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(54) Title: NON-PNEUMATIC TIRE

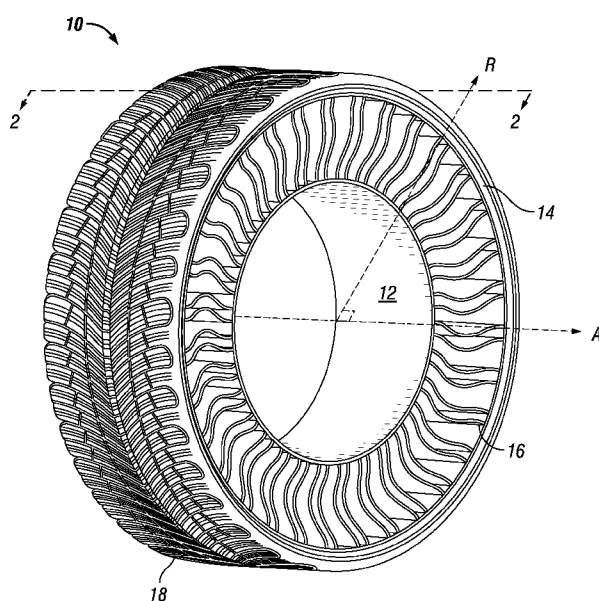


FIG. 1

(57) Abstract: A non-pneumatic tire (10) including a rigid central annular portion (12), an annular shear band (14), one or more deformable spokes (16), a tread (18), a plurality of tread elements, one or more displaced reinforcement layers arranged within the annular shear band (14) such that a longitudinal groove extends through at least one of the one or more displaced reinforcement layers wherein the one or more displaced reinforcement layers are arranged between one or more non-displaced reinforcement layers and the tread (18).

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**Declarations under Rule 4.17:**

— *of inventorship (Rule 4.17(iv))*

**Published:**

— *with international search report (Art. 21(3))*

## NON-PNEUMATIC TIRE

### CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to, and the benefit of, International Patent Application No. PCT/US2016/069388, filed December 30, 2016 with the U.S. Patent Office (acting as the US Receiving Office), which is herein incorporated by reference.

### BACKGROUND

#### Field

**[0002]** The embodiments herein relate generally to shear bands and treads for use with non-pneumatic tires.

#### Description of the Related Art

**[0003]** It is appreciated that a reduction in the rolling resistance of a tire may improve fuel efficiency by reducing the amount of energy wasted during use. However, in an effort to reduce the rolling resistance of a tire, other sacrifices are often made, which may result in the reduction of other performance measures. For example, when reducing the rolling resistance of a tire, the tread thickness is often reduced, along with the voids contained therein. As a result, wet weather performance is negatively impacted due to the reduction in void volume. In instances such as this, there is a desire to reduce the tread thickness to reduce rolling resistance while maintaining a desired groove depth to help maintain a desired level of wet weather performance. Specifically, when reducing the tread thickness, the depth of any longitudinal groove is also reduced, which immediately reduces void volume useful for consuming water to promote tread-road contact. If the grooves are widened to recapture lost void, a reduction in contact surface area decreases, which reduces the amount of traction available and, in turn, reduces certain tire performance measures. Accordingly, there is a need for an improved tire tread capable of reducing rolling resistance while also minimizing any reduction in wet weather performance.

### SUMMARY

**[0004]** Particular embodiments herein comprise a non-pneumatic tire. The non-pneumatic tire comprises a rigid central annular portion, an annular shear band circumferentially arranged about the central annular portion, and one or more deformable spokes arranged between

the annular shear band and the central annular portion. The non-pneumatic tire further includes a tread defining an outer, ground-engaging side of the non-pneumatic tire extending annularly around the non-pneumatic tire. The tread has a length, a thickness extending radially inward from the ground-engaging side to a bottom side of the tread, and a width extending laterally between a pair of opposing lateral sides of the tread. The width of the tread also extends transverse to a direction of the tread thickness and to a direction of the tread length. The non-pneumatic tire further includes a plurality of tread elements arranged along the outer, ground-engaging side of the tread. The plurality of tread elements include at least one pair of tread elements spaced apart by a longitudinal groove, which extends primarily in the direction of the tread length. The non-pneumatic tire further includes one or more displaced reinforcement layers extending circumferentially around the non-pneumatic tire and in a direction of the tread width. The one or more displaced reinforcement layers are arranged within the annular shear band such that the longitudinal groove extends through at least one of the one or more displaced reinforcement layers and, therefore, separates opposing portions of the at least one of the one or more displaced reinforcement layers. The non-pneumatic tire further includes one or more non-displaced reinforcement layers extending circumferentially around the non-pneumatic tire and in the direction of the tread width. The one or more non-displaced reinforcement layers are arranged within the annular shear band. The one or more displaced reinforcement layers are arranged between the tread and the one or more non-displaced reinforcement layers.

