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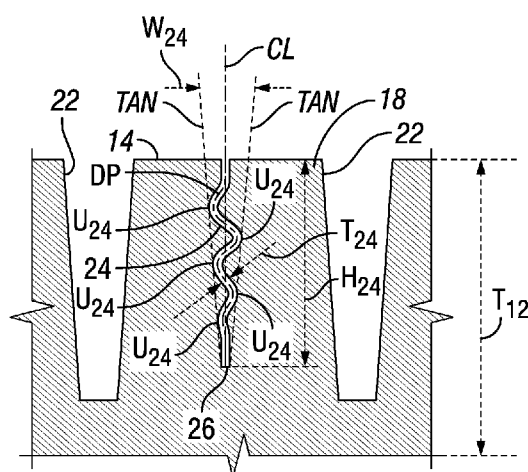


FIG. 2

(57) Abstract: Particular embodiments of the disclosure provide a tire tread (18), the tire tread including at least one sipe (24) extending into the tread thickness along a depthwise path into the tread thickness away from an outer, ground-engaging side of the tread and to a terminal end. The sipe has a thickness extending perpendicular to the depthwise path, the depthwise path being located midway across the sipe thickness, where a portion of the depthwise path undulates back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path extends into the tread thickness to form a plurality of undulations (U24), the undulations decreasing in amplitude relative to a centerline of the depthwise path as the sipe extends further into the tread thickness towards the terminal end (26).

TIRE TREADS HAVING TAPERED, UNDULATING SIPESBACKGROUNDField

[0001] Embodiments of this disclosure relate generally to tire treads for tires.

Description of the Related Art

[0002] Tires, whether pneumatic or non-pneumatic, include a tread configured to develop traction (adherence) between the vehicle and a road surface. Commonly, these tire treads include sipes, which are very thin discontinuities extending within the tire tread. Sipes are generally intended to close when arranged within in a tire contact patch (footprint) during tire rotation, the contact patch being the area of contact between the tire and a ground surface. To the contrary, a groove is thicker than a sipe as it is intended to remain open during tire operation, such as to receive water and snow for the purpose of evacuating the same from the tire footprint to promote traction between the tire and the ground surface.

[0003] Issues can arise, however, when demolding treads from curing molds. More specifically, when removing sipe molding members from a tire tread, where the sipe molding members have a thickness that undulates to form undulating sipes, the tire tread will stretch causing one side of the sipe to become misaligned with the other side of the sipe as interference between the undulations prohibits the tread from returning to its unstretched orientation, resulting in misalignment of the undulations in a direction of the tread thickness. This is often referred to as “ratcheting” within the industry. Therefore, there is a need prevent this misalignment of the tread along a sipe.

SUMMARY

[0004] Particular embodiments of the disclosure provide a tire tread, the tire tread having a tread thickness extending from an outer, ground-engaging side and to a bottom side, the thickness extending in a direction perpendicular to both a length and a width of the tread, the width extending between a pair of lateral sides of the tread, where the tread length is greater than the tread width. The tire tread also includes at least one sipe extending into the tread thickness along a depthwise path into the tread thickness away from an outer, ground-engaging side of the tread and to a terminal end. The sipe has a thickness extending perpendicular to the depthwise path, the depthwise path being located midway across the sipe thickness, where a portion of the depthwise path undulates back and forth in a direction

perpendicular to the direction of the tread thickness as the depthwise path extends into the tread thickness to form a plurality of undulations, the undulations decreasing in amplitude relative to a centerline of the depthwise path as the sipe extends further into the tread thickness towards the terminal end.

[0005] The foregoing and other objects, features, and advantages will be apparent from the following more detailed descriptions of particular embodiments, as illustrated in the accompanying drawings wherein like reference numbers represent like parts of particular embodiments.

DETAILED DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a top perspective view of a portion of a tire, showing a tire tread arranged along a tire carcass, in accordance with an exemplary embodiment;

[0007] FIG. 2 is a side sectional view of the tire tread shown in FIG. 1 taken along line 2-2;

[0008] FIG. 3 is a side sectional view of a sipe in accordance with a particular variation of the sipe shown in FIG. 2;

[0009] FIG. 4 is a side sectional view of a depthwise path of the sipe shown in FIG. 2;

[0010] FIG. 5 is a graph showing the unexpected improvement in both vertical and transverse tread rigidity when employing sipes having tapering undulations;

[0011] FIG. 6 is a side sectional view of a sipe in accordance with another particular variation of the sipe shown in FIG. 2;

[0012] FIG. 7 is a side sectional view of a sipe in accordance with a particular variation of the sipe shown in FIG. 2;

[0013] FIG. 8 is a side sectional view of an inclined sipe in accordance with a particular variation of the sipe shown in FIG. 2.

[0014] FIG. 9 is a front perspective view of a sipe molding member, for use in molding a sipe within a tire tread; and,

[0015] FIG. 10 is a front perspective view of a sipe molding member according to another embodiment where the sipe molding member is configured to form an area of reduced thickness within a sipe.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0016] This disclosure provides improved sipe designs for improved manufacturing and performance. By providing sipes and sipe molding members having undulations that taper or decrease in amplitude as the sipe extends into the tread thickness, demolding operations are improved. In particular, demolding force is reduced, as is the risk of ratcheting and the tearing of blocks and ribs. In addition to these improvements in demolding operations, unexpected improvements in tread rigidity are also achieved.

[0017] The present disclosure concerns tire treads having sipes formed by molding, and sipe molding elements for forming such treads by molding. It is appreciated that the tire treads may be annularly molded when forming a new tire, or separately from any tire or tire carcass, such as when being molded within a flat or annular mold for retreading operations.

[0018] A tire tread according to the present disclosure includes a length, width, and a thickness. The thickness extends from an outer, ground-engaging side of the tread and to a bottom side of the tread. The thickness can be said to extend in a direction perpendicular to both the length and the width of the tread. In other words, the direction of the tread thickness is a direction perpendicular to both the direction of the tread width and the direction of the tread length. The direction of the tread thickness is also perpendicular to the outer, ground-engaging side. When the tire tread is arranged on a tire for use, the direction of the tread thickness extends in a radial direction at a widthwise centerline of the tire tread. The widthwise centerline of the tread coincides with an equatorial centerplane of the tire tread. The tread width extends between a pair of lateral sides of the tread. It can be said that the tread length is greater than the tread width.

