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(54) Title: TIRE SCULPTURE HAVING THIN SIPEs, TEARDROPS AND LOW LATERAL VOID RATIO

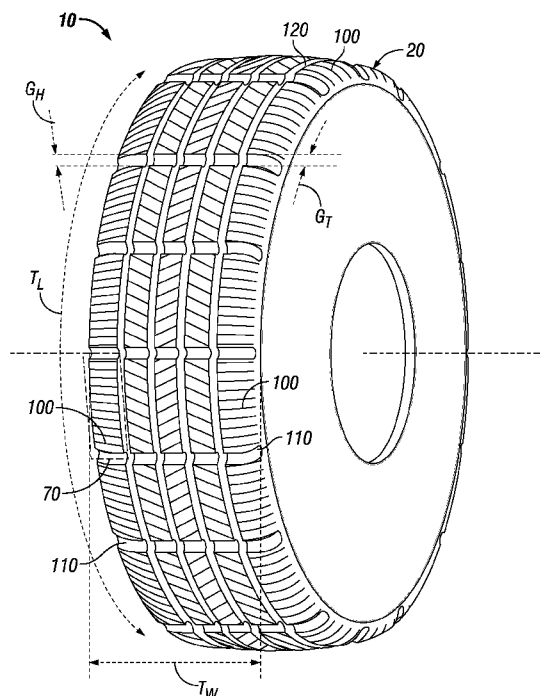


FIG. 6

(57) Abstract: Particular embodiments of the invention form a tire tread. The tire tread is characterized as having a void volume arranged within the thickness of the tread, the void volume being at least formed by a plurality of void features including a plurality of sipes and a plurality of grooves. The plurality of sipes are lateral sipes having a thickness equal to or less than 0.25 millimeter for at least 20% of the respective lateral sipe. At least 60% of the plurality of lateral sipes include a submerged groove arranged at a bottom of each corresponding lateral sipe below the outer, ground-engaging side of the tread and having a cross-sectional void area at least equal to 0.25 square millimeters. The tread is also characterized as having a lateral void ratio equal of 10% or less.



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**TIRE SCULPTURE HAVING THIN SIPES, TEARDROPS
AND LOW LATERAL VOID RATIO**

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates generally to tire treads for use on tires, and more specifically to tire treads having a combination of tread features.

Description of the Related Art

[0002] Tire treads generally extend about the outer circumference of a tire to operate as the intermediary between the tire and a surface upon which it travels (*i.e.*, an operating or ground surface). Contact between the tire tread and the operating surface occurs along a footprint of the tire. Tire treads provide grip to resist tire slip that may result during tire acceleration, braking, and/or cornering in dry and wet conditions. Tire treads may also include tread elements, such as ribs or lugs (also referred to as tread blocks), and tread features, such as grooves and sipes, each of which may assist in providing target tire performance when a tire is operating under particular conditions.

[0003] One common problem faced by tire manufacturers is how to collectively improve the wear performance and noise performance of a tire while additionally improving performance of a tire in wet and/or snowy conditions. For example, when altering tread features to decrease the surface void and/or volumetric tread void, wear performance and noise performance of a tire may improve, however, performance in wet or snow conditions will diminish. By further example, increasing the quantity of tread features, such as lateral voids, may provide improved performance characteristics in snow conditions but negatively impact performance characteristics in wet conditions. Thereby, particular features have not been combined in the prior art since they provide offsetting results.

[0004] Therefore, there is a need for a tire tread that provides improved tire performance, especially in snow conditions, without sacrificing improvement to the wear performance.

SUMMARY OF THE INVENTION

[0005] Embodiments of the present invention include a tire tread and a tire including the tire tread. Particular embodiments of the tire tread include: a length extending in a lengthwise direction, the lengthwise direction being a circumferential direction when

arranged on a tire; a width extending in a lateral direction, the lateral direction being perpendicular to the lengthwise direction; and a thickness extending in a depthwise direction from an outer, ground-engaging side of the tread, the depthwise direction being perpendicular to both the lengthwise direction and the widthwise direction of the tread, the outer, ground-engaging side including a ground-contacting surface. The tire tread is further characterized as having a void volume arranged within the thickness of the tread, the void volume being at least formed by a plurality of void features including a plurality of sipes and a plurality of grooves. The plurality of sipes are lateral sipes, each lateral sipe having a length extending at least partially in the widthwise direction of the tread, a height extending at least partially in the depthwise direction of the tread, and a thickness extending perpendicular to both the length and height of the lateral sipe, the thickness being equal to or less than 0.25 millimeter for at least 20% of the respective lateral sipe. At least 60% of the plurality of lateral sipes include a submerged groove arranged at a bottom of each corresponding lateral sipe below the outer, ground-engaging side of the tread, each submerged groove having a length, a width, and a height extending in the same direction as the length, the width, and the height of the lateral sipe, where a cross-sectional void area measured in the direction of the groove width and the groove height and averaged over the length of each submerged groove is at least 0.25 square millimeters. The tire tread is further characterized as having a lateral void ratio equal of 10% or less.

[0006] The foregoing and other objects, features and advantages of the invention will be apparent from the following more detailed descriptions of particular embodiments of the invention, as illustrated in the accompanying drawing wherein like reference numbers represent like parts of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a perspective view of a tire having a tire tread with lateral sipes, according to an embodiment of the invention.

[0008] FIG. 2 is a top perspective view of a section of the tire tread of FIG. 1, according to an embodiment of the invention.

[0009] FIG. 3 is a top view of a section of the tire tread of FIG. 1, according to an embodiment of the invention.

[0010] FIG. 4 is a sectional view taken along line 4-4 of the tire tread of FIG. 3, according to an embodiment of the invention.

[0011] FIG. 5 is a sectional view taken along line 5-5 of the tire tread of FIG. 3, according to an embodiment of the invention.

[0012] FIG. 6 is a perspective view of a tire having a tire tread with lateral sipes and lateral grooves, according to an embodiment of the invention.

[0013] FIG. 7 is a top perspective view of a section of the tire tread of FIG. 6, according to an embodiment of the invention.

