US 20170174005A1

(19) **United States**

(12) **Patent Application Publication**

VAN RIPER et al.

(10) **Pub. No.: US 2017/0174005 A1**

(43) **Pub. Date: Jun. 22, 2017**

(54) **NON-PNEUMATIC TIRE WITH PARABOLIC DISKS**

(71) Applicant: **THE GOODYEAR TIRE & RUBBER COMPANY**, Akron, OH (US)

(72) Inventors: **Philip Carl VAN RIPER**, Cuyahoga Falls, OH (US); **Joseph Carmine LETTIERI**, Hudson, OH (US); **Rebecca Anne BANDY**, Cuyahoga Falls, OH (US); **Addison Brian SIEGEL**, Cuyahoga Falls, OH (US); **Mahdy MALEKZADEH MOGHANI**, Cuyahoga Falls, OH (US); **Andrew B. MENDENHALL**, Mooresville, IN (US)

(21) Appl. No.: **15/358,379**

(22) Filed: **Nov. 22, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/270,285, filed on Dec. 21, 2015.

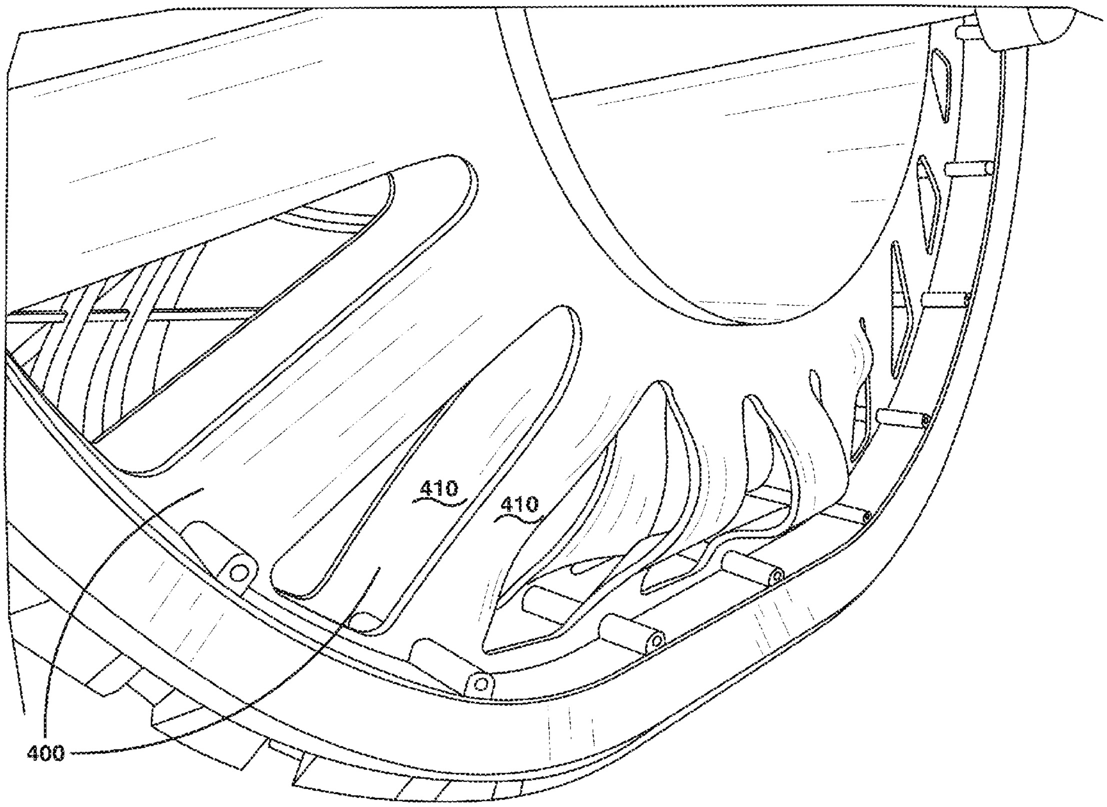
Publication Classification

(51) **Int. Cl.**
B60C 7/14 (2006.01)

(52) **U.S. Cl.**
CPC ***B60C 7/14*** (2013.01); *B60C 2007/146* (2013.04)

(57) **ABSTRACT**

A structurally supported tire includes a ground contacting annular tread portion, an annular shear band and at least one spoke disk connected to the shear band, wherein the spoke disk has at least one spoke, wherein the spoke extends between an outer ring and an inner ring in a first parabolic curve. The spoke disk may further includes a second spoke having a second parabolic curve different from the first curve, and overlapping with the first spoke.