[0019] Due to the presence of void features described herein, the tread includes a plurality of tread elements arranged along the outer, ground-engaging side. The void features comprise longitudinal grooves, and from time-to-time, lateral grooves which may intersect one or more longitudinal grooves. These grooves at least partially define these tread elements, which may form a continuous, annular rib or a tread block. A rib is defined by either a pair of opposing longitudinal grooves or a longitudinal groove and the shoulder of the tread, each being spaced-apart from one another in a direction of the tread width (which is also referred to as a lateral direction). Each tread block is described as having a leading side and a trailing side, each leading and trailing side extending into the tread thickness from the outer, ground-engaging side. In distinguishing between the leading and trailing sides, the leading side

precedes the trailing side in a direction of forward tread rotation, such that the leading side approaches a surface upon which a tire is operating (a tire operating surface) before the trailing side for any such tread block. It is further noted that each tread block has a pair of spaced apart lateral sides, that is, sides spaced is in a general direction of the tread width. The pair of lateral sides define a width of the tread block, while the leading and trailing sides define a length of the corresponding tread block. Each lateral side extends into the tread thickness from the outer, ground-engaging side and is defined by (that is, formed by) either a longitudinal groove or a shoulder of the tread. A shoulder of the tread is a free, exterior side edge arranged at or near a lateral side of the tread. The shoulder defines the widthwise extent of the outer, ground-engaging side of the tread, whereby the width of the outer, ground-engaging surface is defined by a pair of spaced apart shoulders. A longitudinal groove and a shoulder each extend generally in the direction of the tread length. "Generally in the direction of the tread length" indicates that any longitudinal groove or shoulder extends primarily in the direction of the tread length, such that in separating the direction into a pair of vectors, one extending in the direction of the tread length (longitudinal vector) and the other extending in the direction of the tread width (lateral vector), the longitudinal vector is greater than the lateral vector. It is appreciated that the lateral vector may be zero, such that a general direction of the tread length is the direction of the tread length.

[0020] As noted previously, the tire tread includes at least one sipe, and often a plurality thereof, extending into the tread thickness along a depthwise path from the outer, ground-engaging side of the tread and to a terminal end. In doing so, the sipe may extend direction from the outer, ground-engaging side, or may extend indirectly therefrom by extending from groove or other void arranged along the outer, ground-engaging side. Any such sipe also has a length and a thickness, each extending perpendicular to the depthwise path and to one another, where the sipe thickness extends in a direction perpendicular to the sipe length. The sipe length is greater than the sipe thickness. The depthwise path is located midway across the sipe thickness. It is appreciated that in certain variations at least a substantial portion of the depthwise path undulates back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path extends into the tread thickness to form a plurality of undulations. A substantial portion of the depthwise path means that the plurality of undulations form at least 50% of the sipe height, where the height measures the depthwise extent of the sipe within the tire tread. In further instances, a substantial portion of the depthwise path forms is at least 75% of the sipe height. In yet other instances, the depthwise

path undulates back and forth for less than a substantial portion of the sipe height, which, in certain exemplary instances, extends for at least 33% of the sipe height. It is also noted that the undulations decrease in amplitude as the depthwise path extends away from the outer, ground-engaging side and closer to a terminal end of the sipe.

[0021] In certain instances, the sipe thickness is constant as the depthwise path extends into the tread thickness to the terminal end when the tread is arranged annularly around a tire in an installed arrangement for normal tire operation. To achieve this, such as when molding the tire tread separately in a flat mold, the sipe thickness increases as the depthwise path extends into the tread thickness to the terminal end when the tread is in a flat arrangement prior to being arranged annularly around a tire in an installed arrangement for normal tire operation. In other instances, the sipe thickness varies as the depthwise path extends into the tread thickness to the terminal end when the tread is arranged annularly around a tire in an installed arrangement for normal tire operation. Regardless, whether or not the sipe thickness remains constant or varies as the sipe extends depthwise into the tread thickness, the sipe thickness may remain constant and/or may vary along any extent of the sipe length.

[0022] An undulation is a back and forth change in direction of the sipe and its thickness along one side of a sipe centerline, the sipe centerline extending in the direction of the tread thickness. The amplitude of each undulation is measured from the sipe centerline. With regard to the decrease in undulation amplitude as the sipe extends deeper into the tread thickness, in certain instances, the amplitudes of the plurality of undulations decrease in a linear relation. In other instances, whether for a different sipe or for the same sipe at a different location along the sipe length, a plurality of undulations decrease in a non-linear relation.

[0023] With regard to the arrangement of undulations along the depthwise extent of the sipe, the undulations may be constantly spaced, where the plurality of undulations are arranged in association with a constant period. In other variations, the plurality of undulations are arranged in association with a variable period. In any such variation, in certain instances, the plurality of undulations are arranged continuously in the direction of the tread thickness. What this means is that there is no interruption between undulations. Otherwise, linear segments or other void features may be arranged between undulations. In such instances, the plurality of undulations are arranged discontinuously in the direction of the tread thickness at

one or more locations along the sipe length. It is appreciated that any single sipe may include any combination of each of these different features.

[0024] With regard to each undulation, it is appreciated that each undulation may take any desired form. In certain instances, the undulations are smoothly contoured. When continuously arranged, smoothly contoured undulations may form a sinusoidal wave with decreasing amplitudes, in one example. In other instances, the undulations are block-shaped or stepped. In still other variations, the undulations are pointed, such as when forming a V-shape. It is appreciated that with regard to a plurality of undulations arranged along any sipe or depthwise path, any combination of differently shaped undulations may be included within the plurality.