[0014] FIG. 8 is a top perspective view of a section of a tire tread having a thin sipe with a variable thickness, in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[0015] Tire treads generally extend about the circumference of a tire to operate as an intermediary between the tire and a surface upon which it travels (*i.e.*, an operating or ground surface). Tire treads provide grip to resist tire slip that may result during tire acceleration, braking, and/or cornering in dry and wet conditions. Embodiments of the present invention include various configurations of tread features formed in the tread of a tire. Examples of such tread features include grooves and sipes, each of which may assist to provide target tire performance when a tire is operating under particular conditions.

[0016] In particular, embodiments of the present invention combine and arrange various void features to improve wear performance, noise performance, and performance in wet and/or snowy conditions. These void features include combining various configurations and arrangements of lateral void features, including thin sipes and submerged grooves, while maintaining a low lateral void ratio, as discussed in greater detail below. Since each of these features independently provide offsetting results for tread wear, tread noise or performance in wet and/or snow conditions, the combination of these features provide an unexpected collective improvement to wear performance and performance in snowy conditions.

[0017] With regard to the tire treads described herein, it is appreciated that each such tread includes a length, a width and a thickness. The length extends in a lengthwise direction. As the tread may be formed with the tire, or separately for later installation on the tire, such as during retreading operations, for example, the lengthwise direction of the tread is a circumferential (that is, annular) direction when arranged on a tire. The width extends in a lateral direction, the lateral direction being perpendicular to the lengthwise direction. The thickness extends in a depthwise direction from an outer, ground-engaging side of the tread.

The depthwise direction is perpendicular to both the lengthwise direction and the widthwise direction of the tread. The outer, ground-engaging side includes a ground-contacting surface.

[0018] The tread features each form a void within the tread. Voids arranged within a tread can be identified as surface voids or volumetric voids. A surface void generally refers to the amount of void area present along a tire's outer, ground-engaging side at any one time during the life of the tire, that is when new or at a worn depth. The ground-engaging side is the contact interface between the tire and the operating or ground surface (*i.e.*, the surface upon which the tire operates). The amount of surface void present can be characterized by way of a contact surface ratio, which represents the area of tread surface for contacting the ground that is present along the ground-engaging side of the tread divided by total area of the ground-engaging side, where the total area includes both the tread surface and the surface void along the ground-engaging side. As discussed in further detail below, the contact surface ratio may be utilized to characterize the entire tread, or a pitch of the tire tread, which is a segment of the tread containing a pattern of voids forming an arrangement of tread ribs and/or tread blocks. The segment is repeated along the length of the tread to form the entire tread pattern.

[0019] The amount of volumetric void within a tread may also be considered and analyzed, as this void can be useful for consuming and channeling water, mud, etc. from the ground-engaging side for improved traction. Volumetric void (or "void volume") represents the volume of void contained within the tread. Volumetric void ratio is defined as the volume of void contained within a tread divided by the total volume of the tread, the total volume of the tread including both the total volume of the tread material and the total volume of the void arranged in the tread thickness. Also, as used herein, a lateral void ratio associates the total content of volumetric void provided by lateral void features with the total volume present in the tread excluding the void volume provided by all longitudinal void features. As discussed above in relation to the contact surface ratio, the volumetric void ratio and the lateral void ratio may be utilized to characterize the entire tread, or a pitch of the tire tread (where pitch has been described in more detail above).

[0020] In various embodiments of the present invention, the tread has a void volume arranged within the thickness of the tread, the void volume being at least formed by a plurality of sipes and a plurality of grooves. In particular variations, the void volume may be limited to the void volume within a particular rib, that is, each or any rib (that is each or any shoulder, intermediate, or center rib), or to the void volume within all ribs arranged along the

tire. An increase in tread void can reduce the local and overall rigidity of the tread, and likewise, a decrease in tread void can increase the local and overall rigidity of the tread. For example, longitudinal rigidity, which is a measurement of stiffness in the lengthwise direction of the tread, can affect acceleration and braking performance where a change in velocity causes elastic longitudinal deformations in the tire tread. These features can also affect the overall wear and performance of a tire. Accordingly, when increasing tread voids, means for maintaining or increasing tread rigidity may be employed. This may be accomplished in a localized area of a tire tread, or across the entire tire tread.

[0021] It is appreciated that the void features may be shaped in any manner. In other words, each of the void features extend in any direction in a constant or variable manner. For example, in particular embodiments, each of the void features have a constant cross-section taken along any one or more planes. In lieu of having a constant cross-section taken across a particular plane, the thickness of the void feature may vary across any such plane. For example, in particular embodiments, the thickness of the void feature varies linearly or non-linearly as each extends in the depthwise direction of the tread and/or as each extends along the length of the lateral void feature. Additionally, regardless as to whether the thickness is constant or variable, in certain embodiments, the cross-sectional thickness of any void feature extends linearly or non-linearly as each extends in the depthwise direction of the tread and/or as each extends along the length of the lateral void feature.

[0022] As to the various tread features formed in a tire tread, the tire treads include a plurality of lateral void features comprising the plurality of lateral sipes and the plurality of lateral grooves. The grooves having a thickness that is greater than the thickness of the sipes. Sipes form narrow grooves or slits that are configured to close at some instance during tire operation, where grooves remain open to receive water, mud, or other matter that may interfere with traction. The plurality of lateral void features are spaced apart in the lengthwise direction of the tread, each having a length extending primarily in the lateral direction of the tread. By extending primarily in the lateral direction of the tread, it is appreciated that the length of each lateral void feature extends in a lengthwise direction that on average extends primarily in the lateral direction of the tread, where ‘primarily’ connotes that when separating the average lengthwise direction of the lateral void feature into a lateral vector and a longitudinal vector, the lateral vector is greater than the longitudinal vector. It is noted that the lateral vector extends completely in the lateral direction of the tread and is perpendicular to the longitudinal vector, which itself extends in the longitudinal direction of

the tread. Stated differently, the average lengthwise direction of the lateral void feature extends in a direction biased from the lateral direction of the tread in direction of the tread length.

[0023] As for the any void feature described herein, each such feature has a length extending at least partially in a lengthwise or widthwise direction of the tread. The length of each void feature is greater than a height and a thickness of the respective void feature. The height of each such void feature extends at least partially in the depthwise direction of the tread and the thickness extends perpendicular to both the length and height of the respective void feature.