**[0005]** The foregoing and other embodiments, objects, features, and advantages of the embodiments herein 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 the embodiments.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** FIG. 1 is a perspective view of a non-pneumatic tire, in accordance with an embodiment.

**[0007]** FIG. 2 is a sectional view of a prior art non-pneumatic tire tread taken along line 2-2 of the tire shown in FIG. 1.

**[0008]** FIG. 3 is a sectional view of an improved non-pneumatic tire tread, the improved non-pneumatic tire tread being an improvement of the prior art non-pneumatic tire tread shown in FIG. 2, in accordance with an embodiment.

#### DETAILED DESCRIPTION

**[0009]** Embodiments herein describe an improved non-pneumatic tire.

**[0010]** In particular embodiments, a non-pneumatic tire comprises a rigid central annular portion. The non-pneumatic tire further comprises an annular shear band, which is circumferentially arranged about the central annular portion. The annular shear band includes a plurality of reinforcement layers, each such layer including a plurality of elongate reinforcements. Neither the shear band nor the non-pneumatic tire is configured to retain any pressurized air. The non-pneumatic tire further comprises one or more deformable spokes, which are arranged between the annular shear band and the central annular portion. The one or more deformable spokes are spaced apart around a rotational axis of the central annular portion or more generally of the non-pneumatic tire, where a length of the each deformable spoke extends primarily in a radial direction of the central annular portion or non-pneumatic tire. The rotational axis of the central annular portion and the non-pneumatic tire corresponds to an axial direction of the central annular portion and the non-pneumatic tire. The axial direction of the central annular portion or non-pneumatic tire is perpendicular to the radial direction thereof. The annular shear band is operably attached to a radially outward extent of the one or more deformable spokes, which, are in turn, connected at a radially inward extent to the central annular portion.

**[0011]** The non-pneumatic tire further includes a tread. The tread defines an outer, ground-engaging side of the non-pneumatic tire, which extends annularly around the non-pneumatic tire and the shear band. The tread has a length, which extends in a circumferential direction of the non-pneumatic tire. The tread also has a thickness, which extends radially inward from the ground-engaging side of the tread to a bottom side of the tread. The tread thickness extends perpendicular to the tread length. The tread further includes a width, which extends laterally between a pair of opposing lateral sides of the tread. The width of the tread extends perpendicular, or transverse, to both a direction of the tread thickness and a direction of the tread length.

**[0012]** In particular embodiments, the non-pneumatic tire further includes a plurality of tread elements. Tread elements are generally formed by spaced apart voids or a lateral side of the tread spaced apart from any one or more voids. The plurality of tread elements are arranged along the outer, ground-engaging side of the tread and are spaced apart by a longitudinal groove. A longitudinal groove extends primarily in the direction of the tread length (*i.e.*, the circumference of the non-pneumatic tire when utilized therewith), although it is not required to extend the full length of the tread. It is appreciated that the tread may include more than one longitudinal groove.

**[0013]** To permit a reduction of tread thickness without sacrificing longitudinal groove depth, one or more of the shear band reinforcement layers is parsed or separated, such that a portion of the reinforcement layer is eliminated (“displaced”) to create a spacing or void within the layer through which a longitudinal groove extends. By doing so, the depth of the longitudinal groove is equal to or greater than a maximum thickness of the tire tread as measured along a tread element arranged adjacent (next to) the longitudinal groove. The portion of the tread thickness associated with the tread element is measured from the most radially outward point (outermost radial point) of the annular shear band below the tread element to the outer, ground-engaging side of the tread associated with the corresponding tread element. In certain embodiments, the depth of the longitudinal groove is equal to at least one hundred twenty-five percent (125%) of the adjacent tread element thickness. In other embodiments, the depth of the longitudinal groove is equal to at least two hundred percent (200%) of the adjacent tread element thickness. In these embodiments, for example, the depth of the longitudinal groove may be equal to twelve millimeters, and the maximum thickness of the adjacent tread element may be equal to six millimeters. It is appreciated that, if the tread includes more than one longitudinal groove, the depth of each longitudinal groove may not be equal to the depth of all other longitudinal grooves or, in alternate embodiments, the depth of each longitudinal groove may not be equal to the depth of any of the other longitudinal grooves.