[0025] As stated previously, due to issues of stretching during demolding and the occurrence of ratcheting, the greater the sipe length, the more susceptible the sipe may be to ratcheting. Therefore, in certain instances, any sipe contemplated herein may have a length that is at least 60% of the tread thickness, although any sipe contemplated herein may have a length that is greater or less than such length. By further example, in certain instances the sipe length extends at least halfway across a tread element. Because tread elements (ribs or blocks) are most flexible at any side (that is, along a free side), in certain instances, the sipe length extends from at least one side edge of a tread element.

[0026] It is appreciated that this idea of providing sipes extending deeper into the tread thickness along a depthwise path that undulates back and forth with gradually diminishing amplitudes may be incorporated into any desired sipe design. For example, the undulations along the depthwise path may extend continuously or discontinuously in any direction along the length of the sipe, where any such lengthwise extension may form any linear or non-linear path. In one example, where a sipe extends lengthwise along a non-linear path, the sipe length extends along a lengthwise path that undulates back and forth in a direction perpendicular to the sipe length to form a second plurality of undulations. In certain instances, the second plurality of undulations are arranged continuously or discontinuously along the sipe length. One or more areas of reduced sipe thickness may be included within any sipe, where any such area may or may not be characterized as having extending along a depthwise path having tapering/diminishing undulations.

[0027] Certain exemplary embodiments are discussed below in association with the figures.

[0028] With reference to FIG. 1, a sectional perspective view of a tire 10 is shown in accordance with a particular embodiment. Tire 10 includes a tread 12 arranged overtop one or more belt plies 50 and one or more body (carcass) plies 60. Tread 12 includes various void features, including longitudinal grooves 20, lateral grooves 22, and sipes 24 arranged in fluid communication with an outer, ground-engaging side 14 of tread 12 as each extend into the tread thickness T_{12} from the outer, ground-engaging side 14. The tread also includes a plurality of tread elements forming tread blocks 18 at least partially defined by longitudinal grooves 20 and lateral grooves 22. Shoulders 17, which define the width of the outer, ground-engaging side 14, also assist in at least partially defining certain tread blocks 18. Tire tread 12 has a thickness T_{12} bounded by the outer, ground-engaging side 14 and a bottom side 16. Tread thickness T_{12} may remain constant or vary across the tread. Tread thickness T_{12} extends in a direction perpendicular to the outer, ground-engaging side 14 or to the bottom side 16. The radial direction of the tire is identified as **R**. Also, the tread width is identified as W_{12} , while the tread length is identified as L_{12} .

[0029] With reference to FIG. 2, the 24 sipe of FIG. 1 is shown in greater detail. Particularly, sipe 24 extends into the tread thickness T_{12} along a depthwise path represented by curvilinear line **DP**, the sipe from the outer, ground-engaging side 14 and to a terminal end 26 within the tread thickness T_{12} . Sipe 24 also has a length L_{24} (see FIG. 1) and a thickness T_{24} , each extending perpendicular to the depthwise path **DP** and to one another. The sipe thickness T_{24} also extends in a direction perpendicular to the sipe length L_{24} (see FIG. 1), the sipe length being greater than the sipe thickness.

[0030] With continued reference to FIG. 2, depthwise path **DP** is located midway across the sipe thickness T_{24} . The depthwise path **DP** (and of the sipe 24) undulates back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path **DP** extends into the tread thickness, thereby forming a plurality of undulations U_{24} . Accordingly, because the back and forth movement occurs as the sipe extends into the tread thickness, the depthwise path **DP** undulates partially in the direction perpendicular to the direction of the tread thickness and partially in the direction of the tread thickness, when separating the path **DP** into vector components. It is also noted that the undulations are arranged along a substantial portion of the height H_{24} of sipe 24 (and of the height of depthwise path **DP**). It is also noted that undulations U_{24} decrease in amplitude as the sipe and depthwise path each extend deeper into the tread thickness. In FIG. 2, the widthwise extent of the sipe, taking into

account the presence of each oscillation, is identified as W_{24} , where the widthwise extent of sipe **24** decreases as the sipe extends deeper into the tread thickness. In this case, the transverse extent of width W_{24} is defined on each side of the sipe by a straight line **TAN** extending from the peak (or maximum section or widthwise extent) of each undulation (in this case, at a point of tangency with the peak of each undulation). A centerline **CL** of sipe **24** is arranged midway across width W_{24} , as centerline **CL** extends in the direction of the tread thickness. Centerline **CL** is also the centerline of the depthwise path **DP**. The amplitude of each undulation is measured from centerline **CL**, the amplitude extending from centerline **CL** and to the widthwise extent of each undulation U_{24} from the centerline **CL** (that is, at each undulation peak), the amplitude being half of width W_{24} at each corresponding depthwise location along centerline **CL**. As can be seen, the sipe is characterized as having a plurality of undulations U_{24} , where the undulations U_{24} are characterized as having a reduced amplitude as undulations are located deeper within the tread thickness T_{12} . In other words, undulating sipe **24** has a tapering width W_{24} , the width W_{24} narrowing as the sipe **24** extends deeper into the tread thickness T_{12} . This tapering is represented by lines **TAN**, where the tapering of **TAN** is measured relative to centerline **CL**.

[0031] With reference now to FIG. 3, a sipe **24** is shown in accordance to another variation. In this variation, sipe **24** is in fluid communication with the outer, ground-engaging side **14** and extends into the tread thickness T_{12} away from the outer, ground-engaging side **14** and to terminal end **26**. Sipe **24** can be described as including chamfers or transition portions **28** at the location where the sipe intersects the outer, ground-engaging side **14** to provide a widened portion of the sipe. In other variations, sipe **24** can be described as indirectly extending from the outer, ground-engaging side **14** by extending from a void feature (also represented by **28**), such as a shallow groove, arranged along the outer, ground-engaging side **14**.

