US012103335B2

(12) **United States Patent**
Scheifele

(10) **Patent No.: US 12,103,335 B2**
(45) **Date of Patent: Oct. 1, 2024**

(54) **TIRE HAVING A MODULAR TREAD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 341 days.

(21) Appl. No.: **17/612,643**

(22) PCT Filed: **May 26, 2020**

(86) PCT No.: **PCT/US2020/034524**
§ 371 (c)(1),
(2) Date: **Nov. 19, 2021**

(87) PCT Pub. No.: **WO2020/256895**
PCT Pub. Date: **Dec. 24, 2020**

(65) **Prior Publication Data**

US 2022/0234391 A1 Jul. 28, 2022

Related U.S. Application Data

(60) Provisional application No. 62/864,166, filed on Jun. 20, 2019.

(51) **Int. Cl.**
B60C 7/00 (2006.01)
B60C 7/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B60C 11/02*** (2013.01); ***B60C 7/107*** (2021.08); ***B60C 7/146*** (2021.08);
(Continued)

(58) **Field of Classification Search**
CPC .. B60C 7/10; B60C 7/102; B60C 7/14; B60C 7/146; B60C 7/18
See application file for complete search history.

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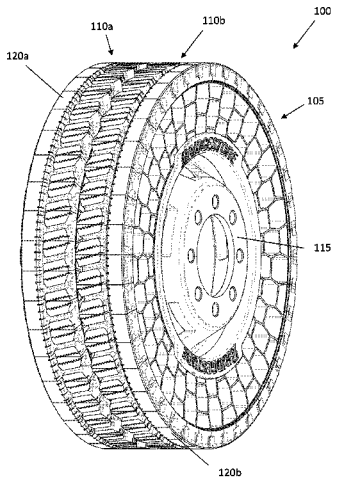
(57) **ABSTRACT**

A modular non-pneumatic tire includes a first annular tire module and a second annular tire module coaxial with the first annular tire module. The first annular tire module includes a first inner ring, a first outer ring coaxial with the first inner ring, first support structure extending between the first inner ring and the first outer ring, and a first circumferential tread extending about the first outer ring. The second annular tire module includes a second inner ring, a second outer ring coaxial with the second inner ring, second support structure extending between the second inner ring and the second outer ring, and a second circumferential tread extending about the second outer ring. The first and second circumferential treads are asymmetrical. The first circumferential tread has a first orientation and the second circumferential tread has a second orientation that is different from the first orientation.

14 Claims, 13 Drawing Sheets



(51) **Int. Cl.**

B60C 7/14	(2006.01)
B60C 11/02	(2006.01)
B60C 11/03	(2006.01)
B60C 11/12	(2006.01)

(52) **U.S. Cl.**

CPC ***B60C 11/0306*** (2013.01); ***B60C 11/1204*** (2013.01); ***B60C 11/1236*** (2013.01); *B60C 2011/0346* (2013.01); *B60C 2011/1213* (2013.01)

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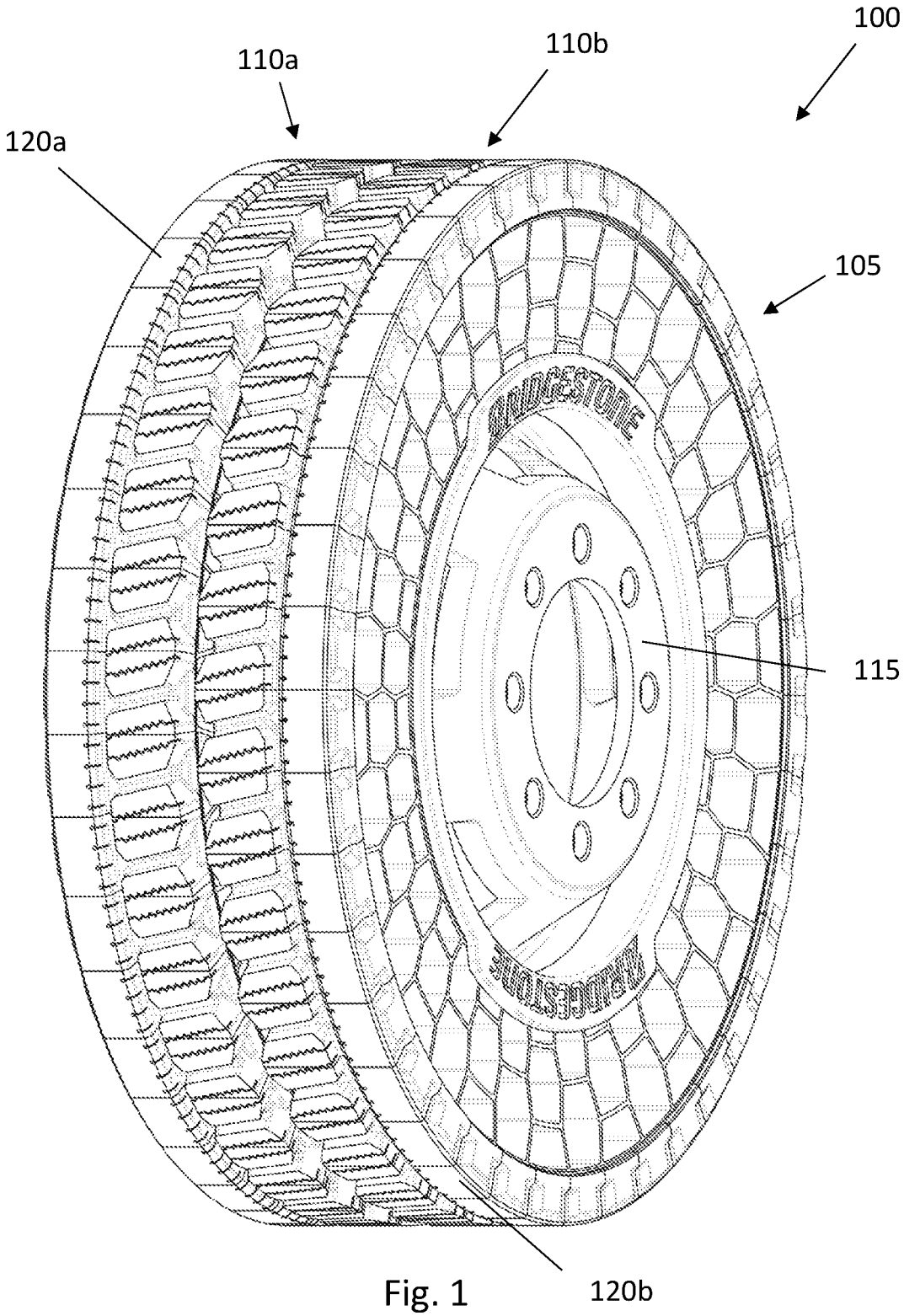