**[0014]** It is appreciated that any tread element may form a rib or a tread block (“lug”). A rib may extend continuously along the tread length, or may include intervening sipes or lateral grooves to form a discontinuous rib. A block is a tread element bounded by spaced apart lateral grooves or sipes. A tread block may be arranged with other blocks to form a discontinuous rib. For example, in certain embodiments, the plurality of tread elements of the non-pneumatic tire

include at least one pair of tread elements spaced apart by a lateral groove. The lateral groove extends primarily in the direction of the tread width (*i.e.*, the axial direction of the non-pneumatic tire when utilized therewith), although it is not required to extend fully across the width of the tread. It is appreciated that the tread may include more than one lateral groove.

**[0015]** As previously noted, the non-pneumatic tire includes a plurality of reinforcement layers arranged within the annular shear band. At least one, or a plurality, of the plurality of reinforcement layers includes one or more displaced (*i.e.*, discontinuous) reinforcement layers extending circumferentially around the non-pneumatic tire and in a direction of the tread width. Each of the one or more displaced reinforcement layers includes a discontinuity (also referred to as a “spacing” or “void”) into which a longitudinal groove extends as noted previously. When multiple displaced reinforcement layers are present, the multiple displaced reinforcement layers are stacked together to create a common discontinuity where the discontinuity of each layer is laterally aligned (or “stacked”) such that the discontinuities together form the common discontinuity. In the end, the one or more displaced reinforcement layers are arranged within the annular shear band such that a longitudinal groove extends through the one or more displaced reinforcement layers. In these embodiments, the longitudinal groove separates opposing portions of the one or more displaced reinforcement layers located below opposing tread elements arranged on either side of the longitudinal groove in the direction of the tread width. The plurality of reinforcement layers also includes one or more non-displaced (*i.e.*, continuous) reinforcement layers extending circumferentially around the non-pneumatic tire and across the tread width and in the direction of the tread width. The one or more non-displaced reinforcement layers are arranged within the annular shear band such that the longitudinal groove does not extend through any of the one or more non-displaced reinforcement layers. The one or more displaced reinforcement layers are arranged between the tread and the one or more non-displaced reinforcement layers.

**[0016]** In particular embodiments, the one or more displaced reinforcement layers and the one or more non-displaced reinforcement layers extend linearly or along a slightly arcuate path in the direction of the tread width. In other words, none of the plurality of reinforcement layers forming the common discontinuity in the shear band extend laterally, that is, in the direction of the tread width, along any alternating non-linear path to form the common discontinuity into which a longitudinal groove extends.

**[0017]** In particular embodiments, due to the structure of the annular shear band in relation to the one or more longitudinal grooves, the one or more longitudinal grooves are able to utilize the entire tread depth, which results in the longitudinal grooves remaining active throughout an entire useful life of the tread. With respect to the stacked arrangement of the plurality of reinforcement layers, the size and depth of the reinforcement stacks are a function of the desired width of the tread element and the required depth of the one or more longitudinal grooves. In this way, a more shallow tread depth may be employed with the one or more longitudinal grooves having an increased depth due to the stacked arrangement of the plurality of reinforcement layers. As a result, the rolling resistance and mass of the non-pneumatic tire is reduced without sacrificing wet weather performance.

**[0018]** Particular embodiments of the non-pneumatic tires discussed above will now be described in further detail below in association with the figures filed herewith exemplifying the embodiments.

