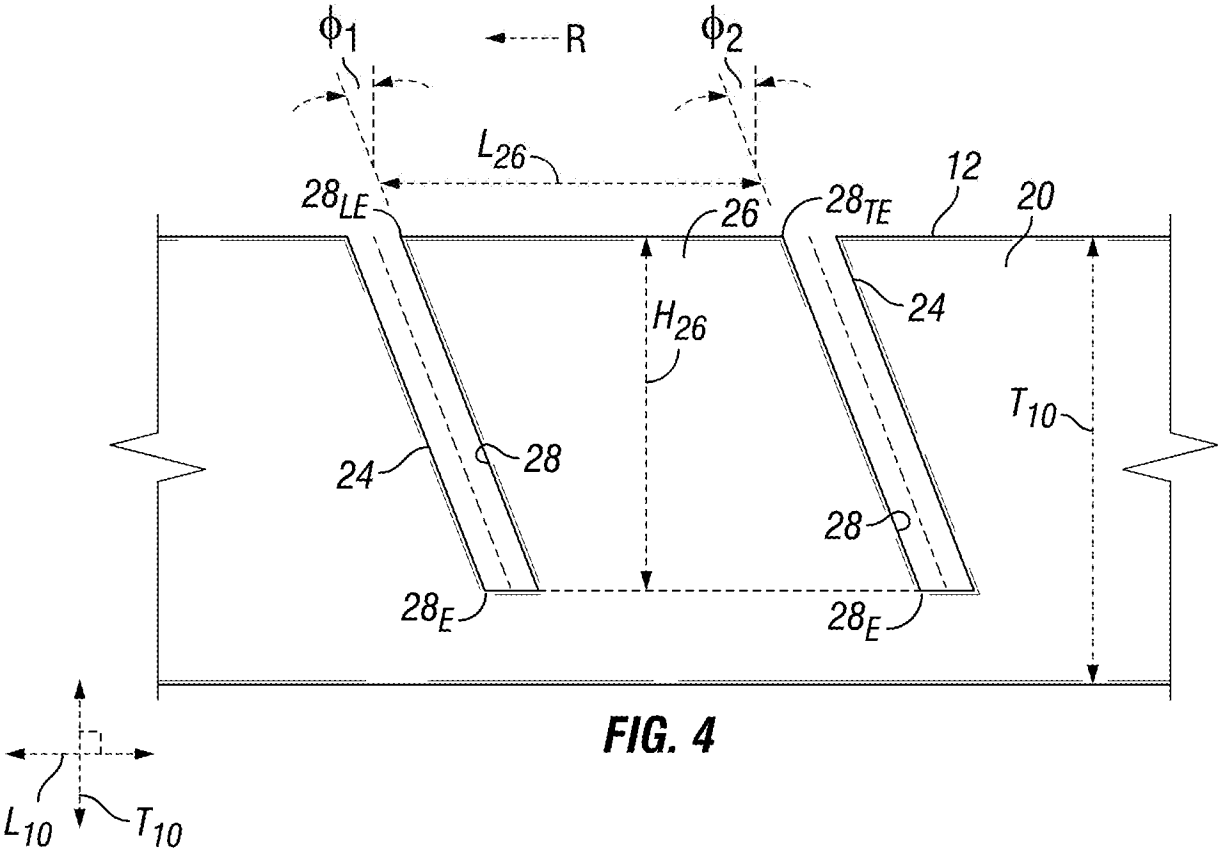

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ϕ_2
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26
28_{TE}
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24
H_{26}
T_{10}
24
28
28
28_E
28_E
L_{10}
T_{10}