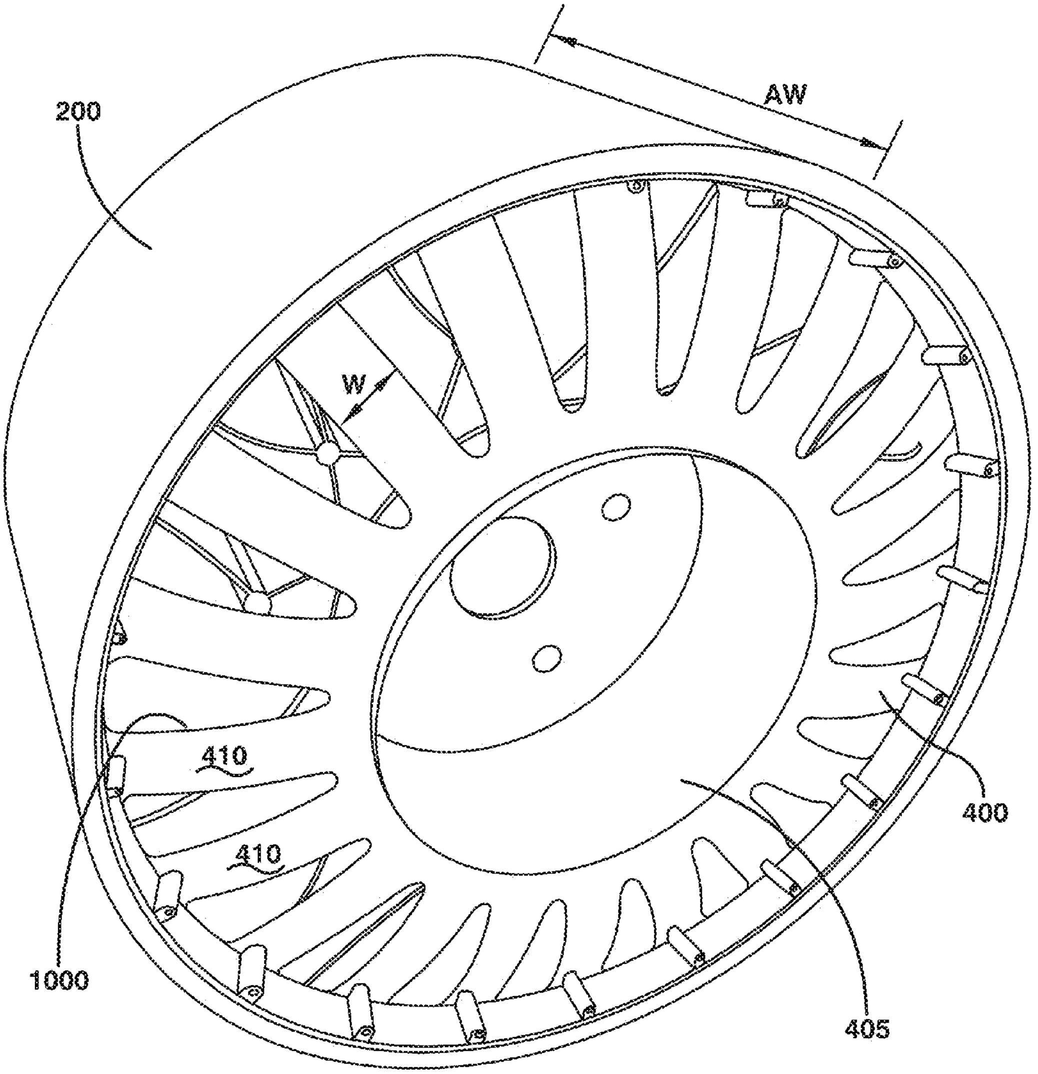


Fig. 1A

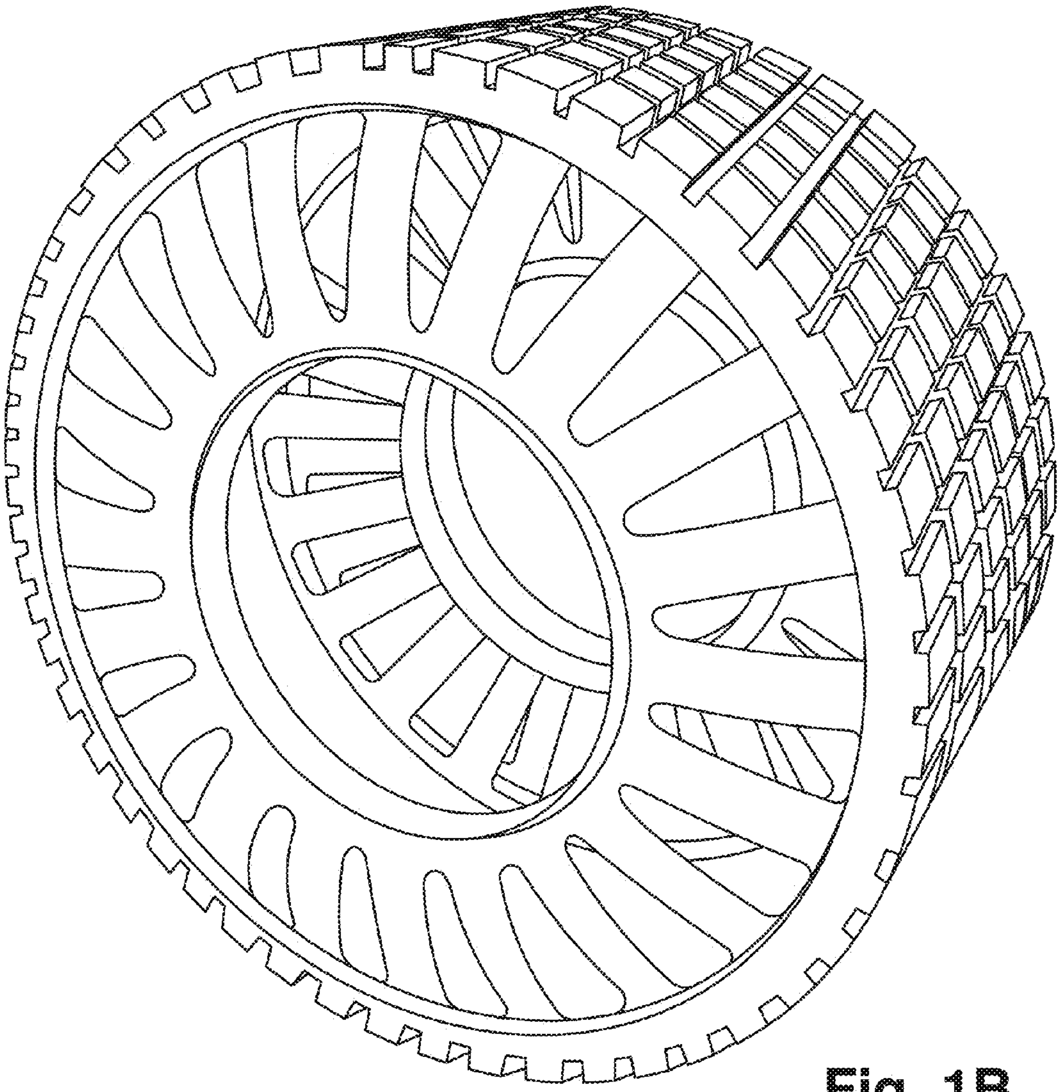


Fig. 1B

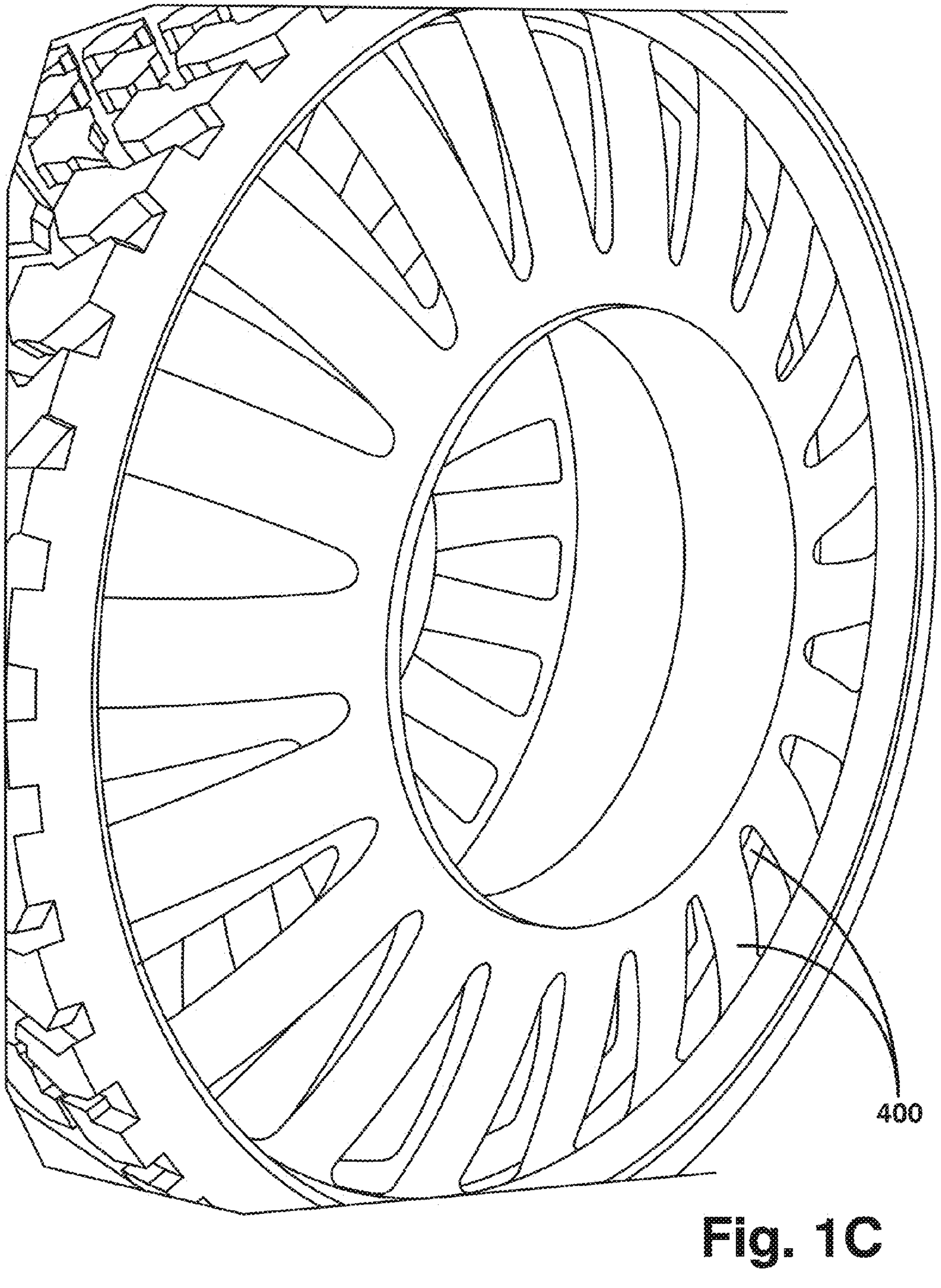


Fig. 1C

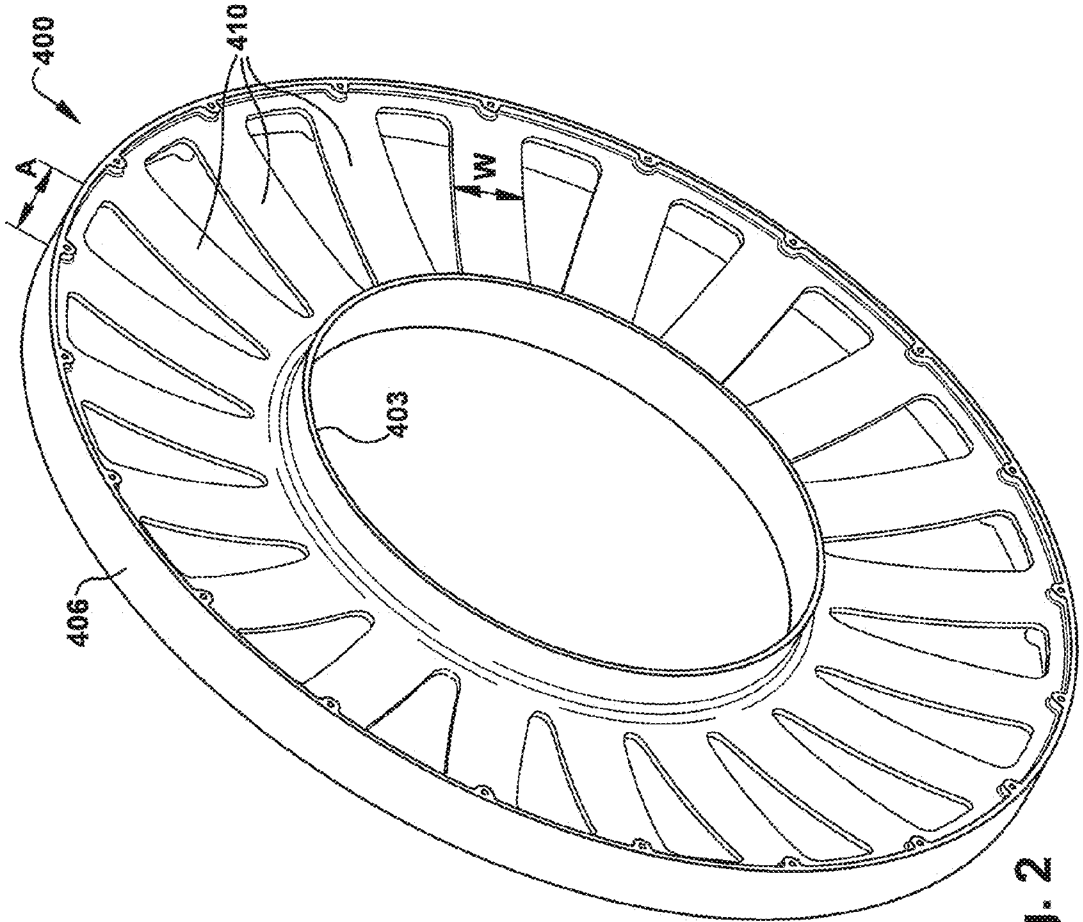


Fig. 2

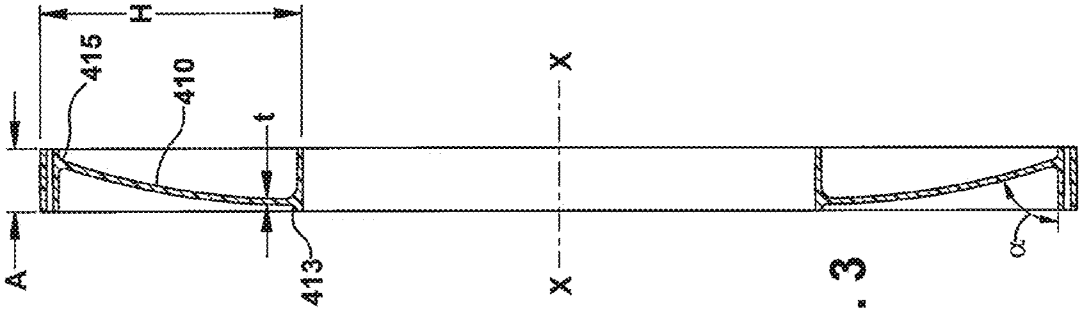


Fig. 3

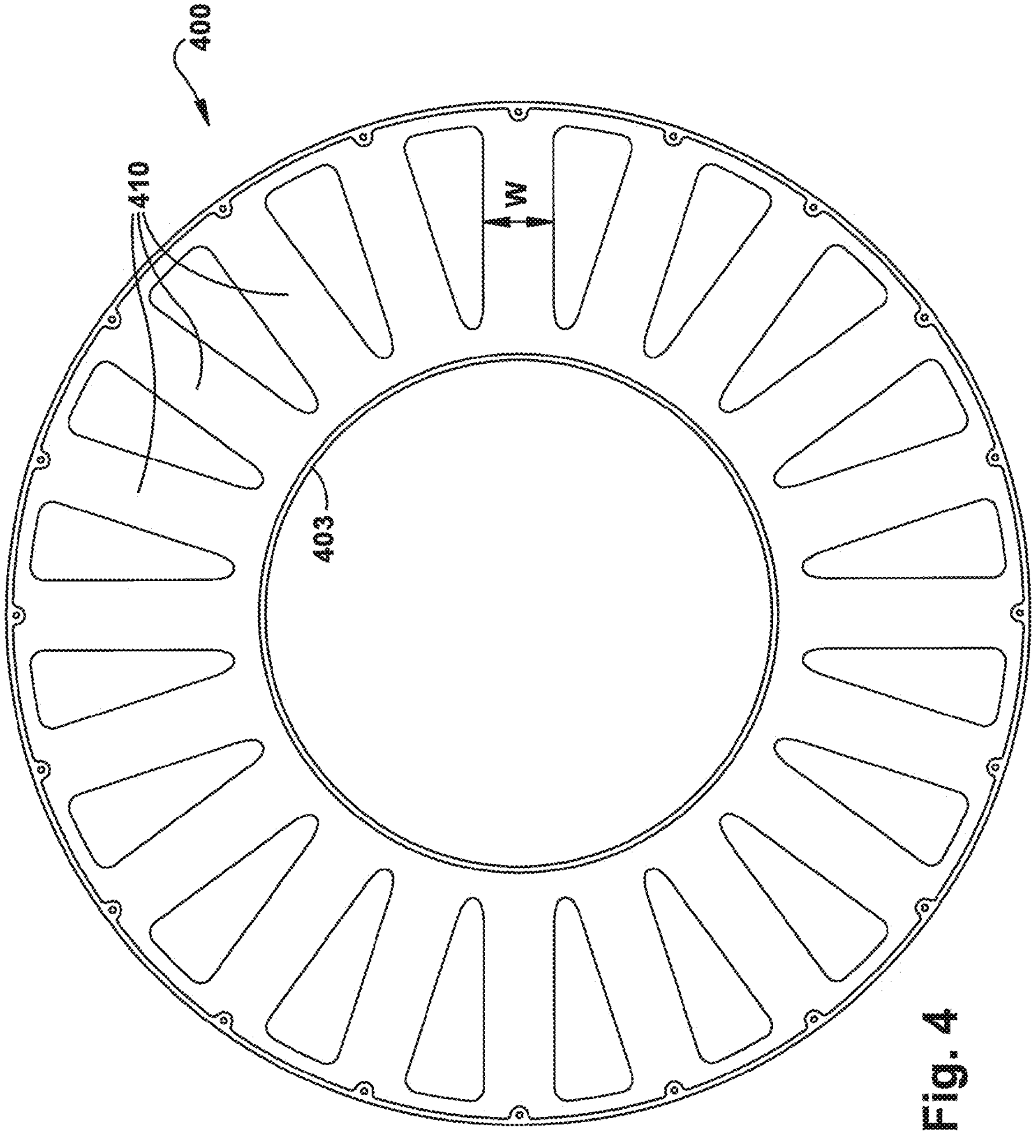


Fig. 4