**[0019]** With reference to an exemplary embodiment shown in FIG. 1, a non-pneumatic tire **10** is illustrated. The non-pneumatic tire **10** comprises a rigid central annular portion **12**. The non-pneumatic tire **10** further comprises an annular shear band **14**, which is circumferentially arranged about the central annular portion **12** but not directly contacting the central annular portion **12**. The non-pneumatic tire **10** further comprises a plurality of deformable spokes **16**, which are arranged between the annular shear band **14** and the central annular portion **12**. The plurality of deformable spokes **16** are spaced apart around a rotational axis of the central annular portion **12**, which is also a rotational axis of the non-pneumatic tire **10**. The rotational axis of the central annular portion **12** and of the non-pneumatic tire **10** corresponds to an axial direction **A** of the central annular portion **12** and of the non-pneumatic tire **10**. In this way, a length of each of the deformable spokes **16** extends in a radial direction **R** of the central annular portion **12** of the non-pneumatic tire **10**. The axial direction **A** of the central annular portion **12** and of the non-pneumatic tire **10** is perpendicular to the radial direction **R** thereof. The annular shear band **14** is operably attached to a radially outward extent of the plurality of deformable spokes **16**, which, are in turn, connected at a radially inward extent to the central annular portion **12**.

[0020] The non-pneumatic tire **10** of FIG. **1** also includes a tread **18**. With specific reference to FIG. **2**, a prior art non-pneumatic tire tread is illustrated. The non-pneumatic tire tread includes an annular shear band **114** configured to extend circumferentially around a central annular portion of a non-pneumatic tire (not shown). The tread **118** includes an outer, ground-engaging side **120** and a bottom side **122**. The tread **118** has a length configured to extend circumferentially around the tire and a thickness  $T_{118}$  extending radially inward from the ground-engaging side **120** to the bottom side **122** of the tread **118**, the length being perpendicular to the thickness. The tread **118** further includes a width  $W_{118}$ , extending laterally between a pair of opposing lateral sides of the tread **118**. The width  $W_{118}$  extends perpendicular to the tread thickness  $T_{118}$  and to the tread length.

[0021] The prior art tread **118** includes a plurality of tread elements **124** arranged along the outer, ground-engaging side **120** of the tread **118**. The portion of the tread thickness  $T_{118}$  arranged within a tread element **124** has a thickness  $T_{124}$ , which extends radially outward from a most radially outward point of the annular shear band **114** below the tread element **124** to the outer, ground-engaging side **120** of the tread **118**. In the exemplary prior art non-pneumatic tire tread shown, a pair of tread elements **124** are spaced apart by a longitudinal groove **126**. Each longitudinal groove **126** has a depth  $D_{126}$ , which extends from the outer, ground-engaging side **120** of the corresponding tread element **124** to a bottom of the longitudinal groove **126**. Of final note, the annular shear band **114** includes a plurality of reinforcement layers **128**, each such layer **128** including a plurality of elongate reinforcements **130**.

[0022] With reference to FIG. **3**, an improved non-pneumatic tire tread **18** is illustrated. The tread **18** defines an outer, ground-engaging side **20** of the non-pneumatic tire **10**. The outer, ground-engaging side **20** of the tread **18** extends annularly around the non-pneumatic tire **10** and the annular shear band **14**. The tread **18** also has a length, which extends in a circumferential direction of the non-pneumatic tire **10**. The tread **18** has a thickness  $T_{18}$ , which extends radially inward from the outer, ground-engaging side **20** of the tread **18** to a bottom side **22** of the tread **18**. The tread thickness  $T_{18}$  extends perpendicular to the tread length. The tread **18** further includes a width  $W_{18}$ , which extends laterally between a pair of opposing lateral sides of the tread **18**. The width  $W_{18}$  extends perpendicular, or transverse, to both a direction of the tread thickness  $T_{18}$  and a direction of the tread length.

**[0023]** As further illustrated in FIG. 3, the tread **18** of the non-pneumatic tire **10** further includes a plurality of tread elements **24**. The plurality of tread elements **24** are arranged along the outer, ground-engaging side **20** of the tread **18** and are spaced apart from each other by longitudinal grooves **26**. Each longitudinal groove **26** extends primarily in the direction of the length of the tread **18**, which corresponds to the circumference of the non-pneumatic tire **10** when the tread **18** is utilized therewith. Further, each longitudinal groove **26** has a depth  $D_{26}$ , which extends primarily in the direction of the tread thickness  $T_{18}$ . The depth  $D_{26}$  of the longitudinal groove **26** greater than a maximum thickness  $T_{24}$  as measured along a tread element **24** arranged adjacent to the longitudinal groove **26**. The thickness  $T_{24}$  of a tread element **24** is measured from the most radially outward point of the annular shear band **14** below the tread element **24** to the outer, ground-engaging side **20** of the tread **18** associated with the corresponding tread element **24**.