[0024] Additional tread features formed in a tire tread also include a plurality of longitudinal void features. Longitudinal void features comprise plurality of longitudinal grooves, and may, in certain instances, include a plurality of longitudinal sipes. Longitudinal void features have a length extending primarily in the circumferential direction of a tire, or length of the tread. Generally, by extending primarily in the longitudinal direction of the tread, it is appreciated that the length of each longitudinal void feature extends in a lengthwise direction of the tread, which is a circumferential direction of a tire when the tread is installed on a tire. “Primarily” connotes that when separating the average longitudinal direction of the longitudinal void feature into a lateral vector and a longitudinal vector (where each are described in more detail above), the longitudinal vector is greater than the lateral vector.

[0025] In particular embodiments, where a tire tread includes a plurality of void features comprising a plurality of lateral sipes, the thickness of each lateral sipe is equal to or less than 0.25 millimeter for at least 20% of the respective lateral sipe, to thereby provide a thin sipe. In this instance, the sipe thickness is as measured on an un-mounted tire. In the mold, the thickness of each lateral sipe is equal to or less than 0.15 millimeter. By providing thin sipes, wear performance increases while other performance measures relating to snow traction improve. Thin sipes may also improve braking performance. Variations of such embodiments also provide a tire tread having a lateral void ratio of 10% or less, where the lateral void features collectively form 10% or less of the void volume, excluding any void volume formed by all longitudinal void features from the total volume, for the entire tread or any pitch thereof. In other variations, the lateral void ratio is 5% or less, or substantially zero. These percentages of lateral void ratio may be measured along or characterize the whole tread, each or any rib (that is each or any shoulder, intermediate, or center rib), or all ribs. It

is understood that an increase in lateral void increases snow performance, so by providing a reduced lateral void volume as reflected by a low lateral void ratio of 10% or less, or 5% or less, or substantially zero (0%), a decrease in snow performance would be expected. As observed in testing, however, an improvement in snow performance was achieved with tire treads characterized as having a low lateral void ratio.

[0026] It is appreciated that lateral void features may be arranged with a particular spacing in the lengthwise direction of the tread. In particular embodiments in combination with any tread feature or characteristic discussed herein, the plurality of lateral sipes are spaced apart from any lateral void feature, such as any lateral sipe, by an average of 25 millimeters (mm) or less, in the lengthwise direction of the tread, for the entire tread or for a particular pitch. In the other embodiments, the average spacing is 20 mm or less, 12 mm or less, 10 mm or less, 4 mm to 25 mm, 4 mm to 20 mm, 4 mm to 15 mm, 4 mm to 12 mm. It is appreciated that for any such stated average spacing, in other embodiments, the average spacing is not an average, but rather the actual measured spacing for each lateral sipe.

[0027] In particular embodiments of the present invention, particular tread features are submerged (*i.e.*, hidden, located or contained) within the tread depth to provide a tire tread having at least two wear layers. The initial wear layer comprises the outer tread surface of a new tire, while the tread features associated with one or more submerged wear layers become exposed after a desired amount of tread is worn from the tire. To provide improved wet or snow performance in a worn tire, a hidden tread layer may include one or more tread features, such as additional sipes and/or additional lateral grooves. Other features that can affect all wear layers include longitudinal grooves having a negative draft angle (*i.e.*, a groove having a width that increases as the groove extends deeper into a thickness of the tread from an outer, ground-engaging side). Additionally and alternatively, the height of each tread feature, extending at least partially in the depthwise direction of the tread, may further include additional voids increasing or decreasing the thickness of the tread feature below the ground-engaging side of the tread or within the thickness of the tread. Thereby, the thickness of each tread feature may be variable such that at least 20% of each lateral sipe has a thickness equal to or less than 0.25 millimeter, as mentioned above. This taper or transition (that is, the variable thickness) may occur in any constant or linear manner, or in any variable or non-linear manner, as the transitional portion extends from the groove portion and to the sipe portion and/or as the transitional portion extends in the depthwise direction of the tread. Further, to recover, maintain, or even increase tread rigidity, undulating or interlocking sipes

may be employed in the shoulder area and/or along more intermediate ribs or tread elements of the tire. Examples of such features may include stone ejectors, groove bumpers, lugs, etc.

[0028] In one particular embodiment, a submerged tread feature is positioned at a bottom, or opposite the ground-engaging side, of a void feature. In particular, a submerged groove, or teardrop sipe, may be positioned at the bottom of a lateral sipe. A teardrop sipe may extend the full length or a partial length of the lateral sipe. Further, a teardrop sipe may be fully submerged in the tire tread or may extend to the ground-engaging side of the tread (i.e., at the shoulder rib having a reduced tread thickness). In an exemplary embodiment, at least 80% of the plurality of lateral sipes include a submerged groove arranged at the bottom of each corresponding lateral sipe below the outer, ground-engaging surface. One variation of this particular embodiment includes providing submerged grooves in at least 60% of the plurality of lateral sipes. Each submerged groove includes a length, width, and height extending in the same direction as the length, width, and height of the lateral sipe. In these particular embodiments, a cross-sectional void area measured in the direction of the groove width and height and averaged over the length for each groove is at least 0.25 square millimeters (0.25 mm^2). In yet another variation of these particular embodiments, the cross-sectional void area may be as much as 1.5 square millimeters (1.5 mm^2). The greater the cross-sectional void area, the greater the flexibility in the tire tread which provides improvement for performance in snow. Again, this particular feature would not be combined with the previously identified features as the perceived improvements would be expected to collectively negate one another.

[0029] In combination with any tread features described above, the void features may be further organized based upon the orientation on the tire. For example, combinations of the above void features and relationships may be formed consistently across each pitch of a tire, including interior ribs and shoulder ribs. Alternatively, various combinations of the above void features and relationships may be variable across each pitch or within each pitch. By example, the combination of each void feature and relationships between void features may be a function of the location, thickness and or width of each respective pitch. By further example, shoulder ribs may comprise a different combination of features or relationship between features than an interior rib. Similarly, one shoulder rib or interior rib may have a different combination of features or relationship between features than a different shoulder rib or interior rib, respectively. Such adjustments or variations would further provide improved performance and/or wear. By example, the configuration of the void features at the

interior ribs may have a greater impact on performance in wet conditions. Moreover, the combination of features and relationships between features may vary along the length of the tire tread in each respective pitch.

