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(71) Applicant: **SHARK WHEEL, INC.** [US/US]; 27285 Las Ramblas #220, Mission Viejo, CA 92691 (US).

(72) Inventors: **FLEISHMAN, Zack**; 27285 Las Ramblas #220, Mission Viejo, CA 92691 (US). **SMITH, Todd**; 6517 NE Deer Run St., Hillsboro, OR 97124 (US).

(74) Agent: **CIONCA, Marin**, Cionca IP Law P.C., 2030 Main St. Suite 1300, Irvine, CA 92614 (US).

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(54) Title: FARM IRRIGATION WHEEL

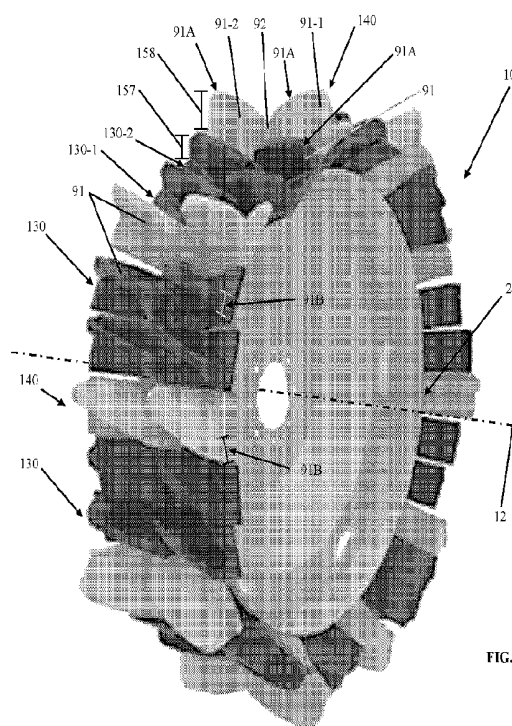


FIG. 17A

(57) Abstract: A wheel having a circular ring is provided. The circular ring has a rotational axis and an outer surface. A plurality of lugs is mounted in side-by-side positions on said outer surface of the circular ring. Each lug of the plurality of lugs has: a center rib, a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other, and a plate adapted to connect the first leg to the center rib. The outermost point of each center rib may form a circular pattern that is coaxial with the rotational axis. The wheel may have a rim nested within said circular ring, said rim having a plurality of alternating scalloped protrusions. The plurality of lugs may include high traction lugs having plates with distal edges configured to radially extend beyond the center rib to provide traction to the wheel on difficult terrain.

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part and claims the benefit of U.S. Non-Provisional Application 17/653,158, filed on March 02, 2022, which is a continuation-in-part of U.S. Non-Provisional Application No. 17/189,645, filed on March 02, 2021, which is a continuation-in-part of U.S. Non-Provisional Application No. 15/979,429, filed on May 14, 2018, all of which are hereby incorporated by reference, to the extent that they are not conflicting with the present application.

BACKGROUND OF INVENTION

1. Field of the Invention:

[0002] The invention relates generally to utility wheels and more particularly, to wheels used in farming applications, such as wheels used in conjunction with crop irrigation equipment.

2. Description of the Related Art

[0003] Currently, center pivot irrigation is a form of overhead sprinkler irrigation, which uses a machine having pipe segments arranged in linear arms, with sprinklers positioned along the arms which may be supported by trusses mounted on wheeled units with such units set at several points along the arms. In one version, the arms are driven in a circular pattern and fed with water from a pivot point at the center of the circle. For a center pivot to be used, the terrain upon which it rotates must be reasonably flat; but may move over an undulating surface. The arms typically may be between 1200 and 1600 feet in length forming a circle radius. These systems may be water-powered, hydraulic powered or electric motor-driven. The outermost wheels set the pace of rotation with a full circle made once every three days for example. The inner wheels are auto-controlled to keep the arms relatively linear during movement. Sprinkler sizes are progressively

larger over the distance from the pivot point to the outer circumference of the circle. Crops may be planted in straight rows or in circles to conform to the travel of the irrigation system.

[0004] Additionally, center-pivot irrigation typically uses less water and require less labor than furrow irrigation. This results in lower labor costs, reduces the amount of soil tillage required, and helps reduce water runoff and soil erosion. Less tillage also encourages more organic materials and crop residue to decompose back into the soil and reduces soil compaction. Inflatable tires are widely used on center-pivot irrigation rigs because they have excellent performance on soft soil and mud due to their compliance causing flattening as they roll in contact with a surface. During flattening the tire's footprint (contact surface) grows, thereby reducing contact pressure and reduced contact pressure reduces the tendency to sink into the ground ruts are less pronounced.

[0005] Furthermore, current center pivot irrigation wheels lack strength and durability in the wheels because of pneumatic tires typically used. Moreover, current center pivot irrigation wheels also do not have any traction support for once the wheel has already entered a rut. Pneumatic tires in the irrigation application also require air pressure maintenance due to air loss and typically have rutting issues.

[0006] Therefore, there is a need to solve the problems described above by providing a device for improved traction for crop irrigation equipment.

[0007] The aspects or the problems and the associated solutions presented in this section could be or could have been pursued; they are not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches presented in this section qualify as prior art merely by virtue of their presence in this section of the application.

BRIEF INVENTION SUMMARY

[0008] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key aspects or essential aspects of the claimed subject matter. Moreover, this Summary is not intended for use as an aid in determining the scope of the claimed subject matter.

[0009] In an aspect, a wheel is provided, the wheel comprising: a circular ring having: an outer surface; and a rotational axis; and a plurality of lugs mounted in side-by-side positions on

said outer surface of the circular ring, each lug having: a center rib; a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other; a first lug plate adapted to connect the first leg to the center rib; and a second lug plate adapted to connect the second leg to the center rib; wherein the plurality of lugs forms a circular pattern that is coaxial with the rotational axis and a distal edge of the first lug plate and a distal edge of the second lug plate are configured to radially extend beyond the center rib. Thus, an advantage is that the wheel will have enhanced traction due to the lugs having a protruding lug plate to better grip the driving surface. Another advantage is that the lug plates may provide structural support to the lugs, increasing their strength. Another advantage is that each lug may be provided with an overmolded rubber layer which may increase lug strength and durability, enhance lug grip, and/or protect internally enclosed lug structures. Another advantage is that modular implementation of the lugs may allow for easy maintenance, repair, or replacement of said lugs as needed, rather than replacement of the whole wheel. Another advantage is that the disclosed wheel may utilize a rim having scalloped protrusions, wherein said scalloped protrusions allow for easier manipulation of lugs and provide enhanced load bearing capabilities to said wheel. Another advantage is that the wheels may be configured and aligned such that a structure having a front wheel and a back wheel may produce a double helical rut having shallow depth, such that the ground is not notably disrupted by the wheels. Another advantage is that lugs having lug plates with varying lengths may be attached to the same wheel, thus providing the wheel with improved traction on more challenging surfaces, such as loose packed and/or sandy soil.

[0010] In another aspect, a wheel is provided, the wheel comprising: a plurality of lugs mounted in side-by-side positions to form a circular ring, each lug having: a center rib; a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other; a first lug plate adapted to connect the first leg to the center rib; and a second lug plate adapted to connect the second leg to the center rib; wherein a distal edge of the first lug plate and a distal edge of the second lug plate are configured to radially extend beyond the center rib.. Again, an advantage is that the wheel will have enhanced traction due to the lugs having a protruding lug plate to better grip the driving surface. Another advantage is that the lug plates may provide structural support to the lugs, increasing their strength. Another advantage is that each lug may be provided with an overmolded rubber layer which may increase lug strength and durability, enhance lug grip, and/or protect internally enclosed lug structures. Another advantage is that

modular implementation of the lugs may allow for easy maintenance, repair, or replacement of said lugs as needed, rather than replacement of the whole wheel. Another advantage is that the disclosed wheel may utilize a rim having scalloped protrusions, wherein said scalloped protrusions allow for easier manipulation of lugs and provide enhanced load bearing capabilities to said wheel. Another advantage is that lugs having lug plates with varying lengths may be attached to the same wheel, thus providing the wheel with improved traction on more challenging surfaces, such as loose packed and/or sandy soil.

[0011] In another aspect, a wheel is provided, the wheel comprising: a plurality lugs, each lug of the plurality of lugs comprising: a center rib; a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other; a first leg paddle associated with the first leg; and a second leg paddle associated with the second leg. An advantage is that a corresponding wheel utilizing the lug may have enhanced traction due to the lug having protruding leg paddles, bladder paddles front paddles and back paddles. Another advantage is that the center rib may be an air bladder configured to increase the buoyancy of the wheel to prevent it from sinking too far into soil. Another advantage is that the lug may be provided with an overmolded rubber layer which may increase lug strength and durability, enhance lug grip, and/or protect internally enclosed lug structures. Another advantage is that the lug may be configured to be suitably compliant and flexible, such that the lug flexes as a load is applied on it, thus reducing the strain exerted on the drivetrain of a vehicle utilizing said lug, as well as the pressure exerted on the ground by the lug.

[0012] The above aspects or examples and advantages, as well as other aspects or examples and advantages, will become apparent from the ensuing description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For exemplification purposes, and not for limitation purposes, aspects, embodiments or examples of the invention are illustrated in the figures of the accompanying drawings, in which:

[0014] **FIG. 1A** illustrates a center pivot irrigation system as used in farming, according to an aspect.

- [0015] FIG. 1B illustrates a perspective view of an embodiment of a wheel used in center pivot irrigation systems, according to an aspect.
- [0016] FIG. 2 illustrates a further perspective view of the farm irrigation wheel, according to an aspect.
- [0017] FIG. 3 illustrates a partial vertical section view of the farm irrigation wheel, according to an aspect.
- [0018] FIG. 4 illustrates a front elevation view of the farm irrigation wheel, according to an aspect.
- [0019] FIG. 5 illustrates a perspective view of a lug of the farm irrigation wheel, according to an aspect.
- [0020] FIG. 6 illustrates a perspective view of the farm irrigation wheel, according to an embodiment.
- [0021] FIG. 7A illustrates a perspective view of the lug, according to an embodiment.
- [0022] FIG. 7B illustrates a perspective view of the lug, according to an embodiment.
- [0023] FIGs. 7C-7F illustrate a side view of the lug, according to an embodiment.
- [0024] FIG. 7G illustrates a perspective view of the lug, according to an embodiment.
- [0025] FIG. 7H illustrates a perspective semitransparent view of the lug, according to an embodiment.
- [0026] FIG. 8 illustrates a perspective view of the farm irrigation wheel hub, according to an embodiment.
- [0027] FIG. 9 illustrates a perspective view of the farm irrigation wheel without the lugs attached, according to an embodiment.
- [0028] FIG. 10A illustrates a perspective view of the farm irrigation wheel during a von Mises stress simulation, according to an embodiment.
- [0029] FIG. 10B illustrates a perspective view of the farm irrigation wheel during a von Mises stress simulation, according to an embodiment.
- [0030] FIG. 10C illustrates a perspective view of the farm irrigation wheel during a vibration simulation, according to an embodiment.
- [0031] FIG. 11A illustrates a perspective view of a lug, according to an embodiment.
- [0032] FIG. 11B illustrates a cross-sectional side view of a lug, according to an embodiment.

[0033] **FIG. 12A** illustrates a perspective view of a farm irrigation wheel attached to a center pivot irrigation system, according to an embodiment.

[0034] **FIG. 12B** illustrates a perspective view of a farm irrigation wheel attached to a center pivot irrigation system, according to an embodiment.

[0035] **FIGs. 13A-13E** illustrates the perspective views of a scalloped farm irrigation wheel, according to an embodiment.

[0036] **FIGs. 14A-14B** illustrate side perspective and front perspective views, respectively, of an alternative embodiment of a wheel having paddle lugs, according to an embodiment.

[0037] **FIGs. 15A-15C** illustrate top elevation, front perspective and bottom perspective views, respectively, of a paddle lug, according to an embodiment.

[0038] **FIGs. 16A-16C** illustrate front perspective views of paddle lugs in various flex states, according to an embodiment.

[0039] **FIG. 17A** illustrates a front perspective view of a high traction embodiment of the farm irrigation wheel, according to an embodiment.

[0040] **FIGs. 17B-17C** illustrate front perspective views of a paddle lug adjacent to a high traction lug, according to an aspect.

[0041] **FIG. 18A** illustrates the tread patterns for correctly installed farm irrigation wheels attached to a structure, according to an embodiment.

[0042] **FIG. 18B** illustrates a top view of aligned front and rear farm irrigation wheels configured for engagement with a structure, according to an embodiment.

[0043] **FIG. 18C** illustrates a side view of aligned front and rear farm irrigation wheels configured for engagement with a structure, according to an embodiment.

[0044] **FIG. 19A-19C** illustrate a front perspective, side perspective and enlarged side perspective views, respectively of an alternative farm irrigation wheel having pneumatic lugs 160, according to an aspect.

[0045] **FIG. 20A** illustrates a front elevation view of a farm irrigation wheel having a plurality of intermediate pneumatic lugs, according to an aspect.

[0046] **FIG. 20B** illustrates a front elevation view of a farm irrigation wheel having a plurality of basic pneumatic lugs 160, according to an aspect.

DETAILED DESCRIPTION

[0047] What follows is a description of various aspects, embodiments and/or examples in which the invention may be practiced. Reference will be made to the attached drawings, and the information included in the drawings is part of this detailed description. The aspects, embodiments and/or examples described herein are presented for exemplification purposes, and not for limitation purposes. It should be understood that structural and/or logical modifications could be made by someone of ordinary skills in the art without departing from the scope of the invention. Therefore, the scope of the invention is defined by the accompanying claims and their equivalents.

[0048] It should be understood that, for clarity of the drawings and of the specification, some or all details about some structural components or steps that are known in the art are not shown or described if they are not necessary for the invention to be understood by one of ordinary skills in the art.

[0049] In the foregoing description, embodiments are described as a plurality of individual parts, and methods as a plurality of individual steps and this is solely for the sake of illustration. Accordingly, it is contemplated that some additional parts or steps may be added, some parts or steps may be changed or omitted, and the order of the parts or steps may be re-arranged, while maintaining the sense and understanding of the apparatus and methods as claimed.

[0050] For the following description, it can be assumed that most correspondingly labeled elements across the figures possess the same characteristics and are subject to the same structure and function. If there is a difference between correspondingly labeled elements that is not pointed out, and this difference results in a non-corresponding structure or function of an element for a particular embodiment, example or aspect, then the conflicting description given for that particular embodiment, example or aspect shall govern.

[0051] **FIG. 1A** illustrates a typical center pivot irrigation operation in progress. As described in detail herein, a utility farm wheel (“wheel,” “farm wheel”) 10 as used in this type of irrigation as best illustrated in **FIG. 1B** is provided. As shown in **FIG. 2**, the wheel 10 may be an assembly of individual parts that may be joined together in various ways. In an embodiment, the individual parts may include a ring 20, a pair of rims 30, one or two disk portions 40, and a plurality of identical lugs 50. In this embodiment, shown in **FIG. 1B** a tensioning device 60B typically either a tension band (not shown) or a tension cable may also be used and may improve

the alignment of the lugs 50. The parts may be made of metal or other materials providing suitable tensile strength, elasticity, flexibility and other characteristics as will be known by those of skill in the mechanical arts and as described herein.

[0052] Additionally, the ring 20 may be manufactured by laser cutting a flat strip of metal and then rolling it to form a cylinder with ends overlapped and welded together. Therefore, the ring 20 may have an outer surface 22 an inner surface 24 and a pair of opposing edges 26. The ring 20 may have a pattern of through holes 28 in its surface as shown in FIG. 2. The rims 30 may be secured to the edges 26 of ring 20 by welding, for instance, and the ends of legs 42 of disk portion 40 may be secured to rim 30 using common hardware. The lugs 50 may be bolted onto the outer surface 22 as shown in FIG. 3. Each lug 50 may be mounted on ring 20 by a bracket 80, possibly of shaped sheet metal, and held in place by bolts 82 as shown. The holes 28 may be arranged in different patterns permitting lugs 50 to be arranged in alternative configurations as will be described. The wheel 10 has a central rotational axis (“wheel rotational axis”, “rotational axis”) 12. As shown in FIG. 2, the lugs 50, as sighted radially toward wheel 10 (see arrow R), are rectangular in shape having a long axis 52 positioned centrally between its opposing long sides, and a short axis 54 positioned centrally between its opposing short sides. The point where long axis 52 and short axis 54 cross is a central point 56 of lug 50.

[0053] The lugs 50 may be fixed to the surface 22 such that long axis 52 are parallel to wheel rotational axis 12, see FIG. 1B. The lugs 50 may be placed in side-by-side positions around ring 20 with their short axis 54 aligned colinearly and centered between opposing edges 26, that is, centered on ring 20; this is one mounting option. However, the lugs 50 may alternately be positioned on ring 20 in laterally offset positions (see FIG. 5) with respect to each other to form a continuously and possibly smoothly varying locus of the central points 56 as shown in FIG. 4. In an embodiment, the smoothly varying locus of central points 56, may execute a sinusoidal curve having a sinusoidal amplitude and a sinusoidal period. The sinusoidal amplitude may be varied by changing the magnitude of the lateral incremental positions of the centers 56 of one lug 50 relative to the next. On the other hand, the distance about the circumference of wheel 10 of a single sinusoidal cycle may be varied by changing the circumferential width of lugs 50. The positions of the lugs 50 may be determined by the position of holes 28 in ring 20. Those of skill in the art will be able to determine the locations of holes 28 to produce a desired sinusoidal or alternate arrangement of the lugs 50.

[0054] As shown in **FIG. 5**, each lug 50 may have an outwardly directed roughly V-shape (as sighted along the circumference of wheel 10). The two opposing legs 58 of said V-shape diverges from surface 22 on either side of axis 54 where the lug 50 is fastened to ring 20. During rotation of wheel 10 each lug 50 contacts a surface upon which wheel 10 rides. Such contact is initially made by the extreme lateral ends of lug 50 along axis 52. Upon further wheel rotation greater weight is brought to bear on the legs causing the divergent angle to lessen and cause greater strain within lugs 50. A rib 57 extends in the direction of axis 52 across the outfacing portion of leg 50 and provides a means for wheel 10 to develop greater traction especially in relatively soft farm soil. At the ends of the legs of lug 50 are ribs 59 positioned orthogonal to rib 57 in order to limit sideways slippage of wheel 10.

[0055] The tensioning device 60B may be made of high-strength Nylon® cable or stainless-steel band stock and may be fixed to lugs 50 on both left and right lateral underside surfaces of the legs by cleats 62 as shown in FIG. 1. The tensioning device 60B may allow a gap between adjacent lugs 50 to remain consistent and also may allow lugs 50 to be pre-tensioned for a desired stiffness, that is, drawing the divergence angle of the legs of lugs 50 away from surface 22 to a greater or lesser degree. This also enables adjacent lugs 50 to share and transfer loads between them which is important for sharing and distributing shock loads when obstacles such as rocks are encountered.

[0056] **FIG. 6** illustrates a perspective view of the farm irrigation wheel 10, according to an aspect. In another embodiment, the individual parts may include a ring 20 (shown in FIG. 9), a hub 70, a plurality of spokes 71, and a plurality of identical lugs 50A. As shown, the farm irrigation wheel 10 may have a hub 70, spokes (“fins”) 71, lugs 50A, and a ring 20. As described herein, the disk portion 40, shown in FIG.2, may be broken up into hub 70 and spokes (“fins”) 71 components. Furthermore, having the hub 70 and the spokes 71 as separates parts may allow for better durability. Additionally, having each spoke 71 as a separate component may allow for easier maintenance. For example, if a spoke 71 were to be damaged, the single spoke 71 may be replaced without the need to replace the entire wheel 10. Again, instead of legs 58 on a rim 30, the farm irrigation wheel 10 may have a hub 70 with spokes 71, which may provide additional strength to the wheel and more traction.

[0057] As shown in FIG. 6, the spokes 71 may be concaved and attach at alternating locations. The spokes 71 of the wheel 10 can provide traction and help the wheel not slip if it is

moving through an existing rut. Typically, wheel hubs and spokes only have a purpose to handle loads, while, as described herein, the spokes 71 may provide additional traction. The spokes 71 may aid in traction, if necessary, by cutting into the ground surface (i.e., soil or dirt). For example, if the wheel 10 begins to sink below ground level (i.e., in a 'rut' or 'trench') the wheel 10 may continue to function due to the spokes 71.

[0058] The spokes ("fins") 71 may have a concave surface 71C to increase their strength. This allows for an increase in strength while keeping the metal very thin, which may keep costs down due to the spoke's 71 thin structure. Additionally, the spokes 71 allow the center of gravity of the wheel to be at the center of the hub at times, allowing the wheel 10 to be well-balanced, which will be described in more detail herein.

[0059] The wheel 10 is 'compliant' and may bend and flex to absorb heavy loads. Furthermore, both the spokes 71 and the lugs 50A may be compliant to allow for the appropriate flex in the wheel 10 to handle larger loads. Additionally, the outer surface of the wheel may help to reduce the formation of ruts and maintenance of traction in soft earth.

[0060] The lugs 50A may also have lug plates that are horizontal and raised higher than the lugs 50 shown in FIG. 5, the lugs 50A provide additional traction to the wheel 10. Furthermore, the spokes 71 may provide traction for the wheel 10 if the wheel does sink in the soil. The sine wave of the ring 20 may further help with traction because the sine wave pushes the soil towards the center to provide more traction for the wheel 10. The geometric shape of the spokes 71 may act as, for example, a person swimming, the spokes 71 help grip soil to dig out of a hole similar to arms while swimming. Furthermore, the spokes 71 may act as paddles to help dig the wheel 10 out of any soil or rut. Additionally, if the wheel 10 sinks in soft soil, the spokes 71 act similarly to the arms and hands of a swimmer to advance and move forward in the alternating arm or paddle like motion.

[0061] For example, a pair of the spokes 71 cut into the ground evenly and push the wheel upwards when necessary (i.e., in a rut). Current wheels do not usually have a center traction element that the spokes 71 provide. Moreover, the crossing and curvature of each spoke 71 may contribute to the traction, only when the wheel 10 has sunk into soft soil.

[0062] As shown, each spoke 71 may have a narrow end 71B and a wider end 71A, and each wider end 71A may be mounted to a sinusoidal peak 78 on the ring 20. The changing width of each spoke 71 may eliminate, or reduce, the resonance force. Each spoke 71 is configured to

attach to the hub 70 by said spoke's narrow end 71B to help reduce the resonance force reaching the hub 70 as the vibrations move through the wheel 10. Reducing the resonance force reaching the hub 70 may help avoid deterioration of the wheel 10.