[0032] With reference to FIG. 4, the undulating depthwise path **DP** of sipe **24** in FIG. 2 is shown in greater detail. The depthwise path **DP** has a plurality of undulations U_{DP} each associated with an undulation U_{24} of sipe **24**. One manner for determining the amount of taper for any transverse side of the sipe **24** is dividing the amplitude A_{min} of the smallest oscillation, which is associated with the undulation located closest to terminal end **26**, by the amplitude of the largest oscillation, which is associated with the undulation located closest to the outer, ground-engaging side. In the variation shown in FIG. 4, the taper is linear as each

tangent line **TAN** extends linearly and is tangent to each undulation **U_{DP}** arranged along a respective transverse side of the depthwise path **DP**. In the case of a linear taper, the taper for any side of the sipe **24** or depthwise path **DP** may also be determined by dividing the difference between the maximum amplitude **A_{max}** (the amplitude associated with the largest undulation) and the smallest amplitude **A_{min}** (the amplitude associated with the smallest undulation) by the largest amplitude **A_{max}**, which is expressed in the following equation:

$$Taper = [A_{max} - A_{min}] / A_{max}.$$

In other variations, as discussed previously, the taper may be non-linear and correspond to any non-linear function. In certain instances, for example, the non-linear taper is a function of the tread depth (that is, in the direction of the tread thickness, also known as the z-direction).

[0033] In any event, whether linear or non-linear, the taper generally decreases as the sipe/depthwise path extends toward the terminal end. “Generally decreases” contemplates that while portions of a non-linear taper provide a decreasing amplitude, other portions of the non-linear taper may not decrease, but also do not decrease and instead are characterized as having a zero slope. Accordingly, any linear or non-linear taper provides a sipe that decreases in width as it extends toward the terminal end. That being said, it is understood that the taper along each side of the sipe (that is, the sides between which the sipe undulates) may be different, such that the tapers and the sipe width are symmetric or asymmetric relative to the centerline.

[0034] In the exemplary embodiments shown in FIGS. 2-4, each sipe **24** is characterized as having symmetric tapers relative centerline **CL**. Also identified in FIG. 4 is the pitch **P** associating the plurality of undulations **U_{DP}** along depthwise path **DP**. It is observed that in this variation, the undulations **U_{DP}** along depthwise path **DP**, as well as the undulations **U₂₄** along sipe **24**, are arranged according to a constant pitch **P**. It is also observed that each undulation **U_{DP}** spans a half pitch $\frac{1}{2} P$. As suggested previously, it is appreciated that in other variations that the pitch may be variable.

[0035] While the benefits of employing the sipes discussed herein include improved demolding between the tread and the mold to notably reduce or eliminate the occurrence of ratcheting, other unexpected benefits have also been realized. In particular, it has been observed that improved contact between opposing sides of the sipe occur as the sipe closes

during tire operation, where the improved contact provides more consistent contact along the height of the sipe. This results in improved rigidity of the tread element, such as a tread rib or tread block. Using finite element analysis, it has been confirmed that when employing the sipes described herein, an increase in rigidity in both the X-direction and the Z-direction is observed as compared to a non-tapering, undulating sipe. The X-direction with reference to the sipes shown in FIGS. 2 and 3 is the direction of the sipe width (that is, the direction in which the undulations undulate, which is a direction perpendicular to both the sipe length and sipe height or, with reference to the tire tread, the direction of the tread length). The Z-direction is the direction of the tread thickness. With reference to the graph shown in FIG. 5, results of the finite element analysis comparison is shown, where sipes undulating with increasing depth with tapers of 50%, 62.5%, 75%, and 90% show improvements in both X and Z rigidity of up to 5% in Z rigidity and up to 8% in X rigidity as compared to reference sipes undulating with increasing depth without any taper (that is, 0% taper). It is also observed that with increasing taper, a further increase in Z rigidity is observed. Increases in Z rigidity further improve rolling resistance performance, which increases in X rigidity further improve wear and rolling resistance performance. While the rigidity of the blocks tend to increase as the tire tread wears, that is, with decreasing tread thickness, by virtue of employing the undulating, tapered sipes contemplated herein, tire treads are better able to maintain optimum rigidities as the tire tread wears. Specifically, the higher amplitude undulations provide increased rigidity when the tire is new and the less-worn. Because the tread elements (that is, tread blocks and ribs) become more rigid as the tread wears, reducing the amplitude of the undulations facilitates improved optimization of rigidities throughout the tread depth during the life of the tire tread.

[0036] As previously discussed, it is appreciated that the undulations may form any shape. With reference to the undulations in FIGS. 2-4, the undulations U_{24} , U_{DP} are contoured, and when viewed together, the plurality of undulations form a sinusoidal wave of decreasing amplitude. By further example, with reference to FIG. 6, a sipe 24 is shown having V-shaped undulations U_{24} . In this instance, taper-defining lines TAN are shown extending peak-to-peak between adjacent undulations U_{24} along each side of sipe 24, each peak being located at the vertex of the V-shape. With reference to another exemplary variation in FIG. 7, a sipe 24 is shown having step-shaped undulations U_{24} . In this instance, taper-defining lines TAN are shown extending peak-to-peak between adjacent undulations U_{24} along each side of sipe 24, each peak forming a linear extension of each step at its widthwise extent, where each line

TAN extends through a midpoint of each linear extension of each step-shaped undulation U_{24} .

[0037] As it is appreciated that the tapered undulations may be employed by any known sipe or sipe configuration, with reference to an exemplary embodiment in FIG. 8, a sipe **24** characterized as having tapering undulations U_{24} is inclined. In this instance, sipe **24** is inclined relative to the outer, ground-engaging side **14** by angle α . It is appreciated that inclination angle α may be any known angle, whether positive or negative. It is also appreciated that sipe **24** may be inclined in any direction, that is, inclined in a direction of the tread length, tread width, or anywhere in between as may be known.