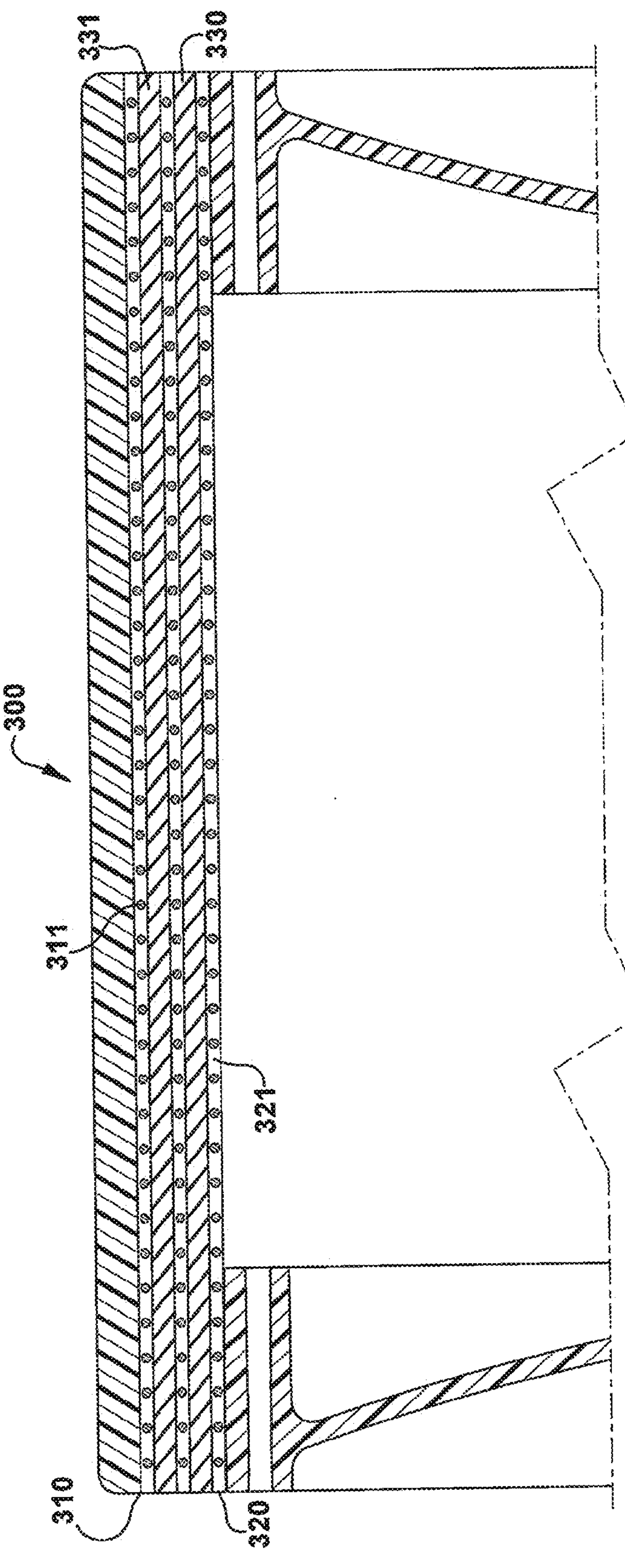


Fig. 5

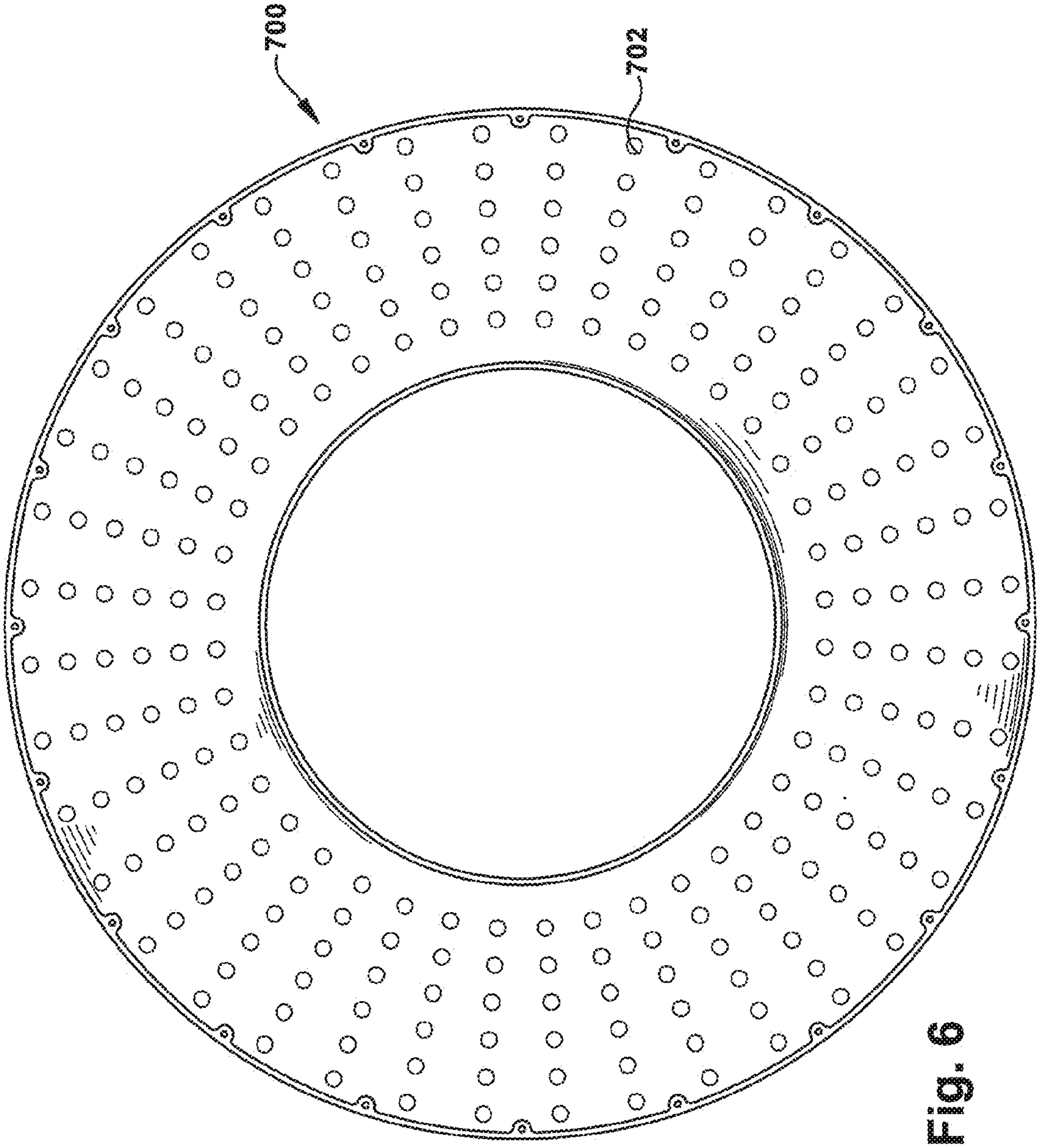


Fig. 6

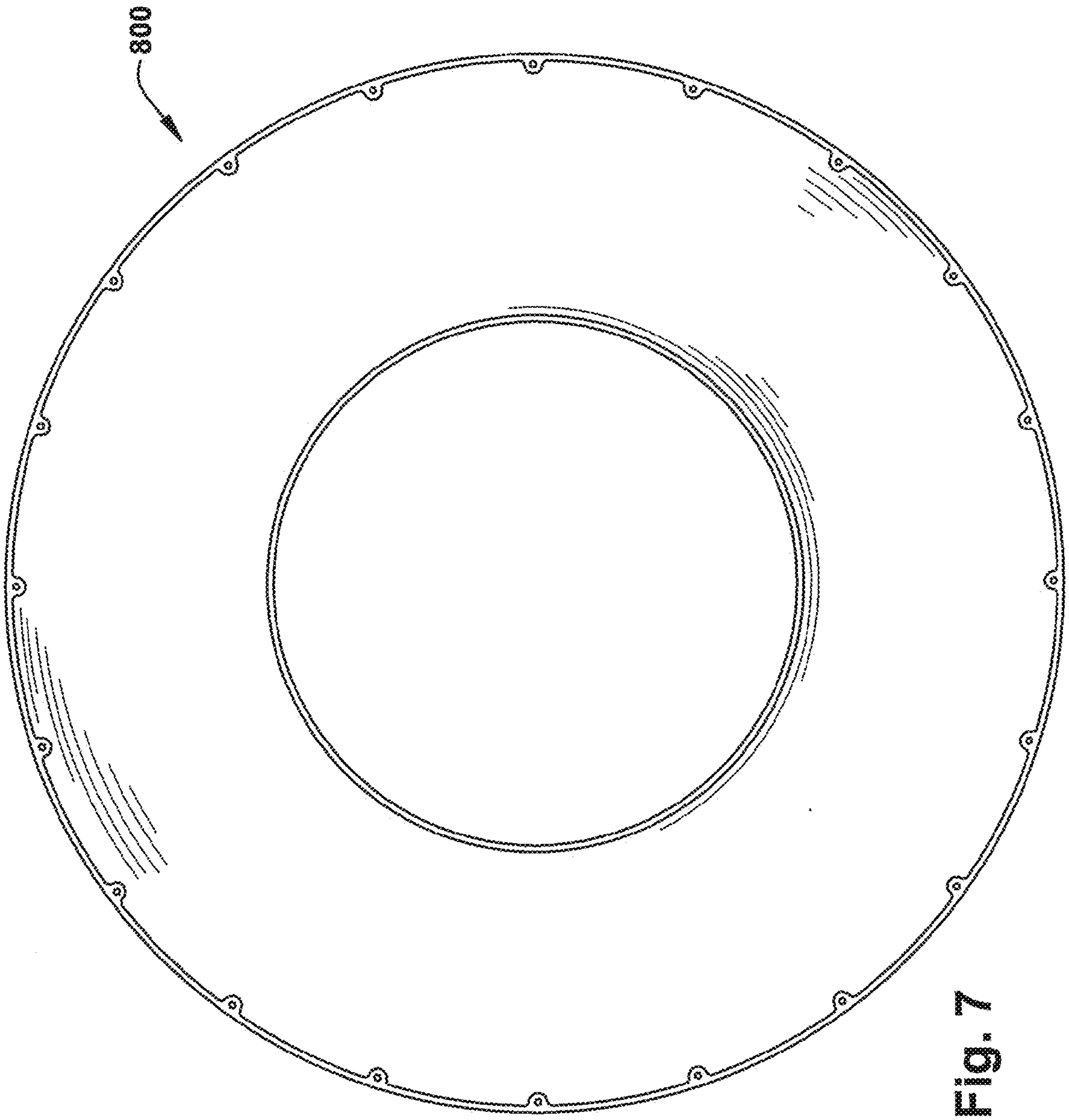


Fig. 7

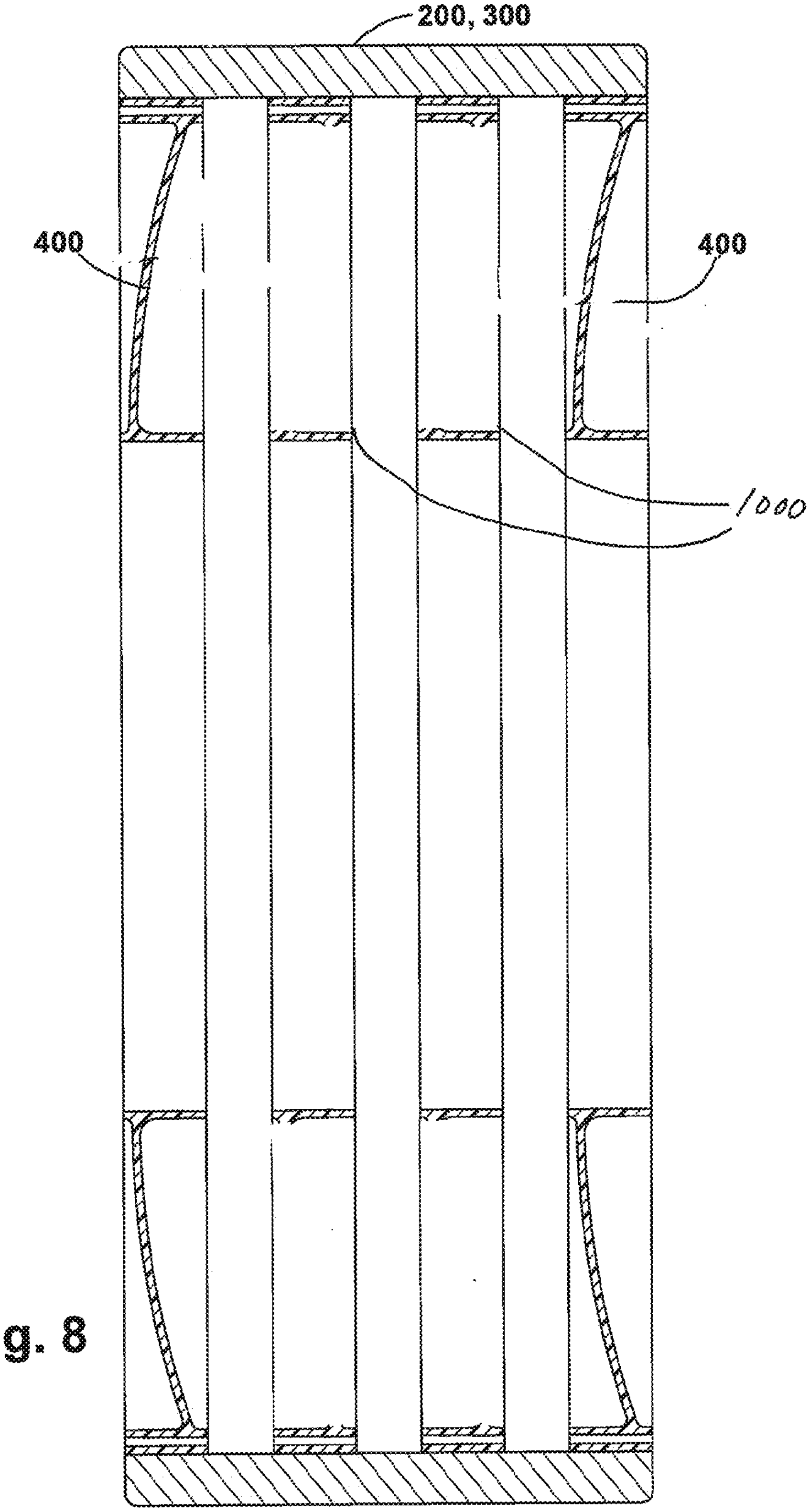


Fig. 8

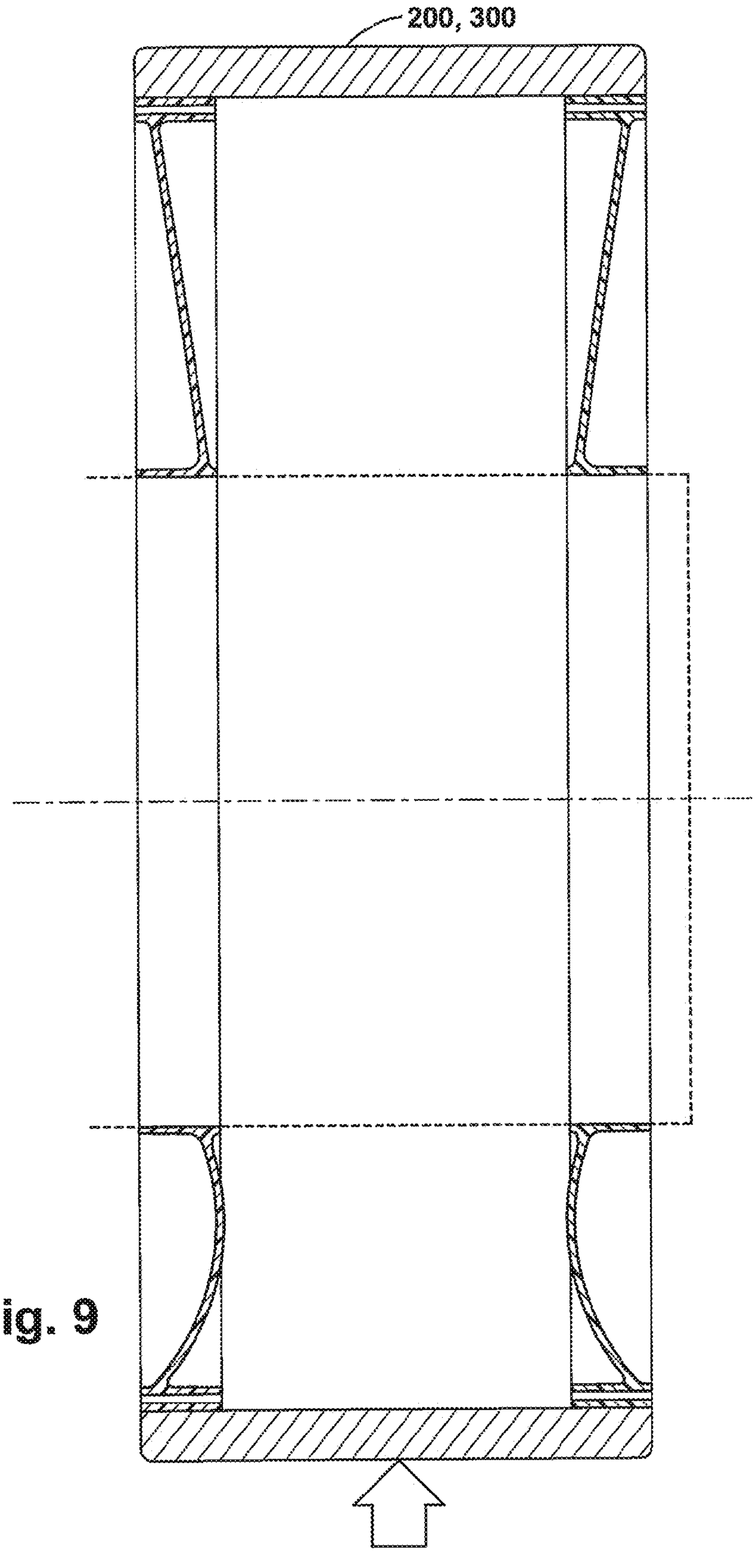


Fig. 9

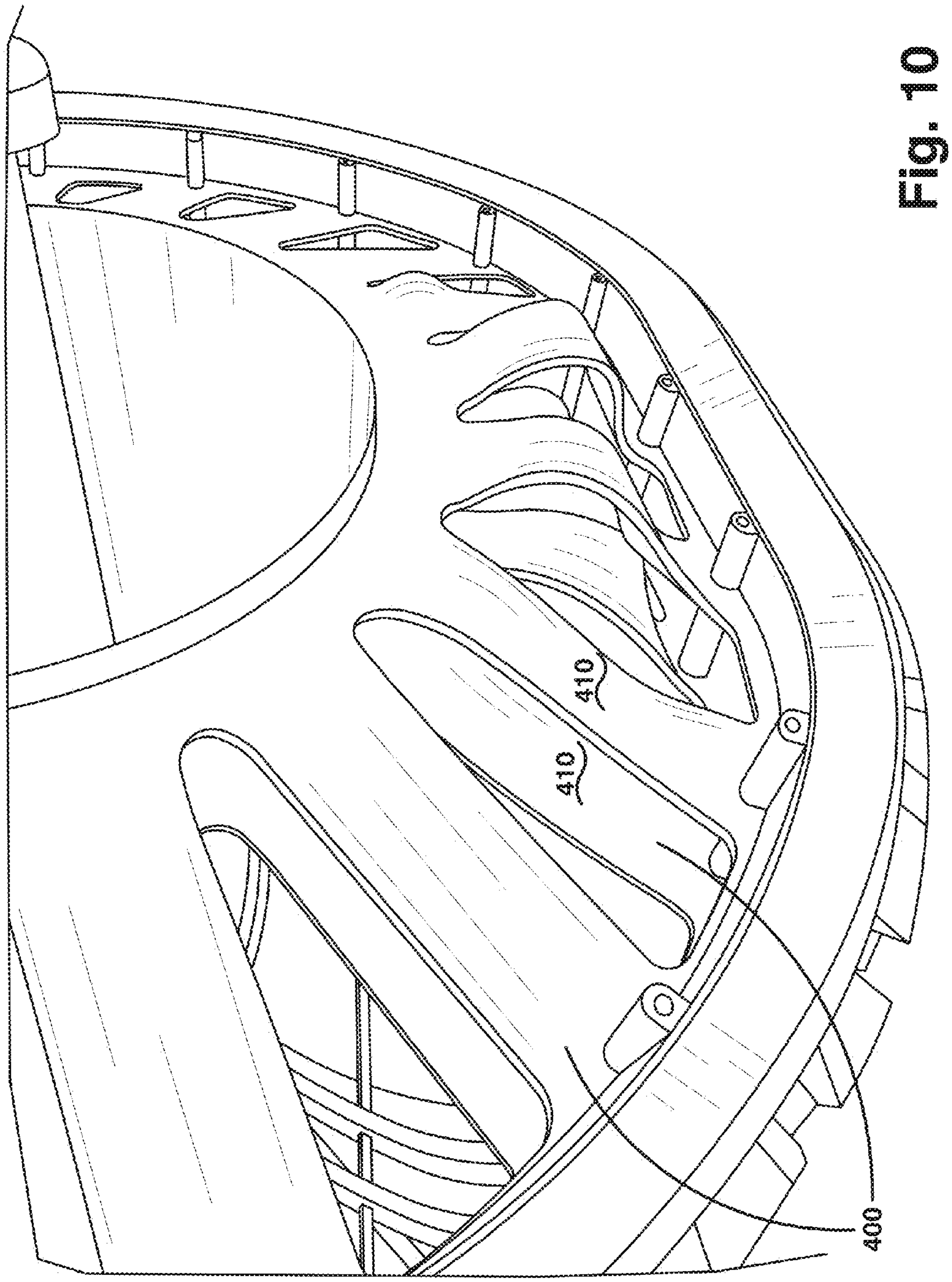


Fig. 10

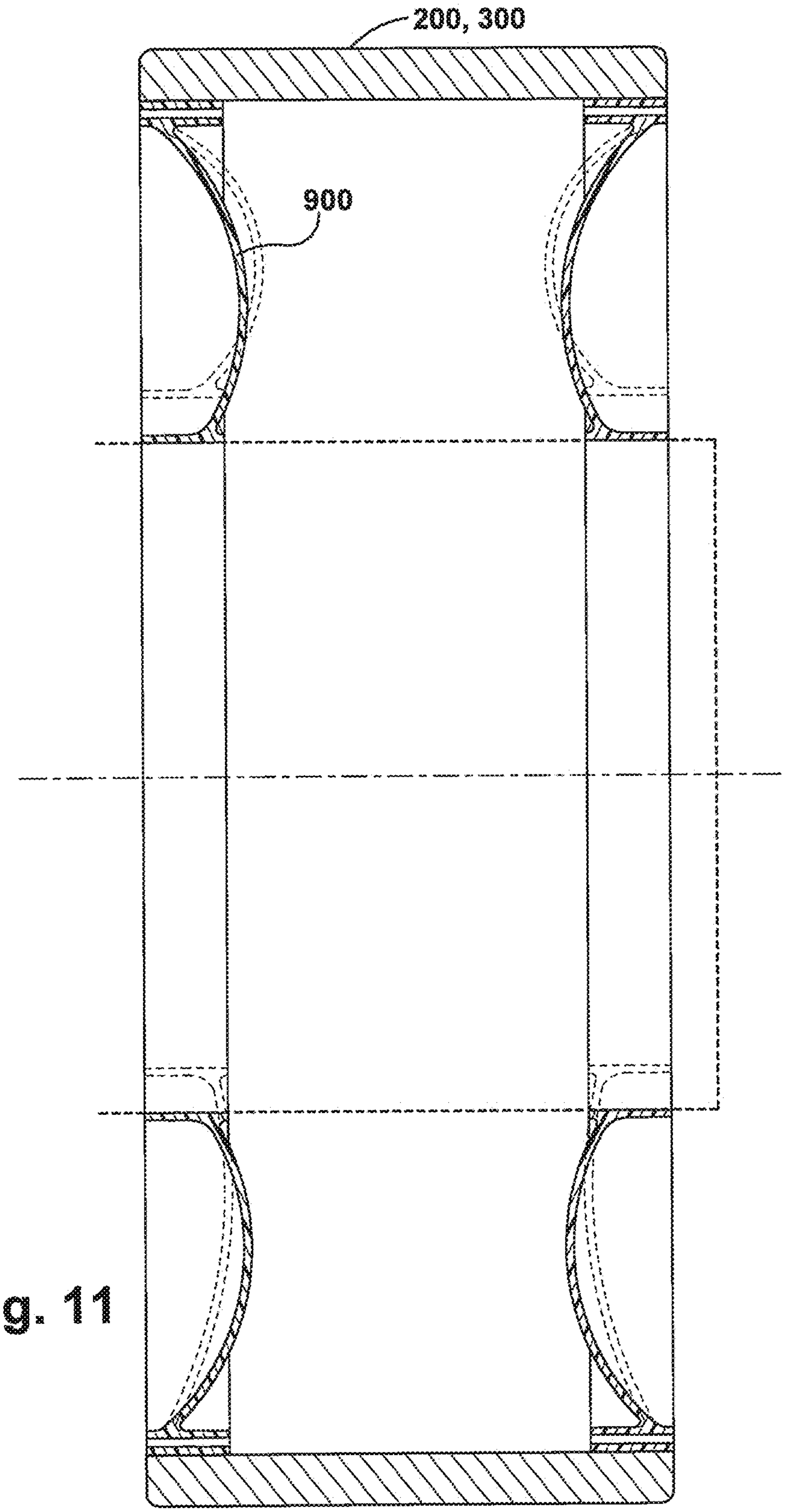