[0063] Additionally, the spokes 71 may act as shocks and absorb vibration, stresses and loads of the wheel, which increases the strength of the wheel 10 by adding a compliant aspect to the design. The concavity of the spokes 71 may increase the strength geometrically speaking, which will be discussed in more detail when referring to FIG. 10C. The concavity of the spoke 71 may be manufactured through metal forming. In another example, the concavity of the spoke 71 may be created during installation of the spokes 71 into the ring 20.

[0064] The wheel may be made of a low-grade carbon steel for cost purposes, but a preferred material may be spring steel. Spring steel may be preferred to control and increase the elasticity and compliance of the wheel 10 and lugs 50A. The geometry of the spokes 71 may allow the spokes 71 to flex, and the spokes 71 may interfere with each other once the spokes 71 bend to a certain point. For example, under a large load, immediately adjacent spokes 71 may support a center flexing spoke 71. The two adjacent spokes 71 may provide the resistance for the spoke 71 between them. While in a resting state, with no load applied the spokes 71 may not be touching. It should be noted the space between the spokes 71 is also narrowing as the spokes 71 move towards the hub 70 and are nearly touching before a load is applied.

[0065] FIG. 7A illustrates a perspective view of the lug, according to an aspect. FIG. 7B illustrates an interior view of the lug, according to an aspect. Additionally, the lug shown in FIGs. 7A and 7B, the lugs 50A may have metal built into the lug 50A interior. Moreover, a liquid rubber may be overmolded onto the metal for additional strength and durability. The metal interior may allow the lug 50A to flex and twist, which is necessary in the typical abusive farming environment. For example, the lugs 50A may be made of spring steel, and may have the additional rubber overmold. Each lug 50A may be mounted on ring 20 by a bolt. The holes 28, shown in FIG. 9, may be arranged in different patterns permitting lugs 50A to be arranged in alternative configurations as will be described. The lugs 50A may have a flat portion with bolt holes 93 to allow the lugs 50A to easily secure to the ring 20.

[0066] A lug plate ("plate") 91 extends in the direction of center rib 92 across the outfacing portion of leg 50 and provides a means for wheel 10 to develop greater traction especially in relatively soft farm soil. At the ends of the legs of lug 50A are lug plate 91 positioned orthogonal

to center rib 92 in order to limit sideways slippage of wheel 10. It should be understood that the lug 50A could be built in other ways such as having, for example, a metal interior frame with an overmolded rubber coat.

[0067] The lugs 50A may have a lug plate 91 to further help with traction while the wheel 10 is in use. The lug plates 91 and the center peak (“center rib”) 92 on the lugs 50A may allow the wheel 10 to have proper traction on the softer farming soils. Additionally, the orientation of the lugs 50A may further help with traction over the farming landscapes. One or more bolt holes 93 may be provided on each lug to allow bolts to be used to secure the lug 50A to the ring 20. As shown, each of the plurality of lugs 50A may have opposing legs 95 forming a W-shape with the center rib 92, wherein the alignment of the outermost point of each center rib 92 may form a sinusoidal pattern that is coaxial with the rotational axis 12. Moreover, the lug plate 91 may connect a lug leg 95 to lug center rib 92, while also being connected to the flat portion 97 of the leg 95. As described herein, the lug plate 91 may provide additional structural support, while also providing additional traction for the wheel 10. As another example, the lug 50A may have a lug plate 91 on both sides of the center rib to provide additional traction and support, shown in FIGs. 7C, 7F, and 7G.

[0068] Additionally, the lugs 50A may be positioned in an alternating pattern, as shown in FIG. 6. The lugs 50A may be oriented to have the lug plate 91 on one side while the next adjacent lug 50A may have the lug plate 91 on the opposing side. For example, as shown in FIG. 6 lug 50B and lug 50C depict the alternating pattern of the lugs 50A orientation along the ring 20. Each of the plurality of spokes 71 may be concaved and arranged in an alternating pattern. The alternating pattern may be, as shown, the top end 71A of each of the plurality of spokes 71 being attached alternately to the first outer edge 20A or the second outer edge 20B of the circular ring 20 and the bottom end 71B of each of the plurality of spokes is attached alternately to the first side 75 or the second side 74 of the hub.

[0069] **FIGs. 7C-7F** illustrate a side view of the lug, according to an embodiment. As another example, the lug 50A may have a lug plate 91 on both sides of the lug, shown in **FIGs. 7C and 7F**. Furthermore, as shown the lug plate 91 may not attach to the flat portion 97. Additionally, the lug plate 91 may have cutouts 98, for example, to lower costs but maintain the structural integrity of the lug 50A. Additionally, these cutouts 98 disposed within each lug plate 91 may allow mud and debris to escape and not get stuck in the lug 50A. As shown in **FIGs. 7E**

and 7F, the lugs 50A may have a solid structure disposed within the center rib 92, such that a solid center rib 92 is present. As an example, the lug 50A may have a solid center rib 92 to provide additional strength. Also, as shown, the bolt holes 93 and bolts 94 may be in the center of the lug 50A instead of positioned in the flat portions.

[0070] **FIG. 7G** illustrates a perspective view of the lug, according to an embodiment. As shown, lugs 50A may have a solid center rib 92. For example, the lug 50A may be made of a spring steel, while the interior 99 of the center rib 92 may be a rubber material. Having spring steel as the exterior of the lug 50A and as the material which is in contact with the ground allows the lugs 50A and wheel 10 to be more durable. Additionally, as shown in FIG. 7G, the lug plate 91 may have a triangular cross section, where the widest portion of the lug plate 91 is where the lug plate meets the flat portions 97. The triangular cross section of the lug 50A, as shown in FIG. 7G, may allow the lug plate 91 to be stronger. The wide bottom of the lug plate 91 may help the lug plate from breaking off during use. As described herein, the lug plate 91 allows for improved traction between the wheel 10 and the ground. Furthermore, the highest point of the lug 50A may be the solid center rib 92, which would help when the wheel 10 may transverse hard surfaces. For example, this is due to the solid center rib 92 having a hard exterior surface while having the additional interior rubber support. Moreover, the solid center rib 92 being the highest point of the lug 50A may allow only the top surface of the center rib 92 to touch the ground while on a harder surface.

[0071] **FIG. 7H** illustrates a perspective semitransparent view of the lug 50A, according to an embodiment. As shown, the lug 50A may have a metal interior frame 100. The metal interior frame 100 may include wires made of spring steel and have an overmolded rubber layer for maximal compliancy. Also, as shown, the bolt holes 93 and bolts 94 may be in the center of the lug 50A instead of positioned in the flat portions. Again, the lug plates 91 allows for improved traction for the wheel 10. For example, as shown, the metal interior frame 100 may be a plurality of wire components to create the lug shape. Furthermore, the highest point of the lug 50A may be the center rib 92, which would help when the wheel 10 may transverse hard surfaces, for example, when on a road prior to the soft farming soil.

[0072] **FIG. 8** illustrates a perspective view of the farm irrigation wheel hub (“hub”) 70, according to an embodiment. As shown, the hub 70 has a narrow end (“second side”) 74 and a wider end (“first side”) 75. The hub 70 may allow the farm irrigation wheel 10 to be attached to a

center pivot irrigation system, as shown in FIG. 1A. The hub 70 also allows the alternating pattern of the spokes 71 to be securely attached. As described herein, the spokes 71 allow the wheel 10 to have traction even if the wheel 10 becomes somewhat submerged in the landscape.

[0073] FIG. 9 illustrates a perspective view of the farm irrigation wheel 10 without the lugs 50 attached, according to an aspect. The plurality of lugs (not shown) may be mounted in side-by-side positions to form a circular ring wherein each of the lugs has laterally extending legs forming a W-shape. The alignment of the outermost point of each center rib 92 may form a sinusoidal pattern that is coaxial with the rotational axis 12. This alignment of the lugs 50 may be the result of the through holes 28 disposed on the outer surface 22 of the ring 20 also being arranged in a sinusoidal pattern that is coaxial with the rotational axis 12. The lugs may have an outfacing rib aligned with the rotational axis 12 and a further outfacing rib orthogonal to the rotational axis. The lugs may be mutually offset around the circular ring in a sinusoidal pattern to further help with traction and wear and tear.

[0074] The ring 20 may have a pattern of through holes 28 in its surface as shown in FIG. 2. The spokes 70 may be secured to ring 20 using support pieces 76, 77 and common hardware (e.g., bolts). Furthermore, as shown in FIG. 9, the spokes 70 may be attached to both the hub 70 and ring 20 by a combination of bolts 78 and support pieces 76, 77. For example, as shown, the spoke 70 may rest on a support piece 77 and have a bolt secure the spoke 71 to the hub 70 by penetrating the holes in all three components. Additionally, the support pieces 76 and 77 may follow the curvature of both the hub 70 and the ring 20 to be flush against each surface, respectively, allowing for more secure connection. As described herein, the lugs 50A may have a flat portion with bolt holes 93 to allow the lugs 50A to easily secure to the ring 20. Additionally, configuring the spokes 71 to be removable allows for a decrease of fatigue on the wheel. Moreover, the modular aspect of the wheel 10 may reduce shipping costs, while also making maintenance easier.

[0075] Furthermore, each spoke may attach to the peak 78 of the sine wave of the ring 20. It should be noted that when the spokes connect to the sinusoidal ring it attaches to the peak 78 as opposed to the valley 79 of the respective sinusoidal edge of the ring 20. It should be noted that the alternating mounting of the spokes 71 contributes to the improved traction in soil while preserving a relatively light weight structure of the wheel. For example, the spoke 71 may be mounted with the top 71A on the first side 20A of the ring 20 and the bottom 71B attached to the

second side 74 of the hub 70. Additionally, for example, the adjacent the spoke 71 may be mounted with the top 71A on the second side 20B of the ring 20 and the bottom 71B attached to the first side 75 of the hub 70. This alternating pattern may continue for the entirety of the mounting of the spokes 71. Moreover, the spokes 71 may be mounted with their concave surface facing outward, as shown in FIG. 9. The alternating spoke orientation may allow for the weight to always be distributed evenly and allow the center of gravity to be perfectly balanced. It should be noted that the spokes 71 being built from a steel sheet provides the advantages of the light weight and lower cost of manufacturing the wheel 10. In another example, the wheel 10 may be made of 1020 steel.

[0076] Additionally, each spoke 71 attaching to the peak 78 of the sinusoidal edge of the ring 20 may allow the wheel 10 to stay balanced even during hard or sharp turns. For example, for hard turns the peak 78 may support the weight more so and thus the spokes 71 and hub 70 may compensate for the force. Moreover, because each spoke 71 crosses the center and attaches to the peak 78 the weight may be distributed evenly, which allows the wheel 10 to be more balanced. For example, while the wheel 10 is moving, the sine shape of the ring 20 shifting from left to right puts the stress on the spoke 71 because it attaches to peak 78.

[0077] **FIG. 10A** and **FIG. 10B** illustrate a perspective view of the farm irrigation wheel during a von Mises stress simulation, according to an embodiment. For example, in a simulation test, a 3D of the wheel 10 without the lugs 50A was evaluated for its strength under varying conditions. During the von Mises Stress test simulation, the wheel 10 without the lugs 50A had a yield strength of $3.500\text{e}+08 \text{ N/m}^2$. Thus, the wheel 10 can withstand a typical load and not deform in any way. Additionally, this farm irrigation wheel 10 has a better yield strength because of the alternating spokes 71, while still being durable and providing traction. As testing showed, each wheel may withstand over 20,000 lbs. of force before breaking with a max load is 6,000 lbs. per wheel (12,000 lbs. per tower). Furthermore, as shown in FIG. 10A, the darkest grey portion of the gradient that corresponds to the lowest stress points on the wheel is found on the outermost portion of the wheel 10. This shows the ring 20 and hub 70 experience the least amount of stress. The lightest portion of the gradient on the wheel is found on the hub 70 - spoke 71 connection, meaning that said connection experienced the most stress of the wheel elements. However, as described herein, the stress the connection experienced was still minimal even under a large load. As shown in FIG. 10B, the lightest portion of the gradient found on the wheel is on

the outer portion of the wheel 10, while under a larger load. This shows the ring 20 may experience some stress under heavy loads, while the hub 70 is relatively stressless.

[0078] **FIG. 10C** illustrates a perspective view of the farm irrigation wheel 10 during a vibration simulation, according to an embodiment. It should also be noted that the wheel 10 may further ensure the hub 70 does not experience a large amount of vibration from the system. Through analysis testing, it showed the vibrations stayed near the outer portions of the wheel and did not permeate to the hub 70 of the wheel 10. As shown in FIG. 10C, the vibrations stay towards the outer portion of the wheel 10 and do not reach the hub 70. The wheel 10 was specifically designed to keep the vibration from reaching the hub 70 of the wheel 10. Typically, the hub 70 is where the drivetrain and gearbox sit, which is the first major part to fail on a pivot machine. Furthermore, on-pneumatic wheels typically accelerate the drivetrain's failure. The alternating positions of the spokes, along with their shape further help to ensure the vibrations do not resonate to the center hub 70. The same spoke shape without concavity was also tested in an ansys computer simulation, the results showed the spoke with no concavity had 10x less strength. Furthermore, the spokes 71 with a concave surface 71C may increase the strength approximately by ten times.

[0079] Furthermore, as shown in FIG. 10C the darkest grey portion of the gradient that corresponds to the greatest vibrational deformation is found on the outer most portion of the wheel 10. This means the most vibration is experienced near the ring 20 of the wheel 10. The black portion of the gradient is found on the hub 70, meaning the hub 70 experienced the minimum amount of vibration of the wheel 10 elements.

[0080] **FIG. 11A** and **FIG. 11B** illustrate a perspective view and a cross-sectional view of a lug 50A, respectively, according to an aspect. As described hereinabove, a lug 50A for use in a wheel 10 may comprise a center rib 92, a first leg 95A and a second leg 95B, each leg extending from the center rib 92 laterally and opposite of each other, and a lug plate 91 adapted to connect the first leg 95A to the center rib 92. The first leg 95A and second leg 95B may form a W-shape with the centrally disposed center rib 92. In an embodiment, a lug 50A may be provided having a singular lug plate 91 with a rectangular cross section configured to connect one of the lug legs 95 to the center rib 92, but that utilizes two bolts 94 to secure to the ring 20. The lug leg that is connected to the lug plate 91 may be referred to as a first leg 95A, while the other leg may be referred to as a second leg 95B. Both the first leg 95A and the second leg 95B of a lug 50A may

each have a flat portion 97 in which a bolt hole 93 is disposed. A bolt 94 may travel through each bolt hole, such as the bolt holes 93 of **FIG. 7B**, disposed within each of the two flat portions 97 of the lug 50A to secure the lug 50A to the circular ring 20. The usage of two bolts 94 to attach said lug 50A to the ring 20 may be helpful in preventing rotation of said lug 50A after installation, as well as providing greater resistance to being broken off of the wheel, when compared to configurations that have a singular bolt 94. Alternative methods of securing the lugs 50A to the circular ring 20 may also be implemented, including implementing compression fittings, magnets, or other suitable fasteners on the lugs 50A to secure them to the ring 20. Some alternative methods, including welding, may not require the usage or presence of through holes 28 within the circular ring 20, but may increase assembly costs.

[0081] An overmolded rubber coat (“overmolded rubber layer,” “rubber coat”) 110 may be disposed on one or more surfaces of a metal interior frame 100 or may completely surround and encase said metal interior frame 100, in order to further strengthen and protect lug 50A. The metal interior frame 100 may be provided as a singular monolithic component, such as a metal plate, as in FIG. 11A-11B, as one or more separate wires, as in FIG. 7H, or in any other form capable of providing the required structural properties. The overmolded rubber coat 110 may cover only a portion of the lug, such as the bottom surface of the metal interior frame 100, as depicted in FIG 11A, or may cover the entire metal interior frame 100, as depicted in FIG 11B. As described hereinabove, an overmolded rubber layer 110 may occupy the interior 99 of the center rib 92 of the lug 50A, such that the bottom surface of the lug 50A is flat between the two flat portions 97 and a solid rubber body is disposed within the center rib 92. The presence of the solid rubber body disposed within the center rib 92 may further increase the strength of said lug 50A.

[0082] The different styles of overmolded rubber layer 110 may provide different benefits, depending on which portions of the metal interior frame 100 are covered. As described previously, an overmolded rubber layer that occupies the interior 99 of the center rib 92 may provide a solid body structure within the center rib 92 interior 99, which may increase the strength of the lug 50A and allow it to withstand a greater force without deforming or breaking. Having an overmolded rubber layer provided only on the bottom surface of the lug as described hereinabove may leave the metal interior frame 100 exposed at the top, which may have the advantage of providing a durable external surface that contacts the ground. Alternatively,

providing the overmolded rubber layer exclusively on the top surface of the lug, such that the overmolded rubber layer contacts the ground may help increase the friction between the wheel and the ground, enhancing the wheel's grip. The primary purpose of the overmolded rubber layer 110 on the top surface of the lug may be to provide the hereinabove described lug plate 91 to the lug 50A, as the metal interior frame 100 may not have a comparable lug plate structure of its own. This lug plate 91 may help provide greater traction between an attached wheel and a driving surface. Finally, by completely encasing and sealing the metal interior frame 100 within an overmolded rubber layer 110, the advantages of increased structural strength and enhanced wheel grip may both be provided, along with the protection of the enclosed metal interior frame 100 from the external elements, which may help increase the longevity metal interior frame 100.

[0083] When implementing an overmolded rubber layer 110 on a lug 50A, the overmolded rubber layer 110 may cover an entire surface of the metal interior frame 100, such that the overmolded rubber layer 110 and metal interior frame 100 have the same length and width. In an embodiment, an overmolded rubber layer 110 disposed on the bottom surface of a metal interior frame 100 may cover the entire bottom surface of said metal interior frame 100, such that the length and width of these two layers are the same, as depicted in FIG. 11A. By implementing an overmolded rubber layer 110 that has the same length and width as the metal interior frame 100 on a lug 50A, an entire surface of the frame metal interior frame 100 may be protected without significantly altering the lug 50A shape. Alternative embodiments in which the overmolded rubber layer 110 completely encases the metal interior frame 100 may require the rubber layer 110 to be slightly wider and longer than the metal interior frame 100 in order to completely encase it, though this slight size differences may not significantly affect the overall shape of the lug 50A. The lugs may be implemented on the wheel in a modular capacity, allowing for easy maintenance, repair or replacement of each lug as needed.

[0084] In an embodiment, the overmolded rubber layer 110 may have the same shape as the metal interior frame 100. In such an embodiment, such as the lug 50A of FIG. 11B, the structure of the lug 50A will have the benefit of enhanced structural stability for all elements of the lug 50A, including the legs 95, center rib 92 and lug plate 91. In alternative embodiments, the geometries of the overmolded rubber layer 110 and the metal interior frame 100 may differ. As seen FIG. 7H, the described lug, including the legs 95, center rib 92 and lug plate 91 may be formed by the overmolded rubber layer 110, while the metal interior frame 100 may comprise

three separate metal wire structures that do not share the disclosed lug shape, as seen in **FIG 7H**. Such an embodiment may be useful in limiting the amount of metal needed to form the lug, in applications in which greatly enhanced lug 50A strength is not required or lighter weight lugs are desirable.

[0085] In an embodiment, each lug secured to a wheel may have the same dimensions. Each lug may have a 15.75" length, 3.75" width and 3.75" height. With said lug dimensions, a standard farm wheel may fit 30 lugs around the outer surface of the ring of said wheel. The described configuration of this embodiment would be cost effective while fitting within the overall width parameters of the central pivot and lateral move irrigation industries.

[0086] **FIG. 12A** and **12B** illustrate perspective views of a farm irrigation wheel 10 attached to a center pivot irrigation system, according to an aspect. In an embodiment, the individual parts of a farm irrigation wheel 10 may include a circular ring 20, a rim 30 disposed within and attached to the circular ring, and a plurality of identical lugs 50A. The wheel 10 may be further comprising of a hub 70 disposed within the rim 30 that is configured to engage with suitable farming equipment. The rim 30 and hub 70 may be formed as a singular monolithic piece, which may help to simplify the wheel's design and enhance the wheel's structural integrity. The circular ring 20 may have an outer surface, such as outer surface 22 of wheel 10 in **FIG 2**, on which the lugs 50A are mounted, as well as rotational axis 12 shared with the wheel 10 itself. Unlike the sinusoidally shaped edges of ring 20 described in **FIG.9**, the pair of opposing edges 26 of ring 20 in **FIG. 12A** and **FIG 12B** of this embodiment are flat, such that ring 20 is cylindrical with level, circular edges 26.

[0087] It should be understood that while the opposite side of a wheel 10 may not be visible in a specific figure, it can be assumed that said opposite side has the same characteristics as the visible side, unless otherwise noted. The rim 30 may be disposed within the ring 20 and secured or otherwise attached to the inner surface 24 of said ring 20 by the rim's outer perimeter 31, such that the rim 30 is parallel with and positioned equidistantly from both opposing edges 26 of the ring 20. A hub 70 disposed at the center of the rim 30 may be configured to attach a center pivot irrigation system, as shown in **FIG. 1A**. Each lug 50A may be bolted to the outer surface of ring 20 as described hereinabove. A plurality of through holes 28 may be disposed within the outer surface of ring 20 such that each hole is centered (equidistantly disposed) between the opposing edges 26 of the ring 20, forming a circular pattern around the outer surface of the ring 20 that

runs parallel with the opposing edges 26 of ring 20. Alternatively, two circular patterns of through holes 28 may be disposed within the outer surface of the ring 20, such that each circular pattern of through holes 28 is disposed a fixed distance away from a corresponding opposing edge 26 as well as around the outer surface of the ring 20.

[0088] As discussed hereinabove, the positions of the lugs 50A may be determined by the position of through holes 28 disposed on the outer surface of the ring 20. As a result of the circular pattern(s) of the through holes 28, the attached lugs 50A may also be arranged in a circular pattern around the outer surface of the ring 20, wherein each of the plurality of lugs is uniformly centered between the opposing edges 26 and around the circular ring in a circular pattern. The outermost point of each center rib 92 from each lug may form a circular pattern that is coaxial with the rotational axis 12 of the circular ring 20. Similarly, the plurality of lugs 50A themselves may also form a circular pattern around the outer surface 22 of the ring 20, wherein said circular pattern is coaxial with the rotational axis. Said circularly arranged lugs 50A may also be arranged in an alternating pattern, similarly to lug 50B and lug 50C of FIG. 6, with the first leg 95A of each lug disposed between the second legs 95B of the adjacent lugs 50A, but with all lugs 50A arranged circularly around the ring 20, as depicted in FIG. 12A. The lugs 50A may be configured to attach to the other suitable wheels to provide the necessary grip for the desired application.