[0038] Referring now to the formation of the sipes previously discussed, a sipe molding element is employed, the sipe molding element forming positive shape of the sipe being formed, the sipe being a negative of the sipe. By way of example, an exemplary sipe molding element **30** is shown in FIG. 9 for forming a molded sipe. The sipe molding element **30** includes a molding portion **32**, configured to form the sipe, and optionally may include a mold mounting portion **34** for mounting the sipe molding element **30** into a mold (not shown). Sipe molding portion **32** has a height H_{32} configured to extend into an uncured tread to form a negative in the tread, the negative resulting in a molded sipe, the height H_{32} extending along path DP_E from the mold mounting portion **34** and to a terminal end **36**. As with any sipe discussed above, path DP_E and thickness T_{32} of molding portion **32** undulates back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path DP_E extends into the tread thickness, thereby forming a plurality of undulations U_{32} . Molding portion **32** also has a length L_{32} and a thickness T_{32} , each extending perpendicular to the depthwise path DP_E and to one another. The molding portion thickness T_{32} also extends in a direction perpendicular to the molding portion length L_{32} , the molding portion length being greater than the molding portion thickness.

[0039] With regard to other known sipe configurations that may adopt any tapering undulation characterization as contemplated herein, with reference to FIG. 10, a sipe molding element **30** is shown having a sipe molding portion **32** for forming a sipe having a like-shaped void. Sipe molding portion **32** includes an area of reduced thickness **38**, which is completely bounded by thicker portions of the sipe molding portion **32**. This sipe molding portion **32** forms a like-shaped sipe having an area of reduced thickness shown in FIG. 10, which is completely bounded by thicker portions of the sipe. In other variations, the area of reduced thickness **38** is at least partially bounded by thicker portions of sipe molding portion

32 to form like-shaped sipes. It is also appreciated, additionally or in the alternative, multiple areas of reduced thickness **38** may be arranged along sipe molding portion **32** for forming a sipe having multiple areas of reduced thickness. While any desired thicknesses may be employed for the thicker portions and areas of reduced thickness in each of the sipe molding portion and a corresponding molded sipe, in certain exemplary instances, the thicker portions are 0.4 mm to 1.2 mm thick and areas of reduced thickness are less than 4 mm thick or 0.1 mm to less than 0.4 mm. Each of these thickness may remain constant or may be variable. Still further, it is appreciated that in any sipe contemplated herein, while tapering undulations may be employed as described herein, any sipe may include additional undulations, where the sipe undulates as it extends in any other direction of the sipe. For example, the sipe may also undulate back and forth as the sipe extends in a direction of the sipe length.

[0040] 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.

[0041] 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 thickness extending from an outer, ground-engaging side and to a bottom side, the thickness extending in a direction perpendicular to both a length and a width of the tread, the width extending between a pair of lateral sides of the tread, where the tread length is greater than the tread width; and,
 - a sipe extending into the tread thickness along a depthwise path away from the outer, ground-engaging side of the tread and to a terminal end, the sipe also having a length and a thickness each extending perpendicular to the depthwise path and to one another, the sipe length being greater than the sipe thickness, the depthwise path being located midway across the sipe thickness, where a portion of the depthwise path undulates back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path extends into the tread thickness to form a plurality of undulations, the undulations decreasing in amplitude as the depthwise path extends toward the terminal end.
2. The tire tread of claim 1, where the sipe thickness is constant as the depthwise path extends into the tread thickness to the terminal end when the tread is arranged annularly around a tire in an installed arrangement for normal tire operation.
3. The tire tread of claim 2, where the sipe thickness increases as the depthwise path extends into the tread thickness to the terminal end when the tread is in a flat arrangement prior to being arranged annularly around a tire in an installed arrangement for normal tire operation.
4. The tire tread of claim 1, where the sipe thickness varies as the depthwise path extends into the tread thickness to the terminal end when the tread is arranged annularly around a tire in an installed arrangement for normal tire operation.
5. The tire tread of any one of claims 1 to 4, where the sipe thickness varies along the sipe length.
6. The tire tread of any one of claims 1 to 5, where the amplitudes of the plurality of undulations decrease in a linear relation.

7. The tire tread of any one of claims 1 to 6, where the plurality of undulations decrease in a non-linear relation.
8. The tire tread of any one of claims 1 to 7, where the plurality of undulations are arranged in association with a constant period.
9. The tire tread of any one of claims 1 to 8, where the plurality of undulations are arranged in association with a variable period.
10. The tire tread of any one of claims 1 to 9, where the plurality of undulations are arranged continuously in the direction of the tread thickness.
11. The tire tread of any one of claims 10, where the plurality of undulations are arranged discontinuously in the direction of the tread thickness at one or more locations along the sipe length.
12. The tire tread of any one of claims 1 to 11, where the undulations are characterized as having variable periods.
13. The tire tread of any one of claims 1 to 12, where the undulations are smoothly contoured.
14. The tire tread of any one of claims 1 to 12, where the undulations are block-shaped.
15. The tire tread of any one of claims 1 to 12, where the undulations are V-shaped.
16. The tire tread of any one of claims 1 to 15, where the sipe length is at least 60% of the tread thickness.
17. The tire tread of any one of claims 1 to 16, where the sipe length extends at least halfway across a tread element.
18. The tire tread of any one of claims 1 to 17, where the sipe length extends from at least one side edge of a tread element.
19. The tire tread of any one of claims 1 to 18, where the sipe length extends along a lengthwise path that undulates back and forth in a direction perpendicular to the sipe length to form a second plurality of undulations.
20. The tire tread of claim 19, where the second plurality of undulations are arranged discontinuously along the sipe length.
21. The tire tread of any one of claims 1 to 20, where the sipe thickness is 1.2 mm or less.

22. The tire tread of any one of claims 1 to 21, where the sipe includes at least one area of reduced thickness.
23. The tire tread of any one of claims 1 to 22, where the portion of the depthwise path undulating back and forth in a direction perpendicular to the direction of the tread thickness as the depthwise path extends into the tread thickness forms a substantial portion of a height of the sipe.