Fig. 11

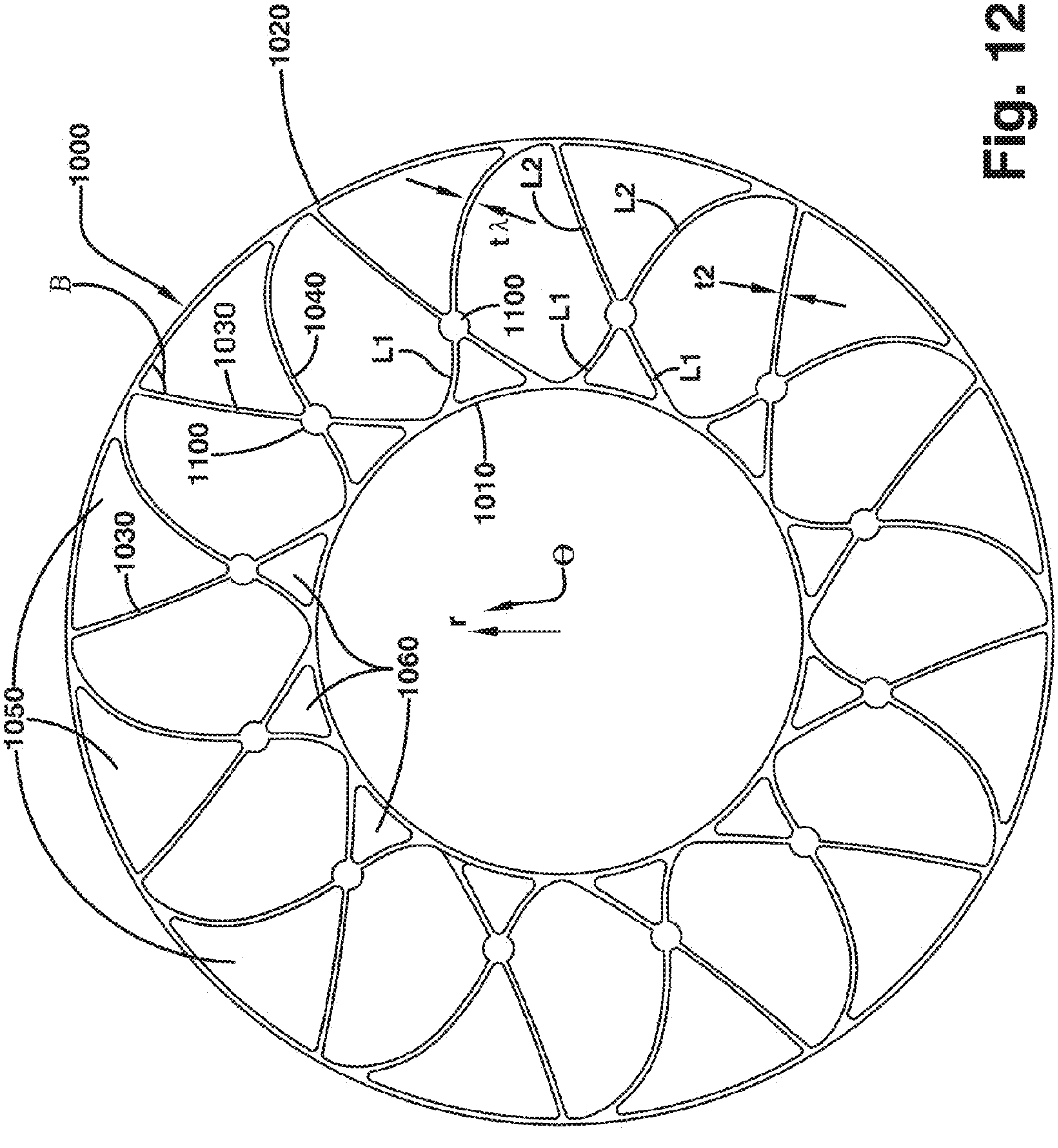


Fig. 12

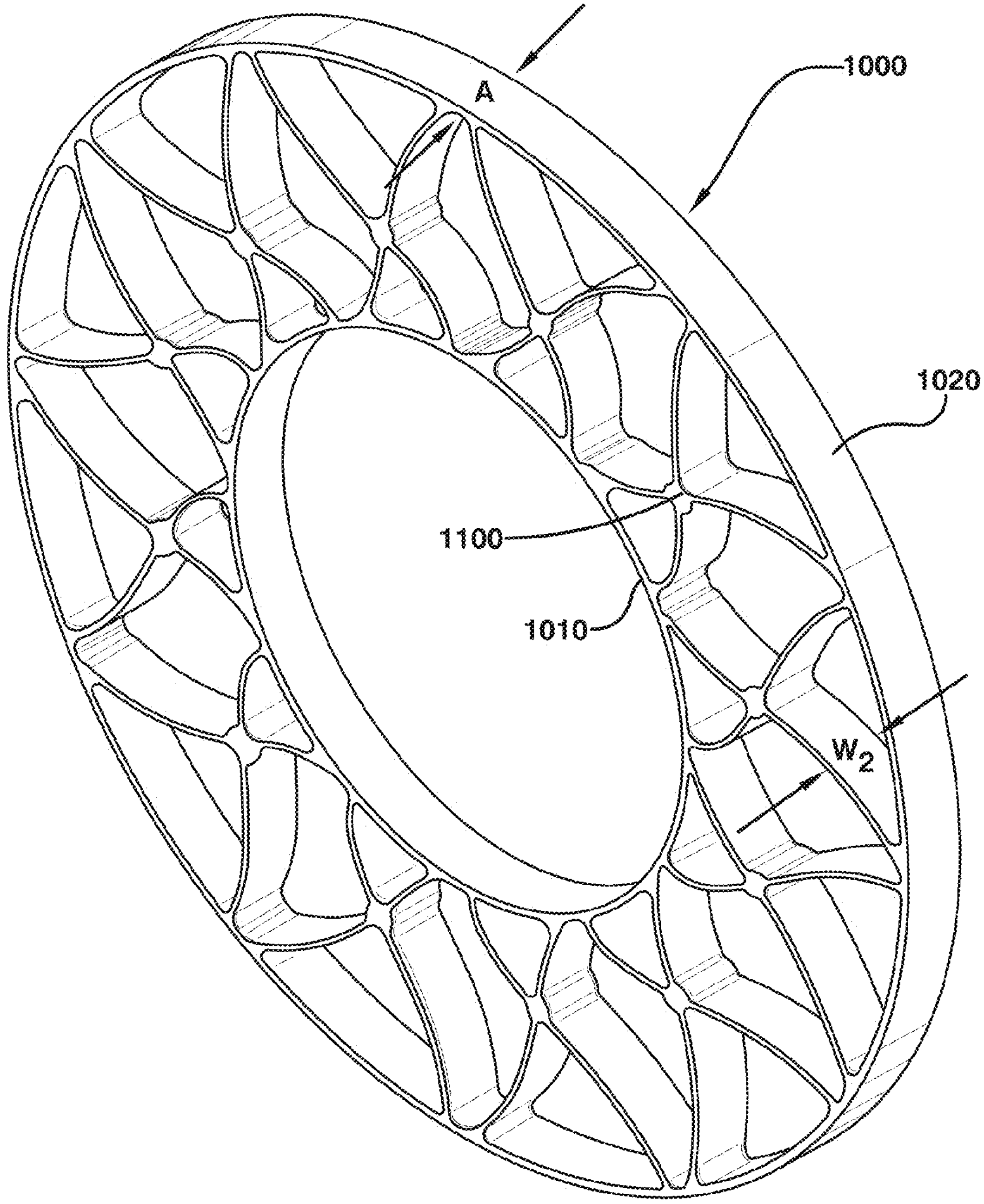


Fig. 13

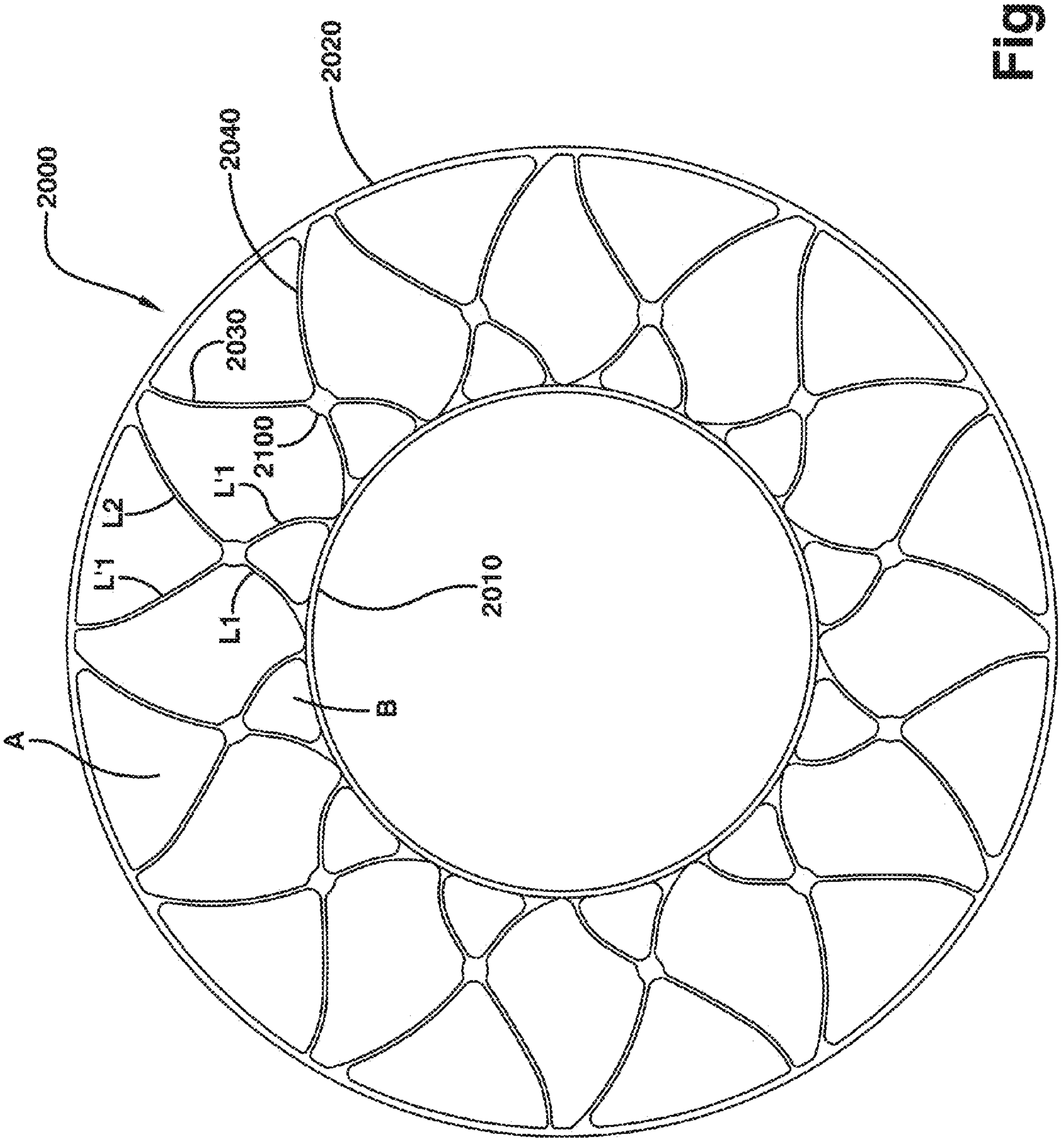


Fig. 14

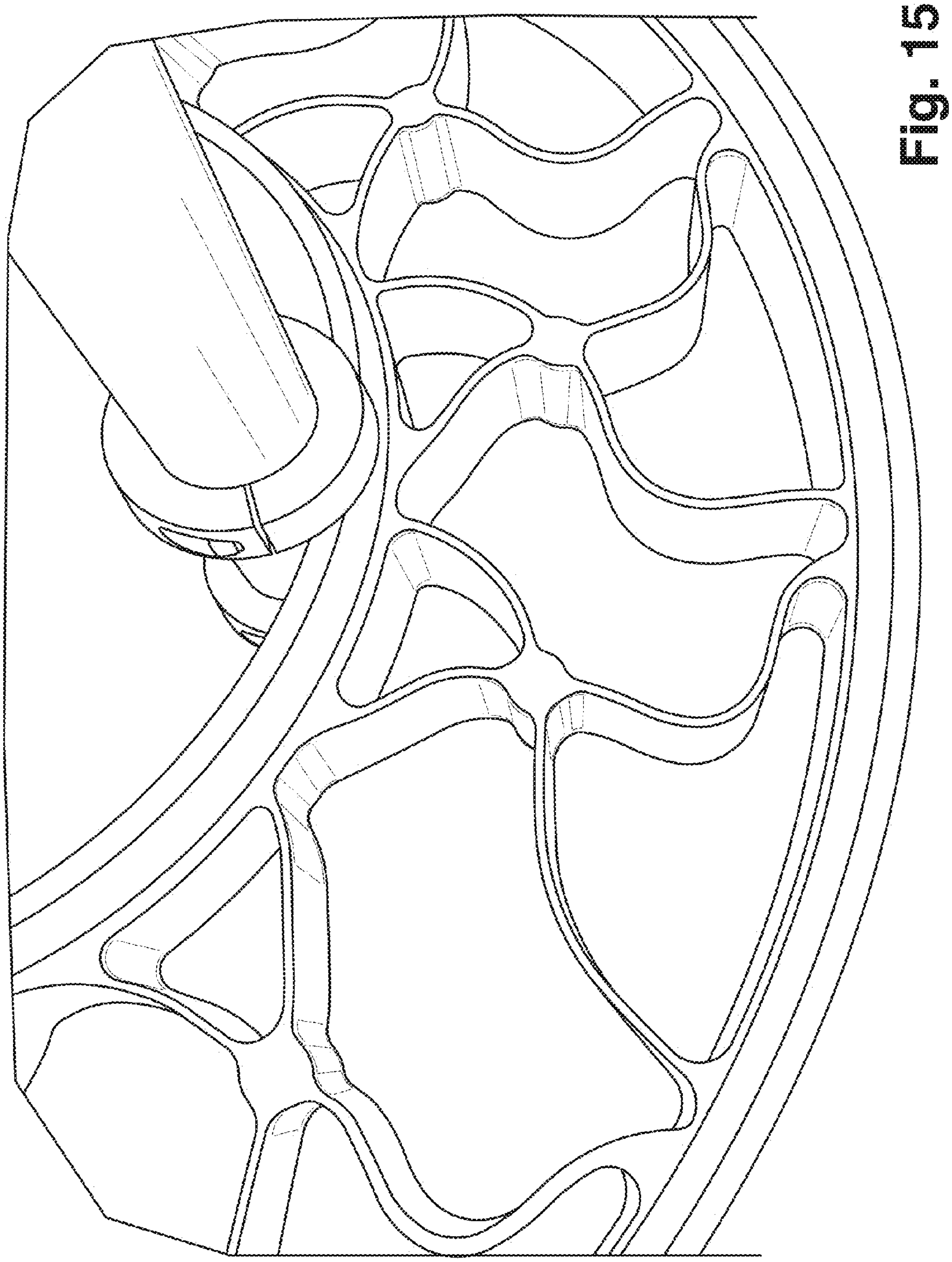


Fig. 15

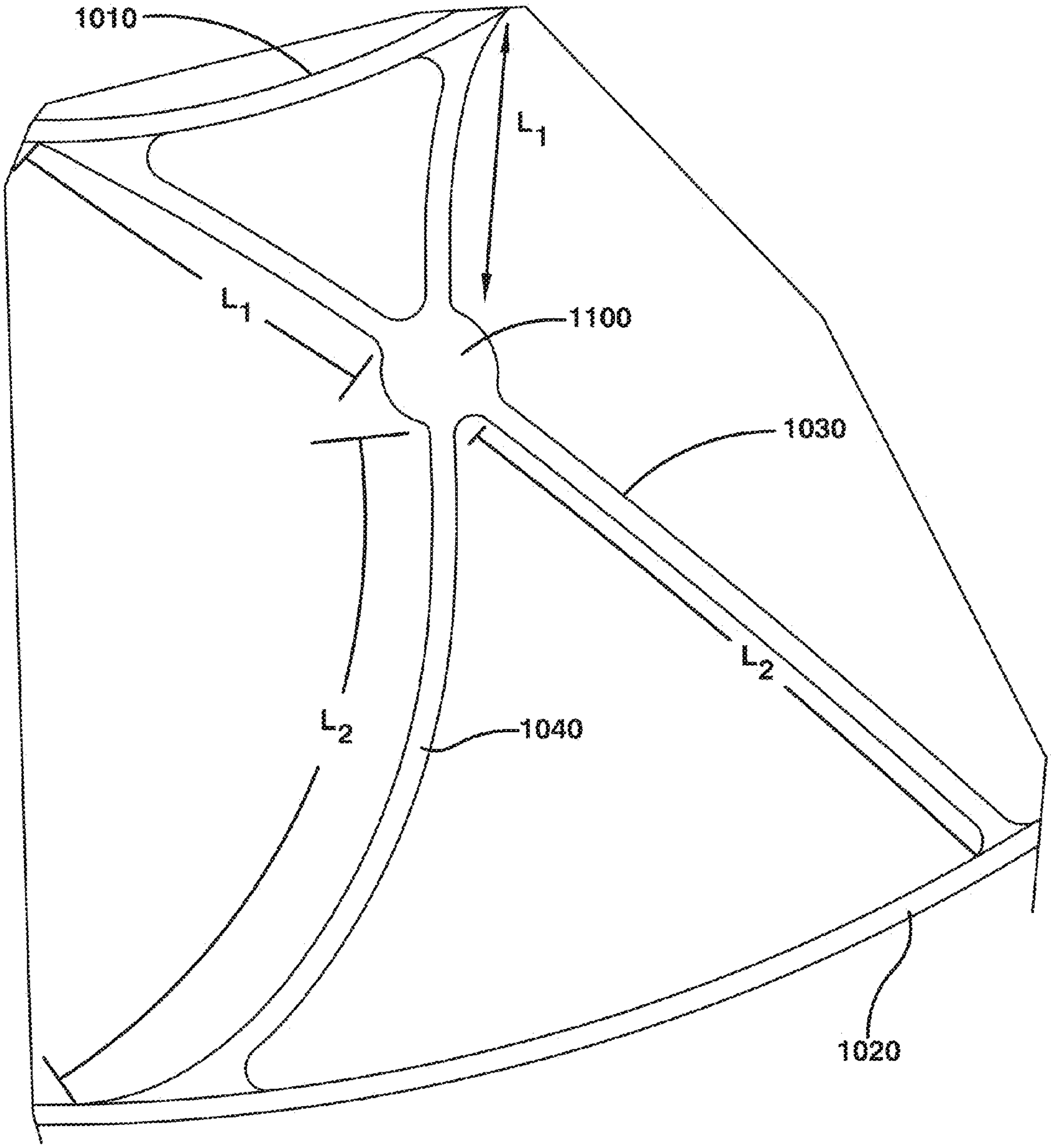


Fig. 16

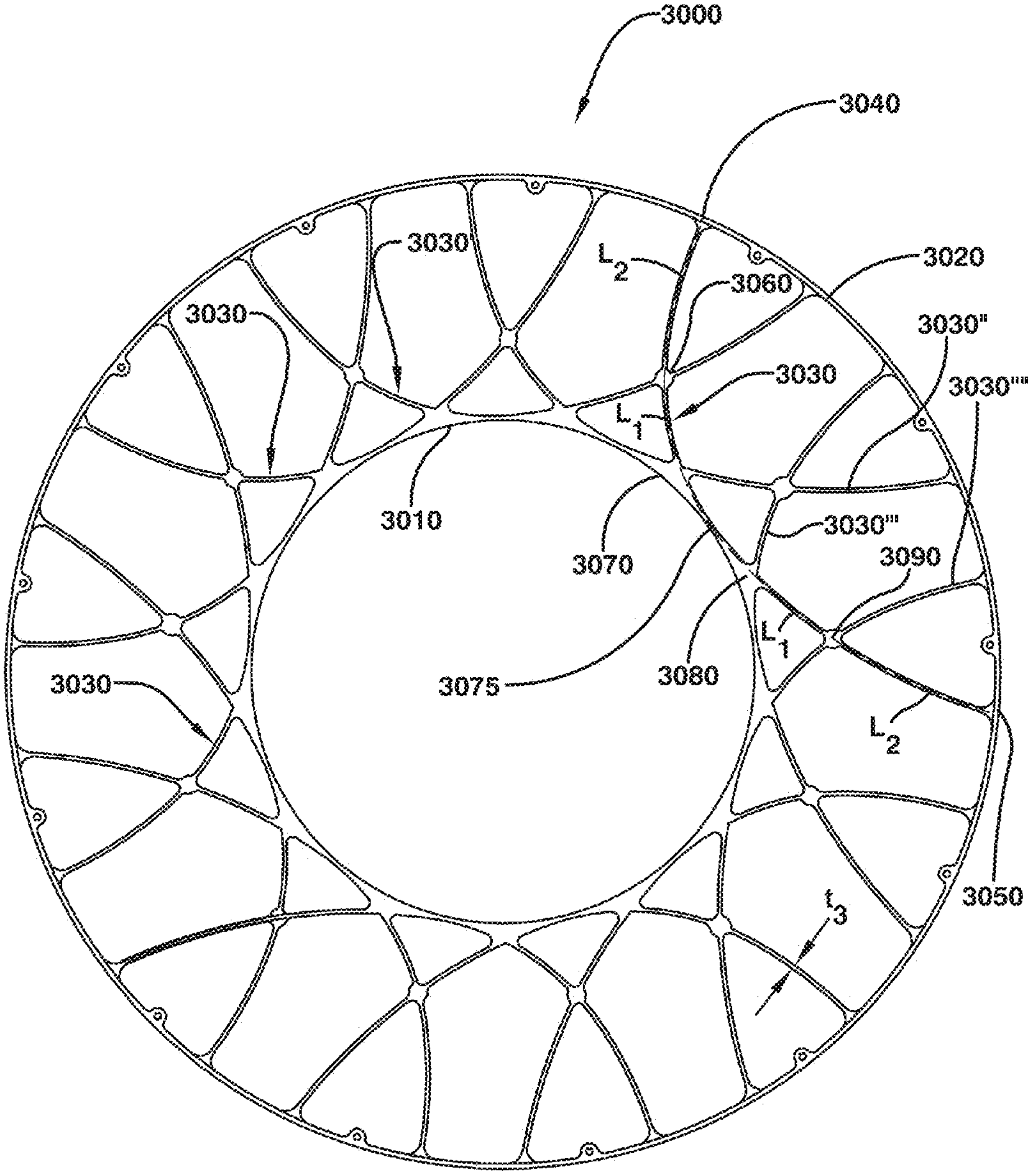