[0089] The wheel depicted in FIG 12A-12B provides an example of a wheel that may be implemented with the disclosed lugs 50A and is not intended to limit the scope of wheels on which said lugs may be implemented. Alternative wheels that may utilize the disclosed lugs includes the spoke-based wheels described hereinabove, as well as other spoke-based wheels that may suitably support the weight of an attached irrigation system. The disclosed lugs and their variations may be implemented on any wheel structure capable of provided the necessary wheel functionality to the aforementioned irrigation system, including wheels with spokes 71, rims 30, legs or other know wheel centers that connect the circular ring 20 to the irrigation system. As such, a wheel 10 intended for use with a farm irrigation system may comprise a wheel center, a circular ring 20 disposed around and attached to the wheel center and a plurality of lugs 50A configured to attach to the circular ring 20. The described wheel center may include a hub 70 or other comparable structure to facilitate the necessary attachment of the wheel to the corresponding piece of equipment. The ring 20 may be described as circular purely on the basis

of its side profile, which is typically circular for the majority wheels in many industries. The outer surface of the circular ring may be provided in a variety of forms, including the sinusoidal and flat edged variants discussed hereinabove, as well as any other form that allows for the maintenance of the circular profile of the ring 20 to enable proper travel of an attached structure.

[0090] **FIG. 13A-13E** illustrates the perspective views of a scalloped farm irrigation wheel (“scalloped wheel”, “scalloped rim”) 120, according to an embodiment. The scalloped farm irrigation wheel 120 of **FIG. 13A-13E** may comprise a ring 20, said ring being cylindrical in shape. The ring 20 of the scalloped farm irrigation wheel 120 may have at least one pattern (“set”) of sinusoidally arranged through holes 28, such that said through holes 28 are disposed on its outer surface 22, similar to ring 20 of **FIG. 9**. Unlike ring 20 of **FIG. 9**, the ring 20 of a scalloped wheel 120 may have flat edges 26 comparable to the flat edges 26 of ring 20 in **FIG 12A**, as seen in **FIG 13A-13E**. The scalloped farm wheel 120 may further comprise a rim 30 nested within the ring 20, said rim 30 having an outer perimeter 31 and a plurality of scalloped protrusions (“scalloped portions”) 121. The term “scalloped protrusion” 121 may be used to describe the pocket-like, alternating protrusions positioned on the rim 30, as seen in **FIG 13A-13E**. The scalloped protrusions 121 may be disposed on the outer perimeter 31 of said rim. The outer perimeter 31 of the rim 30 may be configured to directly engage with the inner surface 24 of the ring 20 such that the positioning of each scalloped portion 121 provides sufficient clearance around each through hole 28 on the ring 20 to allow for easy installation and removal of wheel lugs using an appropriate tool. As can be seen in **FIG 13A-13E**, the scalloped portions are configured to provide space around any through holes adjacent to said scalloped protrusions 121 to ease the process of installing or removing lugs from the scalloped wheel. The rim 30 having scalloped protrusions 121 may be secured to the ring 20 by welding or other suitable methods, or monolithically integrated into the ring 20 during manufacturing, such that rim 30 and ring 20 form a singular unified structure.

[0091] The scalloped protrusions 121 disposed on the rim 30 may cause the outer perimeter 31 of said rim 30 to have a reciprocating lateral offset between the edges 26 of the ring 20 that provides an increased contact surface between the rim 30 and ring 20, when compared to the previously disclosed rims 30 that lack said scalloped protrusions 121. This increased contact surface between the rim 30 and ring 20 may increase the structural integrity of the scalloped wheel 120 and allow it to withstand greater loads without becoming damaged or deformed. This

reciprocating lateral offset of the outer perimeter 31 of the rim 30 may be similar to the arrangement of lugs described for **FIG 4**, in which the engagement surface between the outer surface 31 of the rim 30 and the ring 20 may execute a roughly sinusoidal curve having an amplitude and a period. This roughly sinusoidal curve of the engagement surface between the outer perimeter 31 of the rim 30 and the ring 20 may be coaxial with the rotational axis 12 of the wheel. By having a rim 30 that roughly follows the same pattern as the through holes 28 and any attached lugs (e.g., a sinusoidal pattern), said rim 30 may provide ample support to a central portion of each attached lug, thus providing greater structural integrity to the scalloped wheel 120 when compared to alternative configurations in which the rim 30 does not follow the same pattern as the through hole 28, and thus any attached lugs.

[0092] The reciprocating lateral offset of the outer perimeter 31 may result in the distance between the outer perimeter 31 and each edge 26 of the ring 20 being varied in accordance with the positioning of the nearby through holes 28, which will be described in greater detail hereinbelow. The “lateral” direction in the context of the “reciprocating lateral offset” may refer to the direction defined by the rotational axis 12 of the wheel. A hub 70 may be disposed within and secured to the rim 30, wherein said hub 70 is configured to engage with the drivetrain of a suitable vehicle assembly. Much like the prior disclosed wheels 10, the disclosed scalloped wheel 120 may be configured to rotate about a wheel rotational axis 12 to facilitate vehicle movement.

[0093] In order to more easily accommodate installation/removal of lugs, such as lug 50A of **FIG. 12A**, on the hereinabove described scalloped wheel 120, the orientation and positioning of the scalloped protrusions 121 disposed on the rim 30 may be configured such that the rim 30 avoids blocking or impeding access to each through hole 28 of each pattern or set of sinusoidally arranged through holes on the ring 20. This may be done by having the scalloped protrusions 121 arranged on the rim 30 such that the engagement surface between the outer perimeter 31 of the rim 30 and the ring 20 is sufficiently distant from each through hole 28 on the ring 20, such that an appropriate tool, such as a socket wrench or torque wrench, may be easily maneuvered near the through hole 28 to fasten/remove a bolt, screw or other comparable fastener, securing a lug to the ring 20, without having the rim 30 block or otherwise impede the utilization of said tool. As can be seen in **FIG 13A-13E**, the ring 20 may have two adjacent sets of sinusoidally arranged through holes 28 wherein said sets of sinusoidally arranged through holes 28 are configured to

engage with a plurality of lugs, such as lug 50A of **FIG 7D**, and each lug is configured to attach to the ring 20 using two bolts 94. The two adjacent sets of sinusoidally arranged through holes may be arranged such that a sinusoidal pattern defined by each set is in phase with the sinusoidal pattern of the other set. Both sets being “in phase” with each other would indicate that the maximum and minimum lateral offsets toward a specific edge 26, and thus the maximum amplitude/minimum amplitude of each sinusoidal pattern, would occur at the same radial angles of the wheel for both sets, as can be seen in **FIG 13A-13E**.

[0094] Each lug may be configured to engage with a singular through hole 28 from each set of sinusoidally arranged through holes 28, such that upon installation, each lug is parallel with adjacent lugs, as seen in **FIG 6**. Much like the arrangement of lugs in **FIG. 4**, any lugs secured to the scalloped wheel 120 may be positioned on the outer surface of the ring 20 in laterally offset positions (see **FIG. 5**) with respect to each other to form a continuously and possibly smoothly varying locus of the central points, wherein said lugs form a sinusoidal pattern around the ring 20 of the scalloped wheel 120. As can be seen by the scalloped wheel 120 of **FIG 13A-13E**, the scalloped portions 121 of the rim 30 may be configured such that the engagement surface between the ring 20 and rim 30 is always disposed between corresponding adjacent through holes of the two adjacent sets of sinusoidally arranged through holes 28. In such an embodiment, the positioning of the scalloped portions 121 may provide sufficient clearance around each bolt (not shown) traveling through each through hole 28, thus making it easier to utilize tools configured to ease the installation and uninstallation of lugs to and from the ring 20.

[0095] It should be understood that modifications to the positioning and size of the scalloped protrusions 121 on the rim 30 of a scalloped wheel 120 may be made in order to ease lug installation for alternative scalloped wheel configurations. For example, an alternative scalloped wheel 120 may have a singular set of sinusoidally arranged through holes on its ring 20, similarly to how the through holes 28 are arranged on the ring 20 of **FIG 9**, but wherein said ring 20 has flat edges 26. If a flat rim, such as rim 30 of wheel 10 in **FIG 12A**, were utilized in a wheel having a singular set of sinusoidally arranged through holes 28, a portion of the through holes 28 may be blocked by the positioning of said rim 30 or said through holes may have insufficient surrounding clearance around them to allow for proper utilization of a tool for lug manipulation. The scalloped portions 121 may be selectively positioned on the rim 30 to avoid said the rim 30 from blocking said through holes 28, similarly to what is seen in **FIG 13A**, by

having the scalloped portions 121 laterally offset the outer perimeter 31 of the rim 30 such that the engagement of the outer perimeter 31 of the rim 30 with the ring 20 leaves sufficient clearance around the each through hole 28.

[0096] As described hereinabove, the outer perimeter 31 of the scalloped rim 30 of **FIG. 13A-13E** may have a reciprocating lateral offset that is roughly sinusoidal as a result of the positioning of the scalloped protrusions 121, and thus may need to engage with the ring 20 such that the roughly sinusoidal pattern of the outer perimeter 31 of the rim 30 does not block or otherwise impede access to any through holes. In order to facilitate this engagement, the roughly sinusoidal pattern of the outer perimeter 31 may be sufficiently laterally offset and in-phase with the singular sinusoidal pattern of the through holes 28 in this alternative embodiment. It should be understood that the scalloped rim 30 may be associated with the lugs within a wheel assembly, due to the fact that the scalloped rim 30 and lugs may both be secured to the ring 20 of the scalloped wheel 120.

[0097] The disclosed hub 70 of the scalloped wheel 120 may be configured to suitably engage with the drivetrain of a center pivot irrigation system. Said hub 70 may be secured within an inner perimeter 32 of the rim 30, through welding or comparable methods, or monolithically integrated into the rim 30. The disclosed scalloped wheel 120 may be compatible with two common size variants of drive units utilized in the industry, including short shaft drive unit and long shaft drive unit variants. As a result of both of these drivetrain variants having the same stud pattern, the disclosed stud through holes 72 in the hub 70 of the disclosed scalloped wheel 120 may be suitably arranged to allow engagement of said scalloped wheel 120 with either drivetrain variant. The disclosed scalloped wheel 120 may be provided with a built-in lateral offset 122 between the hub 70 and the ring 20 that provides lateral clearance between the scalloped wheel 120 and drive unit of the short shaft drivetrain variant (not shown) and prevents the scalloped wheel 120 and said drive unit from colliding during operation. It should be understood that the term “built-in lateral offset” is referring to the lateral displacement (e.g., positioning along the wheel rotational axis 12) of the hub 70 when compared to a central portion of the ring 20, wherein said central portion of the ring 20 is centrally disposed between the edges 26 of the said 20. This built-in lateral offset 122 provides an even greater clearance between the scalloped wheel 120 and the drive unit of the long shaft drivetrain variant, thus ensuring proper wheel 120 operation. The capability of the disclosed scalloped wheel 120 of **FIG. 13A-13E** to be utilized

with either of the two driveshaft lengths (short or long) used in the industry simplifies the manufacture of said scalloped wheel 120 to a singular design for use with both described drivetrain variants.

[0098] The disclosed rim 30 of the scalloped wheel 120 may be configured to allow the scalloped wheel 120 to greatly resist deformation and damage while bearing a heavy load. As a result of the solid, unified rim 30 design and the reciprocating lateral offset of the outer perimeter 31 of said rim 30, and thusly the laterally reciprocating interface between the rim 30 and the ring 20 of the scalloped wheel 120, said scalloped wheel 120 may be capable of supporting heavier loads than wheels that utilize spokes or flat rims to attach the wheel hub 70 to the ring 20. The reciprocating interface that results from the reciprocating lateral offset of the outer perimeter 31 of the scalloped rim 30 provides a greater interface area between rim 30 and the ring 20 when compared to prior disclosed flat rims, thus enhancing the structural integrity and load bearing capabilities of the scalloped wheel 120. Similarly to the prior disclosed spokes 71 of **FIG. 6**, the disclosed scalloped protrusions 121 may also help increase each scalloped wheel's engagement with the ground while the wheel is partially submerged in softer soil, as a result of the shape of each scalloped protrusion increasing the attached wheel's surface area, thus increasing the scalloped wheel's traction with the ground when submerged. For example, each scalloped protrusion 121 may act like a paddle to help grip into the soil and dig out the scalloped wheel 120 when it is submerged in soft or loose soil.

[0099] It should be understood that the disclosed scalloped rim 30 of **FIG 13A-13E** having scalloped protrusions 121, and thus a reciprocating outer perimeter 31, may be utilized within any of the rings 20 disclosed herein, as long as the interface between the scalloped rim 30 and the ring 20 is appropriately configured to provide sufficient clearance around each through hole 28 on said ring 20 to allow for suitable access to the lugs for installation or uninstallation. The rim 30 and ring 20 of the disclosed scalloped wheel 120 may be secured to each other through the usage of welding or other suitable attachment methods known in the industry. The disclosed scalloped wheel 120, as well as each of the hereinabove described wheels 10, may also be manufactured as a monolithic body through manufacturing techniques such as injection molding. As with all wheels 10 described herein, the disclosed parts and components of scalloped wheel 120 may be made of metal or other known materials having suitable tensile strength, elasticity, flexibility and other characteristics to achieve the wheels intended purpose. The disclosed

configuration of the scalloped rim 30 seen in **FIG 13A-13E** may be desirable in applications that require a wheel having enhanced load bearing capabilities and maintaining said wheel's ability to provide traction when partially submerged in looser soil, while ensuring the rim 30 leaves sufficient clearance around each through hole 28.

[00100] It should be understood that the term “circular pattern” may also be used to describe the through hole 28 arrangement, and thus a resulting lug arrangement, depicted in **FIGs 13A-13E**, wherein the through holes 28 are arranged sinusoidally around the outer surface 22 of the ring 20 such that said arrangement is depicted as circular from a side profile view, similarly to what is seen in **FIGs 13C-13D**, and sinusoidal from a front profile view, similarly to what is seen in **FIG 13E**. It should also be understood that the term “circular pattern” may be used to describe the type of lug arrangement (and corresponding through hole 28 arrangement) depicted in **FIGs. 12A-12B**, wherein the lugs 50A, and thus the corresponding through holes 28, are arranged linearly around the outer surface of the ring 20, such that said arrangement is depicted as circular from a side profile view and linear from a front profile view. The pattern of through holes 28 depicted in **FIGs 9** and **13A-13E**, and thus the pattern of the correspondingly attached lugs, may be more specifically referred to as a “sinusoidal pattern”. Similarly, the pattern of lugs 50A depicted in **FIGs 12A-12B**, and thus the corresponding pattern of through holes 28 used to secure them, may be more specifically referred to as a “linear pattern”. As such, both the “sinusoidal pattern” and the “linear pattern” described herein should be understood to be different types of “circular patterns.”

[00101] **FIGs. 14A-14B** illustrate side perspective and front perspective views, respectively, of an alternative embodiment of a wheel 10 having paddle lugs 130, according to an embodiment. As is understood, various embodiments of the disclosed lugs may be installed on a corresponding farm irrigation wheel 10, depending on the needs of the application, soil conditions, and other relevant factors. The particular shape and characteristics of the paddle lugs 130 will be discussed in greater detail hereinbelow. While embodiments of the wheel 10 disclosed hereinbelow may utilize paddle lugs 130 and may all have scalloped rims 30 (and thus may be described as “scalloped wheels”), it should be understood that the disclosed paddle lugs 130 may be adapted for compatibility with other wheel/rim types.

[00102] Similarly to the lug of **FIG. 7F**, the paddle lug 130 of **FIG. 14A-14B** may have two lug plates 91, however, the particular characteristics of the lug plates 91 of said paddle lug may differ

from those of FIG. 7F with regards to their size, general shape and attachment angle, as will be described in greater detail hereinbelow. The paddle lugs 130 may also be secured to the circular ring 20 of the wheel 10, such that said paddle lugs 130 form a sinusoidal pattern around the ring 20 of the wheel 10, as described hereinabove.

[00103] It should be understood that the potential dimensions described herein are provided merely as an example, and thus are not intended to limit the dimensions of other potential farm irrigation wheel embodiments. In an embodiment, while not supporting any weight, the outer diameter of the farm irrigation wheel 10 of FIG. 14A may be about 45.425 inches when measured from the distal most points of opposing paddle lugs (e.g., the distal edges 91A of opposing lug plates 91) engaged on “opposing ends” of said farm irrigation wheel 10. In said embodiment, the ring 20 of the scalloped farm irrigation wheel 10 on which the paddle lugs 130 are mounted may have a diameter of about 38.96 inches. This ring 20 may have a width of about 8.418 inches, wherein the width is measured along the wheel rotational axis 12, as seen in FIG. 14B. In an embodiment, the scalloped farm irrigation wheel 10 may be made from hot dip galvanized steel and said scalloped farm irrigation wheel 10 may be configured specifically for the disclosed lugs, such as the paddle lugs 130 of FIG. 14A-14B.

[00104] As is understood, the size and shape of the paddle lugs 130, as well as the operational conditions exerted upon the scalloped farm irrigation wheel 10 may also influence said scalloped farm irrigation wheel's overall dimensions. In an embodiment, each paddle lug may have a width of about 17.909 inches, as measured along the wheel rotational axis 12, as seen in FIG. 14B. In an embodiment, when a scalloped farm irrigation wheel 10 having paddle lugs 130 is being used on soft soil while bearing a load, the rolling diameter of the farm irrigation wheel 10 may be about 42.498 inches (when measured from the distal edges 91A of opposing paddle lugs 130). In contrast, in an alternative embodiment wherein a scalloped farm irrigation wheel 10 having paddle lugs 130 is being used on hard soil while bearing a load, the rolling diameter of the farm irrigation wheel 10 may be about 43.729 inches. Both the hardness of the soil the wheel 10 is rolling on, and the weight of the load supported by the farm irrigation wheel 10 may influence the extent to which the paddle lugs 130 flex, and thus the overall farm irrigation wheel dimensions. In an embodiment, the disclosed farm irrigation wheel 10 may have a rolling circumference of about 140 inches.

[00105] FIGs. 15A-15C illustrate top elevation, front perspective and bottom perspective views, respectively, of a paddle lug 130, according to an embodiment. In an embodiment, the paddle lug 130 may have a somewhat similar shape to the lugs of previously described embodiments, such as lug 50A of FIG. 11A. The paddle lug 130 may comprise a center rib 92, a first leg 95A and a second leg 95B, each leg 95A, 95B extending from the center rib 92 laterally and opposite of each other. The paddle lug 130 may further comprise two lug plates 91-1, 91-2, wherein a first lug plate 91-1 is adapted to connect the first leg 95A to the center rib 92 and the second lug plate 91-2 is adapted to connect the second leg 95B to the center rib. In short, the paddle lug 130 of FIG. 15A may be similar to the lug 50A of FIG. 11A, with several notable exceptions, as described hereinbelow.

[00106] The particular shape of the paddle lug 130 may differ from the previous lug embodiments in several ways. The lug plates 91-1, 91-2 of the paddle lug 130 be notably larger/taller than the lug plates of previously disclosed lug embodiments, and thus may protrude a greater distance away from the first and second legs 95A, 95B, respectively. When compared to the lug plate 91 of lug 50A of FIG. 11A-11B, each lug plate 91 of the paddle lug 130 may extend out further from flat portion 97 of each leg 95A, 95B and beyond the center rib 92, thus resulting in taller lug plates 91 than disclosed in previous embodiments. This increased height of each lug plate 91 of the paddle lug 130 results in the lug plates 91 contacting the ground before the center rib 92 when engaging with a driving surface, thus allowing the lug plates 91 to better dig into a driving surface to provide traction to the attached equipment. In an embodiment, the lug plates 91-1, 91-2 of the paddle lug 130 may have rounded distal edges 91A, rather than flat planar distal edges as seen on previous lug plate embodiments.

[00107] As can also be seen in paddle lugs 130 of FIG. 15A-15C, unlike previously described lug embodiments, each lug plate 91 may not be parallel with the corresponding leg 95A, 95B that it is associated with, and thus not parallel with the long edges 130A of the paddle lug 130. In contrast, each lug plate 91 of the paddle lug 130 may be angled such that each lug plate 91-1, 91-2 is disposed at an angle on a corresponding lug plate axis 131-1, 131-2, respectively. A lug axis 132 may be utilized to help define the corresponding plate angle 133-1, 133-2 of each lug plate axis 131-1, 131-2, wherein the lug axis 132 is parallel with and equidistantly disposed between the long edges 130A of a paddle lug 130, as seen in FIG 15A. A first plate angle 133-1 may be measured between a first plate axis 131-1 and the lug axis 132 and a second plate angle 133-2

may be measured between the second plate axis 131-2 and the lug axis 132. In an embodiment, the first plate angle 133-1 and the second plate angle 133-2 may be within about 1-10 degrees of each other. In another embodiment, the first plate angle 133-1 and the second plate angle 133-2 may be substantially the same (e.g., differ by less than 1 degree). In an embodiment, the first plate angle 133-1 and the second plate angle 133-2 may be non-zero values (e.g., values that are not 0), such that the lug plates 91 are angled with respect to the lug axis 132. In an embodiment the first plate angle 133-1 and the second plate angle 133-2 may be substantially the same value between about 15 degrees and about 20 degrees.

[00108] Due to the rounded distal edges 91A of the lug plates 91-1, 91-2, and the general shape of the paddle lug 130 and its legs 95A, 95B, the height of the lug plates 91-1, 91-2 may appear taller between the flat portion 97 and the distal edge 91A (e.g., center plate height 135A) and shorter as the lug plate 91 extends toward the corresponding short edge 130B of the paddle lug (e.g., exterior plate height 135B), as seen in FIG. 15B. The height of each lug plate 91-1, 91-2 may appear smallest at the center 130C of the paddle lug 130, wherein the center rib 92 already protrudes a significant height above the flat portion 97 of each leg 95A, 95B of the paddle lug 130 (e.g., interior plate height 135C). As with certain previously disclosed lug embodiments, such as the lug of FIG. 7B, the legs 95A, 95B and center rib 92 of the paddle lugs 130 of FIG. 15A-15C may form a W-shape, wherein each lug plate 91 is configured to protrude above and beyond the corresponding legs 95A, 95B and the center rib to which it attaches (when viewed from the perspective of FIG. 15B.)