FIG. 4

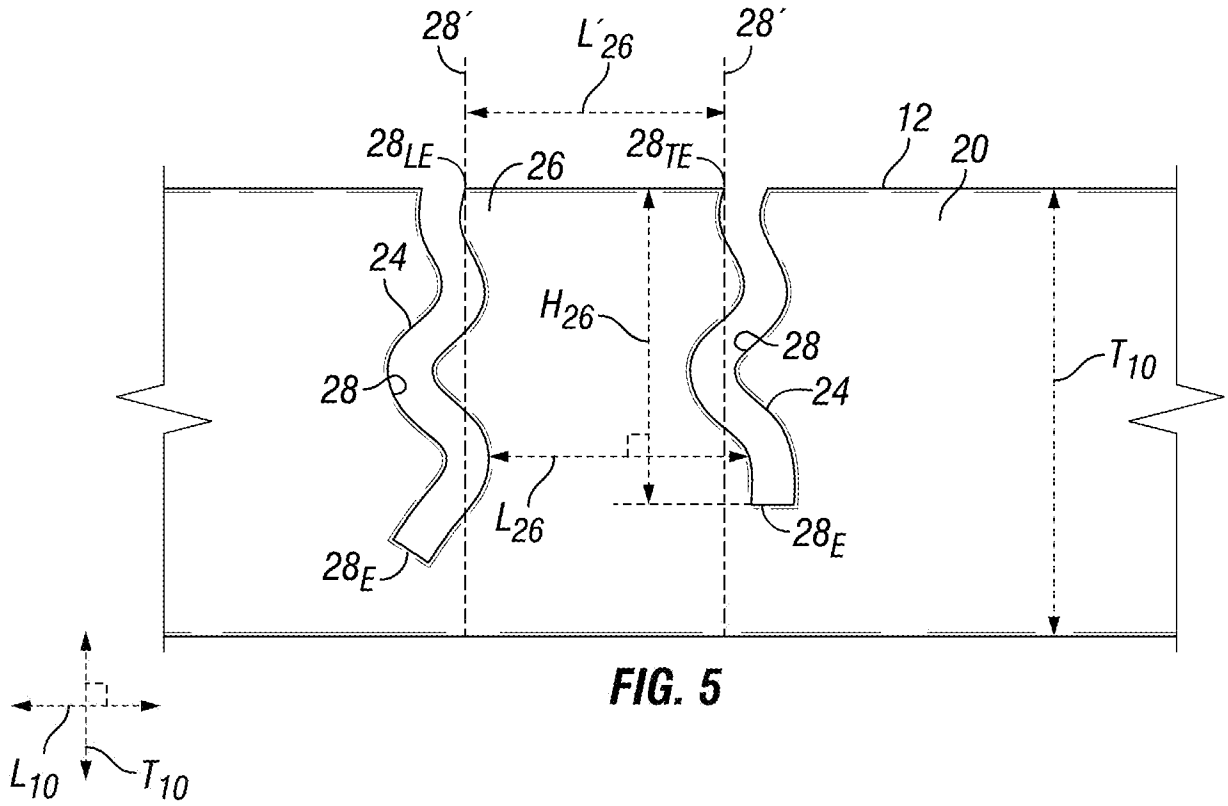

28´
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28´
12
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20
24
H26
28
28
24
T10
L26
28E
28E
L10
T10