3000
3040
3030
3020
L_2
3060
3030
3030"
3030
3030""
L_1
3010
3070
3030'''
3090
3075
3080
L_1
3030
L_2
3050
t_3

Fig. 17

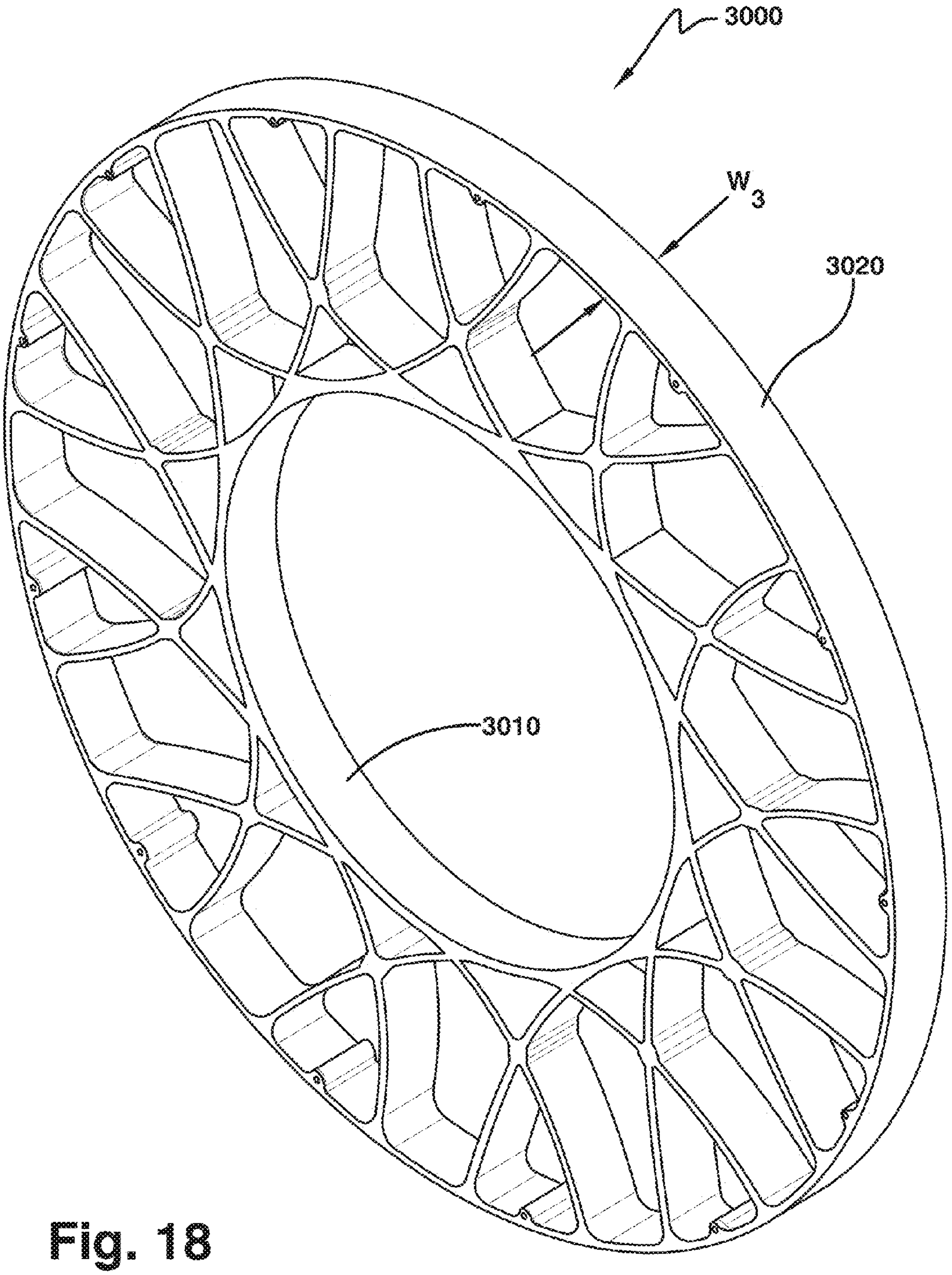


Fig. 18

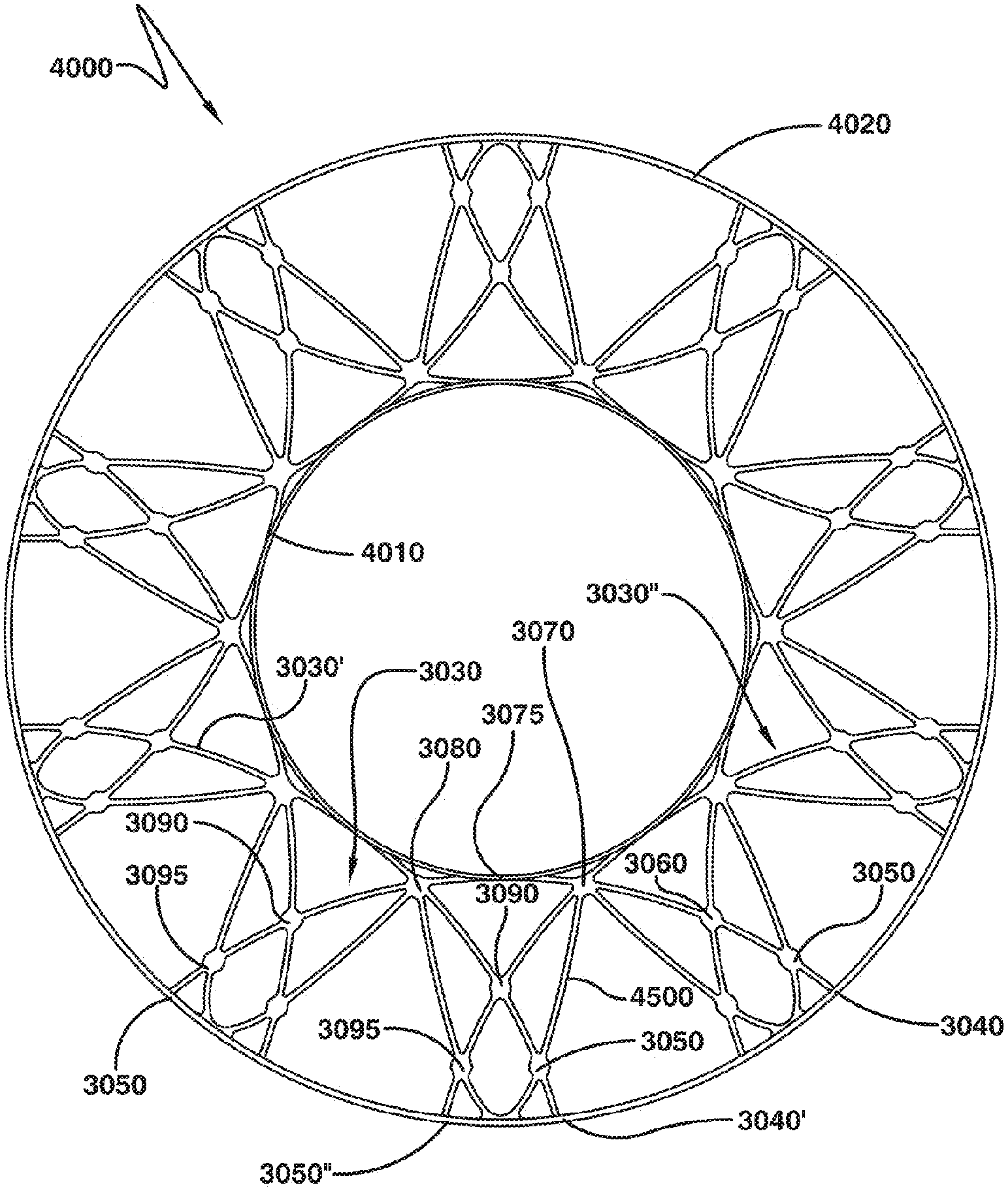

4000
4020
4010
3030"
3070
3030'
3030
3075
3080
3090
3095
3090
3060
3050
4500
3040
3095
3050
3050
3040'
3050"