[00109] As with the prior disclosed lug embodiments, each paddle lug 130 may be secured to the circular ring of a farm irrigation wheel through suitable means. In an embodiment, each paddle lug 130 may be secured to a scalloped farm irrigation wheel, such as scalloped farm irrigation wheel 10 of FIG. 13A by bolts 94, or any other suitable engagement method. In an embodiment, the usage of reversible engagement mechanisms may be preferred for ease of repair/replacement.

[00110] FIGs. 16A-16C illustrate front perspective views of paddle lugs 130 in various flex states, according to an embodiment. In order to reduce the stress exerted on the drivetrain of an attached vehicle, while also increasing contact surface area of a wheel with the ground during operation (e.g., while bearing a load) each paddle lug 130 may be configured flex to different extents depending on the weight of the load that is supported by the wheel and the hardness of

the ground upon which it stands. FIG. 16A may show a paddle lug 130 that is not bearing any load, and thus is in a normal, unflexed state. As is understood, the legs 95A, 95B and center rib 92 of the paddle lug 130 may form a W-shape consistent with the lugs shown in previous embodiments while not supporting any weight. As can be seen in FIG. 16A, while the paddle lug 130 is in the normal, unflexed state (e.g. no load is applied to the attached wheel), the portions of the lug plate 91 disposed on the short edges 130B of the paddle lug 130 may have a greater vertical displacement (e.g., radial displacement off of the surface of an attached circular ring of a wheel) as the portion of the lug plate disposed 91 on the center rib 92 of the paddle lug 130, as articulated by level line 136 of FIG. 16C.

[00111] As with previously disclosed lug embodiments, the legs 95A, 95B and the center rib 92 may form a W-shape having a particular height, wherein one leg 95A forms a first leg of the W-shape, the center rib 92 forms the middle peak of the W-shape, and the other leg 95B forms the opposite leg of the W-shape. In the paddle lug embodiment of FIG. 16A-16C, each lug plate 91 may be configured to extend above a top of the W-shape, such that the distal edge 91A of each lug plate 91 is disposed above said legs 95A, 95B and the center rib 92. In other words, the distal edges 91A of the lug plates 91 may be configured to extend or protrude beyond the W-shape formed by the legs 95A, 95B and the center rib 92, (e.g., radially extend beyond the center rib) and thus above the formed W-shape when viewed from the perspective of FIGS 16A-16C.

[00112] As the weight exerted on the paddle lug 130 is increased, each leg 95A, 95B of the paddle lug may be forced “downward” (e.g., toward the rotational axis of the wheel), thus resulting in the paddle lug 130 becoming shorter and wider, as seen in the partial flex state of FIG. 16B. As the weight exerted on the paddle lug 130 is increased further, each leg 95A, 95B may continue to be forced “downward” until the legs 95A, 95B are almost flat to the surface of the circular ring of the wheel, as seen in the full flex state of FIG. 16C. This may further increase the effective width of the paddle lug 130, thus increasing said paddle lug’s effective surface area that is contacting the ground, allowing it to reduce the pressure it exerts upon the ground while also reducing the stress exerted on the drivetrain and/or gearbox. It should be understood that the extent to which paddle lug flexes is dependent upon the materials used to construct the paddle lug 130 and their thickness. In an embodiment, the paddle lugs 130 may be made of spring steel with overmolded rubber to protect and insulate said spring steel. As can be seen in FIG. 16C, while the paddle lug 130 is in the full flex state, the portions of the lug plate 91 disposed on the

short edges 130B of the paddle lug 130 may have approximately the same vertical displacement as the portion of the lug plate disposed 91 on the center rib 92 of the paddle lug 130, as articulated by level line 136 of FIG. 16C.

[00113] FIG. 17A illustrates a front perspective view of a high traction embodiment of the farm irrigation wheel 10, according to an embodiment. FIGs. 17B-17C illustrate front perspective views of a paddle lug 130 adjacent to a high traction lug 140, according to an aspect. Depending on the type of soil the wheel is rolling on, the weight of the vehicle/structure being supported, etc., certain alterations may be made to the disclosed farm irrigation wheel 10 having paddle lugs 130 of FIG. 14A-14B to facilitate improved traction of the farm irrigation wheel 10 as it rotates.

[00114] In an embodiment, a farm irrigation wheel 10 may have a scalloped rim 20, a plurality of paddle lugs 130 and at least one high traction lugs 140, and thus may be identified as a high traction farm irrigation wheel 10. Said high traction farm irrigation wheel 10 may be configured such that every third lug attached to the wheel 10 is a high traction lug 140, whereas the remainder of the lugs may be the prior disclosed paddle lugs 130 of FIG. 15A-15C. As such, a repeating pattern of a first paddle lug 130-1, followed by a second paddle lug 130-2, followed by a high traction lug 140 may repeat around the ring 20 of the wheel 10, wherein the second paddle lug 130-2 is disposed between the first paddle lug 130-1 and the high traction lug 140. In an embodiment, a total of thirty lugs may be secured to the ring 20 of a wheel 10, wherein ten of the lugs are high traction lugs 140 and twenty of the lugs are paddle lugs 130. It should be understood that alternative, repeating patterns of lugs may also be utilized depending on the amount of traction required, soil composition and soil conditions, amongst other factors that may influence wheel function. For example, in an alternative wheel embodiment, every other lug may be a high traction lug 140, such that each high traction lug is adjacent to two paddle lugs 130, and each paddle lug 130 is adjacent to two high traction lugs.

[00115] In an embodiment, each plate 91 of a paddle lug 130 may have an associated first plate height 157, as measured on the short edge 130B of the lug from the base of the plate 91 that is in direct contact with the corresponding leg of the paddle lug 130 to the distal edge 91A of said plate 91. Furthermore, each plate 91 of a high traction lug 140 may have an associated second plate height 158, as measured on the short edge 140B of the lug from the base of the plate 91 that is in direct contact with the corresponding leg of the high traction lug to the distal edge 91A of

said plate 91. In said embodiment, the second plate height 158 may be greater than the first plate height 157, to provide the resultant wheel 10 with a varied outer diameter configured to better grip more challenging ground surfaces, such as loose soil or soil with high clay content. While being used in soil having high clay content, the alternating lengths of the plate heights 157, 158 of the paddle lugs 130 and the high traction lugs 140 may be configured to prevent the wheel 10 from being filled in with clay as it rolls, thus ensuring the wheel 10 can maintain traction with the ground surface. As such, inclusion of the high traction lugs 140 on the disclosed farm 10 is configured to significantly improve traction performance and reduce slippage of said wheel 10 in clay rich soil. In an embodiment, the second plate height 158 may be about 1-2 inches greater than the first plate height 157, as can be seen in FIGs. 17B-17C. Furthermore, the thickness 91B of each plate 91 on a high traction lug 140 may be greater than the thickness 91B of each plate 91 on a paddle lug 130, to better support the extra height of the corresponding plates 91 on said the high traction lugs 140.

[00116] It should be understood that both the paddle lugs 130 and the high traction lugs 140 may still fall under the classification of “lug” such that the plurality of lugs configured to be mounted on the ring of a wheel may comprise a plurality of paddle lugs 130 and at least one high traction lug 140. It should be understood that the specifications of the paddle lugs 130 and high friction lugs 140 (e.g., the first and second plate heights 157, 158, first and second plate angles, etc.) may need to be suitably adjusted to provide superior grip when rolling over various selected terrains, including heavy clay, loam and sand-based soil types, without losing traction and while maintaining maximum flotation capabilities and reducing drivetrain stresses. As is understood, the plurality of lugs, which comprises the plurality paddle lugs 130 and plurality of high traction lugs 140, may form a circular pattern (such as a sinusoidal pattern) that is coaxial with the rotational axis 12, as can be seen in FIG. 17A.

[00117] As can be seen in FIG. 17A-17B, for each lug 130, 140 of the wheel 10, a distal edge 91A of the first lug plate 91-1 and a distal edge 91A of the second lug plate 91-2 are configured to radially extend beyond the center rib 92. In other words, for a wheel, the radial edges 91A of each lug plate 91-1, 91-2 for each paddle lug 130 and high traction lug 140 may be disposed a greater distance from the wheel rotational axis 12 than the corresponding center rib 92 of each paddle 130, 140. The radial distance from the wheel rotation axis 12 may be articulated by radial extension line 170 of FIG. 17B, wherein the arrowhead of the radial extension line 170 points

further away from the wheel rotational axis, and thus toward increased radial displacement. In an embodiment, these lug plates 91 having distal edges 91A configured to radially extend beyond the center rib may be configured to provide improved grip to the associated wheel, as a result of the longer lug plates 91-1, 91-2 being able to dig into the soil/ground better to provide more traction to the wheel while rolling.

[00118] FIG. 18A illustrates the tread patterns for correctly installed farm irrigation wheels 10-1, 10-2 attached to a structure 180, according to an embodiment. FIG. 18B illustrates a top view of aligned front and rear farm irrigation wheels 10-1, 10-2 configured for engagement with a structure, according to an embodiment. FIG. 18C illustrates a side view of aligned front and rear farm irrigation wheels 10-1, 10-2 configured for engagement with a structure, according to an embodiment. As disclosed hereinabove, embodiments of the farm irrigation wheel 10 having a scalloped rim 30 and a plurality of paddle lugs 130 may still have said paddle lugs 130 arranged in a sinusoidal pattern around the farm irrigation wheel 10. For structures having front mounted wheels and rear mounted wheels, the particular arrangement of the lugs on the front and back wheels may be relevant, as will be discussed hereinbelow.

[00119] As can be seen in FIG. 18A, the sinusoidal pattern of the paddle lugs 130 on the front wheel 10-1 may be configured such that the leading rut 150-1 driven into the soil 151 by the front wheel 10-1 is fully “out-of-phase” with the following rut 150-2 driven into the soil by the back wheel 10-2 (e.g., the sine wave shape of the leading rut 150-1 and the sine wave shape of the following rut 150-2 have the same frequency, but a 180 degrees phase difference/ are 180 degrees out of phase with each other). In other words, when the leading rut 150-1 is hitting a maximum amplitude, the following rut 150-2 is hitting a minimum amplitude, and vice-versa. This fully out-of-phase relationship between the leading rut 150-1 and the following rut 150-2 may produce a double helix/double sinusoidal pattern in the soil 151, as seen in FIG. 18A. This double helix pattern of ruts 150-1, 150-2 may be ensured through proper alignment of the wheels 10-1, 10-2 based on their separation from each other while attached to the supported structure/vehicle.

[00120] In an embodiment, a structure may be configured such that a fixed separation distance 152 is disposed between the front wheel 10-1 and the back wheel 10-2. Depending on the size of the wheels 10-1, 10-2, their corresponding lugs, and the separation distance 152 (which is dictated by the vehicle/machine that the wheels 10-1, 10-2 are attached to), the front wheel 10-1

and back 10-2 may be suitably aligned and rotated prior to engagement with the structure to facilitate production a double helix/double sinusoidal pattern in the soil 151 as the vehicle/structure moves, as shown in FIG. 18A. In an embodiment, in order to produce a double helical rut pattern (e.g., the leading rut 150-1 is fully out-of-phase with the following rut 150-2), it may be necessary to have the front wheel 10-1 be rotated/aligned such that a paddle lug 130-3 engaged with the front wheel 10-1 at the 12 o'clock position on said front wheel 10-1, as seen in FIG. 18B-18C, may have a minimal axial displacement (e.g., be at a minimum amplitude of the sinusoidal pattern formed by the paddle lugs 130, and thus furthest left in FIG. 18B) whereas a paddle lug 130-4 engaged with the back wheel 10-2 at the 11 o'clock position, as seen in FIG. 18B-18C, may have a maximal axial displacement (e.g., be at a maximum amplitude of the sinusoidal pattern formed by the paddle lugs 130, and thus furthest right in FIG. 18C).

[00121] It should be understood that the “double helical” rut pattern, may be alternatively described as a “double sine wave rut pattern” or a “double sinusoidal rut pattern,” as the rut pattern embedded in the soil may suitably be articulated as two axially aligned, fully out-of-phase sinusoidal curves (e.g., a fully out-of-phase, double sinusoidal shape). For example, for a fully out-of-phase double sinusoidal/double helical rut pattern, when the leading rut 150-1 reaches a minimum amplitude offset 154b, the following rut 150-2 reaches a maximum amplitude offset 154a, and vice-versa. Additionally, both the leading and following ruts 150-1, 150-2 may be coaxially aligned on a rut line 155, where the leading and following ruts 150-1, 150-2 may meet at rut junctions 156 disposed between the maximum and minimum amplitude offsets for each rut 150-1, 150-2. In other words, as the lugs on the front wheel 10-1 “move” left to right and leave a shallow sinusoidal leading rut 150-1, the lugs on the rear wheel 10-2 “move” the opposite direction, right to left, producing a fully out-of-phase, shallow sinusoidal following rut 150-2. Furthermore, the rear wheel 10-2 may be configured to more or less push the soil displaced by the front wheel 10-1 back to where it started to mitigate the soil displacement caused by the wheels 10-1, 10-2.

[00122] Having the front wheel(s) 10-1 and the back wheel(s) 10-2 produce ruts 150-1, 150-2 that are fully out-of-phase with each other, and thus produce a double helical pattern in the soil 151 may be helpful for minimizing the disruption caused by the wheels 10-1, 10-2, and thus the supported structure, rolling over the soil 151 in the field. The disclosed wheels 10-1, 10-2 may thusly be configured to push soil toward the center of the wheel tread, rather than push the soil

outwardly away from the wheels 10-1, 10-2. This in turn may minimize the extent to which the soil 151 is disrupted, thus protecting planted crops from being damaged and minimizing the depth of the ruts dug into the soil. Due to the unique structure of the wheels 10-1, 10-2 and their disclosed paddle lugs 130, said wheels may be configured to only leave a 1-inch deep rut in the ground, thus minimizing soil disruption while also reducing soil compaction.

[00123] FIG. 19A-19C illustrate a front perspective, side perspective and enlarged side perspective views, respectively of an alternative farm irrigation wheel having pneumatic lugs 160, according to an aspect. Depending on the application of the disclosed farm irrigation wheel 10, it may be beneficial for the elements of the farm irrigation wheel 10, such as the lugs, to contain hollows or pockets (e.g., air bladder 161) configured to increase the buoyancy of said farm irrigation wheel 10. In said embodiments, the lugs may be pneumatic in nature, and thus may be described as pneumatic lugs 160.

[00124] In an embodiment, each pneumatic lug 160 may comprise a first leg 95A, an opposing, second leg 95B and an air bladder 161 configured to contain pressurized air, wherein this air bladder 161 may be disposed between and associated with a first leg 95A and a second, opposing leg 95B, as seen in FIG. 19A-19B. In order to facilitate the filling of an air bladder 161 of a pneumatic lug 160 with a corresponding volume/pressure of air, each pneumatic lug may further comprise a valve stem 166 in pneumatic communication with the air bladder 161, wherein the valve stem 166 configured to receive air, as seen in FIG. 19B. In an embodiment, each air bladder 161 may be self-contained, and thus function independently of the air bladders 161 of adjacent pneumatic lugs 160, such that moderation of air bladder pressure for each pneumatic lug 160 may be controlled independently. In an alternative embodiment, a plurality of air bladders 161 from different pneumatic lugs 160 may be in pneumatic communication with each other through an air hose 167 that is in pneumatic communication with each corresponding air bladder 161, or more specifically, in pneumatic communication with each corresponding air bladder 161 through their respective valve stems 166, as seen in FIG. 19C.

[00125] In order to provide optimal travel performance for an attached vehicle or structure, the structure of each pneumatic lug 160 may vary somewhat between embodiments. In a first embodiment, the pneumatic lug 160 may comprise a first leg 95A, a second, opposing leg 95B, an air bladder disposed between and associated with the first leg 95A and the second opposing leg 95B, a first leg paddle 162A engaged/associated with the first leg 95A and a second leg

paddle 162B engaged/associated with the second leg 95B. For simplicity, this above described lug embodiment may be described as a basic pneumatic lug, such as basic pneumatic lug 160 of FIG. 20B.

[00126] In another embodiment, the structure of the basic pneumatic lug 160 of FIG. 20B may further comprise a pair of bladder paddles 163A, 163B associated with the air bladder 161. This particular embodiment of the pneumatic lug having the pair of bladder paddles 163A, 163B in addition to all of the features of the basic pneumatic lug 160 of FIG. 20B may be described as an intermediate pneumatic lug, such as intermediate pneumatic lug 160 of FIGS. 19B and 20A.

[00127] In another embodiment, the structure of the intermediate pneumatic lug 160 of FIG. 20A may further comprise a pair of front paddles 164A, 164B associated with the air bladder 161 and disposed on the front end 160A of the pneumatic lug 160 and a pair of back paddles 165A, 165B associated with the air bladder 161 and disposed on the back end 160B of the pneumatic lug 160. This embodiment of the pneumatic lug 160 having a pair of front paddles 164A, 164B, a pair of back paddles 165A, 165B and all of the features of the intermediate pneumatic lug 160 of FIG. 20A may be described as a complex pneumatic lug, such as complex pneumatic lug 160 of FIGS. 19A and 19C. In an embodiment, a wheel utilizing the pneumatic lugs 160 disclosed herein may similarly be configured to produce a sinusoidal rut in the ground, said sinusoidal rut having a minimized depth, as described hereinabove in FIG. 18A-18C, when rolling over soil (or another suitably displaceable materials), such that vehicles having wheels which follow the same path may produce the double sinusoidal pattern described hereinabove in FIG. 18A-18C. Furthermore, similarly to wheel embodiments described above, the plurality of pneumatic lugs 160 may form a circular pattern that is coaxial with a rotational axis of the wheel.

[00128] **FIG. 20A** illustrates a front elevation view of a farm irrigation wheel having a plurality of intermediate pneumatic lugs 160, according to an aspect. As disclosed hereinabove, the intermediate pneumatic lugs 160 of FIG. 20A may comprise a first leg 95A, a second, opposing leg 95B, an air bladder 161 disposed between and associated with the first leg 95A and the second opposing leg 95B, a first leg paddle 162A associated with the first leg 95A, a second leg paddle 162B associated with the second leg 95B, and a pair of bladder paddles 163A, 163B engage with or otherwise associated with the air bladder 161. The intermediate complexity of the gripping structures (e.g., the bladder paddles 163A, 163B and the leg paddles 162A, 162B) included as part of the intermediate pneumatic lug 160 of FIG. 20A may allow a wheel having

said intermediate pneumatic lugs 160 to have better traction with certain ground surfaces when compared to the basic pneumatic lugs 160 of FIG. 10B, while not significantly increasing the complexity of their construction. In an embodiment, each leg paddle 162A, 162B may be parallel with the lug axis 132.

[00129] Similarly to the lug plates 91 of FIG. 15A, each bladder paddle 163A, 163B of the pneumatic lug 160 may be angled such that each bladder paddle 163A, 163B is disposed at an angle on a corresponding bladder paddle axis 168-1, 168-2, respectively. Again, a lug axis 132 may be utilized to help define the corresponding bladder paddle angle 169-1, 169-2 for each bladder paddle 163A, 163B, wherein the lug axis 132 is parallel with and equidistantly disposed between the front end 160A and the back end 160B of the pneumatic lug 160, as seen in FIG. 20A. A first bladder paddle angle 169-1 may be measured between a first bladder paddle axis 168-1 and the lug axis 132 and a second plate angle 133-2 may be measured between the second bladder paddle axis 168-2 and the lug axis 132. In an embodiment, the first bladder paddle axis 168-1 and the second bladder paddle axis 168-2 may be within 1-10 degrees of each other. In another embodiment, the first and second bladder paddle angles 169-1, 169-2 may be non-zero values that are substantially the same to each other.

[00130] **FIG. 20B** illustrates a front elevation view of a farm irrigation wheel having a plurality of basic pneumatic lugs 160, according to an aspect. As described hereinabove, the basic pneumatic lugs 160 of FIG. 20B have fewer features when compared to the complex and intermediate pneumatic lug embodiments of FIG. 19A and 20A, respectively, thus reducing production costs and general manufacturing complexity.

[00131] For simplicity, it should be understood that the air bladder 161 disclosed herein may be classified as a type of center rib, wherein the air bladder 161 may be described a pneumatic variation of the center ribs disclosed hereinabove, such as center ribs 92 of FIGs. 7A, 7B, 7G, 7H, 11A, 11B, etc. As such, the basic pneumatic lug 160 of FIG. 20B (as well as the intermediate and complex pneumatic lug variants) may comprise at least a first leg 95A, a second, opposing leg 95B and a center rib disposed between and engaged with/associated with the first leg 95A and the second opposing leg 95B, wherein center rib is an air bladder 161. In other words, each pneumatic embodiment of the lug may be described similarly to the prior disclosed lugs, wherein each pneumatic lug 160 may comprise at least a center rib (such as the disclosed air bladder 161), a first leg 95A and a second leg 95B, each leg 95A, 95B extending from the center rib

laterally and opposite of each other; a first leg paddle 162A associated with the first leg 95A; and a second leg paddle 162B associated with the second leg 95B.

[00132] It may be advantageous to set forth definitions of certain words and phrases used in this patent document. The term "couple" and its derivatives refer to any direct or indirect communication between two or more elements, whether or not those elements are in physical contact with one another. The term "or" is inclusive, meaning and/or. The phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like.

[00133] Further, as used in this application, "plurality" means two or more. A "set" of items may include one or more of such items. Whether in the written description or the claims, the terms "comprising," "including," "carrying," "having," "containing," "involving," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of," respectively, are closed or semi-closed transitional phrases with respect to claims.

[00134] If present, use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence or order of one claim element over another or the temporal order in which acts of a method are performed. These terms are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements. As used in this application, "and/or" means that the listed items are alternatives, but the alternatives also include any combination of the listed items.

[00135] Throughout this description, the aspects, embodiments or examples shown should be considered as exemplars, rather than limitations on the apparatus or procedures disclosed or claimed. Although some of the examples may involve specific combinations of method acts or system elements, it should be understood that those acts and those elements may be combined in other ways to accomplish the same objectives.

[00136] Acts, elements and features discussed only in connection with one aspect, embodiment or example are not intended to be excluded from a similar role(s) in other aspects, embodiments or examples.