Fig. 1

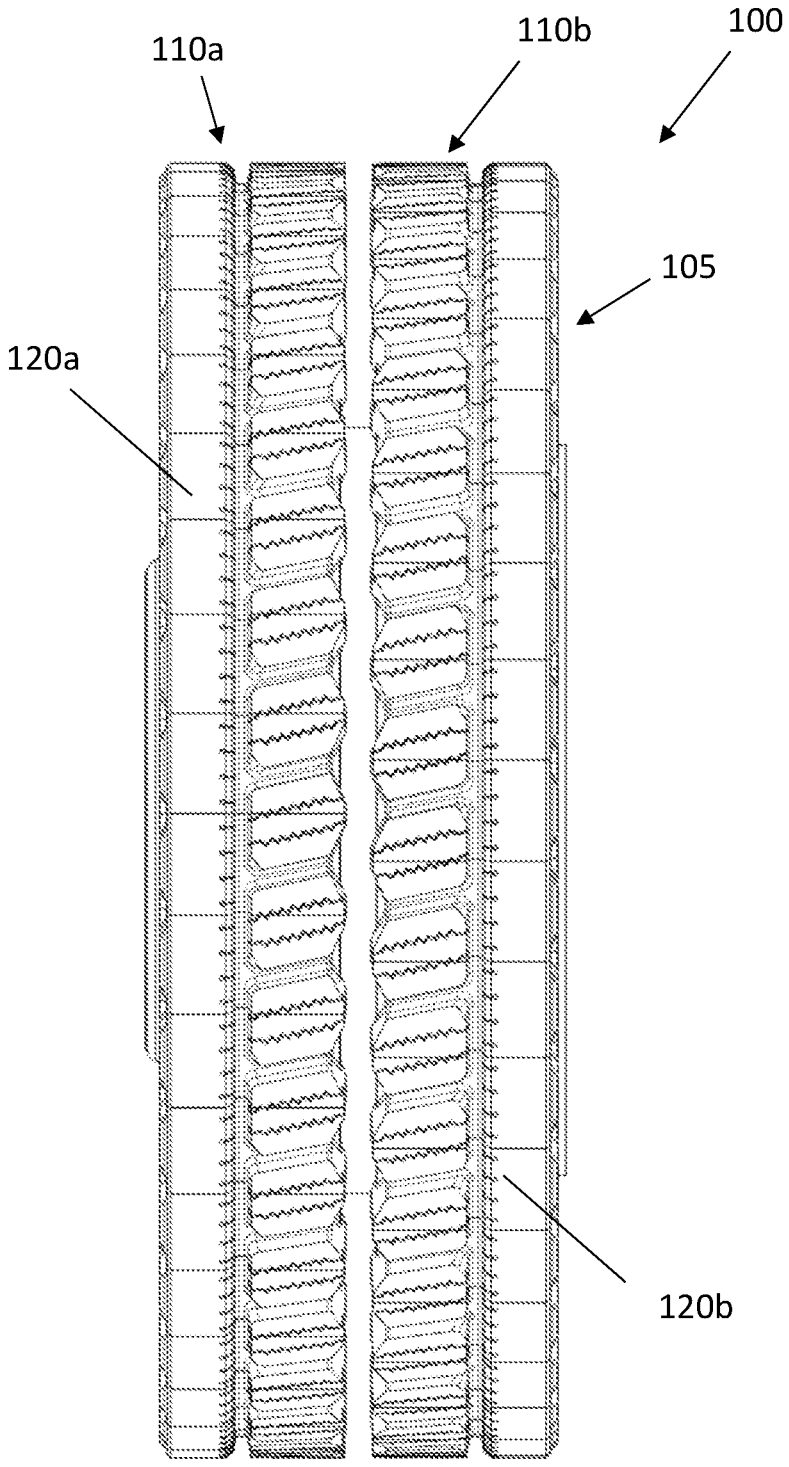

Fig. 2

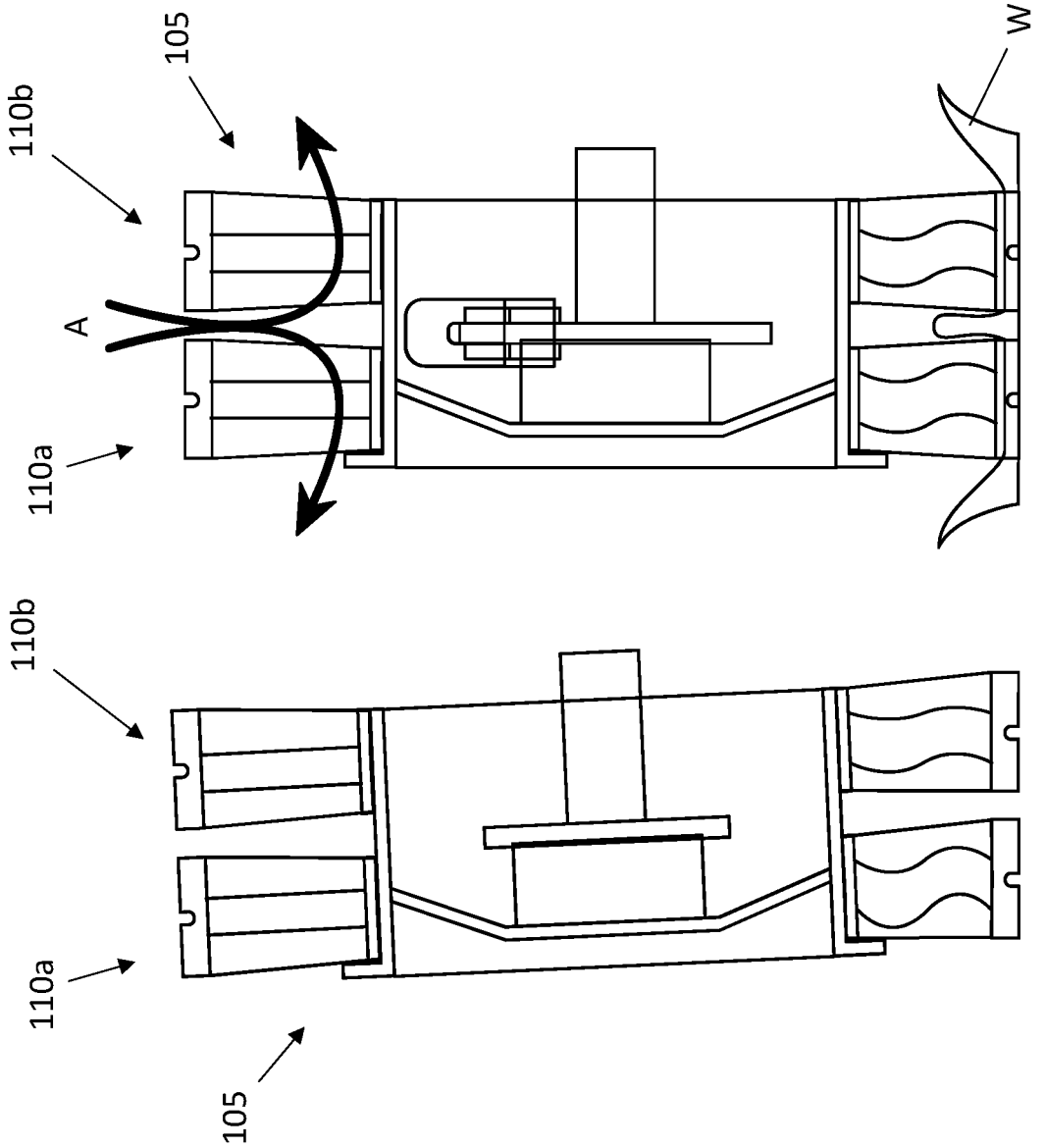

Fig. 3B

Fig. 3A

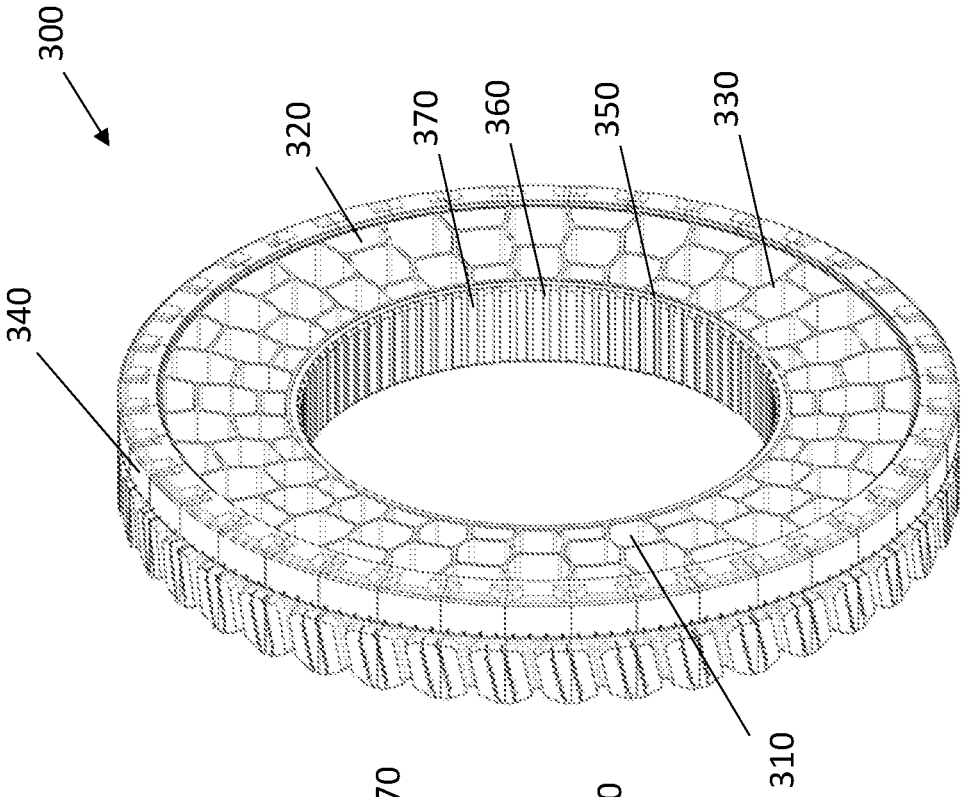

Fig. 4B

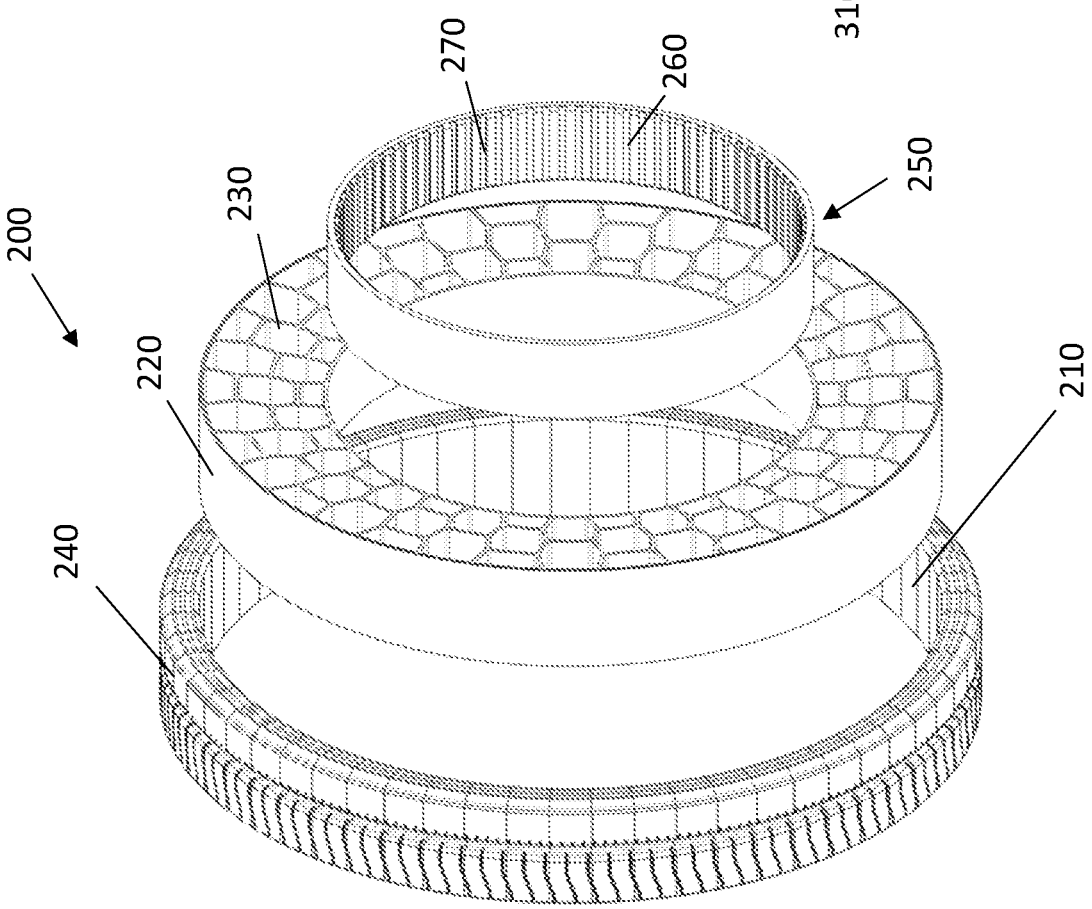

Fig. 4A

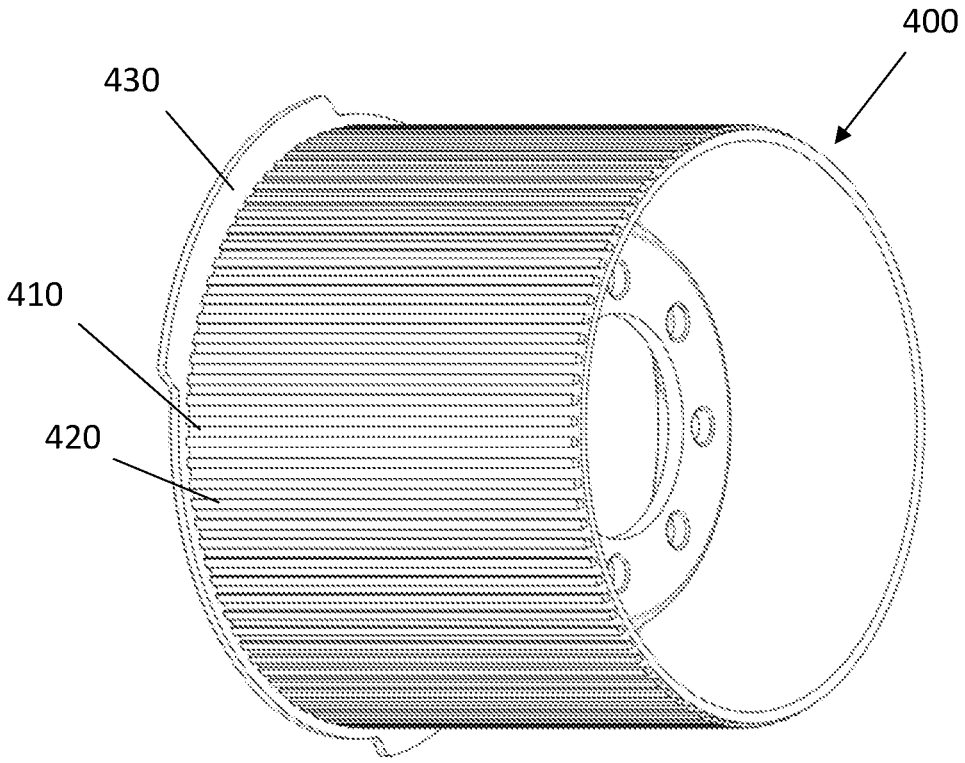

Fig. 5

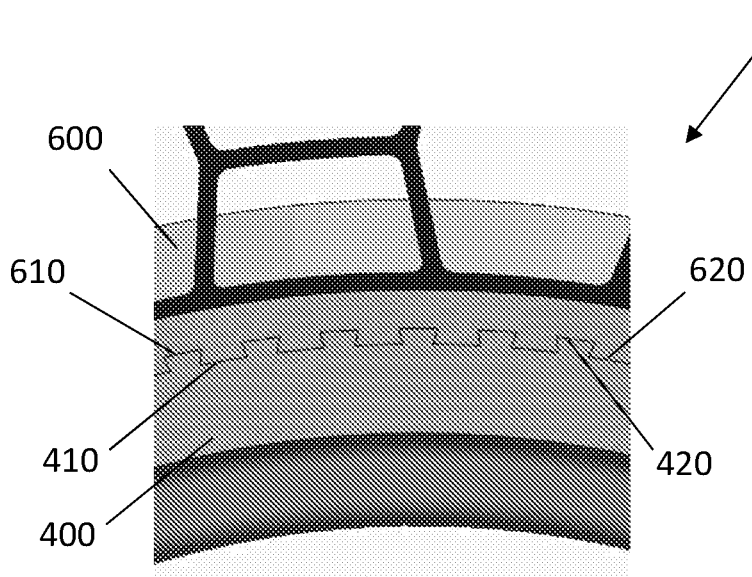

Fig. 6

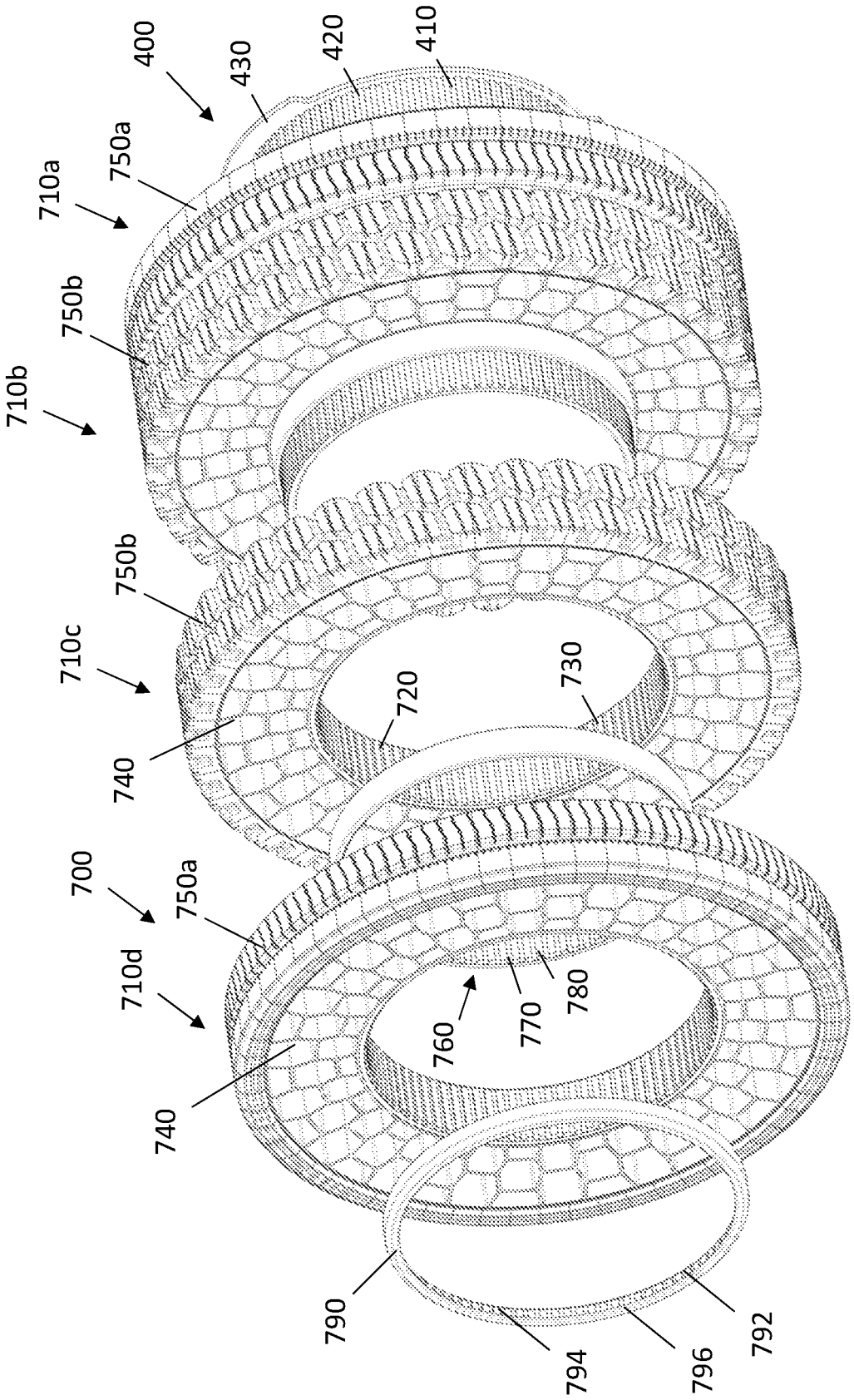
400
430
420
410
750a
710a
750b
710b
750b
710c