[0030] Particular embodiments of the tire treads and methods discussed above will now be described in further detail below in association with the figures filed herewith exemplifying the present invention in association with particular embodiments of the tires.

[0031] With reference to FIG. 1, in an exemplary embodiment, a tire **10** having a tire tread **20** is shown having a plurality of tread ribs **60** separated by longitudinal void features **120**. Each rib **60** extends the tread length T_L about the circumference of the tire **10**, which is also referenced as the lengthwise direction of the tread. Tread **10** also has a tread width T_W extending in a lateral direction, the lateral direction being perpendicular to the lengthwise direction T_L and a depthwise direction of the tread. In this particular embodiment, lateral sipes **100** are arranged along each rib **60**. Each rib **60** can be further described as either a shoulder rib **80** or an interior rib **90** (also referred to as an intermediate rib). The middle interior rib **90** is referred to as a center rib, as it is arranged along a centerline of the tire. The ribs **60** are separated by longitudinal groove **120**. As can be seen, the tread includes a plurality of lateral sipes **100**, which are arranged on each rib **60**. It is noted that tire tread **20** is substantially free of any lateral grooves. Tire tread is shown in further detail in FIGS. 2-4.

[0032] In FIGS. 2-4, a top perspective view, top view, and side view, respectively, of a section of the tire tread from FIG. 1 is shown. Each section is referred to as a pitch of the tire tread, which is a repeating portion of the tread design (*i.e.*, of the tread pattern, or pattern of void features). Also shown are a plurality of submerged grooves **130** located at the bottom of certain lateral sipes **100**. While each lateral sipe **100** is shown to extend a sipe length S_L across the entire width of interior ribs **90**, terminating at each longitudinal void groove **120**, it is appreciated that a lateral sipe **100** have a length may extend partially across (less than) the entire width of any rib **60**.

[0033] As illustrated in FIGS. 2 and 3, each lateral sipe **100** (or more generally each lateral void feature) is separated by a spacing SP_{100} . The spacing SP_{100} is the distance between each lateral sipe **100** and is measured from the void formed at the ground-engaging side **50** of the tread **20**. Various spacings are contemplated, and which are discussed in greater detail above.

[0034] FIG. 5 is a sectional view of the embodiment of FIG. 3 taken along section 5-5. FIG. 5 illustrates the height of each sipe S_H and of each submerged groove G_H formed within the tread thickness T_T . Additionally illustrated is the sipe thickness S_T and spacing SP_{100} as discussed in greater detail in the description above.

[0035] FIG. 6-7 show an alternative embodiment of the tire tread 20 shown in FIG. 1, where lateral grooves 110 with a groove height G_H and a groove thickness G_T have been included.

[0036] FIG. 8 provides a sectional view of a lateral sipe 100 arranged in tire tread 20. In particular, a lateral sipe 100, referred to in this embodiment as a variable sipe, is shown having a variable thickness with a reduced thickness located below the surface of the tread. In this particular embodiment, the variable sipe has a wider thickness VS_{WT} positioned at the top and to the bottom of the sipe. The height of the wider thickness is illustrated by VS_{TH} to the top and VS_{BH} to the bottom. A narrower thickness is positioned between the VS_{TH} and VS_{BH} and is illustrated by an intermediate height VS_{IH} . Together, the VS_{BH} , VS_{IH} , and VS_{TH} form the VS_H . In variations of this particular embodiment the variable sipe or void feature may linearly or non-linearly as each lateral sipe 100 extends in the depthwise direction of the tread. Similarly, the variable sipe or void feature may vary linearly or non-linear the length or width of the tread. Such variations as described herein may be incorporated into the various embodiments of the present invention as described above.

[0037] It is appreciated that any tread discussed herein may be arranged along an annular pneumatic tire, or may be formed separately from a tire as a tire component for later installation on a tire carcass, in accordance with any technique or process known to one of ordinary skill in the art. For example, the treads discussed and referenced herein may be molded with a new, original tire, or may be formed as a retread for later installation upon a used tire carcass during retreading operations. Therefore, when referencing the tire tread, a longitudinal direction of the tire tread is synonymous with a circumferential direction of the tire when the tread is installed on a tire. Likewise, a direction of the tread width is synonymous with an axial direction of the tire or a direction of the tire width when the tread is installed on a tire. Finally, a direction of the tread thickness is synonymous with a radial direction of the tire when the tread is installed on a tire. It is understood that the inventive tread may be employed by any known tire, which may comprise a pneumatic or non-pneumatic tire, for example.

[0038] It is appreciated that any of the tread features discussed herein may be

formed into a tire tread by any desired method, which may comprise any manual or automated process. For example, the treads may be molded, where any or all void features therein may be molded with the tread or later cut into the tread using any manual or automated process. It is also appreciated that any one or both of the pair of opposing void features may be originally formed along, and in fluid communication with, the outer, ground-engaging side of the tread, or may be submerged below the outer, ground-engaging side of the tread, to later form a tread element after a thickness of the tread has been worn or otherwise removed during the life of the tire.

[0039] The following tests were performed to compare the performance of a particular embodiment of the present invention having no lateral grooves against a baseline conventional tread. All tests were performed using new treads (*i.e.*, having full tread depth) on a 205/55 R16 sized tire.

- Sipe Thickness: The conventional tread, as measured on an un-mounted and uninflated tire, had a sipe thickness, measured at the ground-engaging side of the tread, of 0.75 millimeters, on average, where the sipes arranged along the center rib were 0.6 mm thick, the sipes arranged along the shoulder ribs were 1.0 mm thick, and there the sipes arranged along the intermediate ribs between the center rib and each shoulder rib were 0.65 mm. In contrast, the tested embodiment of the present invention had a reduced sipe thickness, measured at the ground-engaging side of the tread, of 0.25 millimeters on at least 40% of the surface (0.15 mm in mold), as measured on an un-mounted and uninflated tire, and which remained generally constant below the ground-engaging side as the sipe extends into the depth of the tread.
- Teardrop Sipes: The conventional tread did not have any teardrop sipes. In contrast, the tested embodiment of the present invention had teardrops at 100% of the lateral sipes and with a teardrop cross section of at least 0.25 square millimeters (mm²).
- Lateral Void Ratio: The conventional tread had a lateral void ratio of 12%, averaging over the entire tire. More specifically, the conventional tire had a lateral void ratio of 11% for the shoulder ribs, a lateral void ratio of 15% for the intermediate ribs between a center rib and the shoulder ribs, and a lateral void ratio of 7% along the center rib. In contrast, the tested embodiment of

the present invention had a lateral void ratio of 7% to 8% for all ribs of the tire.