[00137] Aspects, embodiments or examples of the invention may be described as processes, which are usually depicted using a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a flowchart may depict the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. With regard to flowcharts, it should be understood that additional and fewer steps may be taken, and the steps as shown may be combined or further refined to achieve the described methods.

[00138] If means-plus-function limitations are recited in the claims, the means are not intended to be limited to the means disclosed in this application for performing the recited function but are intended to cover in scope any equivalent means, known now or later developed, for performing the recited function.

[00139] Claim limitations should be construed as means-plus-function limitations only if the claim recites the term “means” in association with a recited function.

[00140] If any presented, the claims directed to a method and/or process should not be limited to the performance of their steps in the order written, and one skilled in the art can readily appreciate that the sequences may be varied and still remain within the spirit and scope of the present invention.

[00141] Although aspects, embodiments and/or examples have been illustrated and described herein, someone of ordinary skills in the art will easily detect alternate of the same and/or equivalent variations, which may be capable of achieving the same results, and which may be substituted for the aspects, embodiments and/or examples illustrated and described herein, without departing from the scope of the invention. Therefore, the scope of this application is intended to cover such alternate aspects, embodiments and/or examples. Hence, the scope of the invention is defined by the accompanying claims and their equivalents. Further, each and every claim is incorporated as further disclosure into the specification.

CLAIMS

What is claimed is:

1. A wheel comprising:
 - a circular ring having:
 - an outer surface; and
 - a rotational axis; and
 - a plurality of lugs mounted in side-by-side positions on said outer surface of the circular ring, each lug having:
 - a center rib;
 - a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other;
 - a first lug plate adapted to connect the first leg to the center rib; and
 - a second lug plate adapted to connect the second leg to the center rib;wherein the plurality of lugs forms a circular pattern that is coaxial with the rotational axis and a distal edge of the first lug plate and a distal edge of the second lug plate are configured to radially extend beyond the center rib.
2. The wheel of claim 1, wherein rotation of the wheel is configured to produce a rut in the ground, the rut having a sinusoidal shape.
3. The wheel of claim 1, further comprising a rim nested within the circular ring, said rim having a plurality of alternating scalloped protrusions on an outer perimeter of said rim.
4. The wheel of claim 1, wherein the plurality of lugs comprises a plurality of paddle lugs having a first plate height and at least one high traction lug having a second plate height, wherein the second plate height is greater than the first plate height.
5. The wheel of claim 4, wherein the plurality of lugs is mounted to the circular ring in a repeating pattern, said repeating pattern starting with a first paddle lug, followed by a second paddle lug disposed adjacent to the first paddle lug, and followed by a high traction lug disposed adjacent to the second paddle lug.
6. The wheel of claim 1, wherein each lug of the plurality of lugs is made of spring steel with an overmolded rubber layer, such that each lug is configured to be compliant.
7. The wheel of claim 1, wherein the first lug plate is disposed on a first plate axis, such that a non-zero first plate angle is defined between the first plate axis and a lug axis.

8. The wheel of claim 1, wherein the first leg and second leg form a W-shape with the center rib, and the first lug plate and second lug plate are configured to protrude beyond a top of said W-shape.
9. A wheel comprising:
 - a plurality of lugs mounted in side-by-side positions to form a circular ring, each lug having:
 - a center rib;
 - a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other;
 - a first lug plate adapted to connect the first leg to the center rib; and
 - a second lug plate adapted to connect the second leg to the center rib;
 - wherein a distal edge of the first lug plate and a distal edge of the second lug plate are configured to radially extend beyond the center rib.
10. The wheel of claim 9, wherein the first leg and second leg form a W-shape with the center rib, and the first lug plate and second lug plate are configured to protrude above said W-shape.
11. The wheel of claim 9, wherein the first lug plate is disposed on a first plate axis, such that a non-zero first plate angle is defined between the first plate axis and a lug axis.
12. The wheel of claim 11, wherein the second lug plate is disposed on a second plate axis, such that a non-zero second plate angle is defined between the second plate axis and a lug axis, wherein the second plate angle is substantially the same as the first plate angle.
13. A wheel comprising a plurality lugs, each lug of the plurality of lugs comprising:
 - a center rib;
 - a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other;
 - a first leg paddle associated with the first leg; and
 - a second leg paddle associated with the second leg.
14. The wheel of claim 13, each lug further comprising a valve stem in pneumatic communication with the center rib, wherein the center rib is an air bladder.
15. The wheel of claim 14, each lug further comprising a first bladder paddle and a second bladder paddle engaged with the center rib.

16. The wheel of claim 15, wherein the first bladder paddle is disposed on a first bladder paddle axis, such that a non-zero first bladder paddle angle is defined between the first bladder paddle axis and a lug axis, and the second bladder paddle is disposed on a second bladder paddle axis, such that a non-zero second bladder paddle angle is defined between the second bladder paddle axis and a lug axis.
17. The wheel of claim 16, wherein the non-zero first bladder paddle angle is substantially the same as the non-zero second bladder paddle angle.
18. The wheel of claim 15, each lug further comprising a pair of front paddles associated with the center rib and disposed on a front end of the lug and a pair of back paddles associated with the center rib and disposed on a back end of the lug.
19. The wheel of claim 16, wherein the first leg paddle and the second leg paddle are both parallel with a lug axis.
20. The wheel of claim 13, wherein the plurality of lugs forms a circular pattern that is coaxial with a rotational axis of the wheel.