720
730
740
700
750a
710d
760
770
780
740
790
794
796
792

Fig. 7

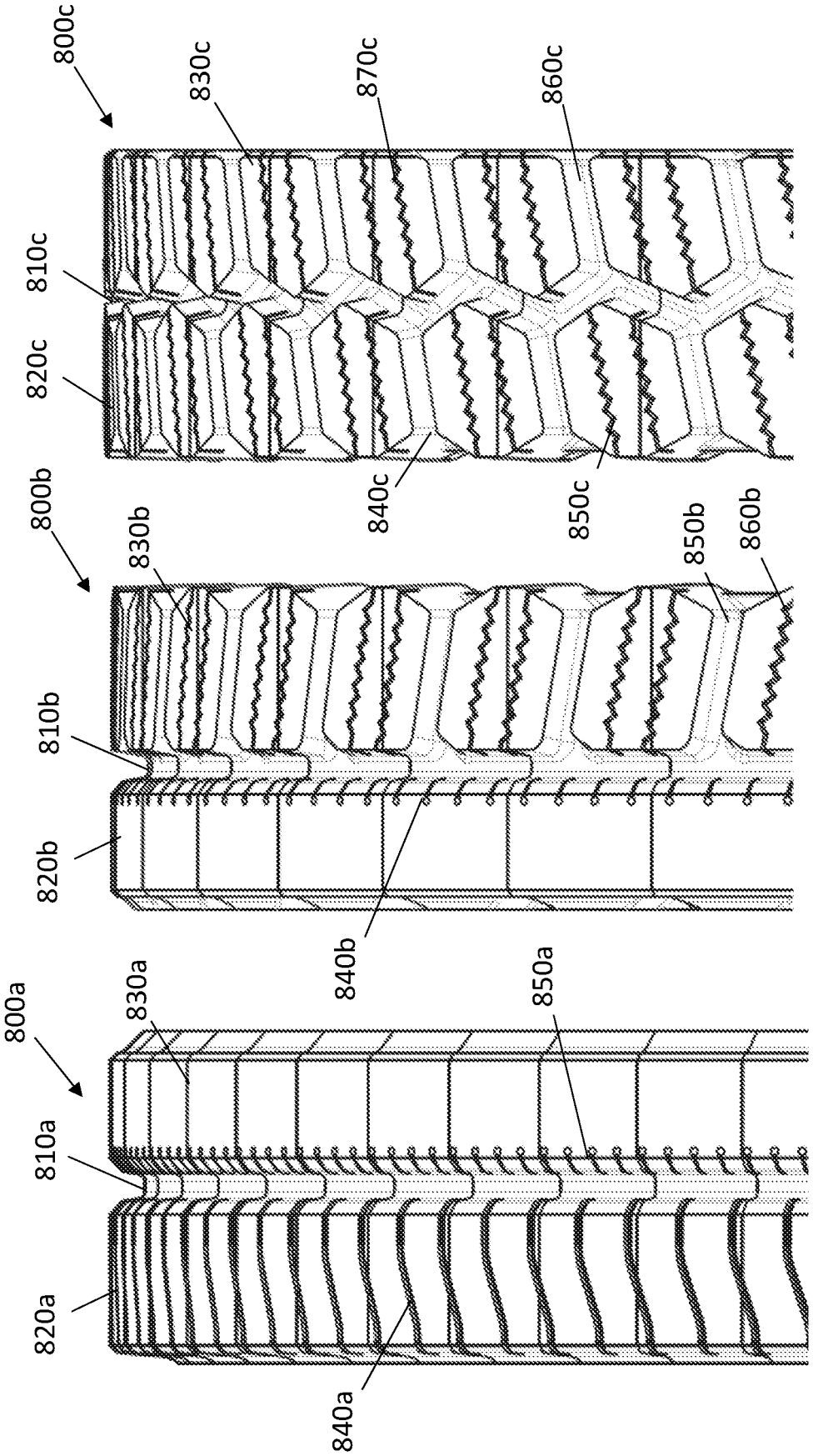

Fig. 8C

Fig. 8B

Fig. 8A

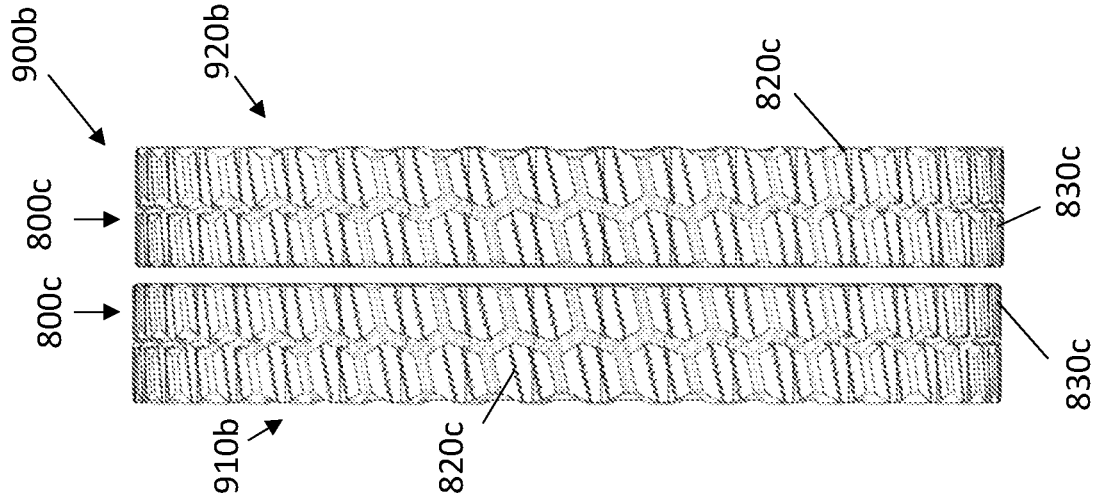
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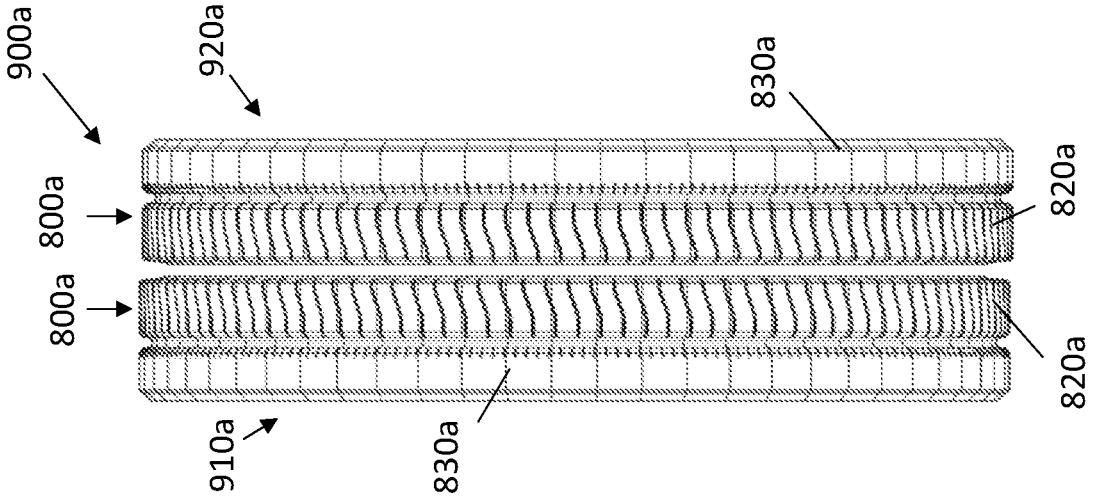
Fig. 9B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800a
820a
800a
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910a
830a