**[0024]** As further shown in FIG. 3, the annular shear band **14** of the non-pneumatic tire **10** includes a plurality of reinforcement layers **28** arranged within the annular shear band **14**, each such layer **28** including a plurality of elongate reinforcements **30**. The plurality of reinforcement layers **28** include both displaced (*i.e.*, discontinuous) reinforcement layers  $28_d$  and non-displaced (*i.e.*, continuous) reinforcement layers  $28_{nd}$ . Each reinforcement layer **28**, including each non-displaced reinforcement layer  $28_{nd}$  and each displaced reinforcement layer  $28_d$ , extend circumferentially around the non-pneumatic tire **10** and in a direction of the tread width  $W_{18}$ . The displaced reinforcement layers  $28_d$  are arranged within the annular shear band **14** such that at least one of the longitudinal grooves **26** extends through at least one of the displaced reinforcement layers  $28_d$ . In this embodiment, the longitudinal groove **26** separates opposing portions  $28_{d1}$  and  $28_{d2}$  of each of the displaced reinforcement layers  $28_d$ . The opposing portions  $28_{d1}$  and  $28_{d2}$  of each of the displaced reinforcement layers  $28_d$  are located below opposing tread elements  $24_1$  and  $24_2$  arranged on either side of the corresponding longitudinal groove **26** in a direction of the tread width  $W_{18}$ . In addition, a plurality of non-displaced reinforcement layers  $28_{nd}$  are arranged within the annular shear band **14** of the non-pneumatic tire **10** such that the corresponding longitudinal grooves **26** do not extend through any of the plurality of non-displaced reinforcement layers  $28_{nd}$ . The plurality of displaced reinforcement layers  $28_d$  are arranged between the tread **18** and the plurality of non-displaced reinforcement

layers **28<sub>nd</sub>**. The plurality of displaced reinforcement layers **28<sub>d</sub>** and the plurality of non-displaced reinforcement layers **28<sub>nd</sub>** extend linearly in the direction of the tread width **W<sub>18</sub>**.

**[0025]** In the embodiment of FIG. 3, the plurality of displaced reinforcement layers **28<sub>d</sub>** are arranged within the annular shear band **14** in a stacked arrangement in the direction of the tread thickness **T<sub>18</sub>**. In this way, the longitudinal grooves **26** extend to a depth within the annular shear band **14** that is more radially inward than a thickness **T<sub>24</sub>** of an adjacent tread element **24**.

**[0026]** 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.

**[0027]** While the embodiments have 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 claims herein. Accordingly, the scope and content herein 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

1. A non-pneumatic tire comprising:
  - a rigid central annular portion;
  - an annular shear band circumferentially arranged about the central annular portion;
  - one or more deformable spokes arranged between the annular shear band and the central annular portion;
  - a tread defining an outer, ground-engaging side of the non-pneumatic tire extending annularly around the non-pneumatic tire, wherein the tread has a length, a thickness extending radially inward from the ground-engaging side to a bottom side of the tread, and a width extending laterally between a pair of opposing lateral sides of the tread, the width extending transverse to a direction of the tread thickness and to a direction of the tread length;
  - a plurality of tread elements arranged along the outer, ground-engaging side of the tread, where the plurality of tread elements include at least one pair of tread elements spaced apart by a longitudinal groove, the longitudinal groove extending primarily in the direction of the tread length;
  - one or more displaced reinforcement layers extending circumferentially around the non-pneumatic tire and in a direction of the tread width, the one or more displaced reinforcement layers being arranged within the annular shear band where the longitudinal groove extends through at least one of the one or more displaced reinforcement layers and thereby separates opposing portions of the at least one of the one or more displaced reinforcement layers; and
  - one or more non-displaced reinforcement layers extending circumferentially around the non-pneumatic tire and in the direction of the tread width, the one or more non-displaced reinforcement layers being arranged within the annular shear band, wherein the one or more displaced reinforcement layers are arranged between the tread and the one or more non-displaced reinforcement layers.
2. The non-pneumatic tire of claim 1, wherein the longitudinal groove has a depth extending primarily in the direction of the tread thickness, further wherein the depth of the

longitudinal groove is greater than a maximum thickness of an adjacent tread element of the plurality of tread elements, the maximum thickness of the adjacent tread element being measured from an outermost radial point of the annular shear band below the tread element to the outer, ground-engaging side of the tread associated with the adjacent tread element.