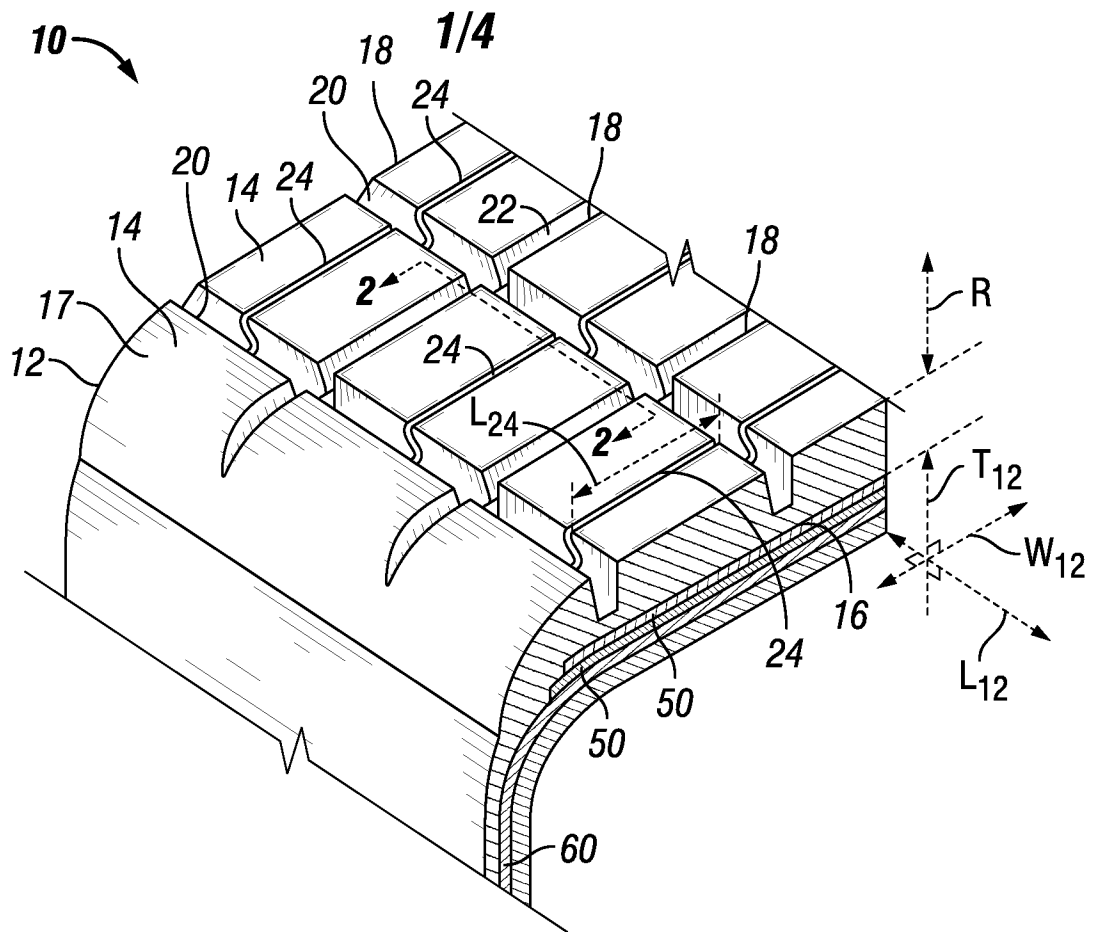


FIG. 1

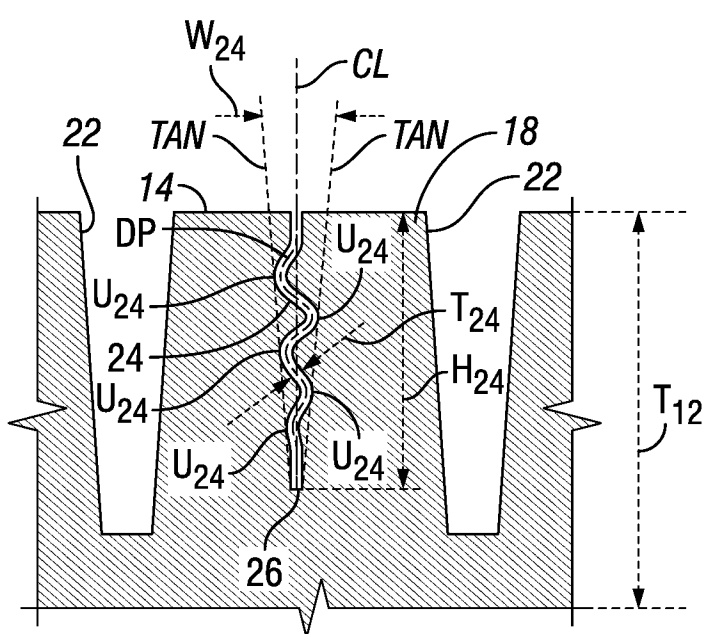


FIG. 2

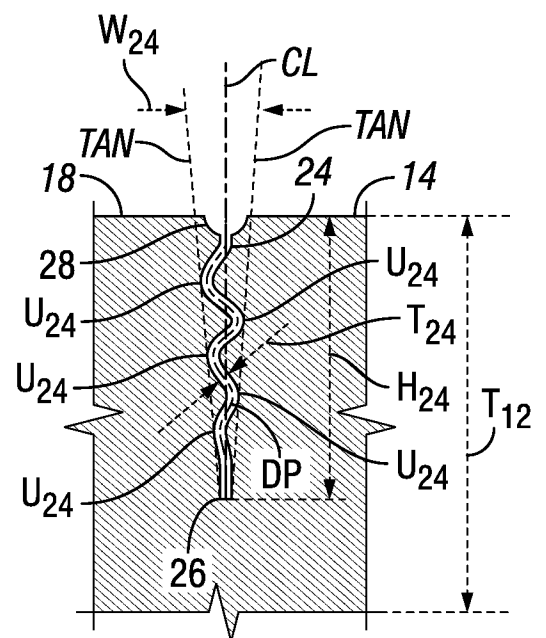
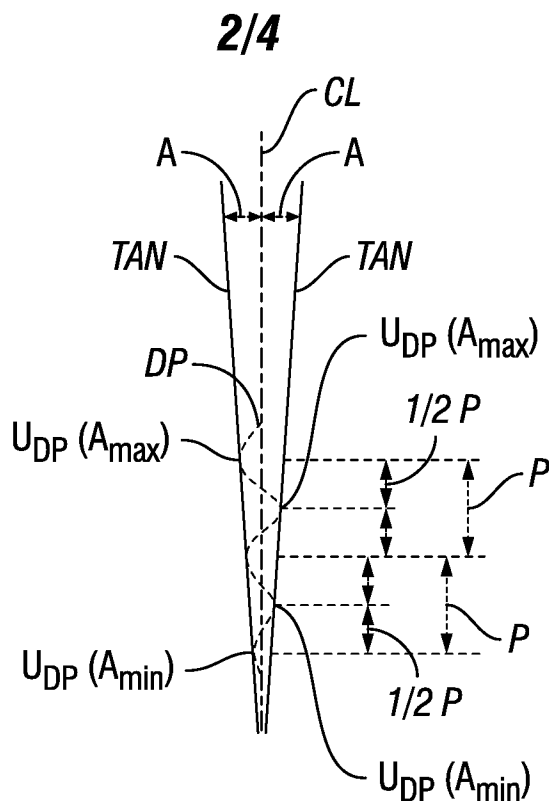