Fig. 9A

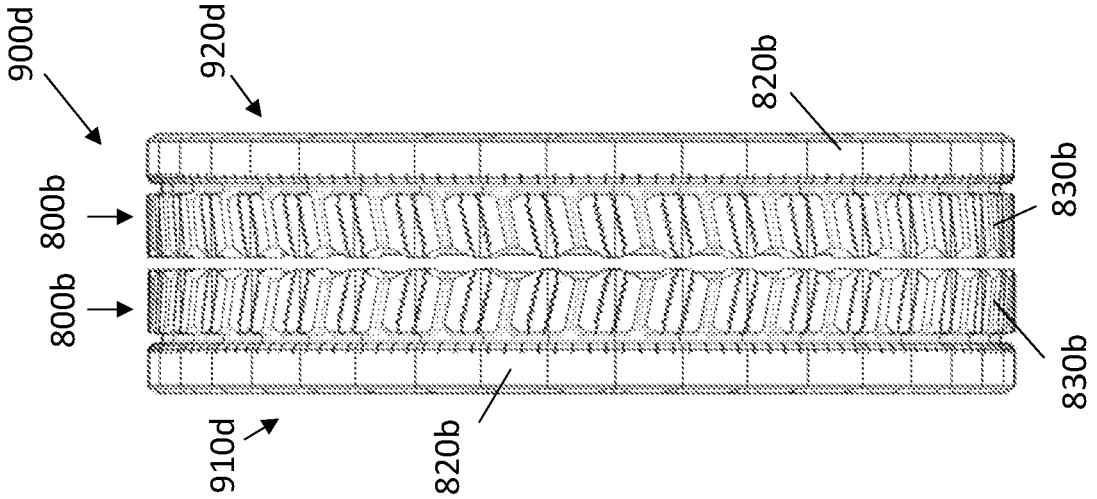
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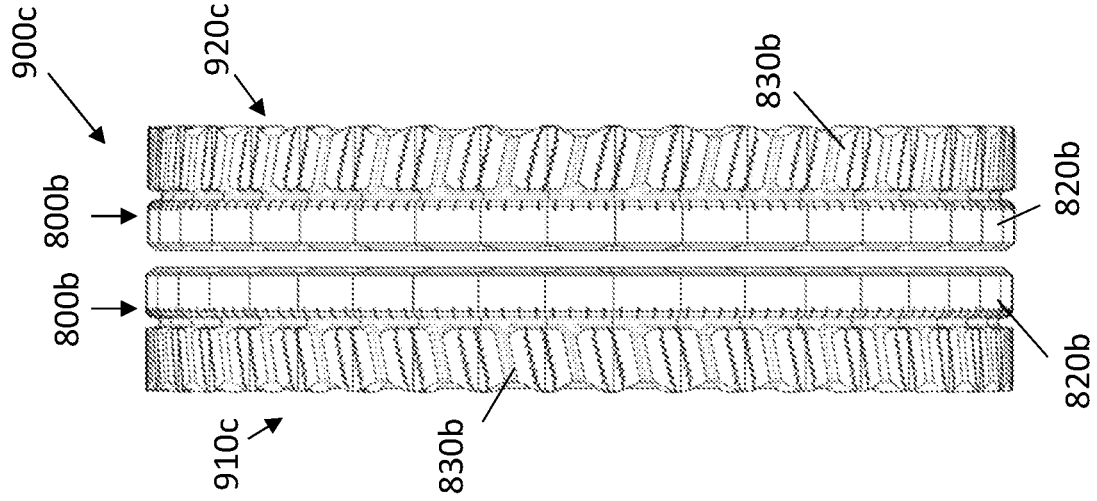
Fig. 9D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820b
800b
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830b