FIG. 5

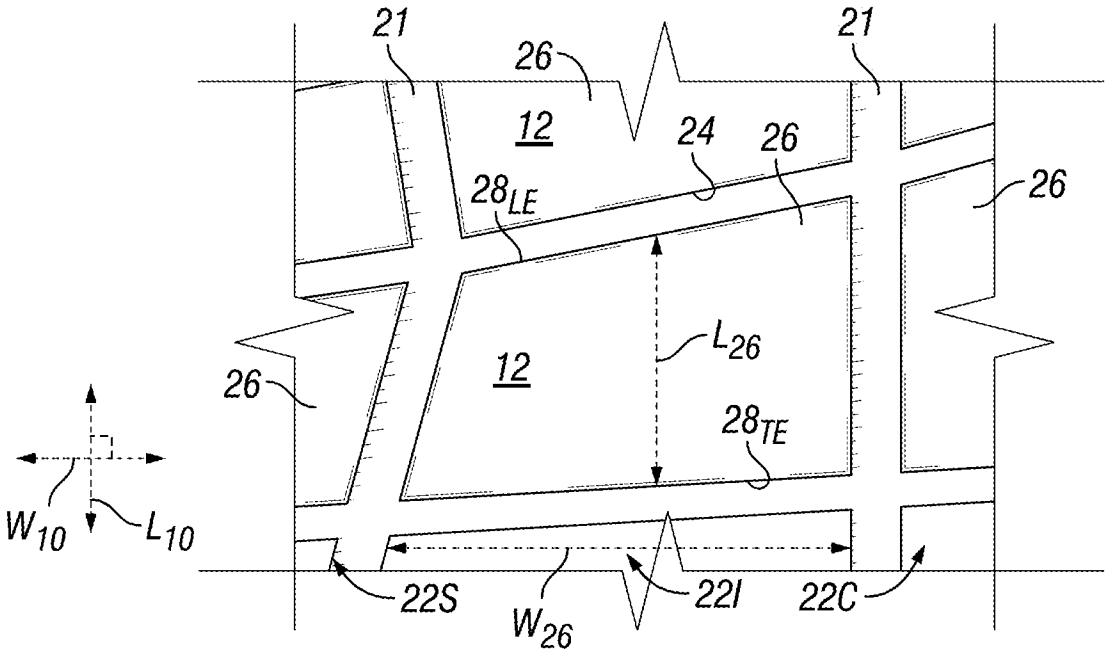

21
26
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L26
12
26
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W10
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22S
W26
22I
22C