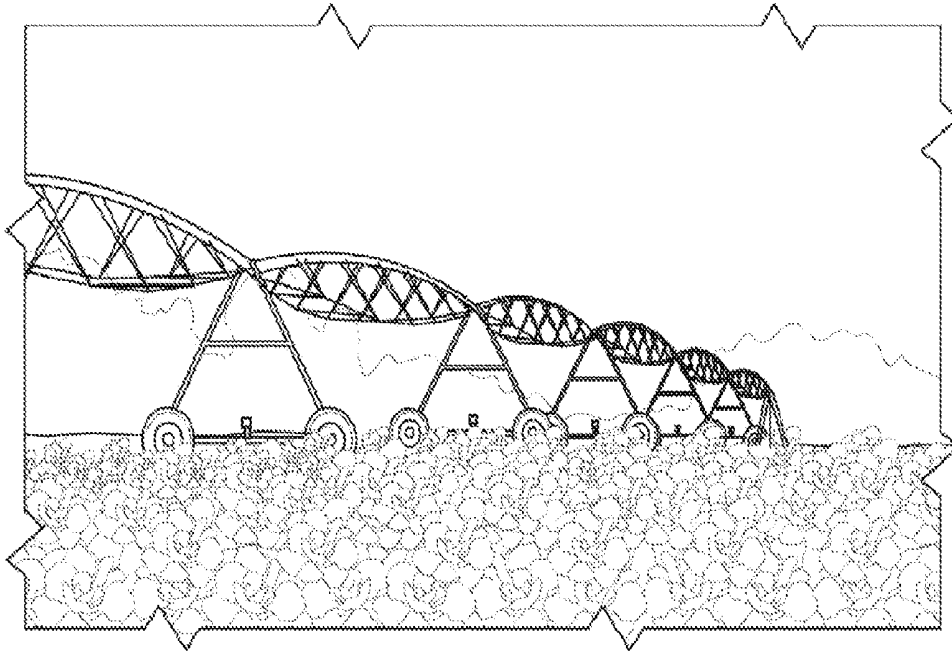


FIG. 1A

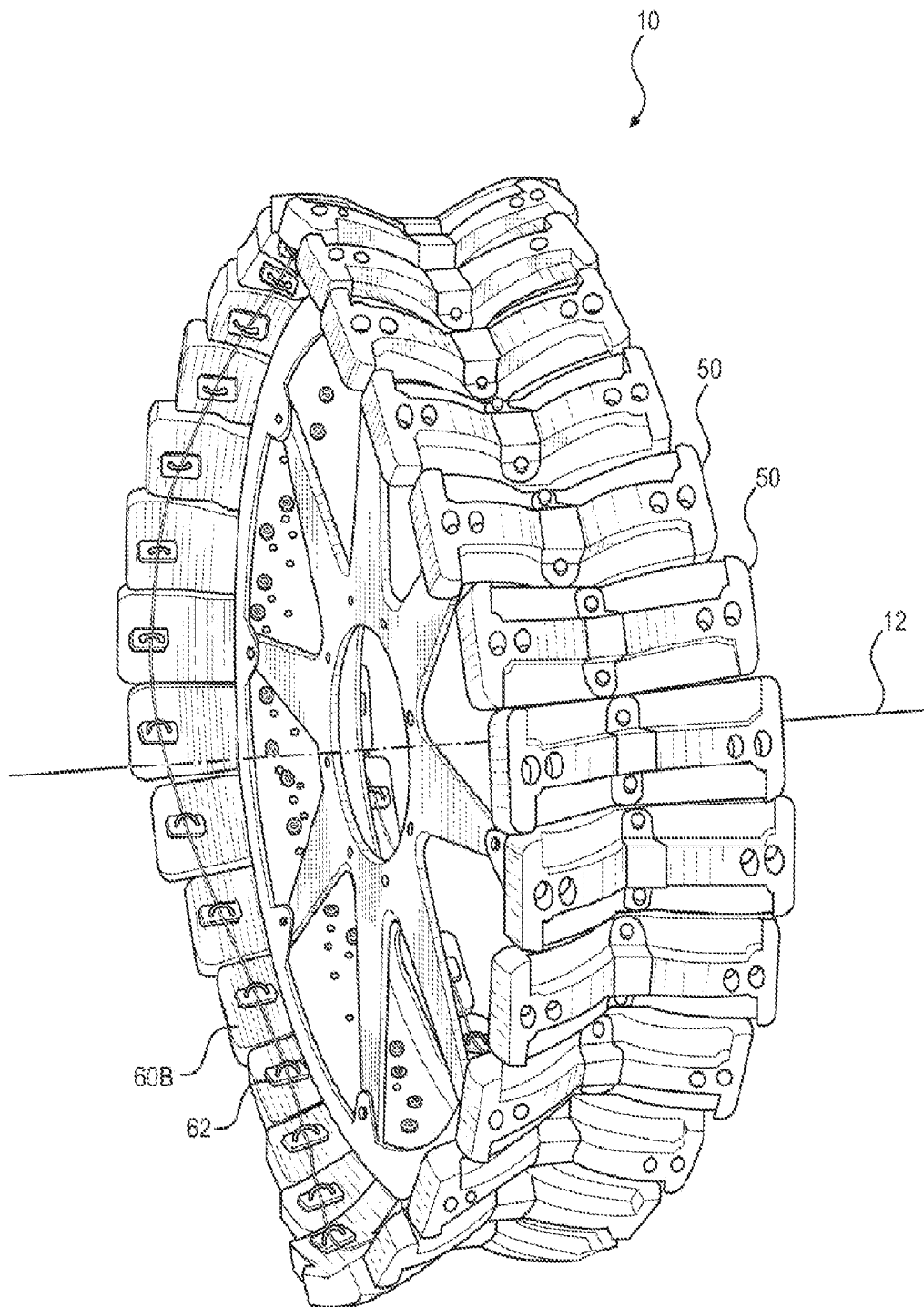


FIG. 1B

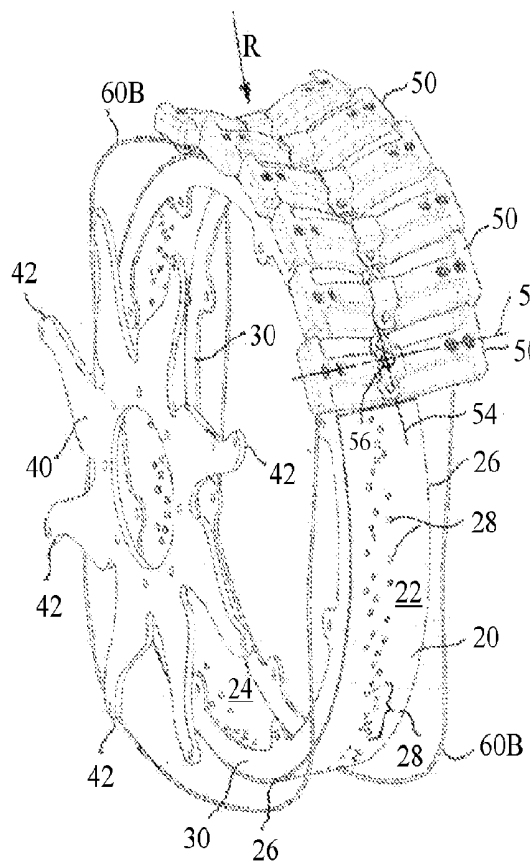


FIG. 2

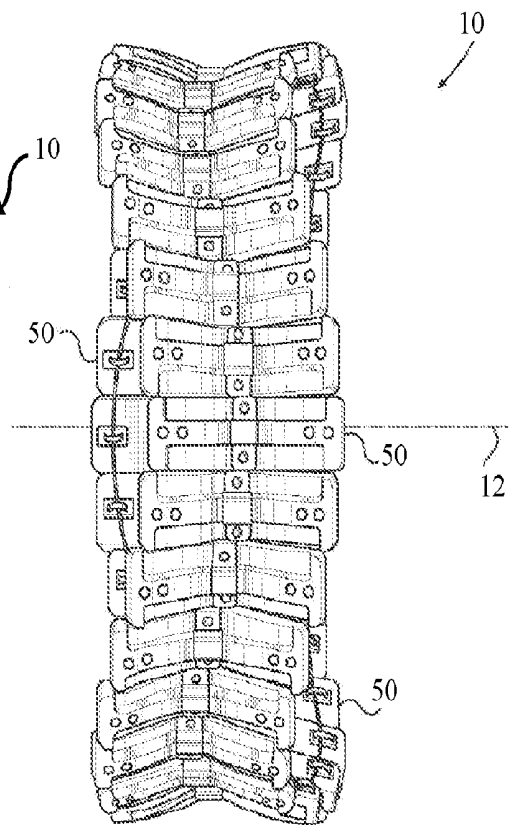


FIG. 4

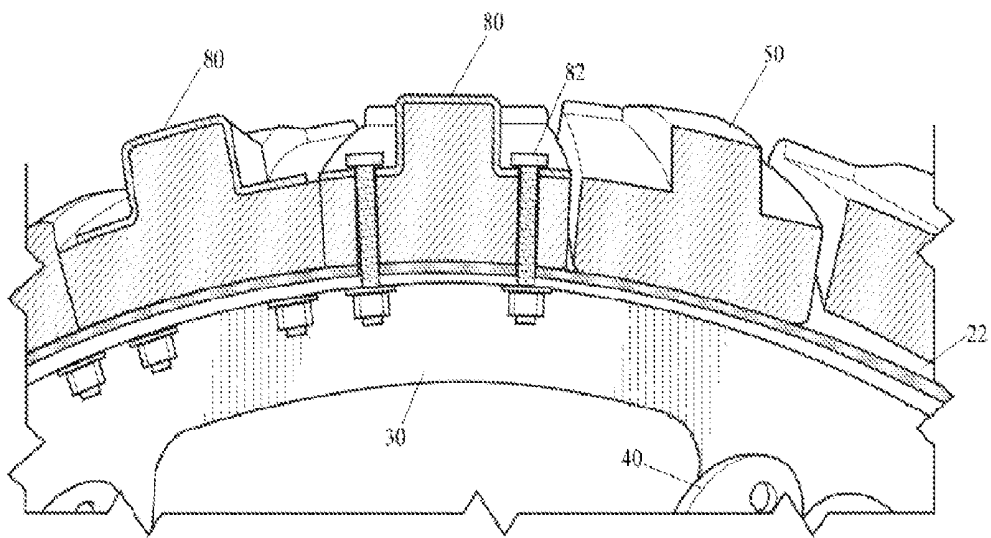


FIG. 3

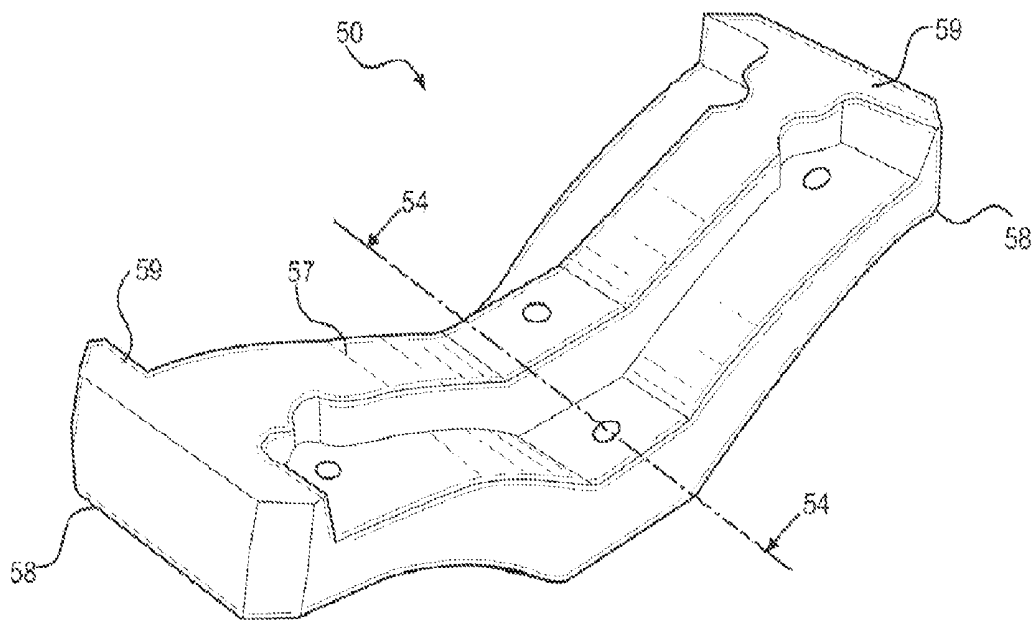


FIG. 5

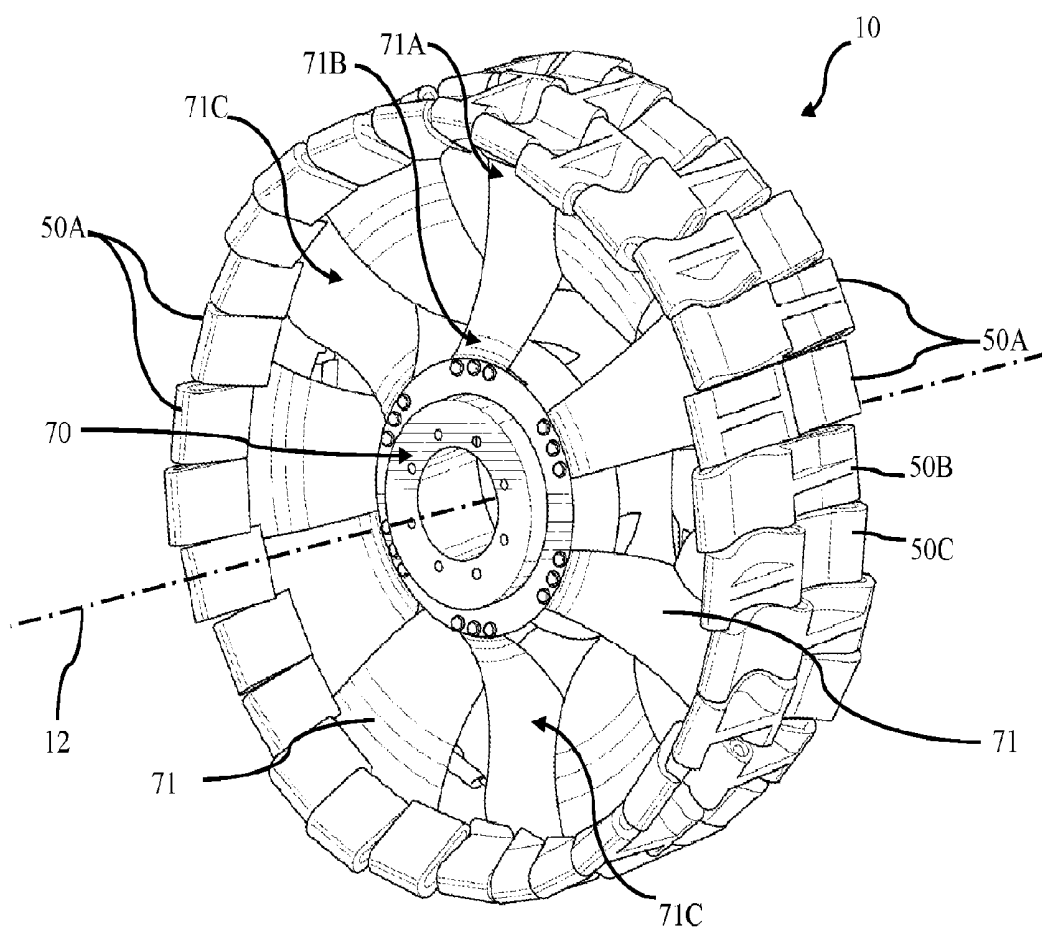


FIG. 6

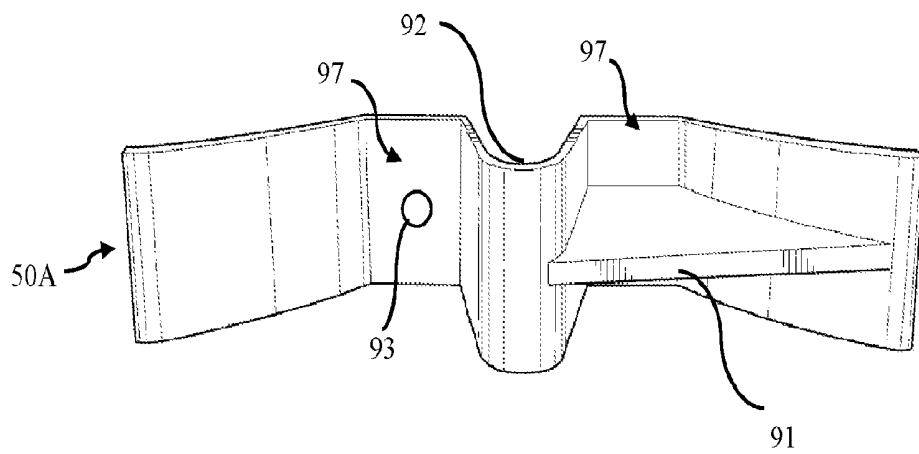


FIG. 7A

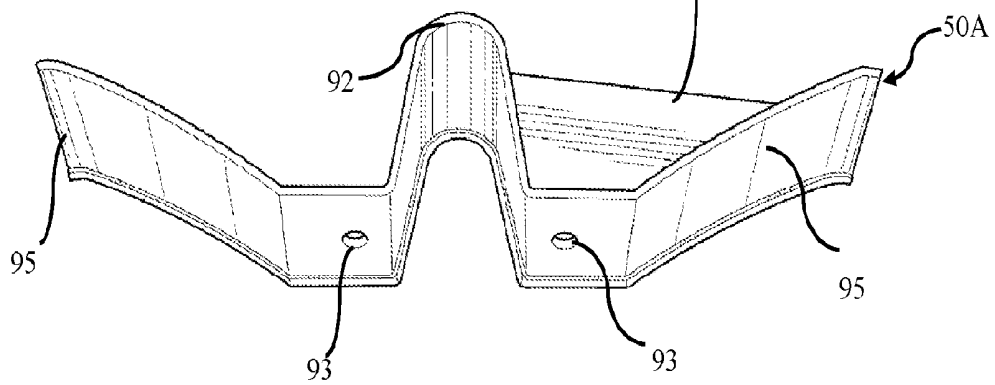


FIG. 7B

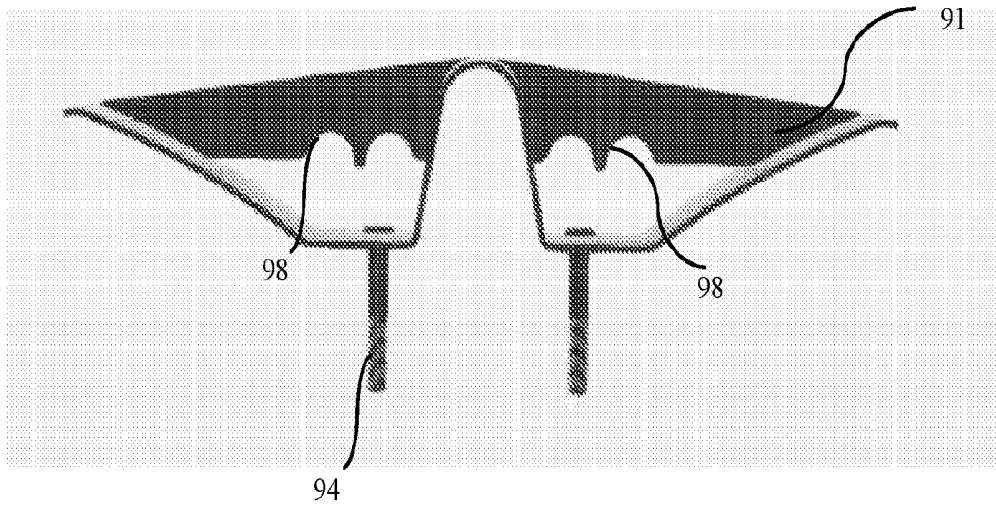


FIG. 7C

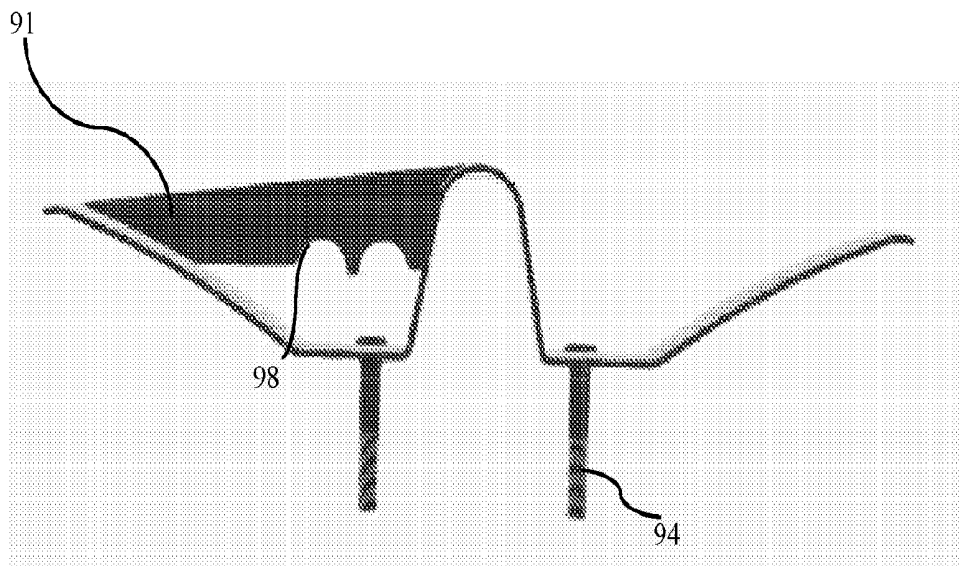


FIG. 7D

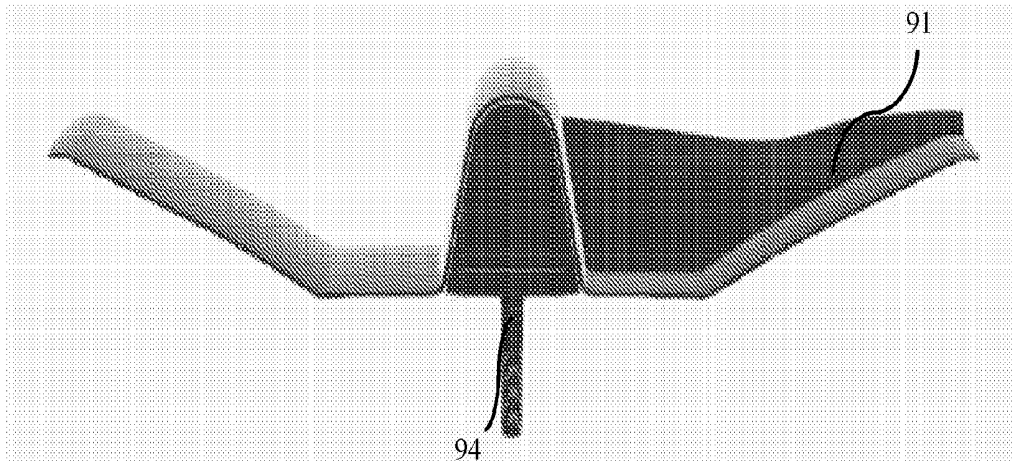


FIG. 7E