Fig. 9C

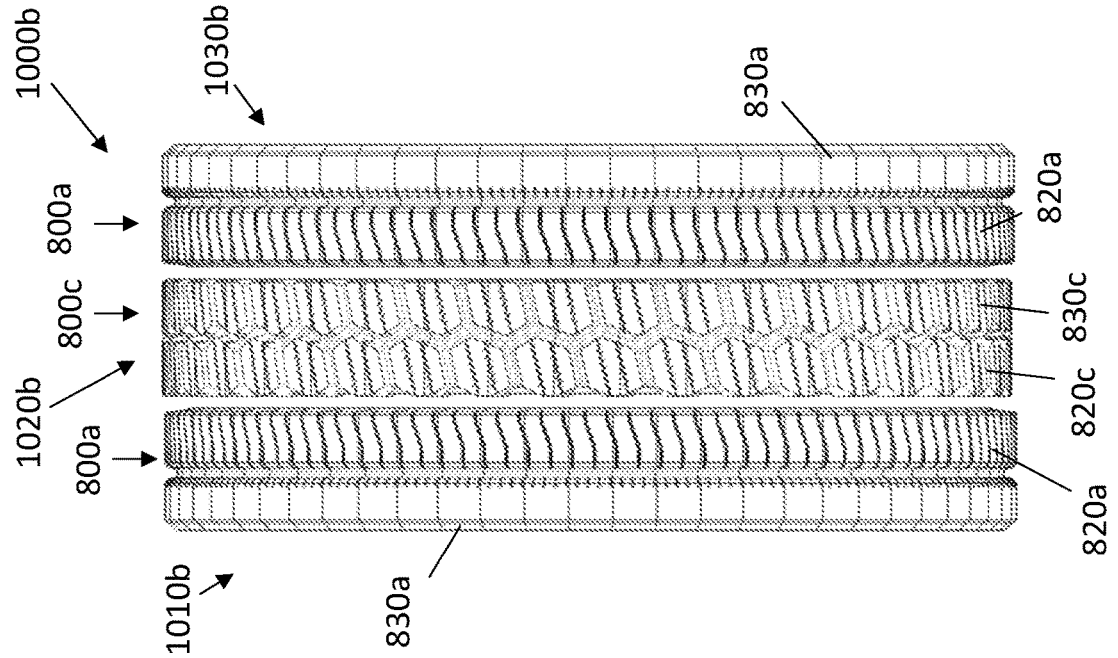

Fig. 10B

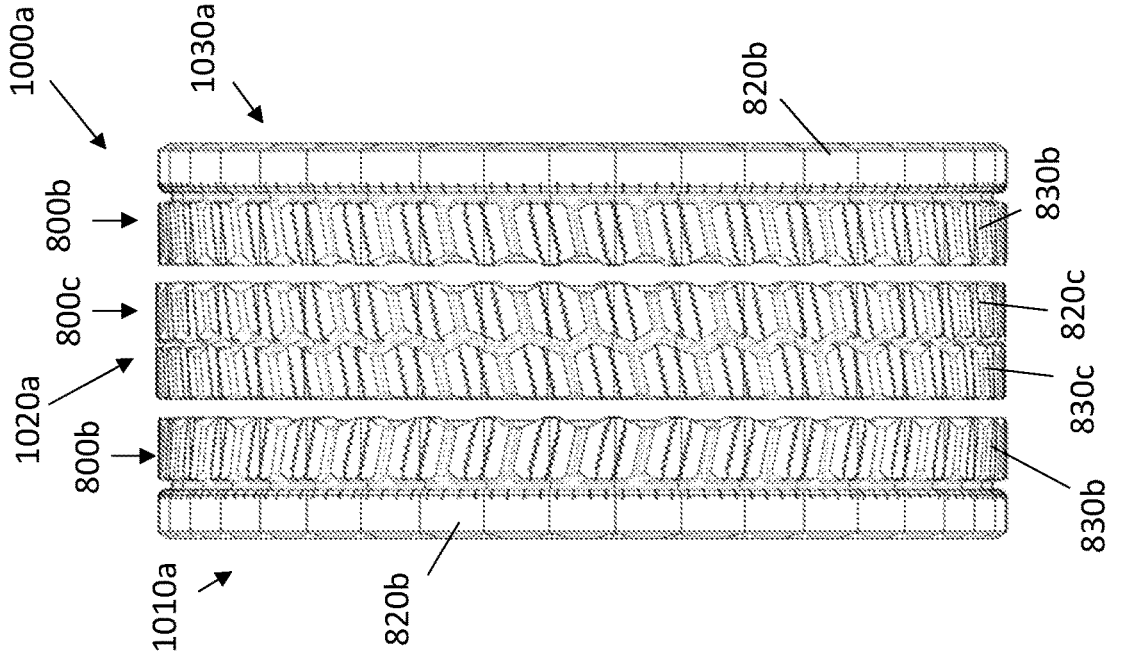

Fig. 10A

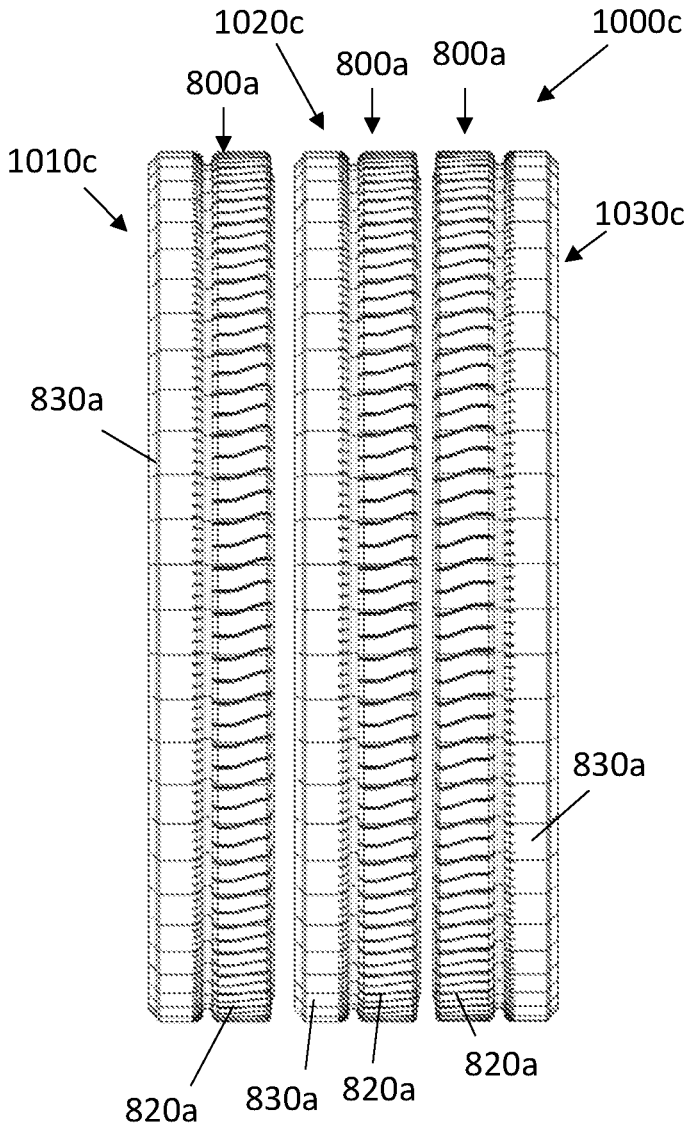
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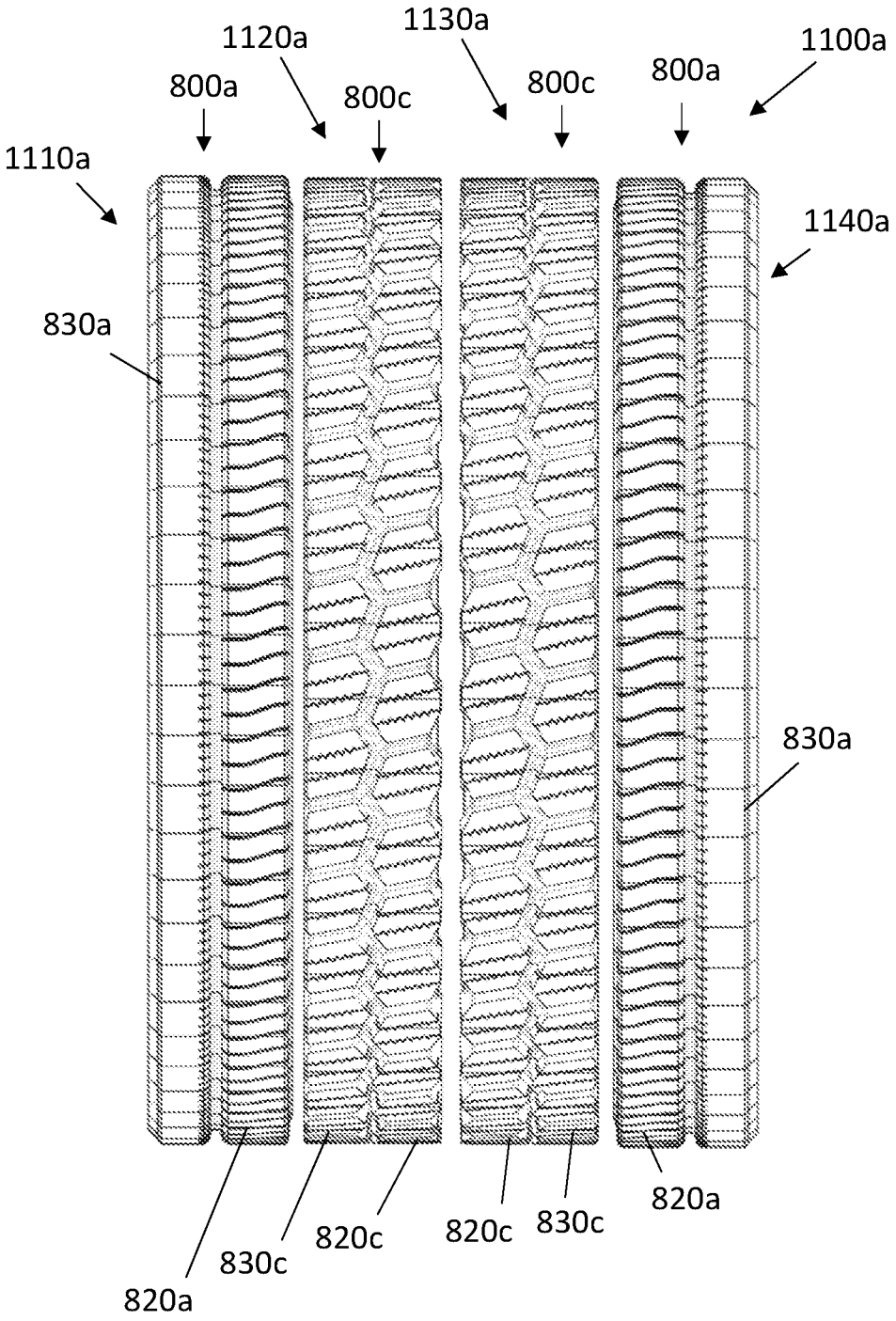
Fig. 10C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800a
800c
800c
800a
1110a
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830a
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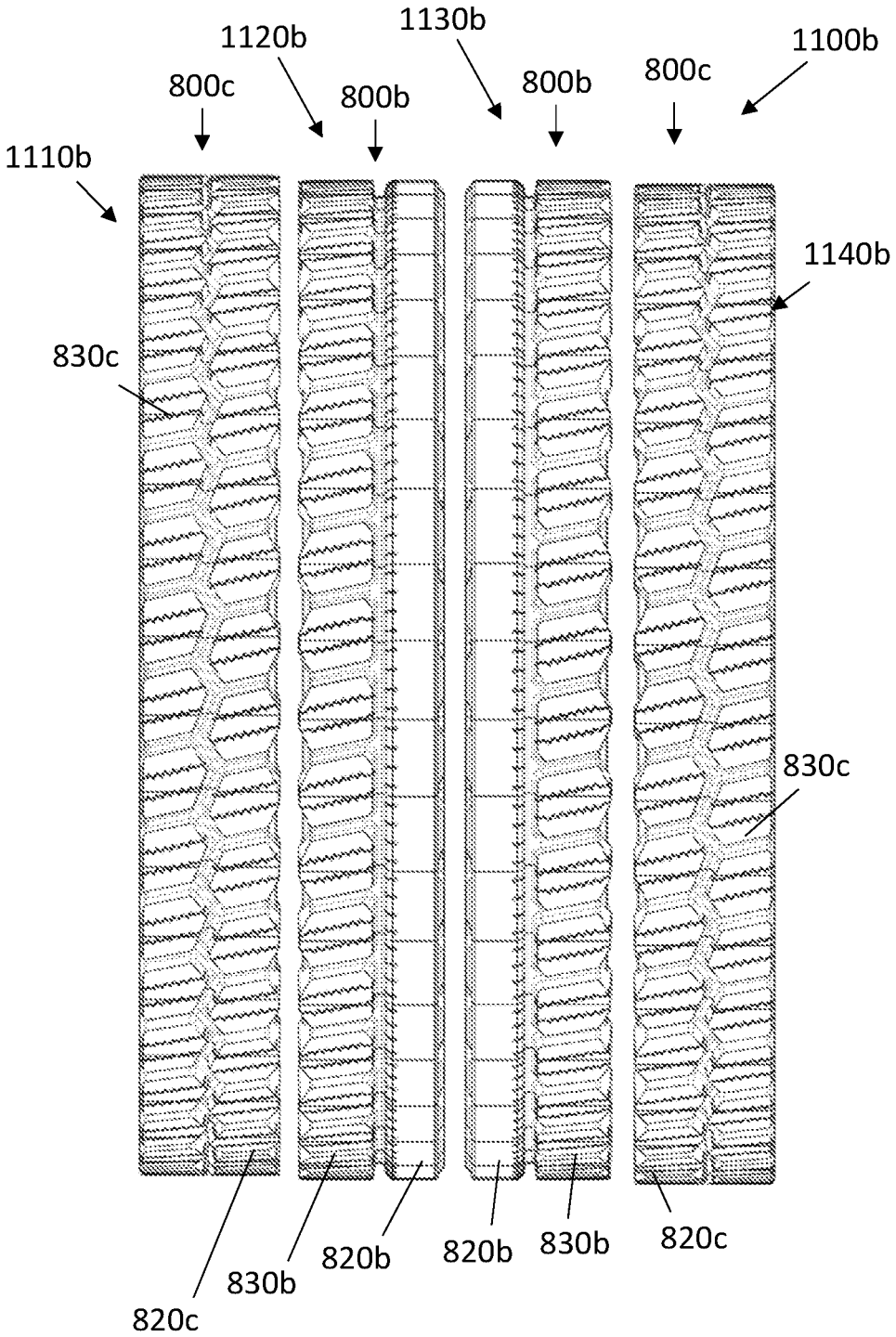
830c
820c
820c
830c
820a

Fig. 11A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1100b
800c
800b
800b
800c
1110b
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830c
830c
820c
830b
820b
820b
830b
820c

Fig. 11B

TIRE HAVING A MODULAR TREAD

FIELD OF INVENTION

The present disclosure relates to a tire and rim assembly for a tire, with a tire having multiple components. More particularly, the present disclosure relates to a tire and rim assembly for a non-pneumatic tire having modular components.

BACKGROUND

Various tire constructions have been developed which enable a tire to run in an uninflated or underinflated condition. Non-pneumatic tires do not require inflation, while "run flat tires" may continue to operate after receiving a puncture and a complete or partial loss of pressurized air, for extended periods of time and at relatively high speeds. Non-pneumatic tires may include a plurality of spokes, a webbing, or other support structure that connects an inner ring to an outer ring.

In current mounting methods, a non-pneumatic tire is mounted to a rim and affixed with adhesive, such that the rim it is difficult to remove the rim from the tire without causing damage to the rim or tire. If the rim is removed from the tire, it is difficult to remove any remaining adhesive from the rim. Thus, when the tire reaches its end of life, it may be resource intensive or expensive to recover the rim. As tires and tire designs become larger, the cost of the non-reusable rims will also increase.

SUMMARY OF THE INVENTION

In one embodiment, a non-pneumatic tire and rim assembly includes a non-pneumatic tire having a plurality of annular tire modules. The non-pneumatic tire has a first annular tire module coaxial with a second annular tire module. The first annular tire module includes a first inner ring, a first outer ring, first support structure extending between the first inner ring and the first outer ring, and a first circumferential tread extending about the first outer ring. The second annular tire module includes a second inner ring, a second outer ring, second support structure extending between the second inner ring and the second outer ring, and a second circumferential tread extending about the second outer ring. The first circumferential tread has a first tread pattern and the second circumferential tread has a second tread pattern that is different from the first tread pattern. The non-pneumatic tire and rim assembly also includes a rim having an outer annular surface that engages the first inner ring and the second inner ring.

In another embodiment, a method of assembling a tire and rim assembly, the method includes a step of providing a plurality of annular tire modules. Each annular tire module has an inner ring, an outer ring, support structure extending between the inner ring and the outer ring, and a circumferential tread extending about the outer ring. The method further includes steps of providing a rim, selecting a first annular tire module from the plurality of annular tire modules, and sliding the first annular tire module onto the rim. The method also includes steps of selecting a second annular tire module from the plurality of annular tire modules and sliding the second annular tire module onto the rim. The method further includes steps of providing a locking ring and sliding the locking ring onto the rim.

In yet another embodiment, a modular non-pneumatic tire includes a first annular tire module and a second annular tire module coaxial with the first annular tire module. The first annular tire module includes a first inner ring, a first outer ring coaxial with the first inner ring, first support structure extending between the first inner ring and the first outer ring, and a first circumferential tread extending about the first outer ring. The second annular tire module includes a second inner ring, a second outer ring coaxial with the second inner ring, second support structure extending between the second inner ring and the second outer ring, and a second circumferential tread extending about the second outer ring. The first and second circumferential treads are asymmetrical. The first circumferential tread has a first orientation and the second circumferential tread has a second orientation that is different from the first orientation.

BRIEF DESCRIPTION OF DRAWINGS

In the accompanying drawings, structures are illustrated that, together with the detailed description provided below, describe exemplary embodiments of the claimed invention. Like elements are identified with the same reference numerals. It should be understood that elements shown as a single component may be replaced with multiple components, and elements shown as multiple components may be replaced with a single component. The drawings are not to scale and the proportion of certain elements may be exaggerated for the purpose of illustration.