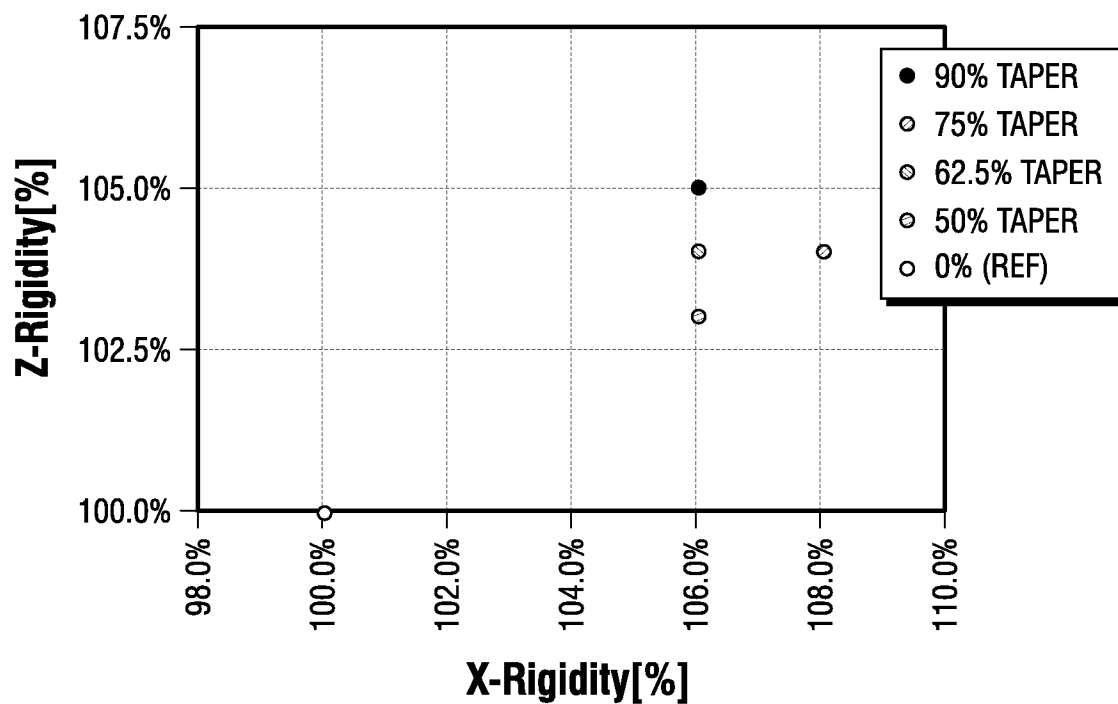


FIG. 3

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

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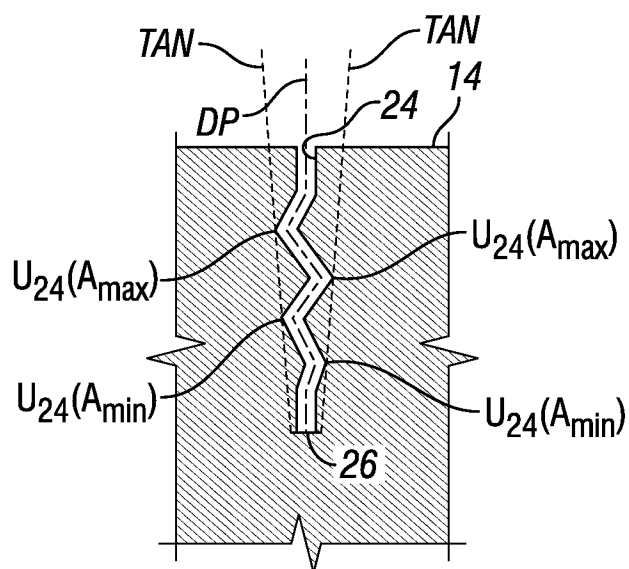