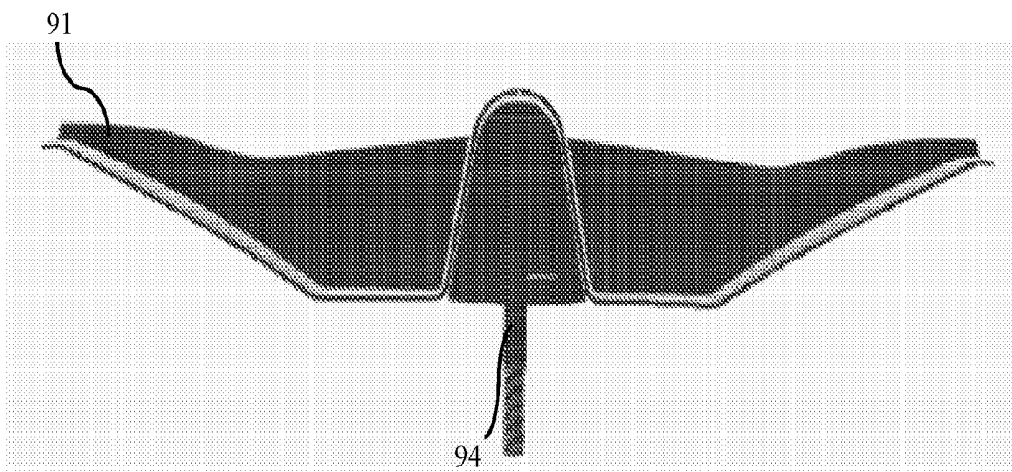


FIG. 7F

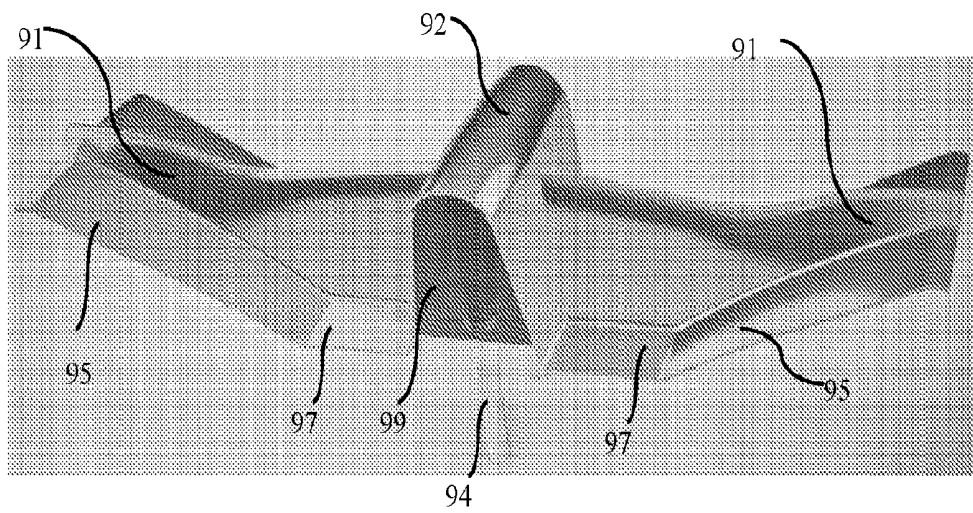


FIG. 7G

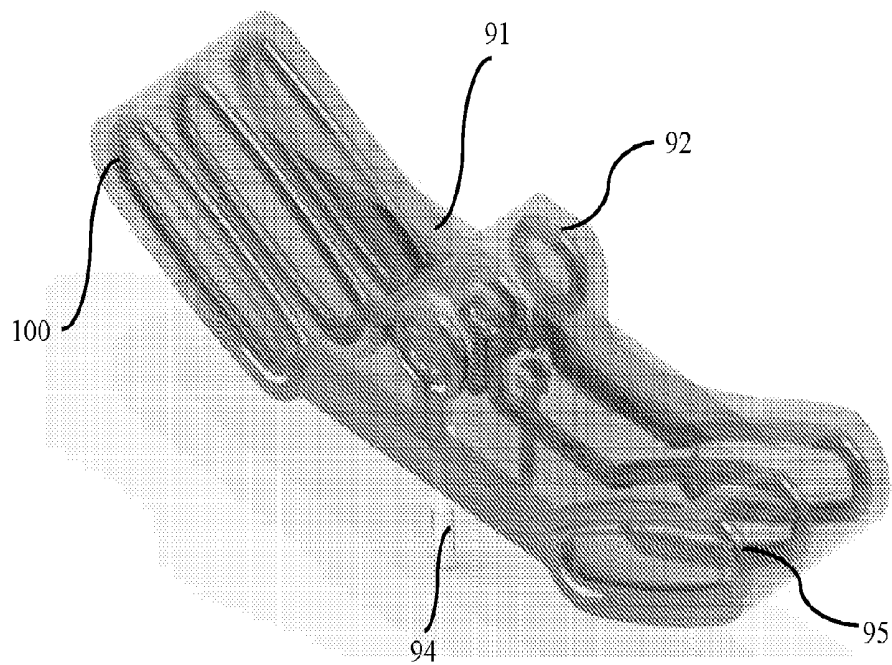


FIG. 7H

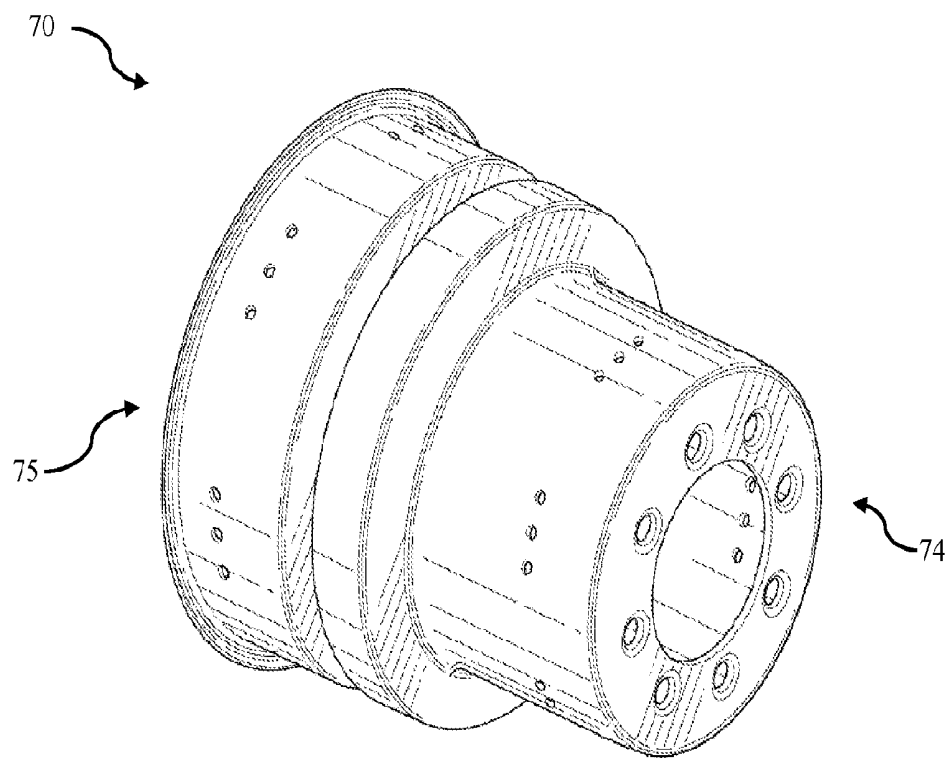


FIG. 8

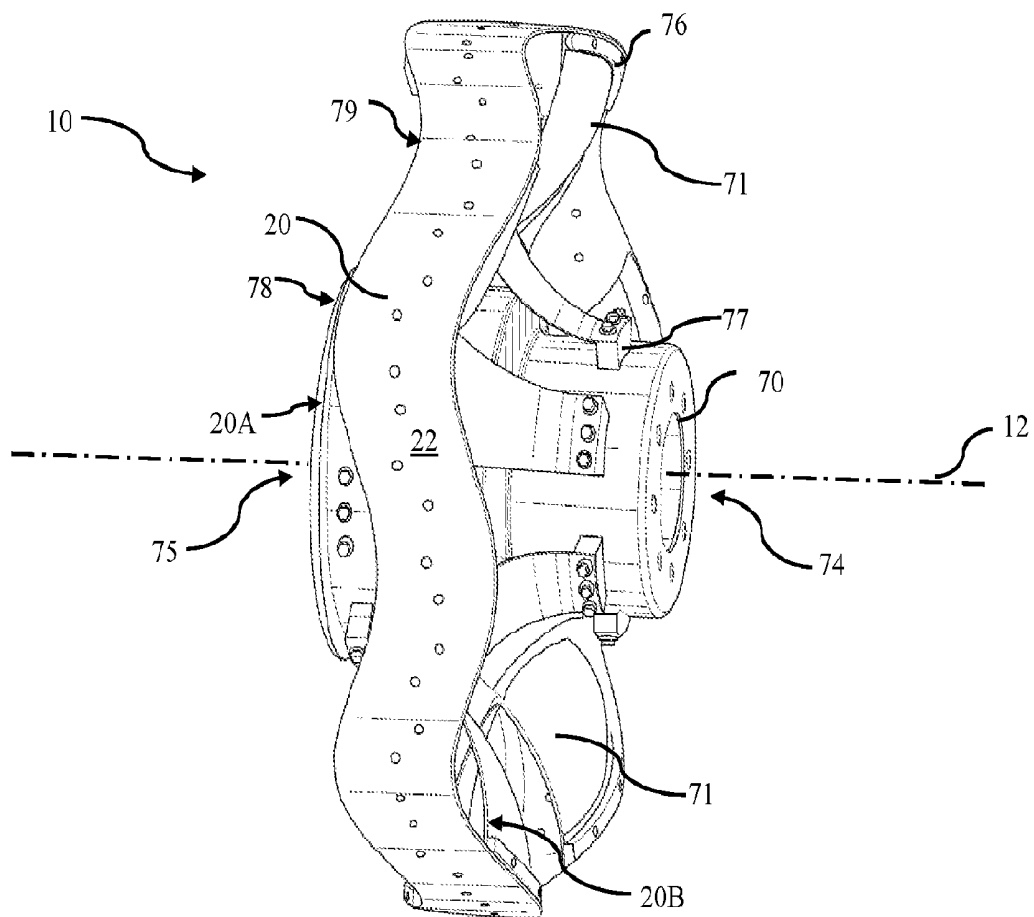


FIG. 9

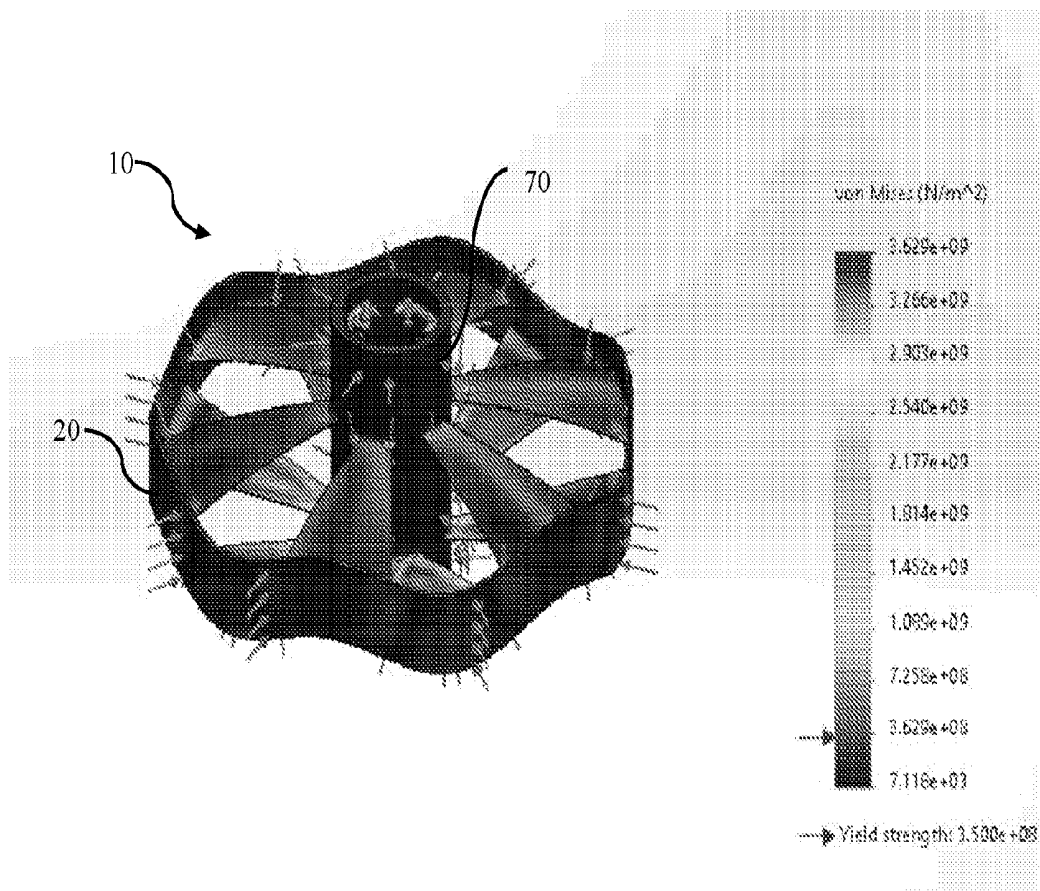


FIG. 10A

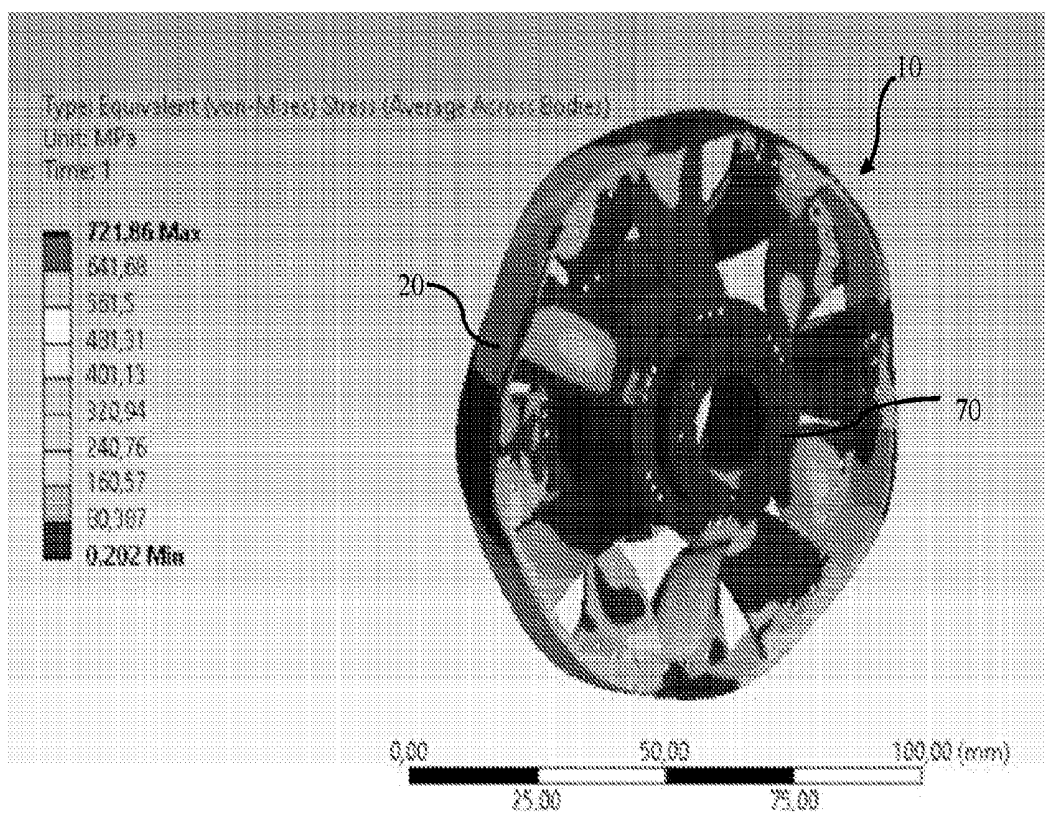


FIG. 10B

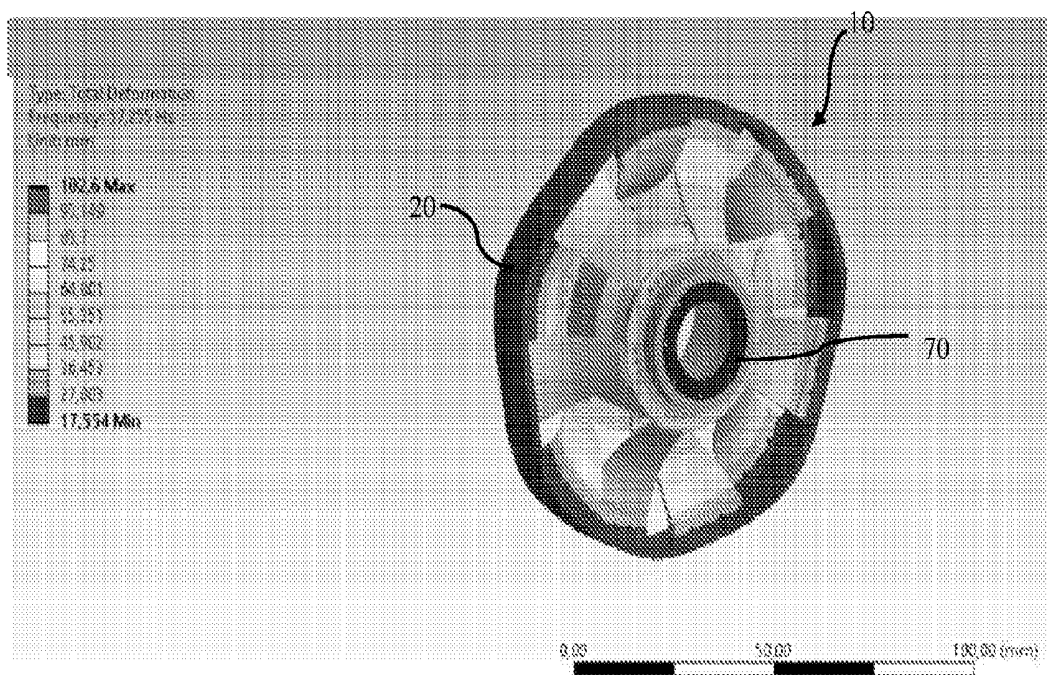
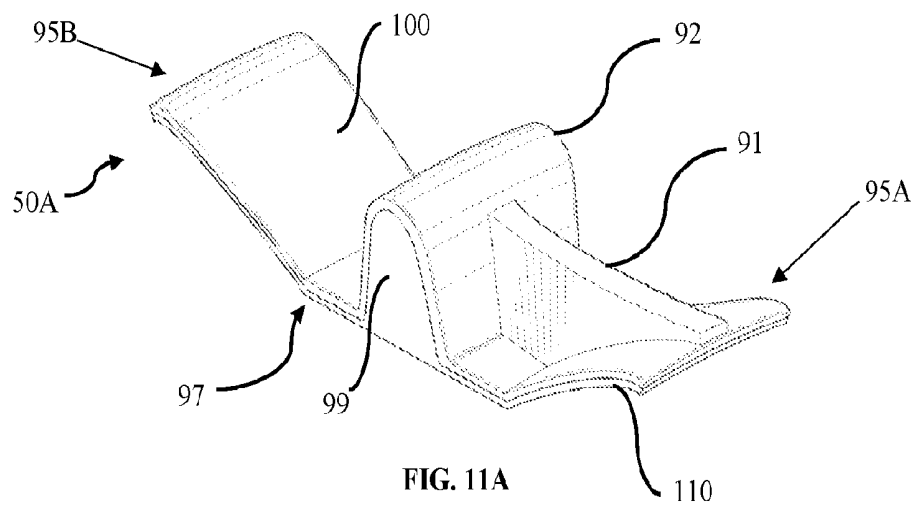
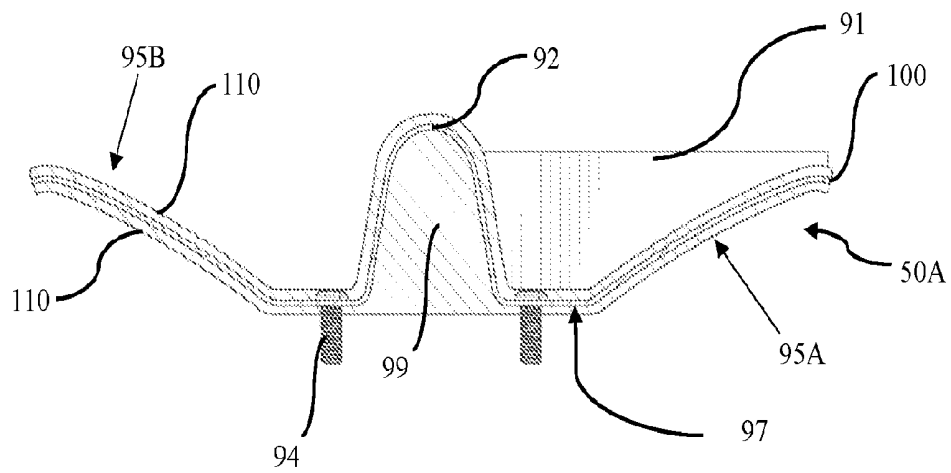


FIG. 10C



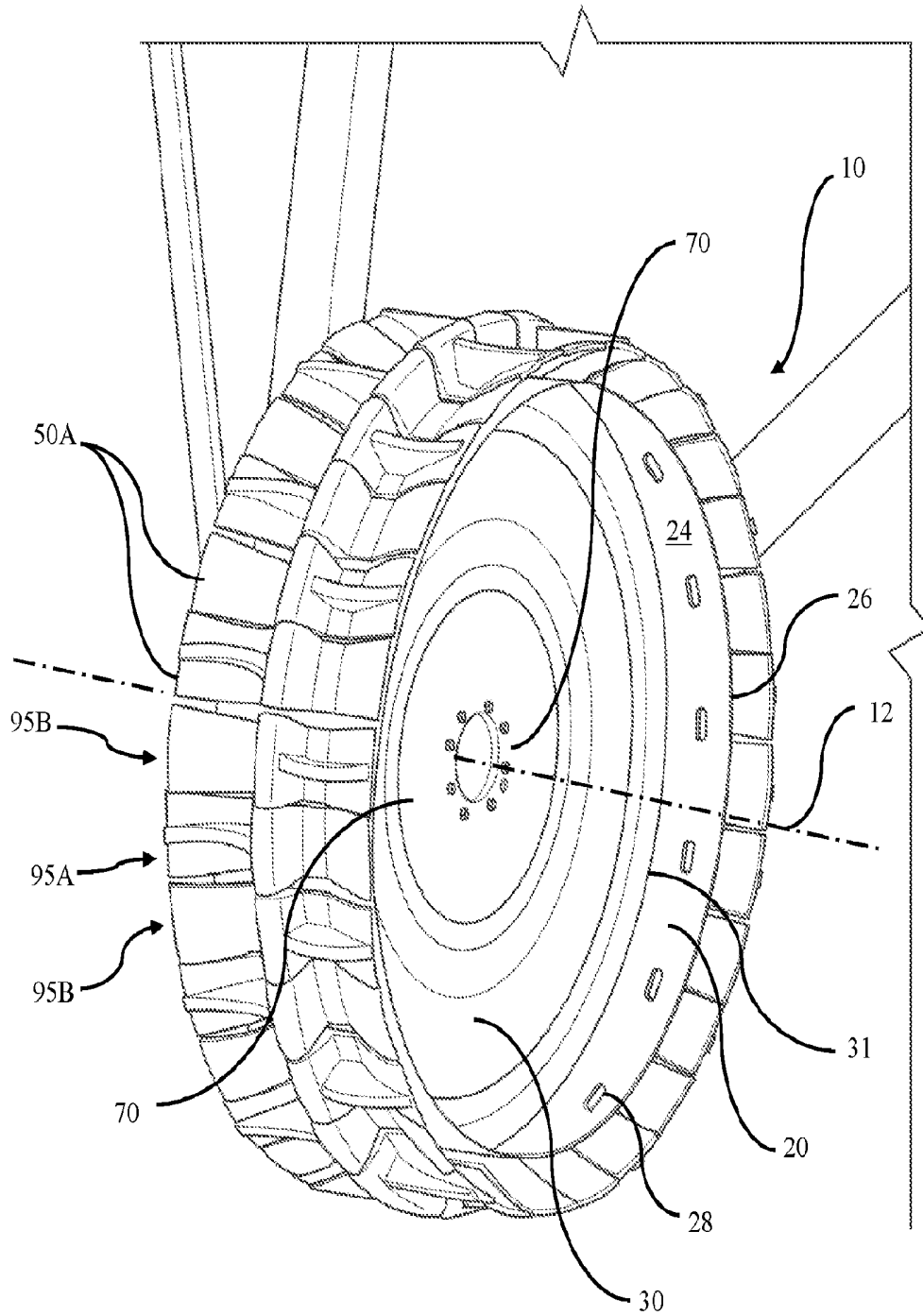


FIG. 12A

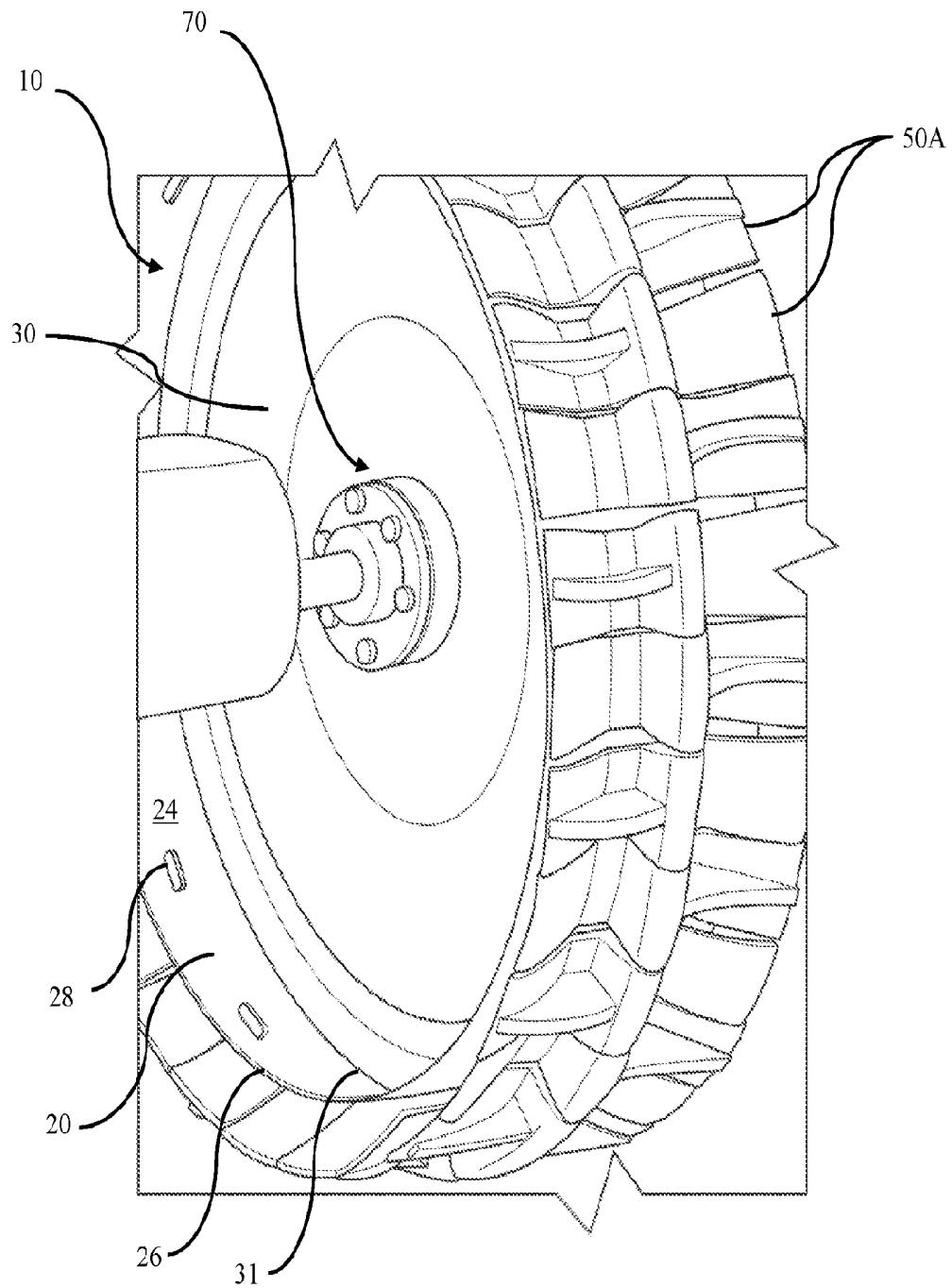
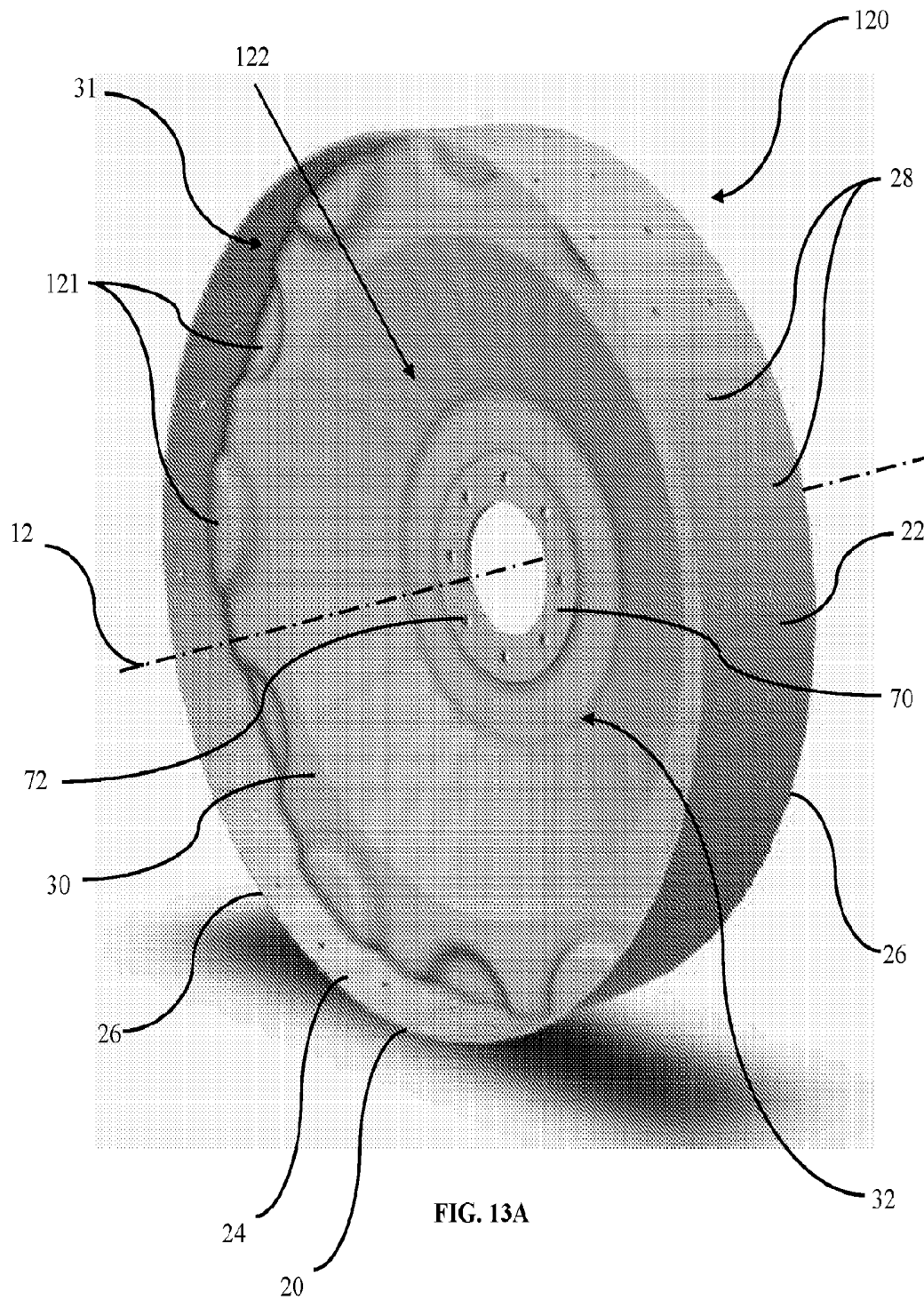