FIG. **1** is a perspective view of one embodiment of a non-pneumatic tire and rim assembly;

FIG. **2** is a front view of the non-pneumatic tire and rim assembly of FIG. **1**;

FIGS. **3**A and **3**B are schematic cross-sectional views of the non-pneumatic tire and rim assembly of FIG. **1**;

FIG. **4**A is an exploded perspective view of one embodiment of an annular tire module;

FIG. **4**B is a perspective view of an alternative embodiment of an annular tire module;

FIG. **5** is a perspective view of one embodiment of a rim;

FIG. **6** is partial cross-section of one embodiment of a tire and rim assembly;

FIG. **7** is an exploded cutaway view of one embodiment of a tire and rim assembly;

FIGS. **8**A-**8**C are partial front views of exemplary treads for annular tire modules;

FIGS. **9**A-**9**D are front views of exemplary non-pneumatic tires having two annular tire modules;

FIGS. **10**A-**10**C are front views of exemplary non-pneumatic tires having three annular tire modules; and

FIGS. **11**A and **11**B are front views of exemplary non-pneumatic tires having four annular tire modules.

DETAILED DESCRIPTION

FIGS. **1** and **2** provide a perspective view and front view, respectively, of one embodiment of a non-pneumatic tire and rim assembly **100**. The assembly **100** includes a non-pneumatic tire **105** having a first annular tire module **110***a* that is coaxial with a second annular tire module **110***b*. The annular tire modules **110***a,b* are mounted on a rim **115**. While two annular tire modules are shown in the illustrated embodiment, alternative embodiments may include three or more tire modules.

The first annular tire module **110***a* includes a first circumferential tread **120***a* and the second annular tire module **110***b* includes a second circumferential tread **120***b*. Each circumferential tread **120***a,b* includes a tread pattern composed of tread elements such as grooves, ribs, blocks, lugs, and sipes.

The tread patterns shown in the illustrated embodiment are merely exemplary. In the illustrated embodiment, the tread pattern of the first circumferential tread **120***a* is substantially the same as the tread pattern of the second circumferential tread **120***b*, and the treads are aligned in opposite orientations. In an alternative embodiment, the tread pattern of the first circumferential tread is substantially the same as the tread pattern of the second circumferential tread, and the treads are aligned in the same orientation. In another alternative embodiment, the first and second circumferential treads have different tread patterns.

In the illustrated embodiment, the first and second circumferential treads **120***a*, **120***b* have asymmetrical tread patterns. In an alternative embodiment, one or both of the first and second circumferential treads has a symmetrical tread pattern.

In the illustrated embodiment, the first annular tire module **110***a* is axially spaced apart from the second annular tire module **110***b*. In an alternative embodiment, the first annular tire module contacts the second annular tire module.

Spacing apart the annular tire modules may have several benefits, as illustrated in the schematic cross-sectional view of FIGS. **3**A and **3**B. Spacing apart the annular tire modules **110***a,b* reduces the mass of the tire **105**, while maintaining wide footprint stability. Additionally, as shown in FIG. **3**A, when the tire **105** is cornering, the outer forces on the first annular tire module **110***a* are isolated from the inner forces on the second annular tire module **110***b*, so that the first annular tire module **110***a* deflects by a different amount than the second annular tire module **110***b*. As shown in FIG. **3**B, spacing apart the annular tire modules **110***a,b* allows for improved air flow A, resulting in improved cooling of the tire **105** as it rotates. Additionally, spacing apart the annular tire modules **110***a,b* result in higher contact pressure in the footprint of the tire, which reduces hydroplaning when the tire **105** contacts water W.

Additional details of the annular tire modules are shown in FIGS. **4**A and **4**B. FIG. **4**A is an exploded perspective view of one embodiment of an annular tire module **200** and FIG. **4**B is a perspective view of another embodiment of an annular tire module **300**. Some details differ between the annular tire module **200** and the annular tire module **300**. For example, the annular tire module **200** has a different tread pattern from the annular tire module **300**. However, the basic components of the tire modules **200**, **300** are substantially the same.

Each tire module **200**, **300** includes an inner ring **210**, **310**, an outer ring **220**, **320**, and support structure **230**, **330** extending between the inner ring **210**, **310** and the outer ring **220**, **320**. In the illustrated embodiment, both the inner surface of the inner ring **210**, **310** and the outer surface of the outer ring **220**, **320** are smooth surfaces. In an alternative embodiment, one or more of these surfaces may include grooves, ribs, or other features.

In the illustrated embodiment, the support structure **230**, **330** is a web. In an alternative embodiment (not shown), the support structure includes a plurality of spokes. In another alternative embodiment (not shown), the support structure is a solid structure.

In one embodiment, the inner ring **210**, **310**, outer ring **220**, **320**, and support structure **230**, **330** are constructed of the same material. In an alternative embodiment, the inner ring **210**, **310**, outer ring **220**, **320**, and support structure **230**, **330** are constructed of different materials. Exemplary materials include polymeric materials and metal. One or more of the inner ring **210**, **310**, outer ring **220**, **320**, and support structure **230**, **330** may include reinforcements.

A circumferential tread **240**, **340** extends about the outer ring **220**, **320**. The circumferential tread **240**, **340** may include a shear element, such as a shear band. Alternatively, a shear layer may be disposed between the circumferential tread and the outer ring.

As explained above, the circumferential tread includes a tread pattern composed of tread elements such as grooves, ribs, blocks, lugs, and sipes. The circumferential tread **240**, **340** may be affixed to the outer ring **220**, **320** by an adhesive. Alternatively, the circumferential tread **240**, **340** may be affixed to the outer ring **220**, **320** by a bonding process, such as by curing. In an alternative embodiment, the separate circumferential tread is omitted and a tread pattern is instead formed directly in the outer ring.

In the illustrated embodiment, an inner hoop **250**, **350** is affixed to the inner ring **210**, **310**. An inner surface of the inner hoop **250**, **350** has a plurality of axial grooves **260**, **360** that define a plurality of axial ridges **270**, **370**. The grooves **260**, **360** and ridges **270**, **370** may have a rectangular, trapezoidal, triangular, or rounded profile. Alternatively, the grooves and ridges may form any geometric shape. In one embodiment, each of the grooves **260**, **360** has the same shape and each of the ridges **270**, **370** has the same shape. In an alternative embodiment, the shapes may vary.

The inner hoop **250**, **350** may be constructed of metal or a polymeric material. The inner hoop **250**, **350** may also include reinforcements. In one embodiment, the an inner hoop **250**, **350** is constructed of the same material as the inner ring **210**, **310**. In an alternative embodiment, the inner hoop **250**, **350** and inner ring **210**, **310** are constructed of different materials.

The inner hoop **250**, **350** may be affixed to the inner ring **210**, **310** by an adhesive. Alternatively, the inner hoop **250**, **350** may be affixed to the inner ring **210**, **310** by a bonding process, such as by curing. In an alternative embodiment, the separate inner hoop is omitted and axial grooves and ridges are instead formed directly on the inner surface of the inner ring.

FIG. **5** is a perspective view of one embodiment of a rim **400**. The rim **115** of FIG. **1** may share the same features of the rim **400** of FIG. **5**, or it may depart from the design in any of the manners discussed below.

The rim **400** has an outer annular surface configured to engage the inner surfaces of the annular tire modules. For example, the outer annular surface of the rim **400** may engage the inner surfaces of a first inner ring and a second inner ring, or the inner surfaces of a first inner hoop and a second inner hoop. In the illustrated embodiment, the outer annular surface of the rim **400** has a plurality of axial grooves **410** that define a plurality of axial ridges **420**. The grooves **410** and ridges **420** may have a rectangular, trapezoidal, triangular, or rounded profile. Alternatively, the grooves and ridges may form any geometric shape. In one embodiment, each of the grooves **410** has the same shape and each of the ridges **420** has the same shape. In an alternative embodiment, the shapes may vary. In another alternative embodiment, the outer annular surface of the rim assembly is a smooth surface. In yet another alternative embodiment, the rim is perforated.

In the illustrated embodiment, the rim **400** has a flange **430** at a first axial end. The second axial end of the rim **400** has no flange. The diameter of the flange **420** varies around its circumference. In an alternative embodiment, the flange has a consistent diameter. In another alternative embodiment, neither end of the rim has a flange.

FIG. **6** is partial cross-section of one embodiment of a tire and rim assembly **500** including the rim **400** of FIG. **5**, and

an annular tire module **600**. The annular tire module **600** may be substantially the same as one of the annular tire modules **110***a*, **110***b*, **200**, **300** described above, or it may depart from those designs. The inner surface of the annular tire module **600** includes a plurality of axial grooves **610** that define a plurality of axial ridges **620**.

As can be seen from this view, the shapes of the grooves **410** of the rim **400** correspond to the shapes of ridges **620** of the inner surface of the annular tire module **600**. Likewise, the shapes of the ridges **420** of the rim **400** correspond to the shapes of grooves **610** on the inner surface of the annular tire module. Thus, the tire module **600** may slide onto the rim **400**. Lubricant may be applied to one or more of the surfaces to assist in assembling the rim **400** and the annular tire module **600**.

Any number of annular tire modules may be placed onto the rim. For example, FIG. **7** is an exploded cutaway view of one embodiment of a tire and rim assembly **700** including the rim **400** and four annular tire modules **710***a*, **710***b*, **710***c*, **710***d*. Each of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d* has an inner surface with grooves **720** and ridges **730** that correspond to the ridges **420** and grooves **410** of the rim **400** in the manner described above. The grooves **720** and ridges **730** of each of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d* has substantially the same geometry as those of the other annular tire modules.

In the illustrated embodiment, each of the four annular tire modules **710***a*, **710***b*, **710***c*, **710***d* has substantially the same diameter, the same axial width, and substantially the same support structure **740**. In alternative embodiments, one or more of the annular tire modules may have a different diameter. In another alternative embodiment, one or more of the annular tire modules may have a different axial width. In yet another alternative embodiment, one or more of the annular tire modules may have a different support structure. For example, the support structure of one or more annular tire modules may be constructed of a different material than the other annular tire modules. As another example, the geometry of the support structure of one or more annular tire modules may be different from the geometry of the other annular tire modules. In one specific example, one of the annular tire modules has spokes as a support structure, while the other annular tire modules have webbing.

The diameter and support structure of each annular tire module may be selected to tune the footprint and the performance of the tire. For example, it may be desirable for certain portions of a tire to have a higher stiffness than other portions. It may likewise be desirable for certain portions of a tire to have a greater diameter. Such factors may affect the performance of the assembled tire. The desired characteristics of an assembled tire may depend on other factors, such as the load on the tire and driving conditions, including temperature and precipitation. Thus a user may select tire modules and assemble a tire according to the desired characteristics of the resulting tire.

In the illustrated embodiment, the outer annular tire modules **710***a* and **710***d* have the same first circumferential tread pattern **750***a*, and the inner annular tire modules **710***b*, **710***c* have the same second circumferential tread pattern **750***b*. In this embodiment, the outer annular tire modules **710***a* and **710***d* are placed on the rim **400** such that the first circumferential tread patterns **750***a* are oriented in opposite orientations. In an alternative embodiment, the outer annular tire modules are placed on the rim such that the first circumferential tread patterns are oriented in the same direction. In other alternative embodiments, the tread patterns may be varied in any combination.

A plurality of spacer rings **760** are also disposed on the rim **400**. Each spacer ring **760** includes a plurality of axial grooves **770** that define a plurality of axial ridges **780**. The axial grooves **770** and axial ridges **780** of the spacer rings **760** are substantially the same as the axial grooves **720** and axial ridges **730** of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*, so that the spacer rings **760** can slide onto the rim **400** in the same manner as the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*. The diameter of each spacer ring **760** is less than the diameter of each of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*.

In the illustrated embodiment, each spacer ring **760** has the same axial width. The spacer rings **760** are disposed between each pair of annular tire modules **710***a*, **710***b*, **710***c*, **710***d* such that each of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d* is spaced from the nearest annular tire module. In an alternative embodiment, spacer rings of different axial widths may be employed. Additionally, spacer rings may be omitted between some annular tire modules, thus allowing the annular tire modules to contact each other. The number and width of the spacer rings may be selected to tune the performance of the assembled tire.