FIG. 6

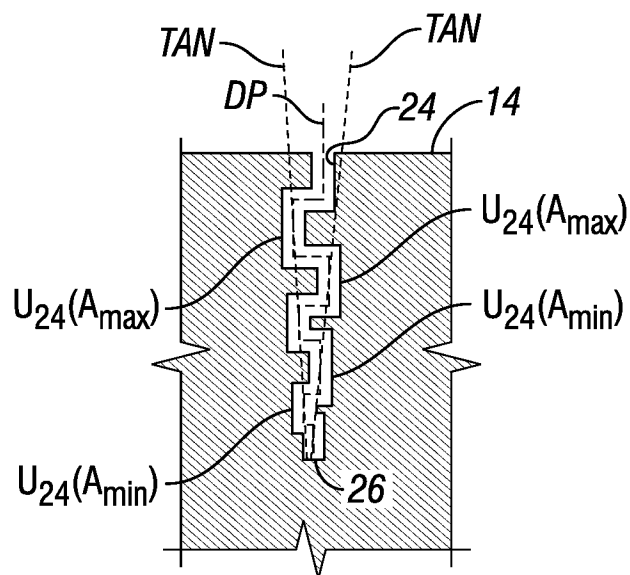


FIG. 7

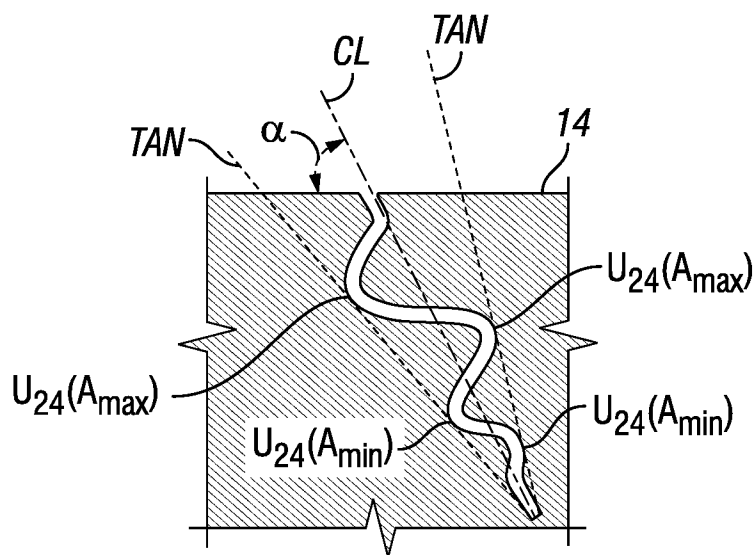


FIG. 8

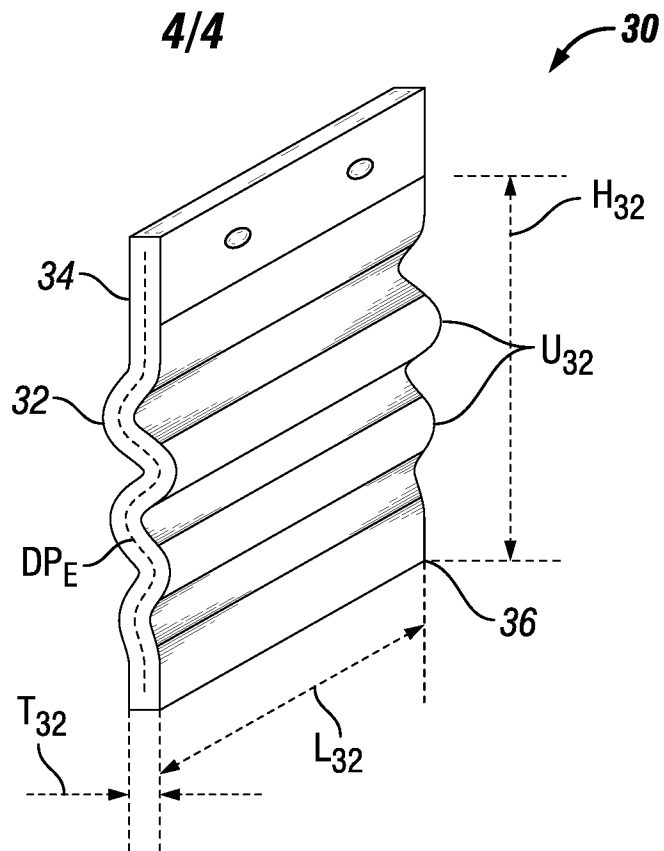


FIG. 9

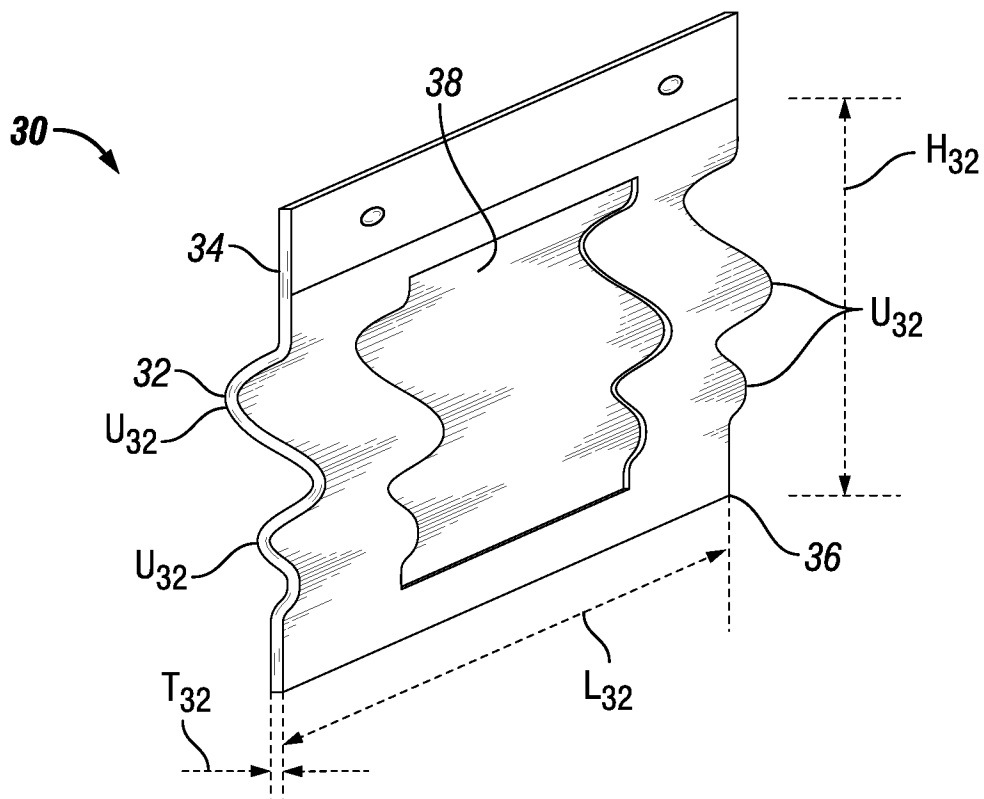


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/047632

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

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Y	claims 1-9; figures 1-3 -----	
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

23 February 2018

Date of mailing of the international search report

15/03/2018

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Authorized officer

Carneiro, Joaquim

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/047632

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International application No

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