[0040] The results of the test illustrated collective improvements in the following areas:

- Wear Performance: An improvement of at least 10% was documented from the conventional tread to the tested embodiment of the present invention. In particular, the conventional tread produced a result at 100% while the tested embodiment of the present invention produced a result of 110%.
- Snow Performance: An improvement of 20% was documented from the conventional tread to the tested embodiment of the present invention. In particular, using a GM Spin Traction test the conventional tread produced a result at 100% while the tested embodiment of the present invention produced a result of 120%.
- Wet Performance: The wet performance was maintained between the treads tested. In particular, both the conventional tread and the tested embodiment of the present invention produced a result of 101% when testing wet braking performance.

[0041] With regard to the tested embodiment, the tests specifically illustrate the tested embodiment of the present invention maintained or improved the collective performance over the tested conventional tread in the categories tested. Specifically, wet performance was maintained, there was a general improvement in wear performance, and there was a significant improvement in snow performance. This is in view of making modifications to a tread pattern known to negatively impact results in each of these particularly tested areas. Thereby, the collective combination of the arrangement of the tested void features maintained or improved performance characteristics which would otherwise decrease performance in these areas when used independently in prior art configurations.

[0042] The terms “comprising,” “including,” and “having,” as used in the claims and 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 invention. Ranges that are described as being “between a and b” are inclusive of the values for “a” and “b” unless otherwise specified.

[0043] While this invention has been described 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 the claimed invention. Accordingly, the scope and content of the invention are to be defined only by the terms of the following claims. 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 length extending in a lengthwise direction, the lengthwise direction being a circumferential direction when arranged on a tire;

a width extending in a lateral direction, the lateral direction being perpendicular to the lengthwise direction;

a thickness extending in a depthwise direction from an outer, ground-engaging side of the tread, the depthwise direction being perpendicular to both the lengthwise direction and the widthwise direction of the tread, the outer, ground-engaging side including a ground-contacting surface;

the tread having a void volume arranged within the thickness of the tread, the void volume being at least formed by a plurality of void features including a plurality of sipes and a plurality of grooves;

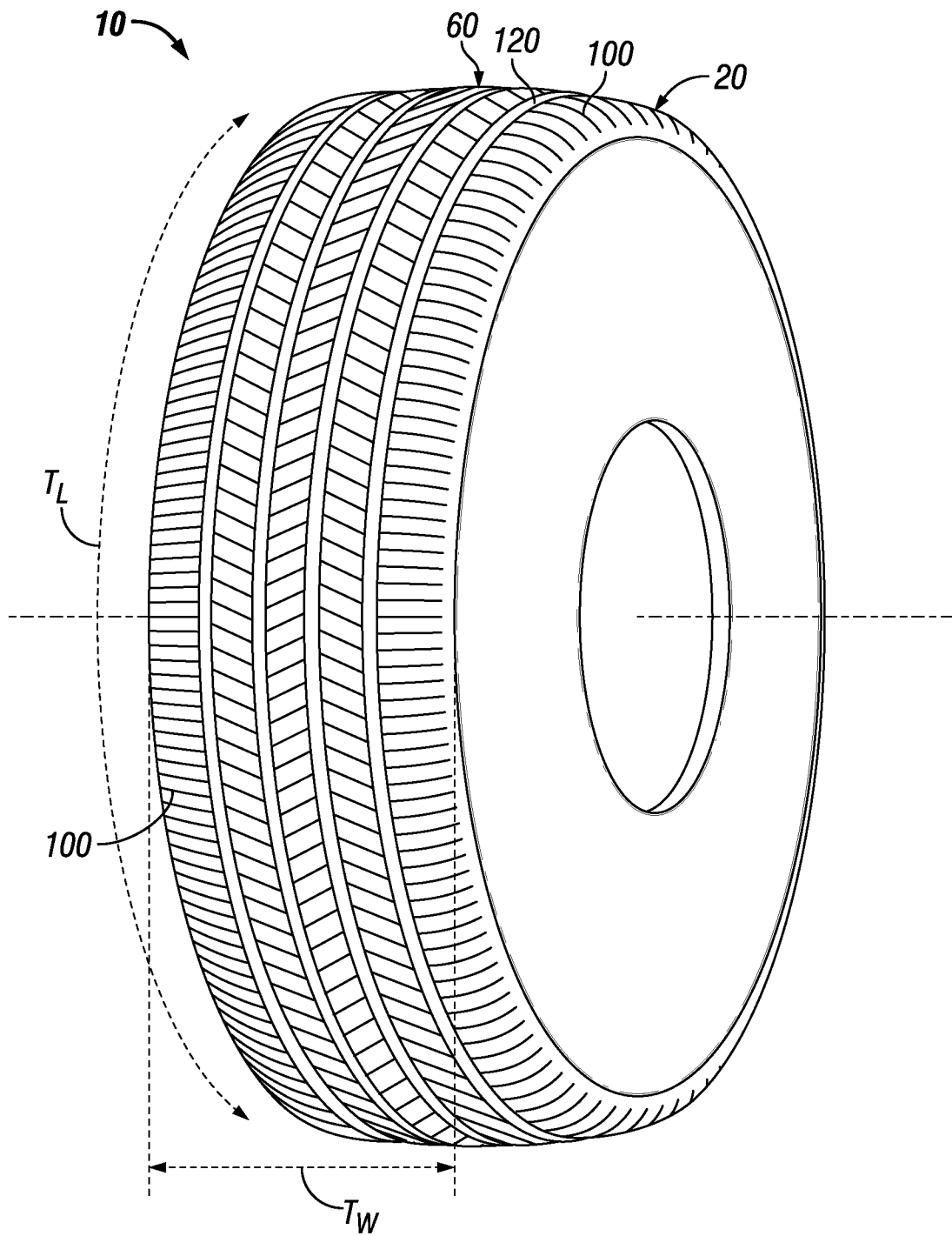
where the plurality of sipes are lateral sipes, each lateral sipe having a length extending at least partially in the widthwise direction of the tread, a height extending at least partially in the depthwise direction of the tread, and a thickness extending perpendicular to both the length and height of the lateral sipe, the thickness being equal to or less than 0.25 millimeter for at least 20% of the respective lateral sipe;