3. The non-pneumatic tire of claim 2, wherein the depth of the longitudinal groove is equal to at least 125% of the maximum thickness of the adjacent tread element of the plurality of tread elements.
4. The non-pneumatic tire of any one of claims 1 to 3, wherein the one or more displaced reinforcement layers comprises a plurality of displaced reinforcement layers in a stacked arrangement in the direction of the tread thickness.
5. The non-pneumatic tire of any one of claims 1 to 4, wherein the one or more displaced reinforcement layers and the one or more non-displaced reinforcement layers extend linearly or along an arcuate path in the direction of the tread width.
6. The non-pneumatic tire of claim 4, wherein more than one additional displaced reinforcement layer forms the stacked arrangement.
7. The non-pneumatic tire of any one of claims 6, wherein each of an additional reinforcement layer of the one or more non-displaced reinforcement layers is continuous.
8. The non-pneumatic tire of any one of claims 1 to 7, wherein the plurality of tread elements include at least one pair of tread elements spaced apart by a lateral groove, the lateral groove extending primarily in the direction of the tread width.

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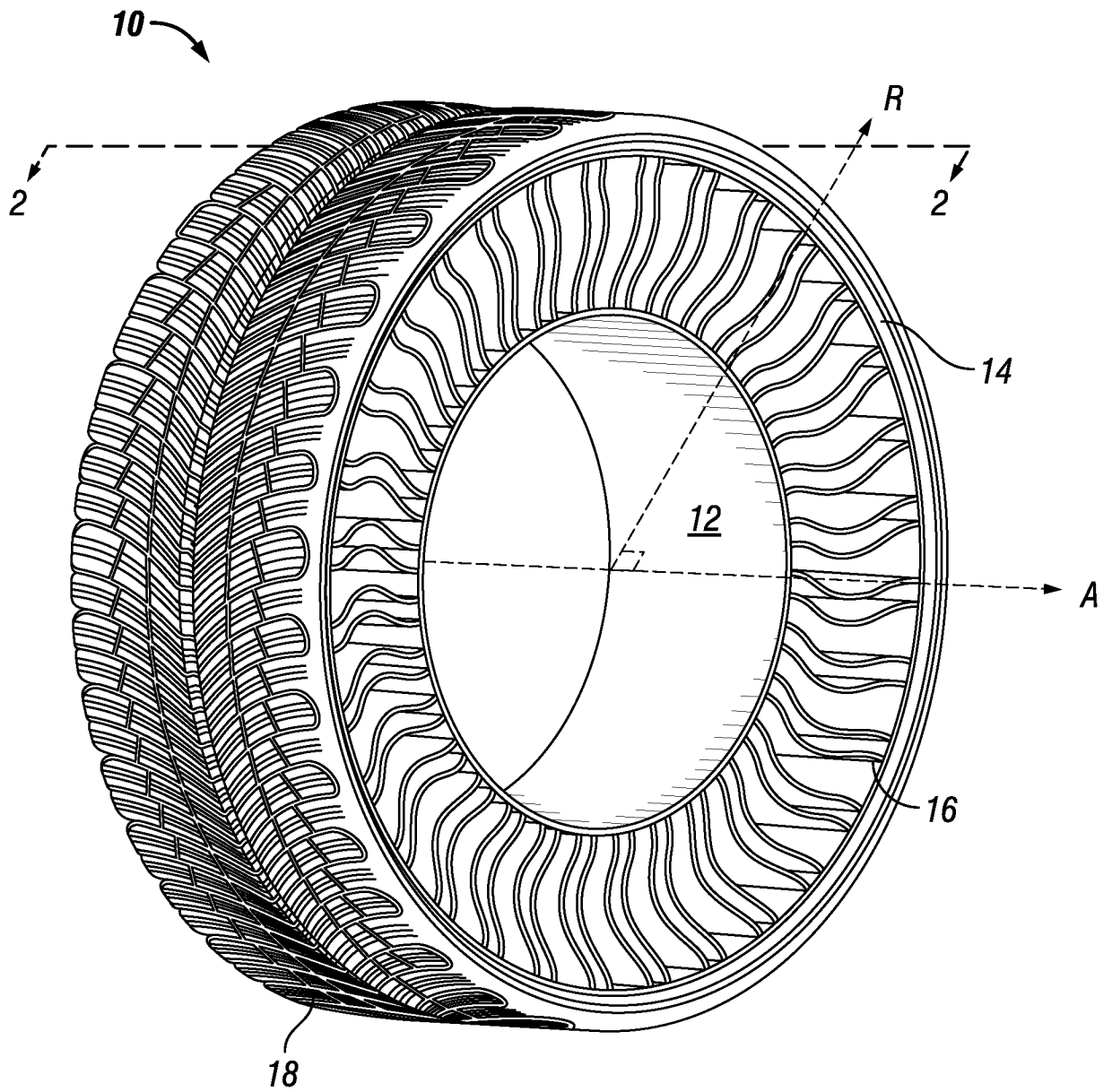
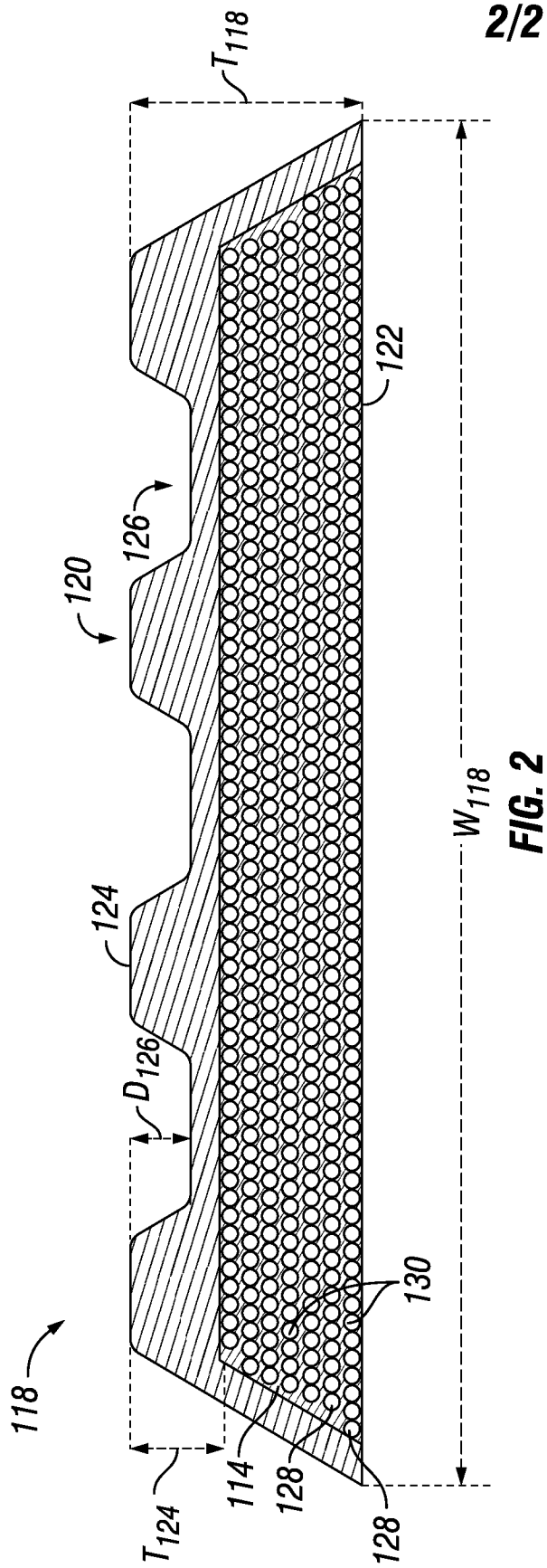
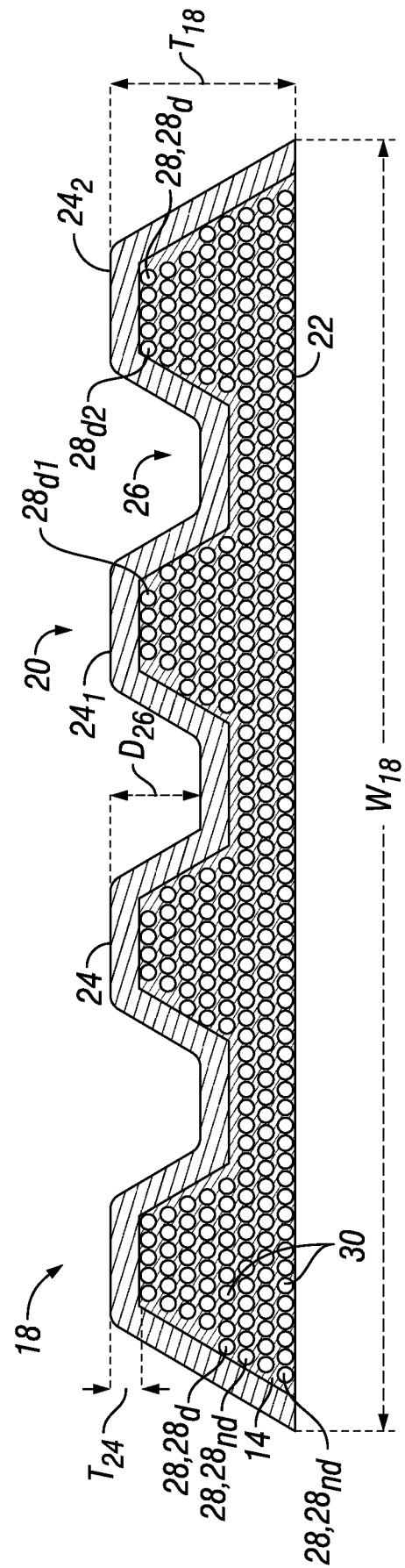