FIG. 6

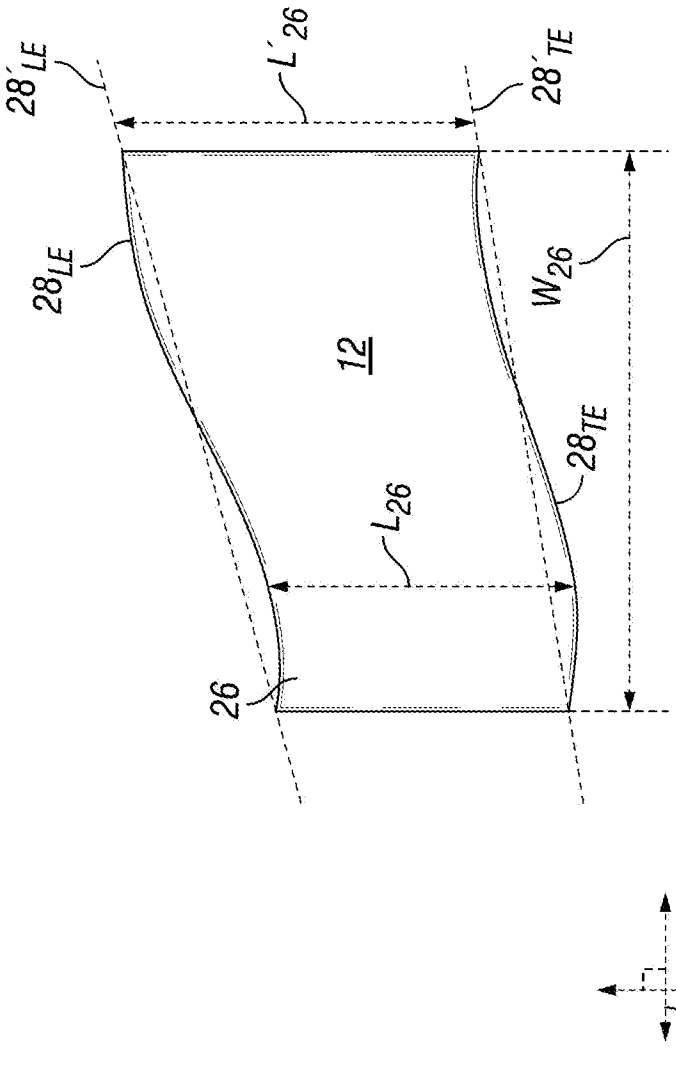


FIG. 7

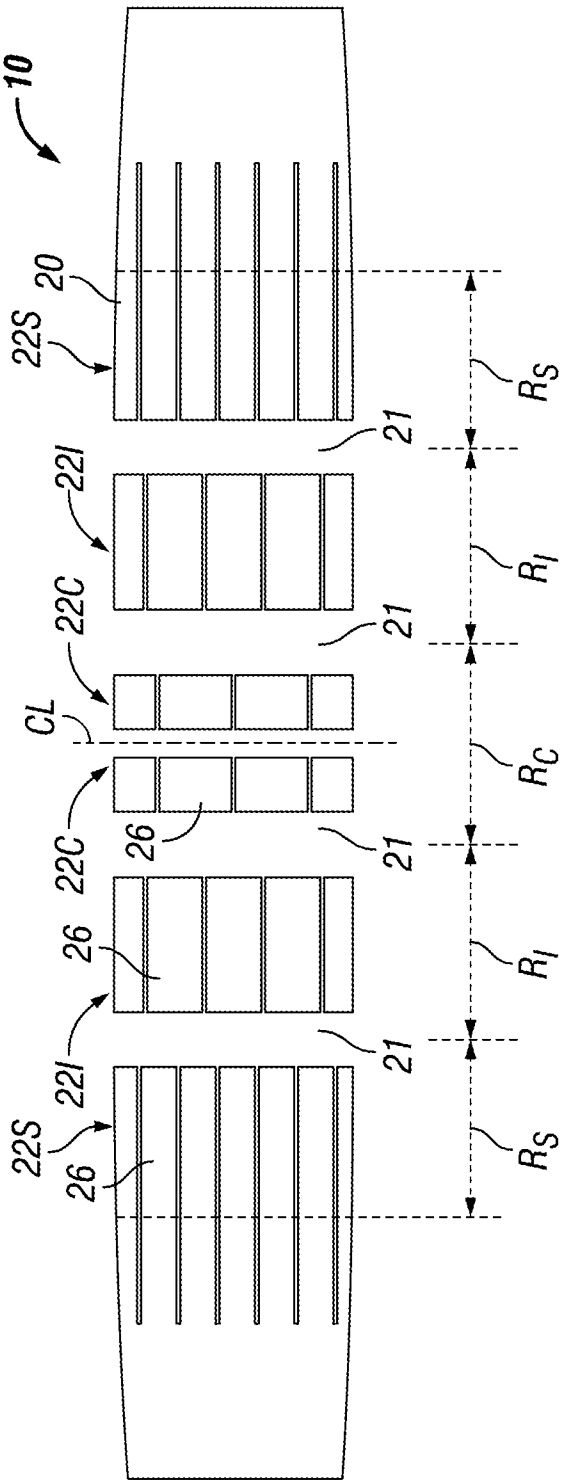

10
20
22S
22I
22C
21
26
CL
R_S
R_I
R_C

FIG. 8

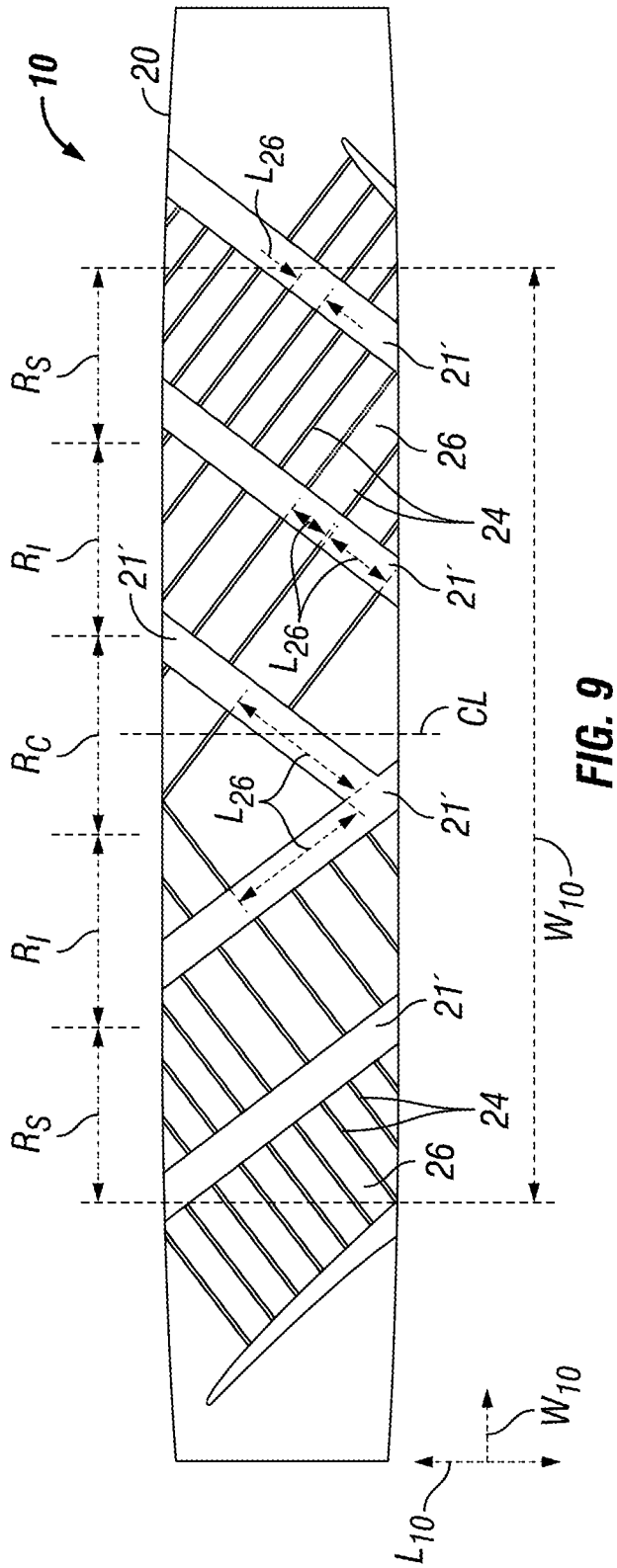

10
20
L_{26}
21′
26
24
CL
R_S
R_I
R_C
W_{10}
L_{10}

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/063990

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60C11/03 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/088622 A1 (YOKOHAMA RUBBER CO LTD [JP]) 9 June 2016 (2016-06-09)	1,2,5, 8-12,14, 16,17
Y	paragraphs [0019] - [0021], [0028]; figure 2	16,17

X	WO 2015/030101 A1 (BRIDGESTONE CORP [JP]) 5 March 2015 (2015-03-05)	1-5,8-17
Y	paragraph [0016]; figure 3	16,17

X	US 5 804 000 A (SHIRAI KENICHI [JP] ET AL) 8 September 1998 (1998-09-08)	1,2, 5-12,14, 16,17
Y	column 2, line 60 - column 3, line 45; figure 1	16,17

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 February 2018	02/03/2018

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/063990