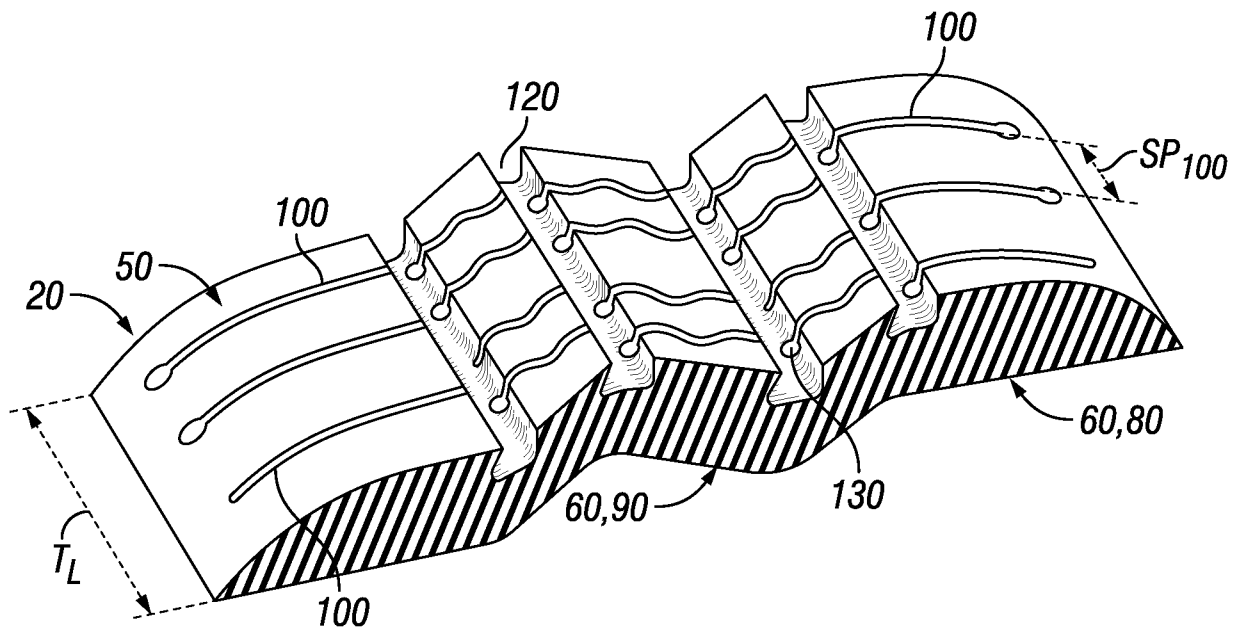
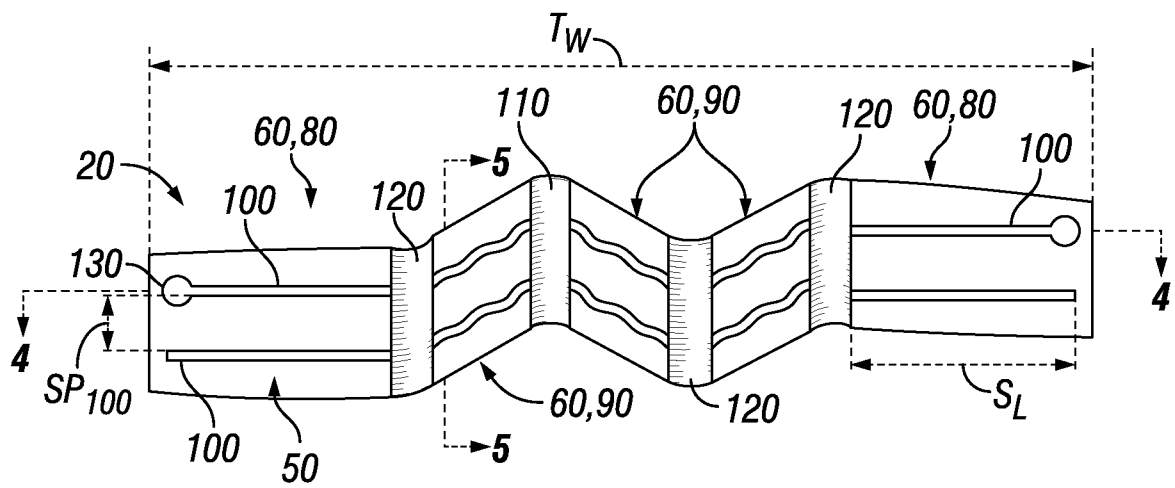
where at least 60% of the plurality of lateral sipes include a submerged groove arranged at a bottom of each corresponding lateral sipe below the outer, ground-engaging side of the tread, each submerged groove having a length, a width, and a height extending in the same direction as the length, the width, and the height of the lateral sipe, where a cross-sectional void area measured in the direction of the groove width and the groove height and averaged over the length of each submerged groove is at least 0.25 square millimeters; and