The tire and rim assembly **700** further includes a locking ring **790** that is disposed at the second axial end of the rim **400**, opposite the flange **430** at the first axial end of the rim **400**. The locking ring **790** includes a plurality of axial grooves **792** that define a plurality of axial ridges **794**. The axial grooves **792** and axial ridges **794** of the locking ring **790** are substantially the same as the axial grooves **720** and axial ridges **730** of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*, so that the locking ring **790** can slide onto the rim **400** in the same manner as the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*. The diameter of the locking ring **790** is less than the diameter of each of the annular tire modules **710***a*, **710***b*, **710***c*, **710***d*. The diameter of the locking ring **790** may be variable, such that the locking ring **790** can be tightened and remain fixed in place at the second axial end of the rim **400**. Alternatively, the locking ring may be crimped, adhered, or otherwise bonded to the second axial end of the rim **400**. Examples of bonding methods include brazing, welding, or chemical bonding. As another alternative, mechanical fasteners such as bolts or screws may extend through holes in the locking ring and engage with threaded holes in the rim to lock the locking rim in place.

The locking ring **790** may be fixed onto the second axial end of the rim **400** in a temporary or permanent manner. If the locking ring **790** is fixed to the second axial end of the rim **400** in a temporary manner, the tire and rim assembly **700** may be disassembled when desired. In such an embodiment, one or more of the tire modules and spacer rings may be replaced or rearranged, and the tire and rim assembly may then be assembled in a different orientation.

In embodiments where the rim does not include a flange at either end, two locking rings may be employed. A first locking rim is locked onto a first axial end of the rim and a second locking rim is locked onto a second axial end of the rim.

In the embodiments shown in FIGS. **4-7**, all of the ridges and grooves on the outer surface of the rim and the inner surface of the annular tire modules, spacer rings, and locking ring extend in axial directions. In alternative embodiments (not shown), the ridges and grooves may be spiraled or helical shaped. Such grooves and ridges may be referred to as "rifled" grooves. The direction of the ridges and grooves of the rim, tire modules, spacer rings, and locking ring

would correspond to each other, such that the tire modules, spacer rings, and locking ring may be twisted onto the rim.

As described above, a variety of different tread patterns may be employed on the tire modules. Each tread pattern may exhibit different performances under different conditions such as wet, dry, or snow conditions. The stiffness of each tread pattern may also differ. Thus, certain tread patterns may be more desirable for an end portion of a tire in certain conditions and other tread patterns may be more desirable for a central portion of a tire in certain conditions. FIGS. **8**A-**8**C are partial front views of exemplary treads for annular tire modules. These examples a not intended to be limiting. It should be understood that the tread patterns may vary in any number of ways.

FIG. **8**A illustrates one example of a solid rib tire tread **800***a*. The solid rib tire tread **800***a* includes a circumferential groove **810***a* that defines a first rib **820***a* and a second rib **830***a*. The first rib **820***a* has a first plurality of sipes **840***a* extending laterally across the entire first rib **820***a*. The second rib **830***a* has a second plurality of sipes **850***a* that partially extend into the second rib **830***a* in a lateral direction. Both of the first and second ribs **820***a*, **830***a* have linear sidewalls.

FIG. **8**B illustrates one example of a hybrid rib tire tread **800***b*. The hybrid rib tire tread **800***b* includes a circumferential groove **810***b* that defines a first rib **820***b* and a second rib **830***b*. In the illustrated embodiment, the first rib **820***b* has a first plurality of sipes **840***b* partially extending into the first rib **820***b* in a lateral direction. The second rib **830***b* has a plurality of lateral grooves **850***b* that divide the second rib **830***a* into a plurality of blocks. Each block has a pair of zigzag sipes **860***b* that extend across the block in a lateral direction. Both of the first and second ribs **820***b*, **830***b* have non-linear sidewalls.

FIG. **8**C illustrates one example of a blocked rib tire tread **800***c*. The blocked rib tire tread **800***c* includes a circumferential groove **810***c* that defines a first rib **820***c* and a second rib **830***c*. The circumferential groove **810***c* extends around the tread in a zigzag configuration. In the illustrated embodiment, the first rib **820***c* has a first plurality of lateral grooves **840***c* that divide the first rib **820***c* into a first plurality of blocks. Each of the first plurality of blocks has a pair of zigzag sipes **850***c* that extend across the block in a lateral direction. The second rib **830***c* has a plurality of lateral grooves **860***c* that divide the second rib **830***c* into a second plurality of blocks. Each of the second plurality of blocks has a pair of zigzag sipes **870***c* that extend across the block in a lateral direction. The first rib **820***c* has a non-linear sidewall, while the second rib **830***c* has a linear sidewall.

While each of the exemplary tread patterns shown in FIGS. **8**A-**8**C illustrate a tread pattern having a single circumferential groove defining two ribs, it should be understood that any number of grooves and ribs may be employed. For example, it may be desirable to provide a wider tire module with three or more ribs. It also may be desirable to provide a narrower tire module with a single rib.

The tire modules and rims described herein are modular, such that they may be assembled in any number of desirable combinations. Using the three exemplary tread patterns provided in FIGS. **8**A-**8**C, FIGS. **9**-**11** illustrate some of the different combinations that can be formed. The same nomenclature and reference numerals of FIGS. **8**A-**8**C are used for convenience in FIGS. **9**-**11**. It should be understood that the illustrated combinations are not limiting, and that any number of tread patterns can be assembled as any desirable combination.

FIGS. **9**A-**9**D are front views of exemplary non-pneumatic tires having two annular tire modules. FIG. **9**A illustrates one embodiment of a non-pneumatic tire **900***a* that is constructed of first and second annular tire modules **910***a* and **920***a*, each of which has a solid rib tire tread **800***a*. The first and second annular tire modules **910***a* and **920***a* are spaced apart and in opposite orientations, such that the first rib **820***a* of the first annular tire module **910***a* is adjacent to the first rib **820***a* of the second annular tire module **920***a*. The second ribs **830***a* of the first and second annular tire modules **910***a*, **920***a* thus form the outer ribs of the non-pneumatic tire **900***a*. In alternative embodiments (not shown), the first and second annular tire modules are reversed such that the second rib of the first annular tire module is adjacent to the second rib of the second annular tire module, and the first ribs of the first and second annular tire modules form the outer ribs of the non-pneumatic tire. In another alternative embodiment, the first and second annular tire modules are oriented in the same direction.

FIG. **9**B illustrates an alternative embodiment of a non-pneumatic tire **900***b* that is constructed of first and second annular tire modules **910***b* and **920***b*, each of which has a blocked rib tire tread **800***c*. The first and second annular tire modules **910***b* and **920***b* are spaced apart and in opposite orientations, such that the second rib **830***c* of the first annular tire module **910***b* is adjacent to the first rib **830***c* of the second annular tire module **920***b*. The first ribs **820***c* of the first and second annular tire modules **910***b*, **920***b* thus form the outer ribs of the non-pneumatic tire **900***b*. In alternative embodiments (not shown), the first and second annular tire modules are reversed such that the first rib of the first annular tire module is adjacent to the first rib of the second annular tire module, and the second ribs of the first and second annular tire modules form the outer ribs of the non-pneumatic tire. In another alternative embodiment, the first and second annular tire modules are oriented in the same direction.

FIG. **9**C illustrates another alternative embodiment of a non-pneumatic tire **900***c* that is constructed of first and second annular tire modules **910***c* and **920***c*, each of which has a hybrid rib tire tread **800***b*. The first and second annular tire modules **910***c* and **920***c* are spaced apart and in opposite orientations, such that the first rib **820***b* of the first annular tire module **910***c* is adjacent to the first rib **820***b* of the second annular tire module **920***c*. The second ribs **830***b* of the first and second annular tire modules **910***c*, **920***c* thus form the outer ribs of the non-pneumatic tire **900***c*. In another alternative embodiment, the first and second annular tire modules are oriented in the same direction.

FIG. **9**D illustrates yet another alternative embodiment of a non-pneumatic tire **900***d* that is constructed of first and second annular tire modules **910***d* and **920***d*, each of which has a hybrid rib tire tread **800***b*. The first and second annular tire modules **910***d* and **920***d* are spaced apart and in opposite orientations, such that the second rib **830***b* of the first annular tire module **910***d* is adjacent to the second rib **830***b* of the second annular tire module **920***d*. The first ribs **820***b* of the first and second annular tire modules **910***d*, **920***d* thus form the outer ribs of the non-pneumatic tire **900***d*.

In still other alternative embodiments, an annular tire module having a solid rib tread may be used with an annular tire module having a blocked rib tread or a hybrid rib tread, in any orientation. Likewise, an annular tire module having a blocked rib tread may be used with an annular tire module having a hybrid rib tread in any orientation.

FIGS. **10**A-**10**C are front views of exemplary non-pneumatic tires having three annular tire modules. FIG. **10**A

illustrates one embodiment of a non-pneumatic tire **1000***a* that is constructed of a first annular tire module **1010***a* having a hybrid rib tire tread **800***b*, a second annular tire module **1020***a* having a blocked rib tire tread **800***c*, and a third annular tire module **1030***a* having a hybrid rib tire tread **800***b*. The annular tire modules **1010***a*, **1020***a*, **1030***a* are spaced apart from each other.

The first annular tire module **1010***a* is oriented such that its first rib **820***b* forms an outer rib of the non-pneumatic tire **1000***a*. The second annular tire module **1020***a* is oriented such that its second rib **830***c* is adjacent to the second rib **830***b* of the first annular tire module **1010***a*. The third annular tire module **1030***a* is oriented such that its second rib **830***b* is adjacent to the first rib **820***c* of the second annular tire module **1020***a*. Thus, the first rib **820***b* of the third annular tire module **1030***a* forms an outer rib of the non-pneumatic tire **1000***a*. In alternative embodiments, the tire modules **1010***a*, **1020***a*, **1030***a* may be arranged in any order and any orientation.

FIG. **10**B illustrates an alternative embodiment of a non-pneumatic tire **1000***b* that is constructed of a first annular tire module **1010***b* having a solid rib tire tread **800***a*, a second annular tire module **1020***b* having a blocked rib tire tread **800***c*, and a third annular tire module **1030***b* having a solid rib tire tread **800***a*. The annular tire modules **1010***b*, **1020***b*, **1030***b* are spaced apart from each other.

The first annular tire module **1010***b* is oriented such that its second rib **830***a* forms an outer rib of the non-pneumatic tire **1000***b*. The second annular tire module **1020***b* is oriented such that its first rib **820***c* is adjacent to the first rib **820***a* of the first annular tire module **1010***b*. The third annular tire module **1030***b* is oriented such that its first rib **820***a* is adjacent to the second rib **830***c* of the second annular tire module **1020***b*. Thus, the second rib **830***a* of the third annular tire module **1030***b* forms an outer rib of the non-pneumatic tire **1000***b*. In alternative embodiments, the tire modules **1010***b*, **1020***b*, **1030***b* may be arranged in any order and any orientation.

FIG. **10**C illustrates another alternative embodiment of a non-pneumatic tire **1000***c* that is constructed of first, second, and third annular tire modules **1010***c*, **1020***c*, **1030***c*, each having a solid rib tire tread **800***a*. The annular tire modules **1010***c*, **1020***c*, **1030***c* are spaced apart from each other.