Fig. 19

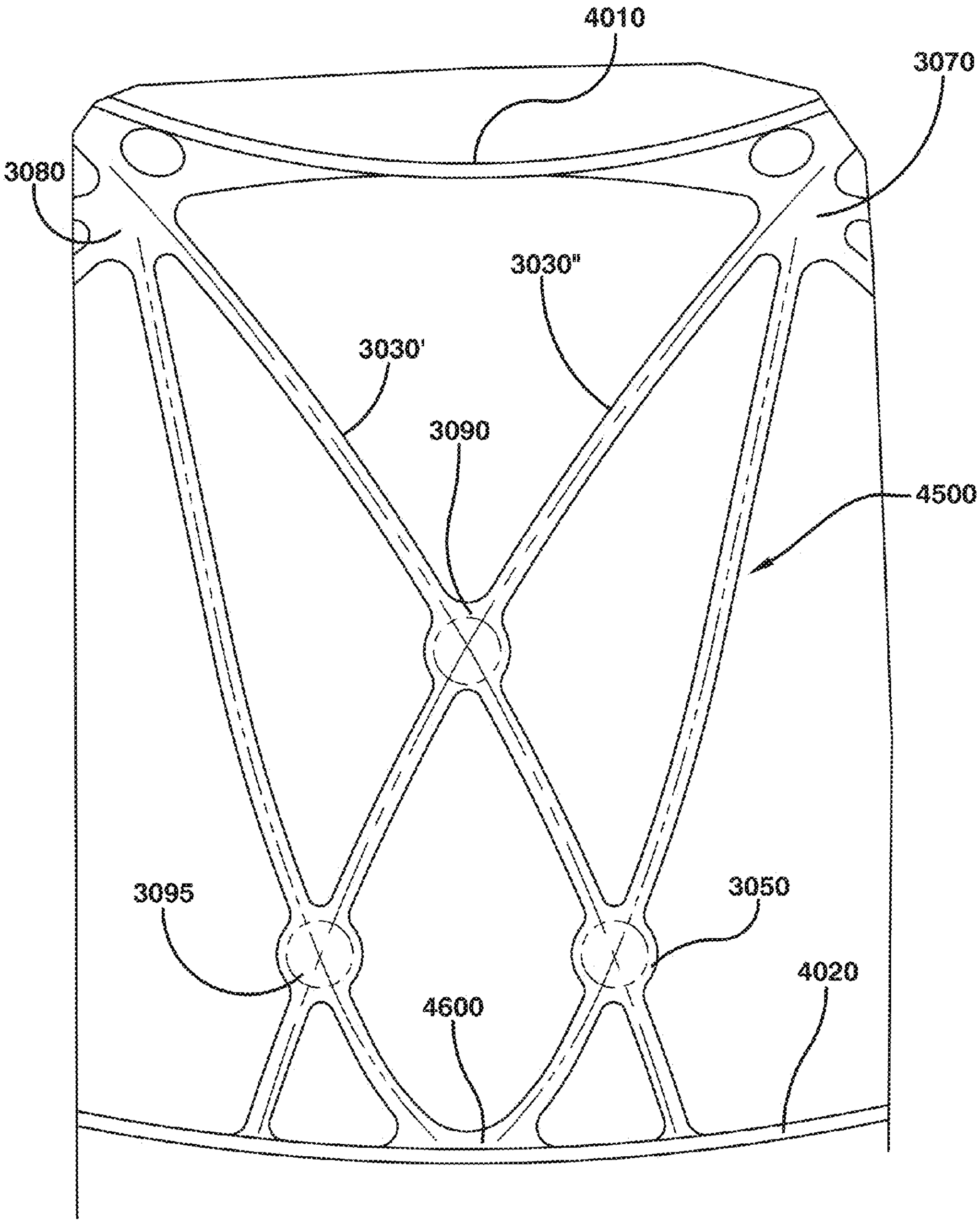


Fig. 20

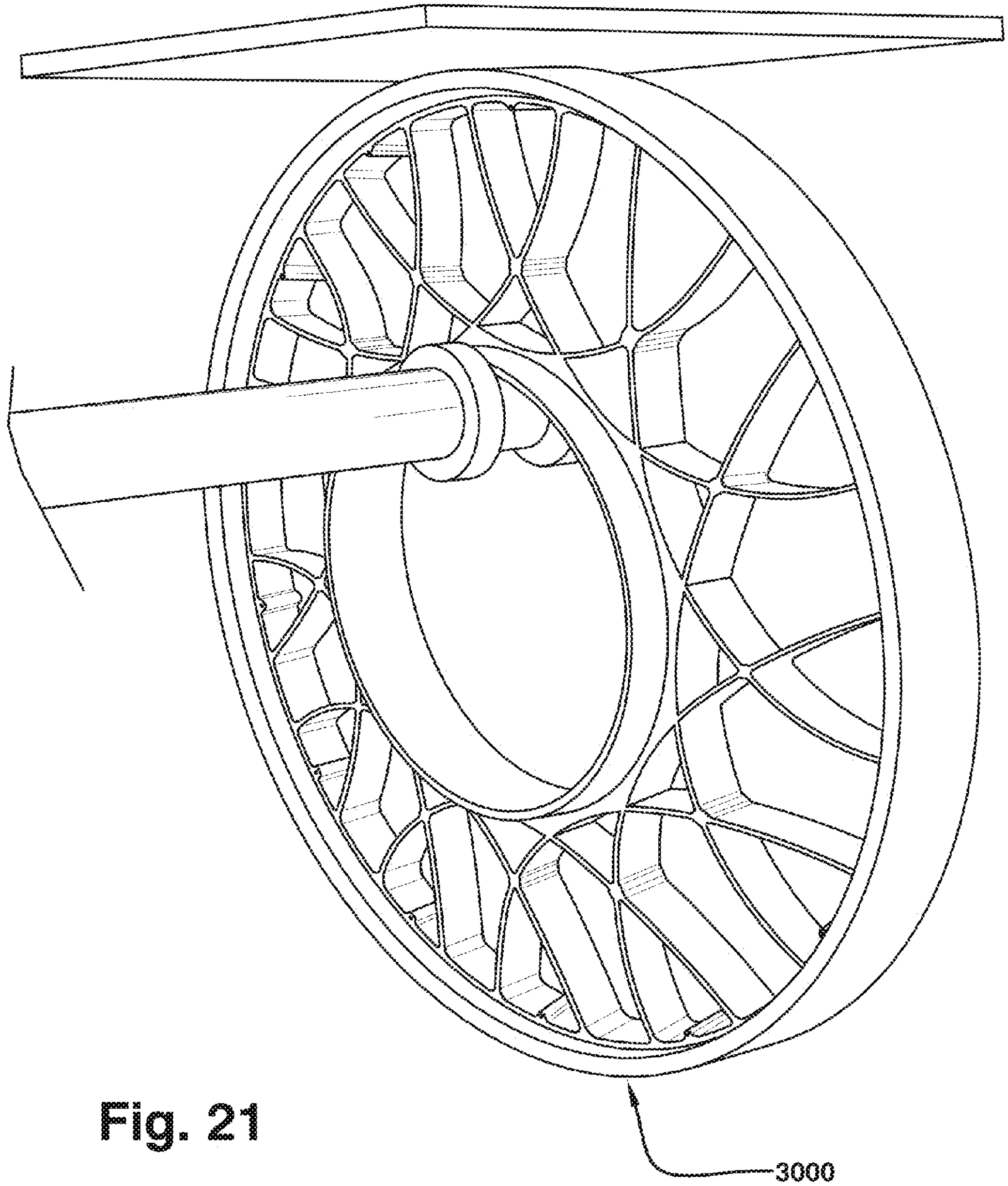


Fig. 21

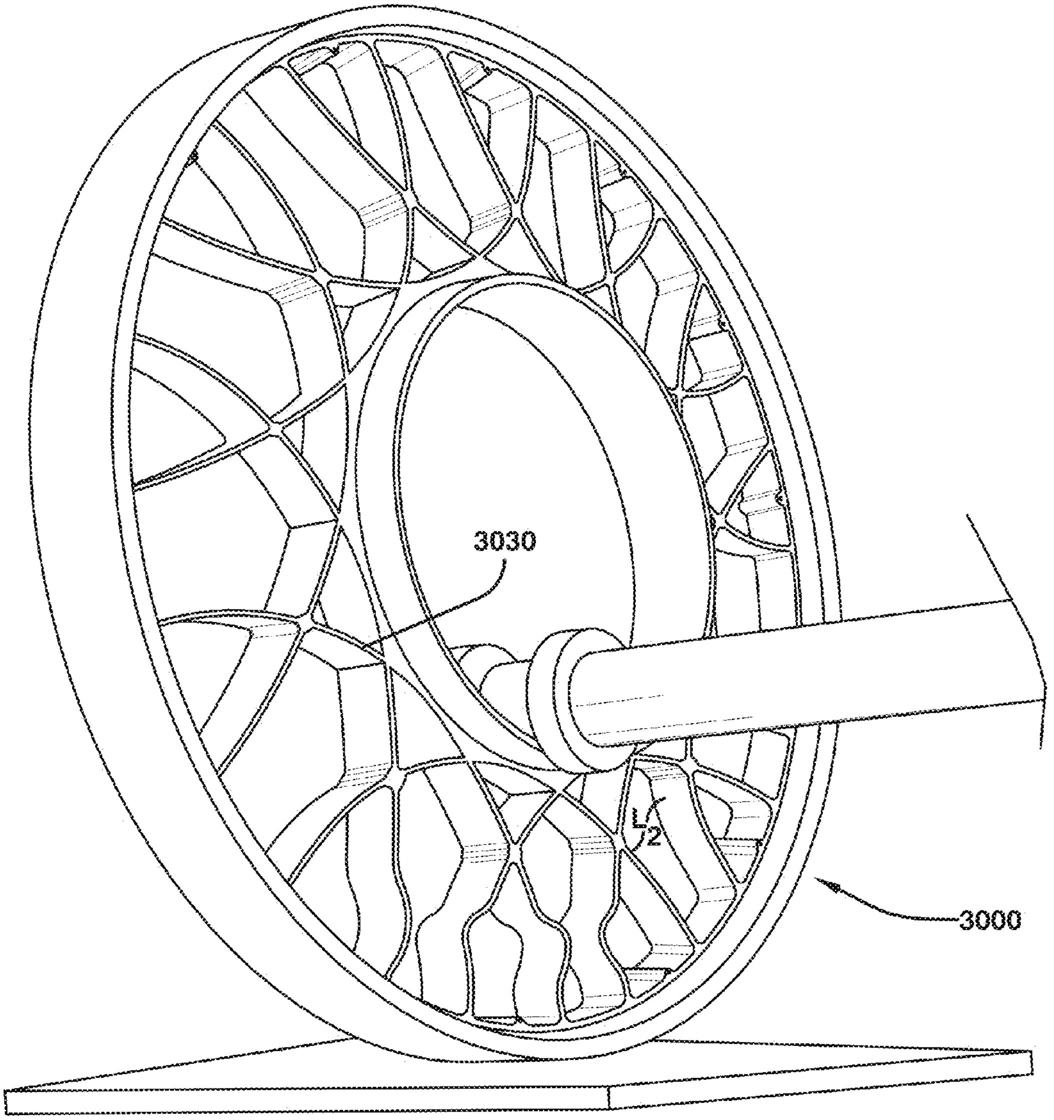


Fig. 22

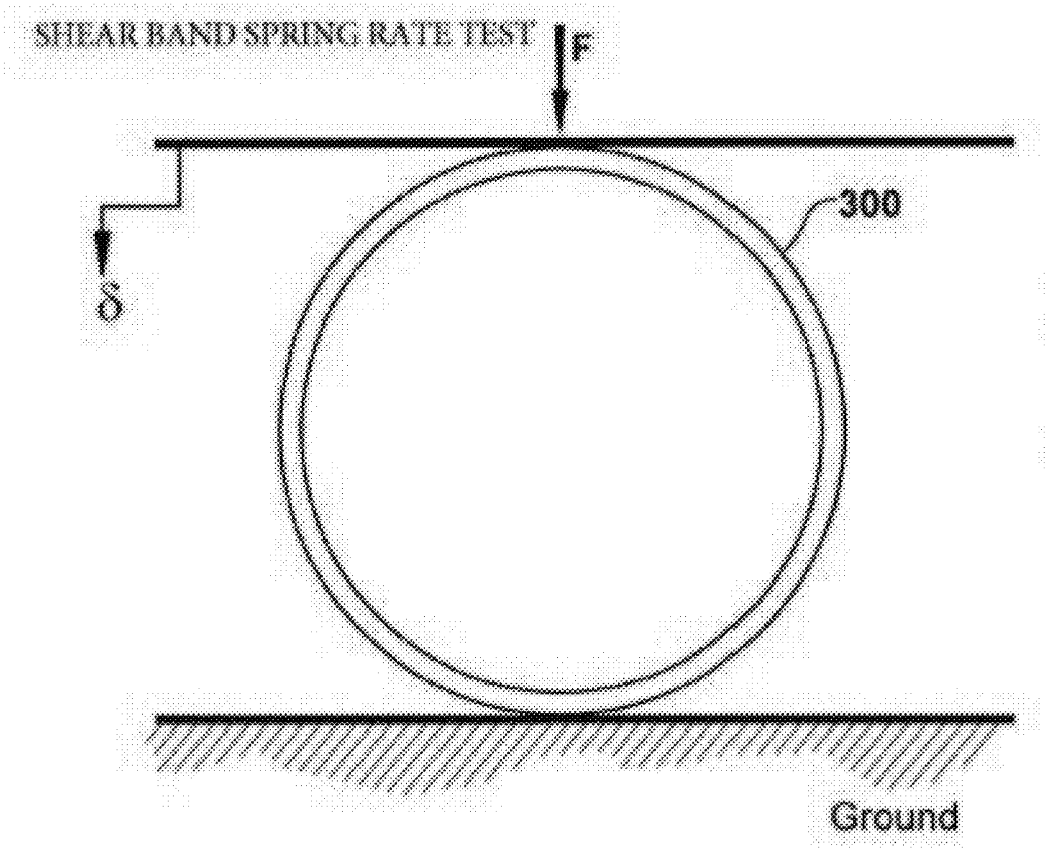


Fig. 23a

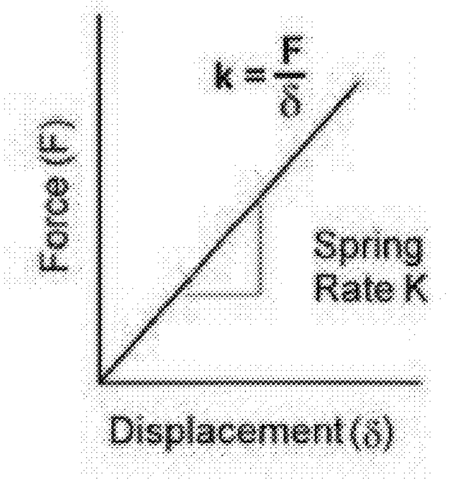


Fig. 23b

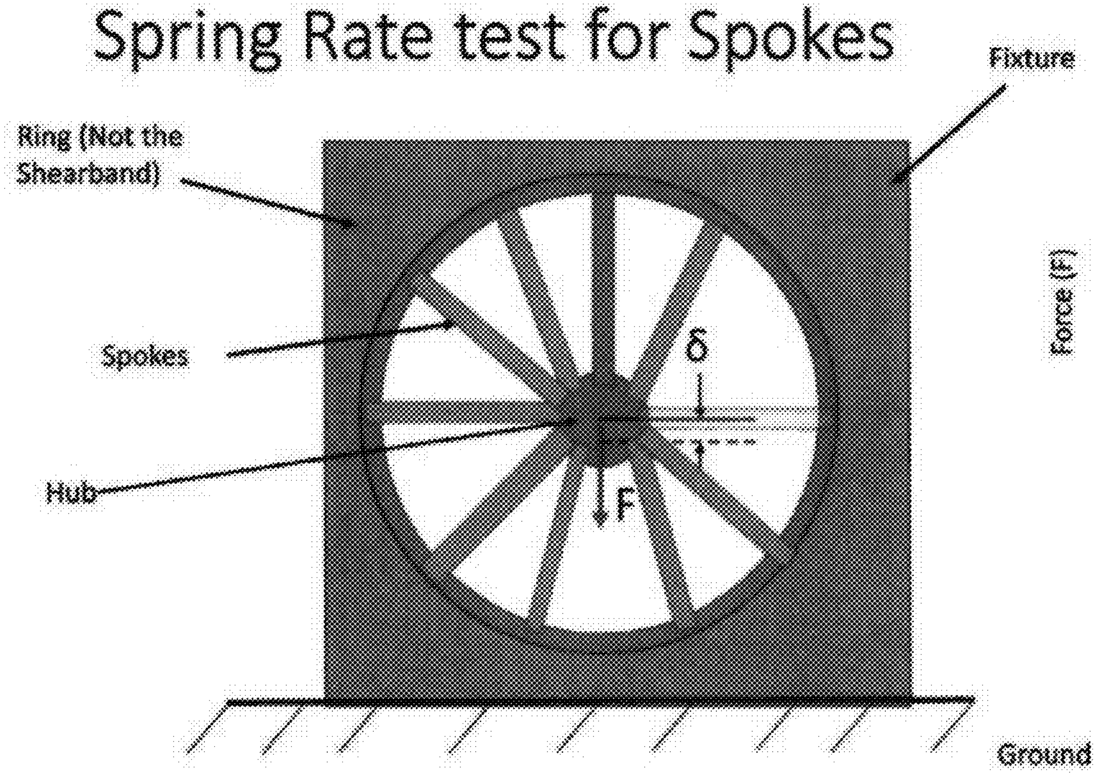


Fig. 24a

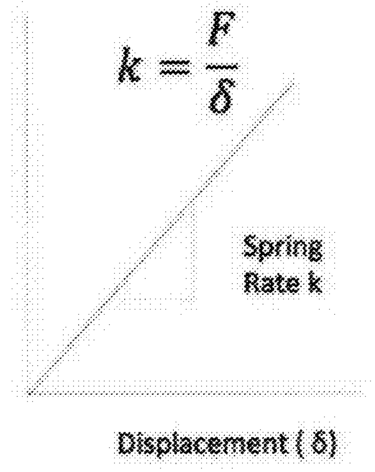


Fig. 24b

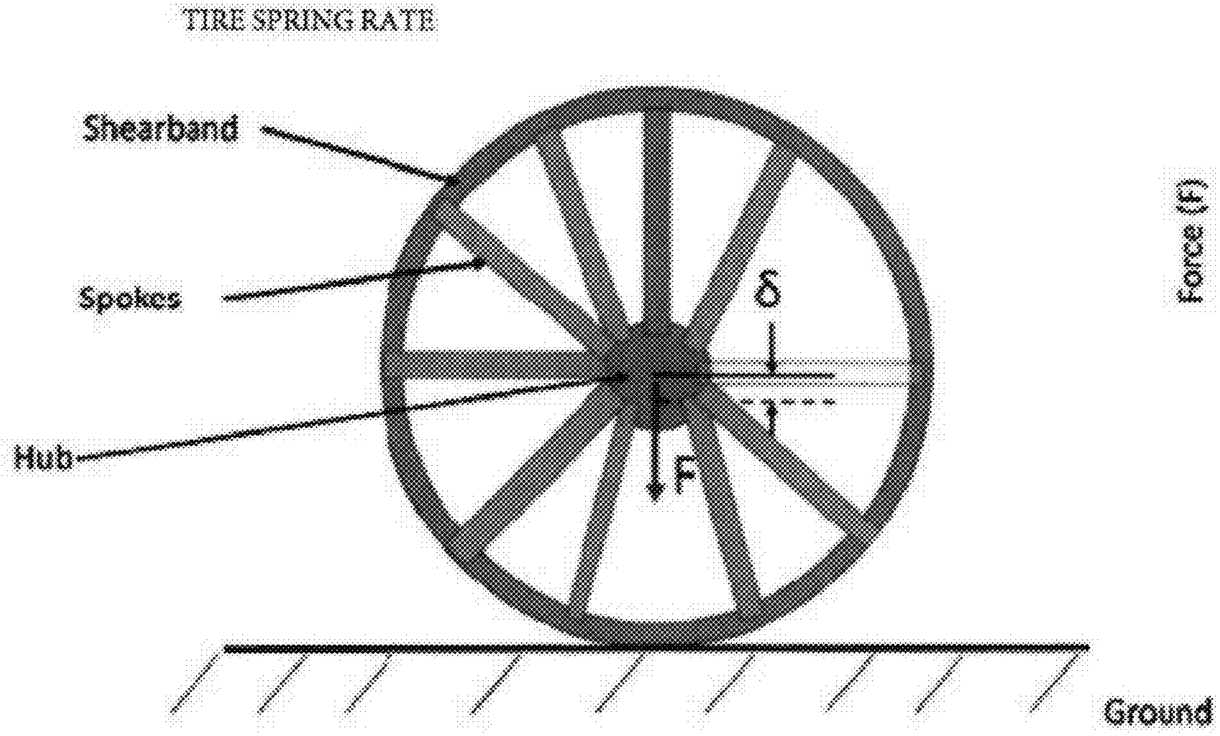


Fig. 25a

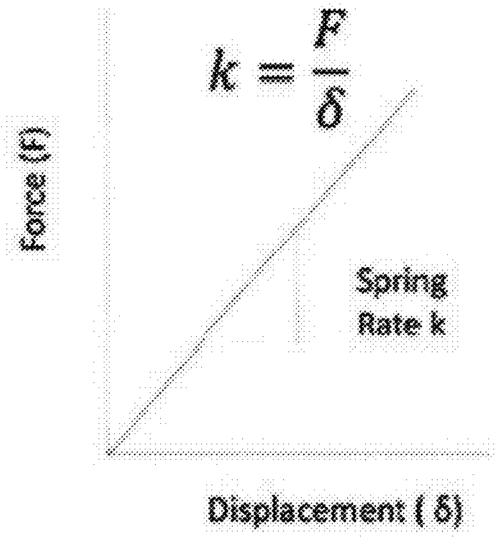


Fig. 25b

NON-PNEUMATIC TIRE WITH PARABOLIC DISKS

FIELD OF THE INVENTION

[0001] The present invention relates generally to vehicle tires and non-pneumatic tires, and more particularly, to a non-pneumatic tire.

BACKGROUND OF THE INVENTION

[0002] The pneumatic tire has been the solution of choice for vehicular mobility for over a century. The pneumatic tire is a tensile structure. The pneumatic tire has at least four characteristics that make the pneumatic tire so dominate today. Pneumatic tires are efficient at carrying loads, because all of the tire structure is involved in carrying the load. Pneumatic tires are also desirable because they have low contact pressure, resulting in lower wear on roads due to the distribution of the load of the vehicle. Pneumatic tires also have low stiffness, which ensures a comfortable ride in a vehicle. The primary drawback to a pneumatic tire is that it requires compressed fluid. A conventional pneumatic tire is rendered useless after a complete loss of inflation pressure.

[0003] A tire designed to operate without inflation pressure may eliminate many of the problems and compromises associated with a pneumatic tire. Neither pressure maintenance nor pressure monitoring is required. Structurally supported tires such as solid tires or other elastomeric structures to date have not provided the levels of performance required from a conventional pneumatic tire. A structurally supported tire solution that delivers pneumatic tire-like performance would be a desirous improvement.

[0004] Non-pneumatic tires are typically defined by their load carrying efficiency. "Bottom loaders" are essentially rigid structures that carry a majority of the load in the portion of the structure below the hub. "Top loaders" are designed so that all of the structure is involved in carrying the load. Top loaders thus have a higher load carrying efficiency than bottom loaders, allowing a design that has less mass.

[0005] Thus an improved non-pneumatic tire is desired that has all the features of the pneumatic tires without the drawback of the need for air inflation is desired.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention will be better understood through reference to the following description and the appended drawings, in which:

[0007] FIG. **1**A is a perspective view of a first embodiment of a non-pneumatic tire of the present invention;

[0008] FIG. **1**B is a perspective view of a second embodiment of a non-pneumatic tire of the present invention;

[0009] FIG. **1**C is a perspective view of a third embodiment of a non-pneumatic tire of the present invention;

[0010] FIG. **2** is a perspective front view of a first embodiment of a spoke disk;

[0011] FIG. **3** is a schematic cross section view of the first embodiment of the spoke disk of FIG. **2**;

[0012] FIG. **4** is a front view of the first embodiment of the spoke disk of FIG. **2**;

[0013] FIG. **5** is a cross-sectional view of the non-pneumatic tire of FIG. **1**;

[0014] FIG. **6** is a second embodiment of a spoke disk of the present invention;

[0015] FIG. **7** is a third embodiment of a spoke disk of the present invention;

[0016] FIG. **8** is a cross-sectional view of an alternate embodiment of a non-pneumatic tire of the present invention illustrating multiple spoke disks with the same orientation;

[0017] FIG. **9** is a cross-sectional view of the non-pneumatic tire of FIG. **1**, shown with two spoke disks in opposed orientation so that the spokes bow axially inward when under load.

[0018] FIG. **10** is a cross-sectional view of the non-pneumatic tire of FIG. **1** shown with two disk spokes having a different orientation so that the spokes bow axially outward when under load.

[0019] FIG. **11** is a cross-sectional view of the non-pneumatic tire of FIG. **1** shown with the disk spokes having a curved cross-section, shown under load.

[0020] FIG. **12** is a front view of a fourth embodiment of a spoke disk of the present invention.

[0021] FIG. **13** is a perspective view of the fourth embodiment of the spoke disk of FIG. **12**.

[0022] FIG. **14** is a front view of a fifth embodiment of a spoke disk of the present invention.

[0023] FIG. **15** is a perspective view of the fifth embodiment of the spoke disk of FIG. **14** shown under loading.

[0024] FIG. **16** is a close-up view of the first and second spoke members of the fourth, fifth embodiments of FIGS. **12**,**14**.

[0025] FIG. **17** is a front view of a sixth embodiment of a spoke disk.

[0026] FIG. **18** is a perspective view of the sixth embodiment of a spoke disk.

[0027] FIG. **19** is a front view of a seventh embodiment of a spoke disk.

[0028] FIG. **20** is a close up view of the spoke disk of FIG. **19**.

[0029] FIG. **21** is a perspective view of the sixth embodiment of a spoke disk shown with no load.

[0030] FIG. **22** is a perspective view of the sixth embodiment of the spoke disk shown with load.