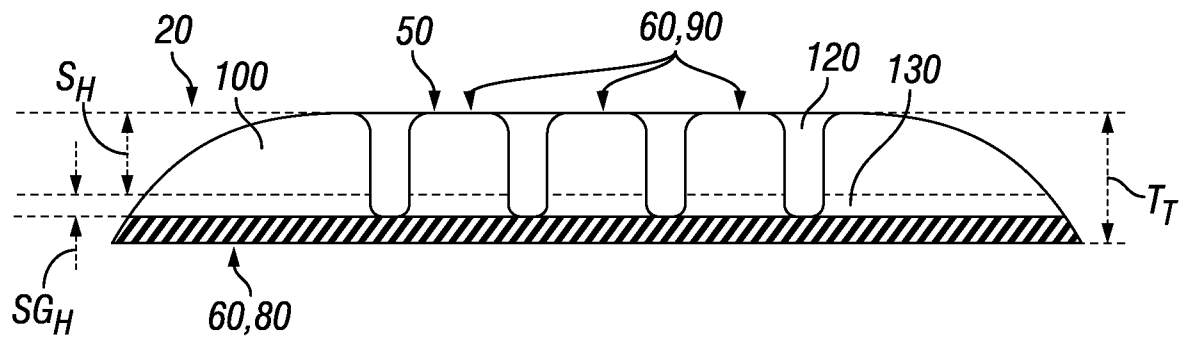
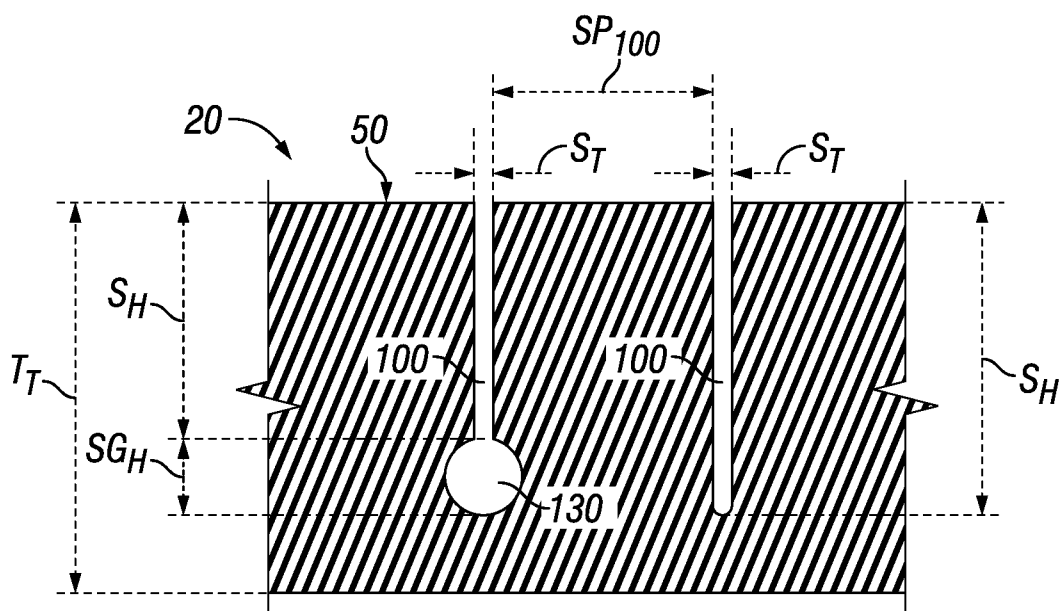
where the tread is characterized as having a lateral void ratio equal of 10% or less.

2. The tire tread of claim 1 where the tire tread is substantially free of any lateral groove.

3. The tire tread of any one of claim 1 and 2, where the plurality of lateral sipes are spaced apart by an average distance of 25 mm or less.
4. The tire tread of any one of claim 1 and 2, where the plurality of lateral sipes are spaced apart by an average distance of 12 mm or less.
5. The tire tread of any one of claims 1 to 4, where at least 80% of the plurality of lateral sipes include one of the submerged grooves arranged at the bottom of each corresponding lateral sipe below the outer, ground-engaging side of the tread.
6. The tire tread of any one of claims 1 to 5, where the cross-sectional void area measured in the direction of the groove width and the groove height and averaged over the length of each submerged groove is at least 1.5 square millimeters
7. The tire tread of any one of claims 1 to 6, where the tread is characterized as having a lateral void ratio equal of 5% or less.
8. The tire tread of any one of claims 1 to 7, where one or more lateral sipes have a variable thickness.