The first annular tire module **1010***c* is oriented such that its second rib **830***a* forms an outer rib of the non-pneumatic tire **1000***c*. The second annular tire module **1020***c* is oriented such that its second rib **830***a* is adjacent to the first rib **820***a* of the first annular tire module **1010***c*. The third annular tire module **1030***c* is oriented such that its first rib **820***a* is adjacent to the first rib **820***a* of the second annular tire module **1020***c*. Thus, the second rib **830***a* of the third annular tire module **1030***c* forms an outer rib of the non-pneumatic tire **1000***c*. In alternative embodiments, the tire modules **1010***c*, **1020***c*, **1030***c* may be arranged in any order and any orientation.

In still other alternative embodiments, three tire modules having any tread pattern may be arranged in any order and in any orientation.

FIGS. **11**A and **11**B are front views of exemplary non-pneumatic tires having four annular tire modules. FIG. **11**A illustrates one embodiment of a non-pneumatic tire **1100***a* that is constructed of a first annular tire module **1110***a* having a solid rib tire tread **800***a*, a second annular tire module **1120***a* having a blocked rib tire tread **800***c*, a third annular tire module **1130***a* having a blocked rib tire tread **800***c*, and a fourth annular tire module **1140***a* having a solid rib tire tread **800***a*. The annular tire modules **1110***a*, **1120***a*, **1130***a*, **1140***a* are spaced apart from each other.

The first annular tire module **1110***a* is oriented such that its second rib **830***a* forms an outer rib of the non-pneumatic tire **1100***a*. The second annular tire module **1120***a* is oriented such that its second rib **830***c* is adjacent to the first rib **820***a* of the first annular tire module **1110***a*. The third annular tire module **1130***a* is oriented such that its first rib **820***c* is adjacent to the first rib **820***c* of the second annular tire module **1120***a*. The fourth annular tire module **1140***a* is oriented such that its first rib **820***a* is adjacent to the second rib **830***c* of the third annular tire module **1130***a*. Thus, the second rib **830***a* of the fourth annular tire module **1140***a* forms an outer rib of the non-pneumatic tire **1100***a*. In alternative embodiments, the tire modules **1110***a*, **1120***a*, **1130***a*, **1140***a* may be arranged in any order and any orientation.

FIG. **11**B illustrates an alternative embodiment of a non-pneumatic tire **1100***b* that is constructed of a first annular tire module **1110***b* having a blocked rib tire tread **800***c*, a second annular tire module **1120***b* having a hybrid rib tire tread **800***b*, a third annular tire module **1130***b* having a hybrid rib tire tread **800***b*, and a fourth annular tire module **1140***b* having a blocked rib tire tread **800***c*. The annular tire modules **1110***b*, **1120***b*, **1130***b*, **1140***b* are spaced apart from each other.

The first annular tire module **1110***b* is oriented such that its second rib **830***c* forms an outer rib of the non-pneumatic tire **1100***b*. The second annular tire module **1120***b* is oriented such that its second rib **830***b* is adjacent to the first rib **820***c* of the first annular tire module **1110***b*. The third annular tire module **1130***b* is oriented such that its first rib **820***b* is adjacent to the first rib **820***b* of the second annular tire module **1120***b*. The fourth annular tire module **1140***b* is oriented such that its first rib **820***c* is adjacent to the second rib **830***b* of the third annular tire module **1130***b*. Thus, the second rib **830***c* of the fourth annular tire module **1140***b* forms an outer rib of the non-pneumatic tire **1100***b*. In alternative embodiments, the tire modules **1110***b*, **1120***b*, **1130***b*, **1140***b* may be arranged in any order and any orientation.

In still other alternative embodiments, four tire modules having any tread pattern may be arranged in any order and in any orientation.

To assemble a non-pneumatic tire and rim using the principles discussed herein, a user is provided a plurality of annular tire modules. Each annular tire module has an inner ring, an outer ring, support structure extending between the inner ring and the outer ring, and a circumferential tread extending about the outer ring. The user is also provided a rim.

As discussed above, the circumferential tread of the first annular tire module may be an asymmetrical tread. Likewise, the circumferential tread of the second annular tire module may be an asymmetrical tread.

The user then selects a first annular tire module from the plurality of annular tire modules. The user may select an orientation of the first annular tire module and slide the first annular tire module onto the rim while the first annular tire module is in the selected orientation. The user then selects a second annular tire module from the plurality of annular tire modules. The user may select an orientation of the second annular tire module and slide the second annular tire module onto the rim while the second annular tire module is in the selected orientation. The user is also provided a locking ring, and slides the locking ring onto the rim.

In one embodiment, the user is provided a spacer ring. In such an embodiment, the user slides the spacer ring onto the rim. The user may slide the spacer ring onto the rim after sliding the first annular tire module onto the rim, but before sliding the second annular tire module onto the rim. Alternatively, the user may slide the spacer ring onto the rim after sliding the second annular tire modules onto the rim.

As should be understood from the disclosure above, certain steps of this method may be repeated, to build a tire and rim assembly having three or more annular tire modules or two or more spacer rings.

After the tire and rim assembly has been assembled, a user may wish to disassemble the tire and rim assembly. For example, a user may desire to perform maintenance on one or more of the components, or replace one or more of the components. The user may also wish to replace all of the annular tire modules. To disassemble the tire and rim assembly, a user removes the locking ring from the rim, and remove the second annular tire module from the rim, and removes the first annular tire module from the rim. If spacer rings have been placed on the rim, they are also removed from the rim. If any additional annular tire modules have been placed on the rim, they are also removed from the rim.

After the tire and rim assembly has been disassembled, a user may wish to build a different tire and rim assembly. In such instances, the user selects a third annular tire module from the plurality of annular tire modules and slides the third annular tire module onto the rim. The user also selects a fourth annular tire module from the plurality of annular tire modules and slides the fourth annular tire module onto the rim. As with the initial assembly, the user may select the orientation of the third and fourth annular tire modules before sliding them onto the rim. The user may also slid spacer rings and any additional annular tire modules onto the rim. The user then slides the locking ring onto the rim.

To the extent that the term "includes" or "including" is used in the specification or the claims, it is intended to be inclusive in a manner similar to the term "comprising" as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term "or" is employed (e.g., A or B) it is intended to mean "A or B or both." When the applicants intend to indicate "only A or B but not both" then the term "only A or B but not both" will be employed. Thus, use of the term "or" herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage 624 (2d. Ed. 1995). Also, to the extent that the terms "in" or "into" are used in the specification or the claims, it is intended to additionally mean "on" or "onto." Furthermore, to the extent the term "connect" is used in the specification or claims, it is intended to mean not only "directly connected to," but also "indirectly connected to" such as connected through another component or components.

While the present application has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the application, in its broader aspects, is not limited to the specific details, the representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's general inventive concept.

What is claimed is:

1. A non-pneumatic tire and rim assembly comprising:

a non-pneumatic tire having a plurality of annular tire modules, including a first annular tire module coaxial with a second annular tire module,

wherein the first annular tire module includes a first inner ring, a first outer ring, first support structure extending between the first inner ring and the first outer ring, and a first circumferential tread extending about the first outer ring,

wherein an inner surface of the first inner ring has a first plurality of axial grooves that define a first plurality of axial ridges,

wherein the second annular tire module includes a second inner ring, a second outer ring, second support structure extending between the second inner ring and the second outer ring, and a second circumferential tread extending about the second outer ring,

wherein an inner surface of the second inner ring has a second plurality of axial grooves that define a second plurality of axial ridges, and

wherein the first circumferential tread has a first tread pattern and the second circumferential tread has a second tread pattern that is different from the first tread pattern; and

a rim having an outer annular surface that engages the first inner ring and the second inner ring,

wherein the outer annular surface of the rim has a third plurality of axial grooves that define a third plurality of axial ridges,

wherein the third plurality of axial grooves have a cross-sectional geometry corresponding to a cross-sectional geometry of the first plurality of axial ridges and to a cross-sectional geometry of the second plurality of axial ridges, and

wherein the third plurality of axial ridges have a cross-sectional geometry corresponding to a cross-sectional geometry of the first plurality of axial grooves and to a cross-sectional geometry of the second plurality of axial grooves.

2. The non-pneumatic tire and rim assembly of claim **1**, wherein the first annular tire module has a first diameter and the second annular tire module has a second diameter substantially equal to the first diameter.

3. The non-pneumatic tire and rim assembly of claim **1**, wherein the first annular tire module contacts the second annular tire module.

4. The non-pneumatic tire and rim assembly of claim **1**, wherein the first annular tire module is axially spaced from the second annular tire module.

5. The non-pneumatic tire and rim assembly of claim **4**, further comprising a spacer ring engaging the rim,

wherein the spacer ring is disposed between the first annular tire module and the second annular tire module,

wherein the first annular tire module has a first diameter,

wherein the second annular tire module has a second diameter substantially equal to the first diameter, and

wherein the spacer ring has a third diameter that is less than the first diameter and less than the second diameter.

6. The non-pneumatic tire and rim assembly of claim **1**, wherein the plurality of annular tire modules further includes a third annular tire module having a third inner ring, a third outer ring, third support structure extending between the third inner ring and the third outer ring, and a third circumferential tread extending about the third outer ring.

7. The non-pneumatic tire and rim assembly of claim **1**, wherein the rim has a flange at a first axial end.

8. The non-pneumatic tire and rim assembly of claim 7, further comprising a locking ring that engages a second axial end of the rim, such that the first annular tire module and the second annular tire module are disposed between the flange and the locking ring.

9. A non-pneumatic tire and rim assembly comprising:

a non-pneumatic tire having a plurality of annular tire modules, including a first annular tire module coaxial with a second annular tire module,

wherein the first annular tire module includes a first inner ring, a first outer ring, first support structure extending between the first inner ring and the first outer ring, and a first circumferential tread extending about the first outer ring,

wherein the second annular tire module includes a second inner ring, a second outer ring, second support structure extending between the second inner ring and the second outer ring, and a second circumferential tread extending about the second outer ring,

wherein the first circumferential tread has a first tread pattern and the second circumferential tread has a second tread pattern that is different from the first tread pattern;

a rim having an outer annular surface that engages the first inner ring and the second inner ring; and

a spacer ring engaging the rim,

wherein the spacer ring is disposed between the first annular tire module and the second annular tire module, such that the first annular tire module is axially spaced from the second annular tire module,

wherein the first annular tire module has a first diameter,

wherein the second annular tire module has a second diameter substantially equal to the first diameter, and

wherein the spacer ring has a third diameter that is less than the first diameter and less than the second diameter.

10. The non-pneumatic tire and rim assembly of claim 9,

wherein an inner surface of the first inner ring has a first plurality of axial grooves that define a first plurality of axial ridges,

wherein an inner surface of the second inner ring has a second plurality of axial grooves that define a second plurality of axial ridges,

wherein the outer annular surface of the rim has a third plurality of axial grooves that define a third plurality of axial ridges,

wherein the third plurality of axial grooves have a cross-sectional geometry corresponding to a cross-sectional geometry of the first plurality of axial ridges and to a cross-sectional geometry of the second plurality of axial ridges, and

wherein the third plurality of axial ridges have a cross-sectional geometry corresponding to a cross-sectional geometry of the first plurality of axial grooves and to a cross-sectional geometry of the second plurality of axial grooves.

11. The non-pneumatic tire and rim assembly of claim 9, wherein the outer annular surface of the rim is a smooth surface.

12. The non-pneumatic tire and rim assembly of claim 9, wherein the plurality of annular tire modules further includes a third annular tire module having a third inner ring, a third outer ring, third support structure extending between the third inner ring and the third outer ring, and a third circumferential tread extending about the third outer ring.

13. The non-pneumatic tire and rim assembly of claim 9, wherein the rim has a flange at a first axial end.

14. The non-pneumatic tire and rim assembly of claim 13, further comprising a locking ring that engages a second axial end of the rim, such that the first annular tire module and the second annular tire module are disposed between the flange and the locking ring.

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