[0031] FIG. **23***a* illustrates a spring rate test for a shear band, while FIG. **23***b* illustrates the spring rate k determined from the slope of the force displacement curve.

[0032] FIG. **24***a* illustrates a spring rate test for a spoke disk, while FIG. **24***b* illustrates the spring rate k determined from the slope of the force displacement curve.

[0033] FIG. **25***a* illustrates a spring rate test for a spoke disk, while FIG. **25***b* illustrates the tire spring rate k determined from the slope of the force displacement curve.

DEFINITIONS

[0034] The following terms are defined as follows for this description.

[0035] "Equatorial Plane" means a plane perpendicular to the axis of rotation of the tire passing through the centerline of the tire.

[0036] "Meridian Plane" means a plane parallel to the axis of rotation of the tire and extending radially outward from said axis.

[0037] "Hysteresis" means the dynamic loss tangent measured at 10 percent dynamic shear strain and at 25° C.

DETAILED DESCRIPTION OF THE INVENTION

[0038] Examples of a non-pneumatic tire **100** of the present invention are shown in FIGS. **1A-1C**. The tire of the present invention includes a radially outer ground engaging tread **200**, a shear band **300**, and one or more spoke disks **400**. The spoke disks **400** may have different designs, as described in more detail, below. The non-pneumatic tire of the present invention is designed to be a top loading structure, so that the shear band **300** and the one or more spoke disks **400** efficiently carry the load. The shear band **300** and the spoke disks **400** are designed so that the stiffness of the shear band is directly related to the spring rate of the tire. The spokes of each disk are designed to be stiff structures that buckle or deform in the tire footprint and do not compress or carry a compressive load. This allows the rest of the spokes not in the footprint area the ability to carry the load. Since there are more spokes outside of the footprint than in, the load per spoke would be small enabling smaller spokes to carry the tire load which gives a very load efficient structure. Not all spokes will be able to elastically buckle and will retain some portion of the load in compression in the footprint. It is desired to minimize this load for the reason above and to allow the shearband to bend to overcome road obstacles. The approximate load distribution is such that approximately 90-100% of the load is carried by the shear band and the upper spokes, so that the lower spokes carry virtually zero of the load, and preferably less than 10%.

[0039] The non-pneumatic tire may have different combination of spoke disks in order to tune the non-pneumatic tire with desired characteristics. For example, a first spoke disk **400** may be selected that carries both shear load and tensile load. A second spoke disk may be selected that carries a pure tensile load. A third spoke disk **1000**, **2000** may be selected that is stiff in the lateral direction. See exemplary tire disk configurations as shown in FIGS. **1A-1C**.

[0040] The tread portion **200** may have no grooves or may have a plurality of longitudinally oriented tread grooves forming essentially longitudinal tread ribs there between. Ribs may be further divided transversely or longitudinally to form a tread pattern adapted to the usage requirements of the particular vehicle application. Tread grooves may have any depth consistent with the intended use of the tire. The tire tread **200** may include elements such as ribs, blocks, lugs, grooves, and sipes as desired to improve the performance of the tire in various conditions.

Shear Band

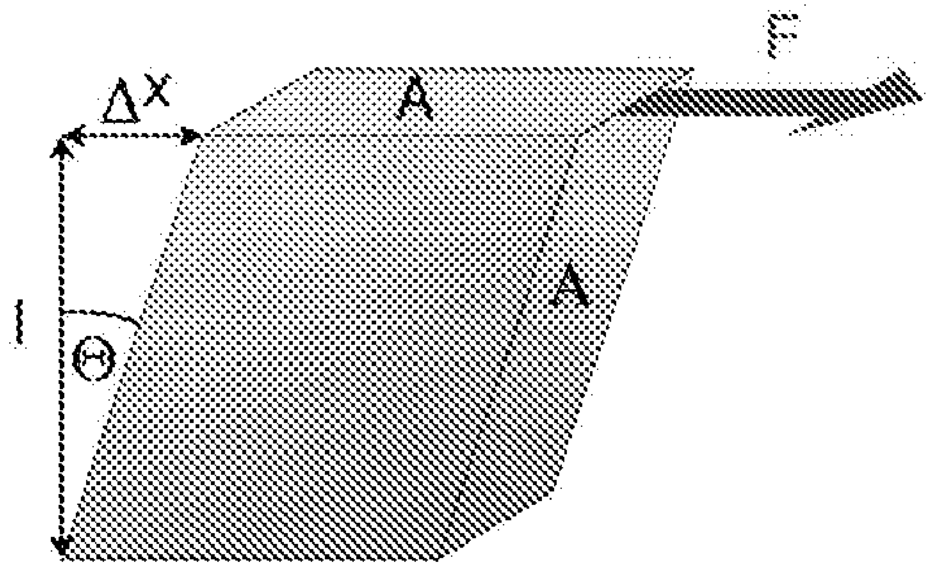
[0041] The shear band **300** is preferably annular, and is shown in FIG. **5**. The shear band **300** is located radially inward of the tire tread **200**. The shear band **300** includes a first and second reinforced elastomer layer **310**,**320**. In a first embodiment of a shear band **300**, the shear band is comprised of two inextensible layers arranged in parallel, and separated by a shear matrix **330** of elastomer. Each inextensible layer **310**,**320** may be formed of parallel inextensible reinforcement cords **311**,**321** embedded in an elastomeric coating. The reinforcement cords **311**,**321** may be steel, aramid, or other inextensible structure. In a second embodiment of the shear band, the shear band **300** further includes a third reinforced elastomer layer located between the first and second reinforced elastomer layers **310**,**320**.

[0042] In the first reinforced elastomer layer **310**, the reinforcement cords **311** are oriented at an angle Φ in the range of 0 to about +/−10 degrees relative to the tire equatorial plane. In the second reinforced elastomer layer **320**, the reinforcement cords **321** are oriented at an angle ϕ in the range of 0 to about +/−10 degrees relative to the tire equatorial plane. Preferably, the angle Φ of the first layer is in the opposite direction of the angle ϕ of the reinforcement cords in the second layer. That is, an angle $+\Phi$ in the first reinforced elastomeric layer and an angle $-\phi$ in the second reinforced elastomeric layer.

[0043] The shear matrix **330** has a thickness in the range of about 0.10 inches to about 0.2 inches, more preferably about 0.15 inches. The shear matrix is preferably formed of an elastomer material having a shear modulus Gm in the range of 15 to 80 MPa, and more preferably in the range of 40 to 60 MPA.