**FIG. 1**

**FIG. 2****FIG. 3**

**FIG. 4****FIG. 5**

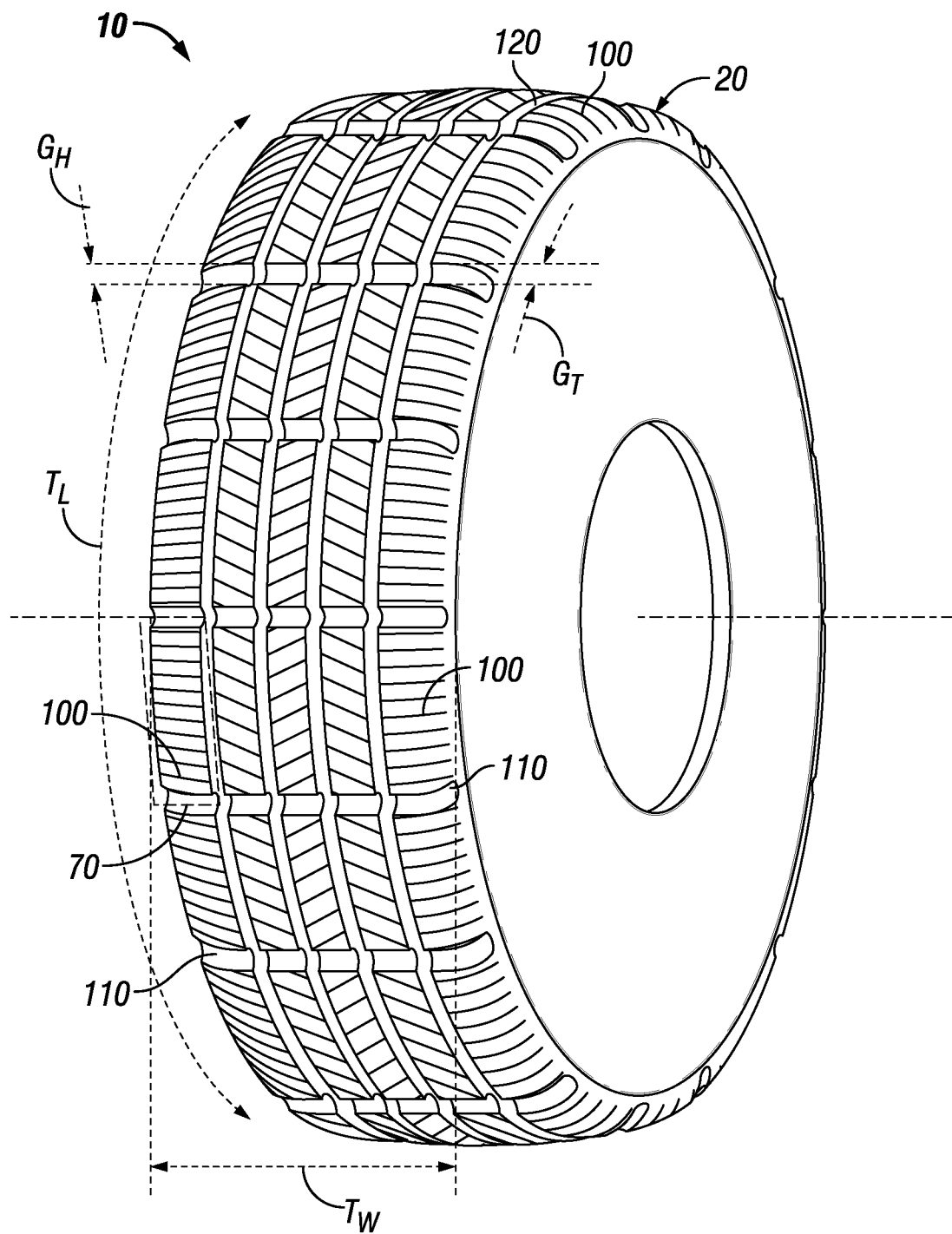


FIG. 6

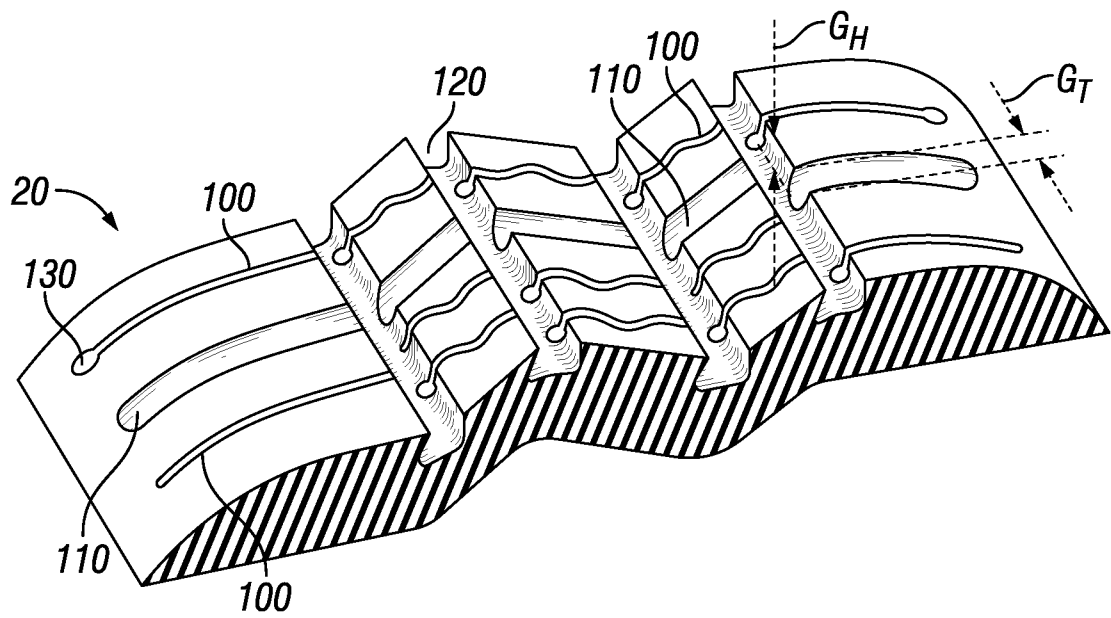


FIG. 7

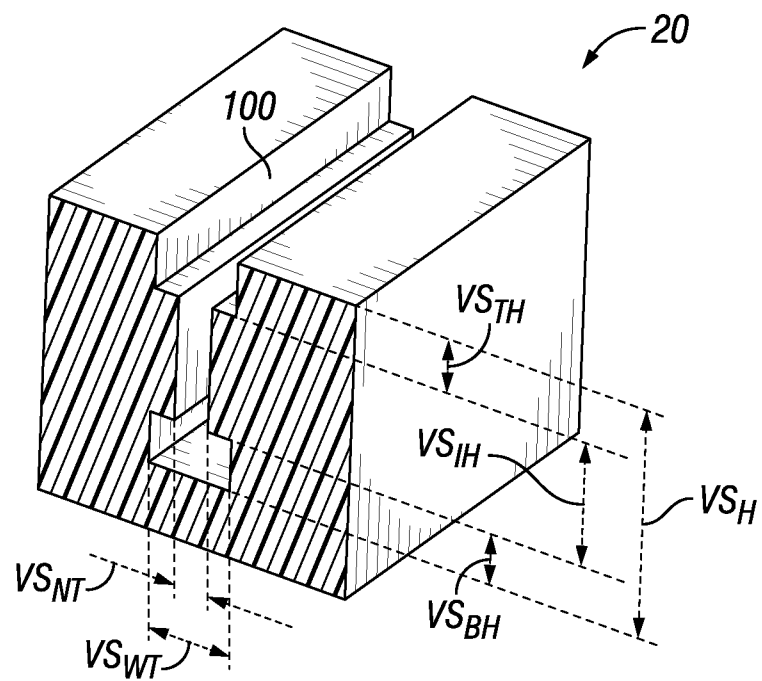


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/058463

A. CLASSIFICATION OF SUBJECT MATTER
INV. 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

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X	WO 2012/058171 A1 (MICHELIN RECH TECH [CH]; MICHELIN SOC TECH [FR]; WARFFORD JEFFREY THOM) 3 May 2012 (2012-05-03) abstract; figures 1,2,5,12,13 paragraphs [0030], [0049], [0050] -----	1,2,4-8
X	EP 2 546 080 A1 (BRIDGESTONE CORP [JP]) 16 January 2013 (2013-01-16) paragraph [0051]; figures 3,7,9-12 ----- -/-	1,3,6,8



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 June 2016

Date of mailing of the international search report

23/06/2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/058463

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	abstract; claims 1,14,20,22; figures 1,3,4,6,7, paragraphs [0022] - [0025] -----	8
X	US 6 467 517 B1 (RADULESCU ROBERT CIPRIAN [FR]) 22 October 2002 (2002-10-22)	1,2,7
A	abstract; figures 3,5-7 -----	3,4,6

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