FIG. 1



**FIG. 2**  
**(Prior Art)**



**FIG. 3**

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/068499

## A. CLASSIFICATION OF SUBJECT MATTER

INV. B60C7/18 B60B9/04 B60B9/26  
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 B60B

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 03/018332 A1 (MICHELIN SOC TECH [FR]; MICHELIN RECH TECH [CH]; RHYNE TIMOTHY B [US];) 6 March 2003 (2003-03-06) paragraphs [0031] - [0088]; figure 5<br>-----      | 1-8                   |
| A         | WO 2016/116491 A1 (MICHELIN & CIE [FR]; MICHELIN RECH TECH [CH])<br>28 July 2016 (2016-07-28)<br>paragraphs [0051] - [0061]; figures 1-6<br>-----                     | 1-8                   |
| A         | WO 2013/095499 A1 (MICHELIN RECH TECH [CH]; MICHELIN SOC TECH [FR]; CRON STEVE [US]; RHYN) 27 June 2013 (2013-06-27) paragraphs [0021] - [0050]; figures 1-9<br>----- | 1-8                   |



Further documents are listed in the continuation of Box C.



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

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Date of the actual completion of the international search

28 February 2018

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

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| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)  | Publication<br>date       |
|-------------------------------------------|---------------------|-----------------------------|---------------------------|
| WO 03018332                               | A1                  | 06-03-2003                  | AT 378193 T 15-11-2007    |
|                                           |                     | CA 2458002 A1 06-03-2003    |                           |
|                                           |                     | CN 1545454 A 10-11-2004     |                           |
|                                           |                     | DE 60131469 T2 18-09-2008   |                           |
|                                           |                     | EP 1420964 A1 26-05-2004    |                           |
|                                           |                     | JP 4855646 B2 18-01-2012    |                           |
|                                           |                     | JP 2005500932 A 13-01-2005  |                           |
|                                           |                     | KR 20040027984 A 01-04-2004 |                           |
|                                           |                     | MX PA04001568 A 17-05-2004  |                           |
|                                           |                     | US 2004159385 A1 19-08-2004 |                           |
|                                           |                     | WO 03018332 A1 06-03-2003   |                           |
| WO 2016116491                             | A1                  | 28-07-2016                  | CN 107438524 A 05-12-2017 |
|                                           |                     | EP 3247575 A1 29-11-2017    |                           |
|                                           |                     | FR 3031931 A1 29-07-2016    |                           |
|                                           |                     | US 2017368878 A1 28-12-2017 |                           |
|                                           |                     | WO 2016116491 A1 28-07-2016 |                           |
| WO 2013095499                             | A1                  | 27-06-2013                  | CA 2858370 A1 27-06-2013  |
|                                           |                     | CN 103987534 A 13-08-2014   |                           |
|                                           |                     | EP 2794292 A1 29-10-2014    |                           |
|                                           |                     | JP 2015506300 A 02-03-2015  |                           |
|                                           |                     | KR 20140100528 A 14-08-2014 |                           |
|                                           |                     | RU 2014130090 A 10-02-2016  |                           |
|                                           |                     | US 2014326374 A1 06-11-2014 |                           |
|                                           |                     | WO 2013095499 A1 27-06-2013 |                           |
|                                           |                     | ZA 201404069 B 26-08-2015   |                           |