[0044] The shear band has a shear stiffness GA. The shear stiffness GA may be determined by measuring the deflection on a representative test specimen taken from the shear band. The upper surface of the test specimen is subjected to a lateral force F as shown below. The test specimen is a representative sample taken from the shear band and having the same radial thickness as the shearband. The shear stiffness GA is then calculated from the following equation:

$$GA=F*L/\Delta X$$


F
Δx
A
A
l
Θ

[0045] The shear band has a bending stiffness EI. The bending stiffness EI may be determined from beam mechanics using the three point bending test. It represents the case of a beam resting on two roller supports and subjected to a concentrated load applied in the middle of the beam. The bending stiffness EI is determined from the following equation: $EI=PL^3/48*\Delta X$, where P is the load, L is the beam length, and ΔX is the deflection.

[0046] It is desirable to maximize the bending stiffness of the shearband EI and minimize the shear band stiffness GA. The acceptable ratio of GA/EI would be between 0.01 and 20, with an ideal range between 0.01 and 5. EA is the extensible stiffness of the shear band, and it is determined experimentally by applying a tensile force and measuring the change in length. The ratio of the EA to EI of the shearband is acceptable in the range of 0.02 to 100 with an ideal range of 1 to 50.

[0047] The shear band **300** preferably can withstand a maximum shear strain in the range of 15-30%.

[0048] The non-pneumatic tire has an overall spring rate k_t that is determined experimentally. The non-pneumatic tire is mounted upon a rim, and a load is applied to the center of the tire through the rim, as shown in FIG. **25***a*. The spring rate k_t is determined from the slope of the force versus deflection curve, as shown in FIG. **25***b*. Depending upon the desired application, the tire spring rate k_t may vary. The tire spring rate k_t is preferably in the range of 650 to 1200 lbs/inch for a lawn mower or slow speed vehicle application.

[0049] The shear band has a spring rate k that may be determined experimentally by exerting a downward force on a horizontal plate at the top of the shear band and measuring the amount of deflection as shown in FIG. **23***a*. The spring rate is determined from the slope of the Force versus deflection curve as shown in FIG. **23***b*.

[0050] The invention is not limited to the shear band structure disclosed herein, and may comprise any structure which has a GA/EI in the range of 0.01 to 20, or a EA/EI ratio in the range of 0.02 to 100, or a spring rate in the range of 20 to 2000, as well as any combinations thereof. More preferably, the shear band has a GA/EI ratio of 0.01 to 5, or an EA/EI ratio of 1 to 50, or a spring rate of 170 lb/in, and any subcombinations thereof. The tire tread is preferably wrapped about the shear band and is preferably integrally molded to the shear band.

Spoke Desk

[0051] The non-pneumatic tire of the present invention further includes at least one spoke disk **400**,**700**,**800**, **900** or **1000** and preferably at least two disks which may be spaced apart at opposed ends of the non-pneumatic tire as shown in FIG. **1**B, **8**. The spoke disks may have different cross-sectional designs as shown for example in FIGS. **4**, **6**, **7**, **12**, and **14**. The spoke disk functions to carry the load transmitted from the shear layer. The disks are primarily loaded in tension and shear, and carry no load in compression. A first exemplary disk **400** that may be used in the non-pneumatic tire is shown in FIG. **2**. The disk **400** is annular, and has an outer edge **406** and an inner edge **403** for receiving a metal or rigid reinforcement ring **405** to form a hub. Each disk as described herein has an axial thickness A that is substantially less than the axial thickness AW of the non-pneumatic tire. The axial thickness A is in the range of 5-20% of AW, more preferably 5-10% AW. If more than one disk is utilized, than the axial thickness of each disk may vary or be the same.

[0052] Each spoke disk has a spring rate SR which may be determined experimentally by measuring the deflection under a known load, as shown in FIG. **24***a*. One method for determining the spoke disk spring rate k is to mount the spoke disk to a hub, and attaching the outer ring of the spoke disk to a rigid test fixture. A downward force is applied to the hub, and the displacement of the hub is recorded. The spring rate k is determined from the slope of the force deflection curve as shown in FIG. **24***b*. It is preferred that the spoke disk spring rate be greater than the spring rate of the shear band. It is preferred that the spoke disk spring rate be in the range of 4 to 12 times greater than the spring rate of the shear band, and more preferably in the range of 6 to 10 times greater than the spring rate of the shear band.

[0053] Preferably, if more than one spoke disk is used, all of the spoke disks have the same spring rate. The spring rate of the non-pneumatic tire may be adjusted by increasing the number of spoke disks as shown in FIG. **8**. Alternatively, the spring rate of each spoke disk may be different by varying the geometry of the spoke disk or changing the material. It is additionally preferred that if more than one spoke disk is used, that all of the spoke disks have the same outer diameter.

[0054] FIG. **8** illustrates an alternate embodiment of a non-pneumatic tire having multiple spoke disks **400**. The spokes **410** preferably extend in the radial direction. The spokes of disk **400** are designed to bulge or deform in an axial direction, so that each spoke deforms axially outward as shown in FIG. **10** or axially inward as shown in FIG. **9**. If only two spoke disks are used, the spoke disks may be oriented so that each spoke disk bulges or deforms axially inward as shown in FIG. **9**, or the opposite orientation such that the spoke disks bulge axially outward as shown in FIG. **10**. When the non-pneumatic tire is loaded, the spokes will deform or axially bow when passing through the contact patch with substantially no compressive resistance, supplying zero or insignificant compressive force to load bearing. The predominant load of the spokes is through tension and shear, and not compression.

[0055] The spokes have a rectangular cross section as shown in FIG. **2**, but are not limited to a rectangular cross-section, and may be round, square, elliptical, etc. Preferably, the spoke **410** has a cross-sectional geometry selected for longitudinal buckling, and preferably has a spoke width W to spoke axial thickness ratio, W/t, in the range of about 15 to about 80, and more preferably in the range of about 30 to about 60 and most preferably in the range of about 45 to about 55. A unique aspect of the preferred rectangular spoke design is the ability of the spokes to carry a shear load, which allows the spring stiffness to be spread between the spokes in tension and in shear loading. This geometric ability to provide shear stiffness is the ratio between the spoke thickness t and the radial height H of the spoke. The preferred ratio of H/t is in the range of about 2.5 and 25 (about means +/−10%) and more preferably in the range of about 10 to 20 (about means +/−10%), and most preferably in the range of 12-17.

[0056] The spokes preferably are angled in the radial plane at an angle alpha as shown in FIG. **3**. The angle alpha is preferably in the range of 60 to 88 degrees, and more preferably in the range of 70 to 85 degrees. Additionally, the radially outer end **415** is axially offset from the radially inner end **413** of spoke **410** to facilitate the spokes bowing or deforming in the axial direction. Alternatively, the spokes **900** may be curved as shown in FIG. **11**.

[0057] FIG. **6** is a second embodiment of a spoke disk **700**. The spoke disk is annular, and primarily solid with a plurality of holes **702**. The holes may be arranged in rows oriented in a radial direction. FIG. **7** is a third embodiment of a spoke disk **800**. The spoke disk is annular and solid, with no holes. The cross-section of the spoke disk **700**, **800** is the same as FIG. **3**. The spoke disks **700**, **800** have the same thickness, axial width as shown in FIG. **3**.

[0058] FIGS. **12-13** illustrates a fourth embodiment of a spoke disk **1000**. The spoke disk **1000** has an axial thickness A substantially less than the axial thickness AW of the non-pneumatic tire. The spoke disk **1000** has a plurality of spokes that connect an inner ring **1010** to an outer ring **1020**. The shear band **300** is mounted radially outward of the spoke disks. The spoke disk **1000** has a first spoke **1030** that is linear and joins the outer ring **1020** to the inner ring **1010**. The first spoke **1030** forms an angle Beta with the outer ring **1020** in the range of 20 to 80 degrees. Beta is preferably less than 90 degrees. The spoke disk **1000** further includes a second spoke **1040** that extends from the outer ring **1020** to the inner ring **1010**, preferably in a curved shape. The second spoke **1040** is joined with the first spoke **1030** at a junction **1100**. The curved spoke **1040** has a first curvature from the outer ring to the junction **1100**, and a second curvature from the junction to the inner ring **1010**. In this example, the first curvature is convex, and the second curvature is concave. The shaping or curvature of the first and second spokes control how the blades deform when subject to a load. The blades of the spoke disk **1000** are designed to buckle in the angular direction theta.

[0059] The joining of the first spoke **1030** to the second spoke **1040** by the junction results in an upper and lower generally shaped triangles **1050**,**1060**. The radial height of the junction **1100** can be varied as shown in FIG. **16**, by varying the ratio of L_1/L_2. The ratio of L_1/L_2 may be in the range of 0.2 to 5, and preferably in the range of 0.3 to 3, and more preferably in the range of 0.4 to 2.5. The spokes **1030**,**1040** have a spoke thickness t in the range of 2-5 mm, and an axial width W in the axial direction in the range of about 25-70 mm. The ratio of the spoke axial width W_2 to thickness t_2, W_2/t_2 is in the range of 8-28, more preferably 9-11. The spoke disk **1000** is designed to carry the load primarily in tension, while the other spoke disks **400**,**700**, **800** are able to carry the load both in tension and in shear. The spoke disk **1000** buckles in the radial plane, while the other spoke disks **400**,**700**, **800** are designed to buckle in a different plane in the axial direction.

[0060] FIG. **14** illustrates a fifth embodiment of a spoke disk **2000**, which is similar to the spoke disk **1000**, except for the following differences. The spoke disk **2000** has a first and second spoke **2030**, **2040** which are joined together by a junction **2100**, forming two approximate triangular shapes A,B, that have curved boundaries. Both the first and second spokes **2030**,**2040** extend from an outer ring **2020** to an inner ring **2010**. Both the first and second spokes **2030**, **2040** are curved. The curve of the outer radial portion L2 of each spoke has a first curvature, and the inner radial portions L1 have a curve in the opposite direction of the first curvature. FIG. **15** illustrates the spoke disk **2000** buckling under load. The radially outer portions of **2040**,**2030** buckle in the angular direction.

[0061] FIG. **17** illustrates a sixth embodiment of a spoke disk **3000**. The spoke disk **3000** has multiple curved spokes **3030** that overlap with each other. Preferably, the spokes are curved in a parabolic manner. The spoke **3030** has a first end **3040** connected to the outer ring **3020** of the spoke disk. The spoke **3030** intersects with another adjacent spoke **3030'** at junction **3060**. The radially outer portion of the spoke between the junction **3060** and the end **3040** is designated as **L2**. The radially inner portion of the spoke **3030** between the junction **3060** and the point of tangency **3075** with the inner ring **3010** is designated as L_1. The spoke **3030** intersects with another spoke **3030"** at **3070** located on the inner ring **3010**. The spoke **3030** intersects with another spoke **3030"** at **3080** located on the inner ring **3010**. The spoke **3030** intersects with another spoke **3030"** at **3090**. The spoke **3030** has a terminal end **3050** located on the outer ring **3020**. FIG. **18** illustrates a perspective view of the parabolic spoke disk. The axial thickness W_3 of the spoke disk is substantially less than the axial thickness AW of the tire. The axial thickness W_3 of the spoke disk may be in the range of about 25 to about 70 mm. The spoke thickness t_3 is preferably in the range of 2 to 5 mm. The axial thickness of the spoke disk may be different than the other axial thicknesses of the other spoke disks. The ratio of **L2**/**L1** is preferably in the range of about 0.2 to 5, and more preferably 0.3 to 3, and most preferably 0.4 to 2.5.

[0062] FIG. **21** illustrate the spoke disk **3000** prior to loading, and FIG. **22** illustrates the spoke disk **3000** in the loaded position. When a load is applied to the rim as shown, the outer radial portions L2 deform as shown in FIG. **22**.

[0063] FIG. **19** illustrates a seventh embodiment of a double parabolic spoke disk **4000**. The spoke disk includes the first parabolic curves **3030**,**3030'**,**3030"** as spoke disk **3000**, except that a second parabolic curve **4500** is added (shown in Pink). The first parabolic curves **3030**,**3030'** preferably overlap. The second parabolic curve **4500** intersects with the first parabolic curves **3030** at multiple junctions. The second parabolic curve **4500** intersects a single first parabolic curve **3030** at junctions **3070**,**3080**. The second parabolic curve **4500** intersects a second first parabolic curve **3030'** at junctions **3080**,**3090**,**3050**. The second parabolic curve **4500** intersects with a third parabolic curve **3030"** at junctions **3070**,**3090**,**3095**. Each first parabola curve **3030** intersects with three other first parabola curves **3030'**, **3030"**, **3030'"**. The second parabola curve **4500** has an apex **4600** located on the radially outer ring **4030**, and radially inner legs **4510**,**4520** terminating at vertices **3080**, **3070** respectively. The apex **3075** of the first parabola curve **3030** intersects with the radially inner ring **4010**.

[0064] A preferred embodiment of a non-pneumatic tire is shown in FIG. 1B. The spoke disks on the outer axial ends are the spoke disks **400**, and are oriented so that they buckle axially outward. Located between the opposed spoke disks **400** are at least one disk **1000**,**2000**,**4000**. The outer spoke disks are designed to carry both shear and tension loads, while the disks **1000**,**2000** carry loads in tension only. The number of inner disks may be selected as needed. The outer disks buckle in a first plane, while the inner disks buckle in a different plane. The disks **1000**,**2000** are designed to be laterally stiff, so that they can be combined to tune the tire lateral stiffness. The outer disks **400** are not as stiff in the lateral direction as the disks **1000**,**2000**.

[0065] The spoke disks are preferably formed of an elastic material, more preferably, a thermoplastic elastomer. The material of the spoke disks is selected based upon one or more of the following material properties. The tensile (Young's) modulus of the disk material is preferably in the range of 45 MPa to 650 MPa, and more preferably in the range of 85 MPa to 300 MPa, using the ISO 527-1/-2 standard test method. The glass transition temperature is less than −25 degree Celsius, and more preferably less than −35 degree Celsius. The yield strain at break is more than 30%, and more preferably more than 40%. The elongation at break is more than or equal to the yield strain, and more preferably, more than 200%. The heat deflection temperature is more than 40 degree C. under 0.45 MPa, and more preferably more than 50 degree C. under 0.45 MPa. No break result for the Izod and Charpy notched test at 23 degree C. using the ISO 179/ISO180 test method. Two suitable materials for the disk is commercially available by DSM Products and sold under the trade name ARNITEL PL 420H and ARNITEL PL461.

[0066] Applicants understand that many other variations are apparent to one of ordinary skill in the art from a reading of the above specification. These variations and other variations are within the spirit and scope of the present invention as defined by the following appended claims.

What is claimed:

1. A non-pneumatic tire comprising
a ground contacting annular tread portion;
a shear band; and
at least one spoke disk connected to the shear band, wherein the spoke disk has one or more first spokes having a parabolic curvature, wherein the one or more first spokes extends from an outer ring to an inner ring.

2. The non-pneumatic tire of claim **1** having one or more spokes a second parabolic curvature.

3. The non-pneumatic tire of claim **1** wherein there are a plurality of first spokes that overlap with each other.

4. The non-pneumatic tire of claim **1** wherein an apex of the first spokes is located on the inner ring.

5. The non-pneumatic tire of claim **1** wherein the one or more first spokes extend from the outer ring to the inner ring.

6. The non-pneumatic tire of claim **1** wherein the one or more first spokes extend from the outer ring to the inner ring, and then from the inner ring to the outer ring.

7. The non-pneumatic tire of claim **1** wherein a first spoke intersects with an adjacent first spoke at a junction, wherein each first spoke has a L**2** portion radially outwards of the junction, and a L**1** portion located radially inward of the junction, wherein the ratio of L**2**/L**1** ranges from about 0.2 to 5.

8. The non-pneumatic tire of claim **1** wherein said first spoke has a thickness t**3** in the range of 2 to 5 mm.

9. The non-pneumatic tire of claim **1** wherein said first spoke has an axial thickness w**3** in the range of 25 to 70 mm.

10. The non-pneumatic tire of claim **1** wherein said first spoke has a ratio of spoke axial width w**3** to spoke thickness t**3** in the range of 8 to 28.

11. The non-pneumatic tire of claim **1** wherein the spoke disk further includes a second spoke having a second curvature different than the first curvature.

12. The non-pneumatic tire of claim **11** wherein the second curvature is a parabolic cure having an apex intersecting the outer ring.

13. The non-pneumatic tire of claim **11** wherein the second spoke intersects with two of the first spokes.

* * * * *