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2011/062595 A1 (MICHELIN RECH TECH; MICHELIN SOC TECH; GUICHON CYRIL [US]) 26 May 2011 (2011-05-26) figures 1, 2, 3, 4A -----	16,17

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/063990

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016088622 A1	09-06-2016	CN 107000493 A	01-08-2017
		JP 5939296 B2	22-06-2016
		JP 2016104593 A	09-06-2016
		US 2017320360 A1	09-11-2017
		WO 2016088622 A1	09-06-2016
WO 2015030101 A1	05-03-2015	CN 104417280 A	18-03-2015
		CN 204149780 U	11-02-2015
		JP 5890361 B2	22-03-2016
		JP 2015047947 A	16-03-2015
		WO 2015030101 A1	05-03-2015
US 5804000 A	08-09-1998	AU 699293 B2	26-11-1998
		DE 69618926 D1	14-03-2002
		DE 69618926 T2	12-09-2002
		EP 0798137 A1	01-10-1997
		JP H09109613 A	28-04-1997
		US 5804000 A	08-09-1998
		WO 9714567 A1	24-04-1997
WO 2011062595 A1	26-05-2011	BR 112012012276 A2	09-08-2016
		CN 102666135 A	12-09-2012
		EP 2504179 A1	03-10-2012
		JP 2013511438 A	04-04-2013
		US 2012267021 A1	25-10-2012
		WO 2011062595 A1	26-05-2011