FIG. 12B



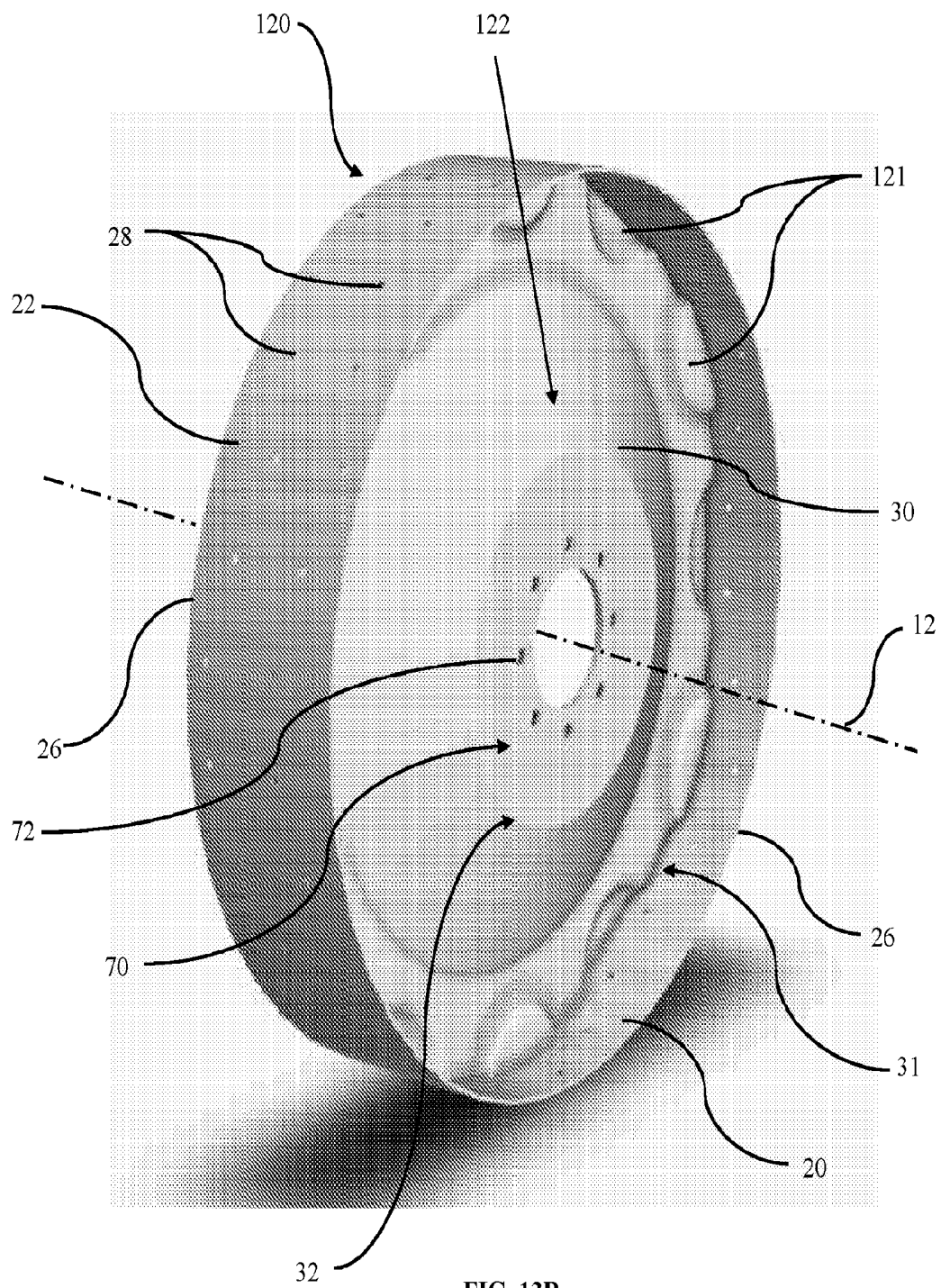


FIG. 13B

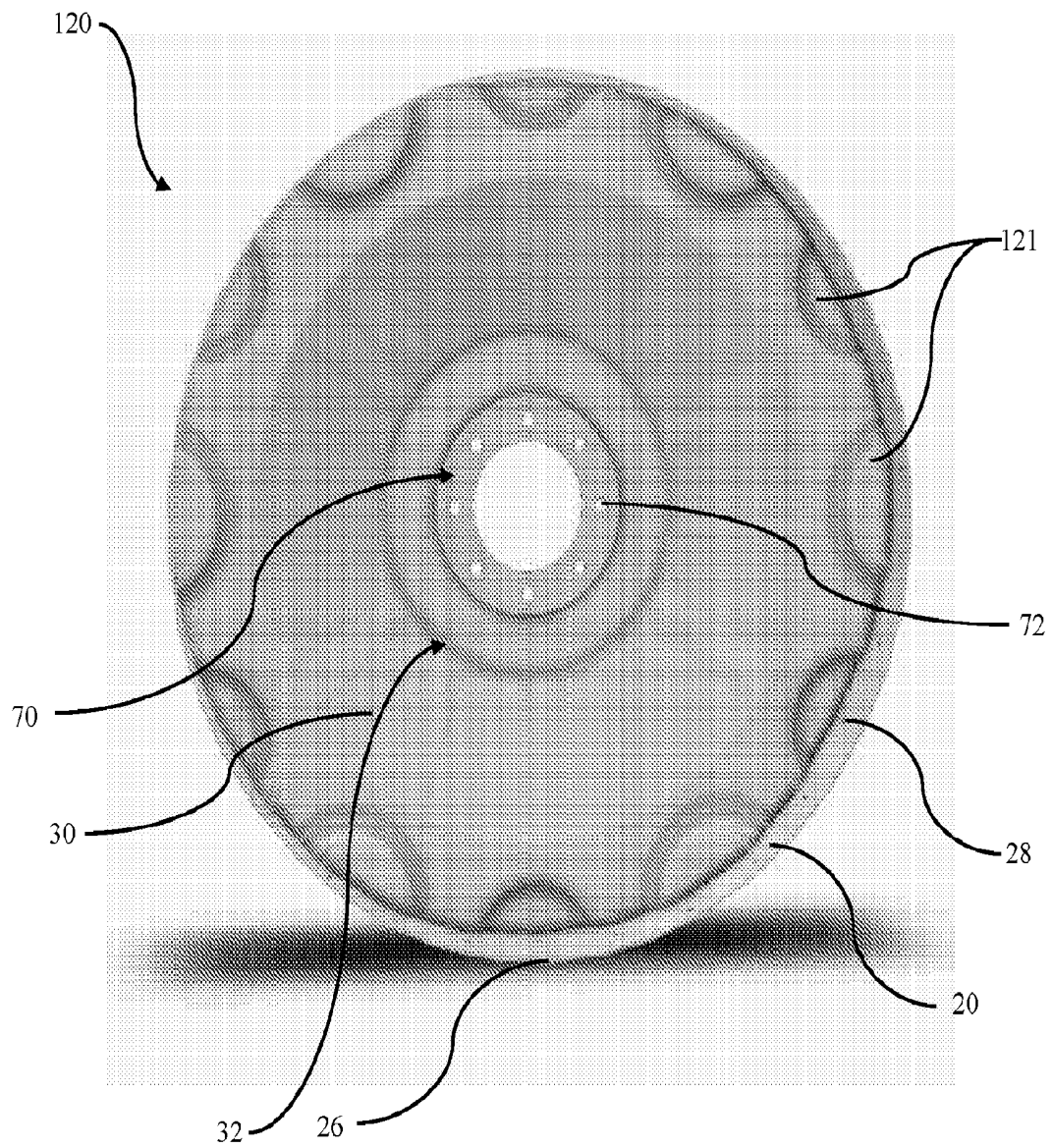
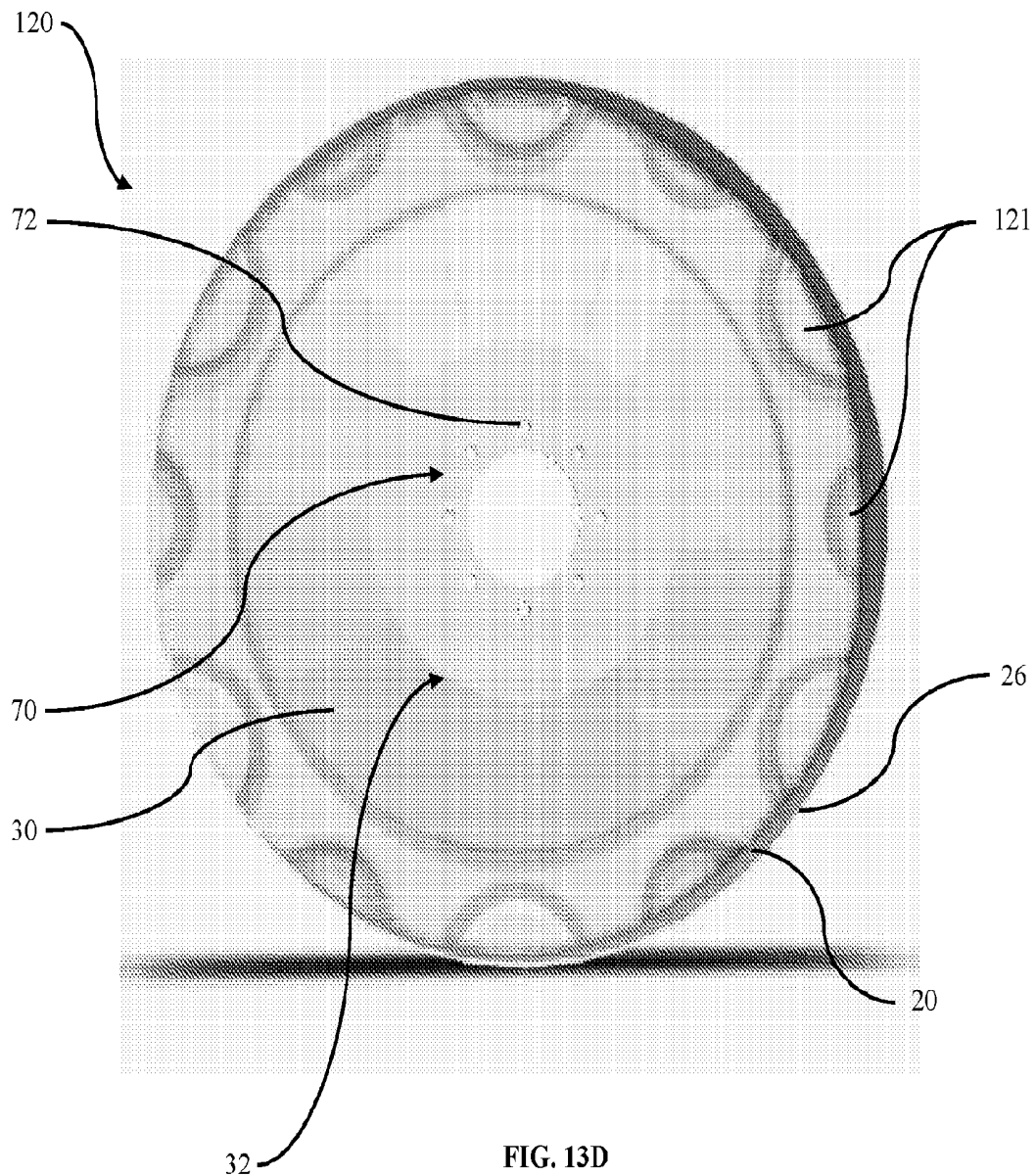


FIG. 13C



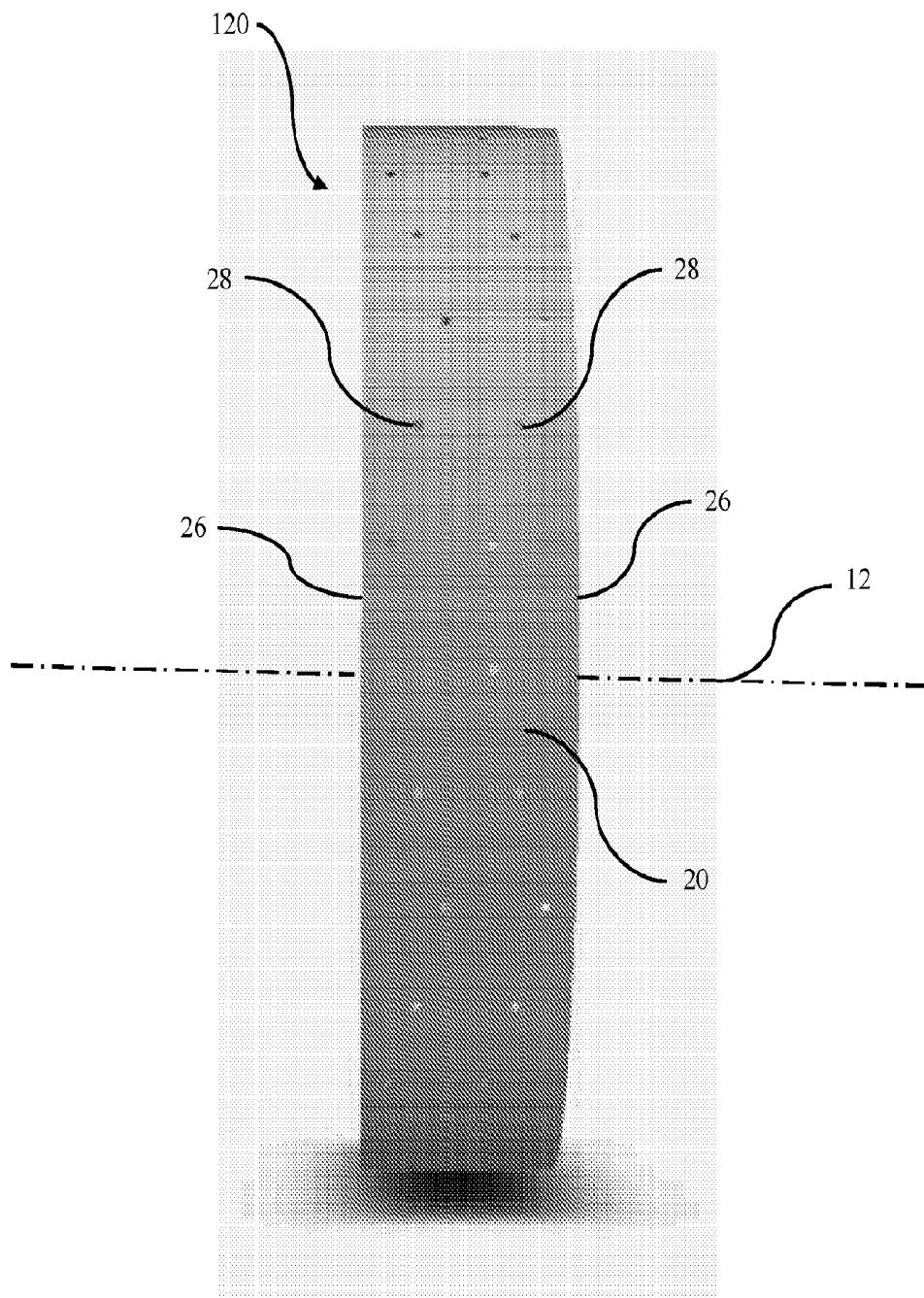


FIG. 13E

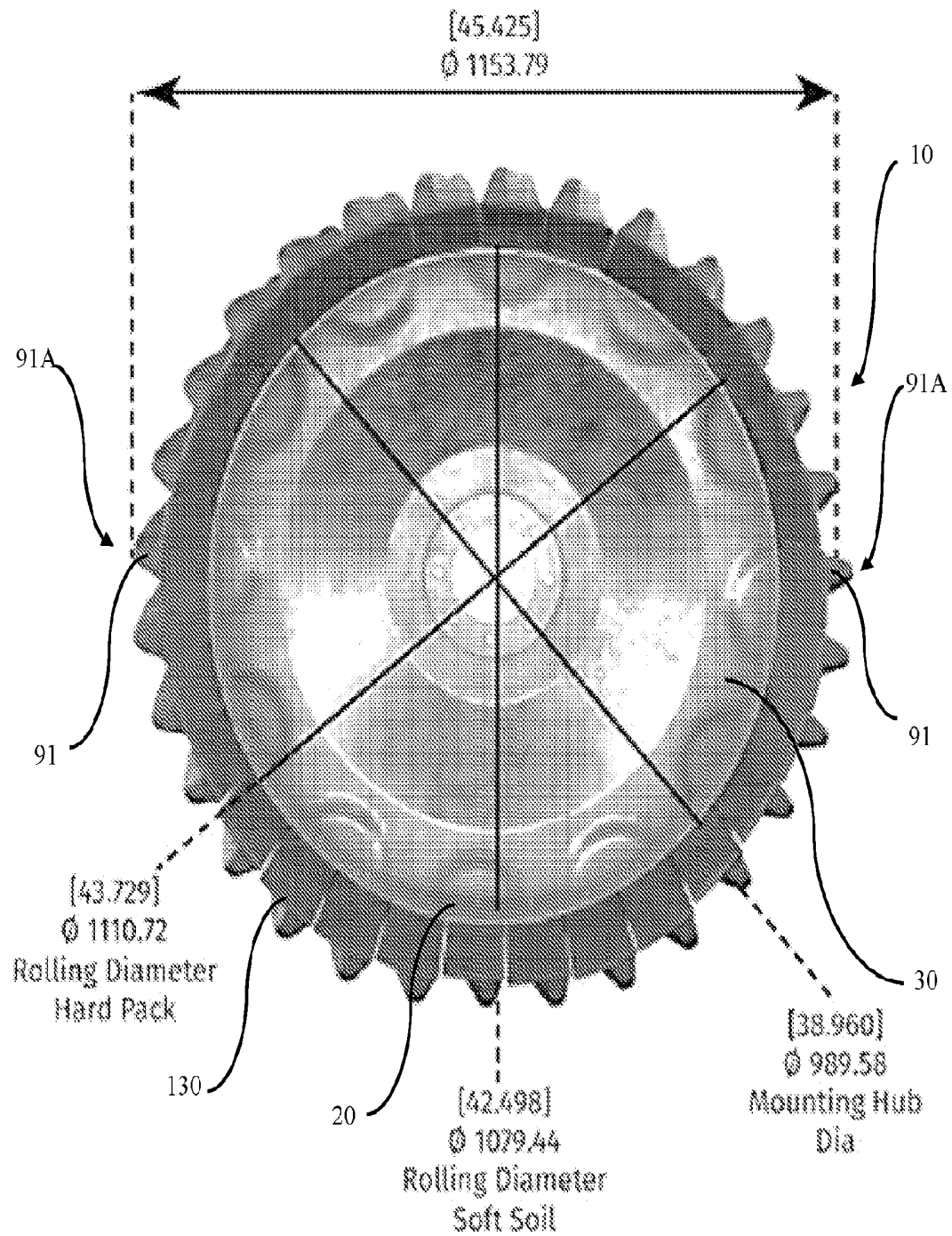


FIG. 14A

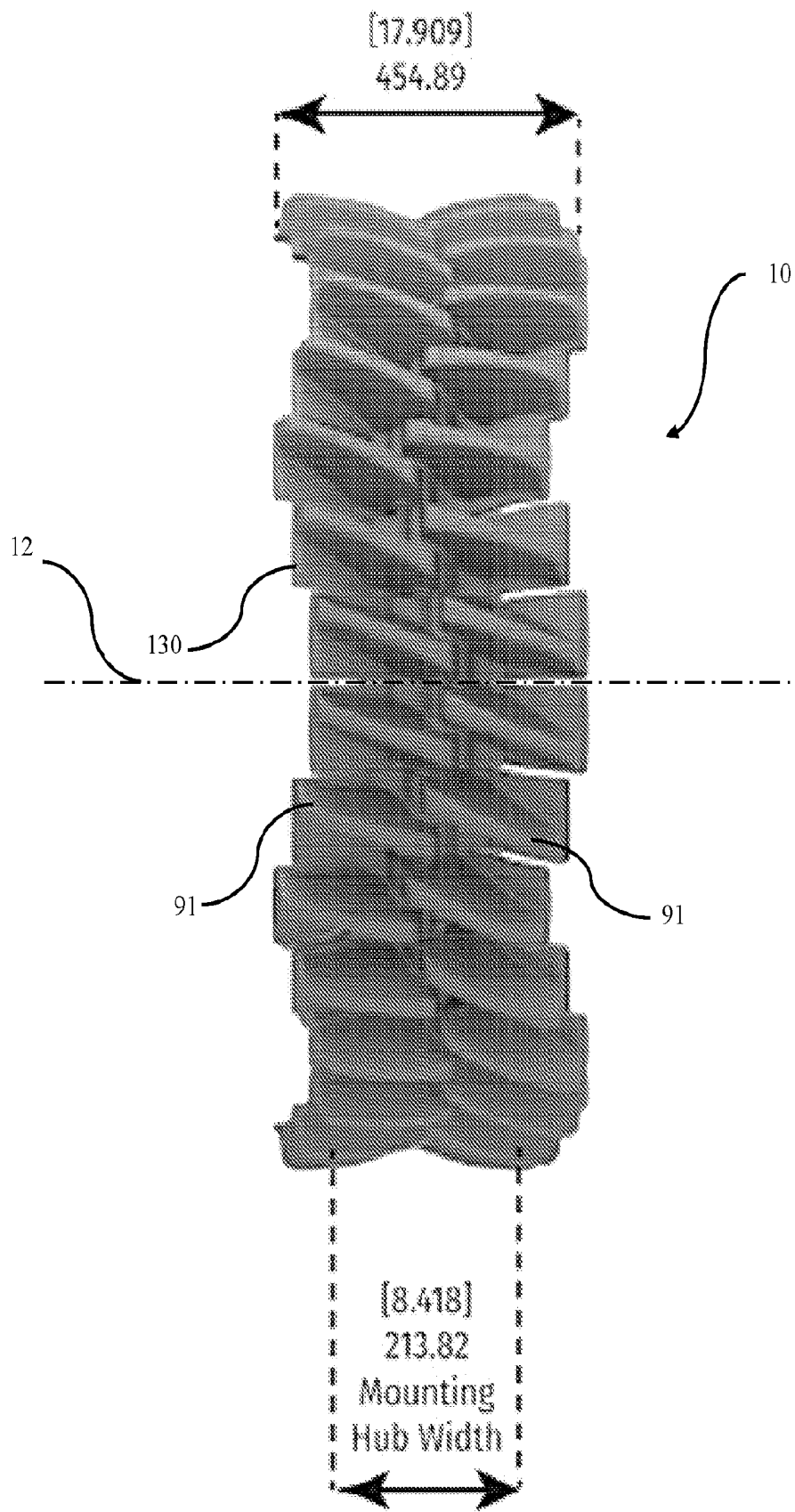
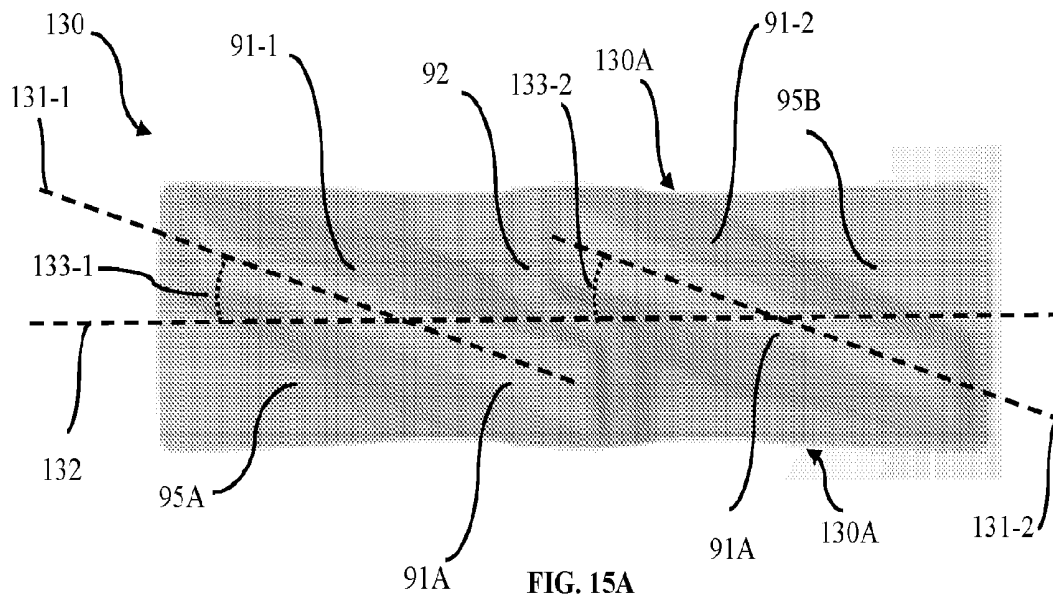
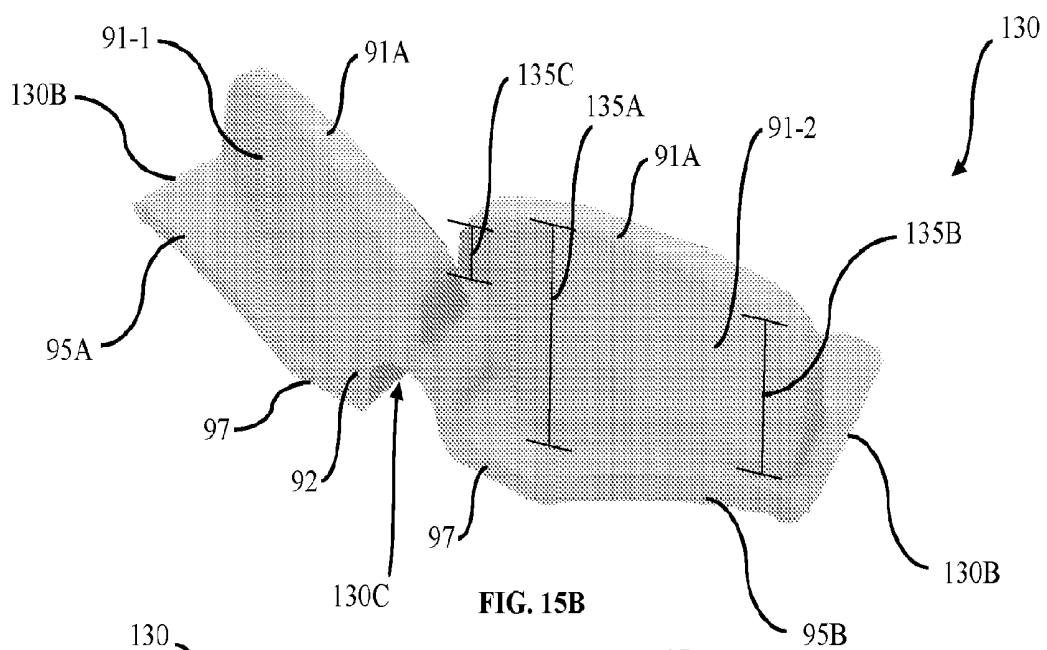
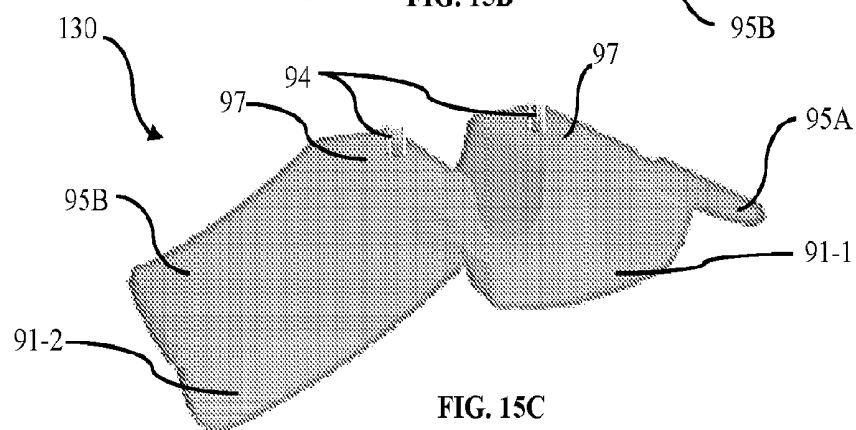


FIG. 14B



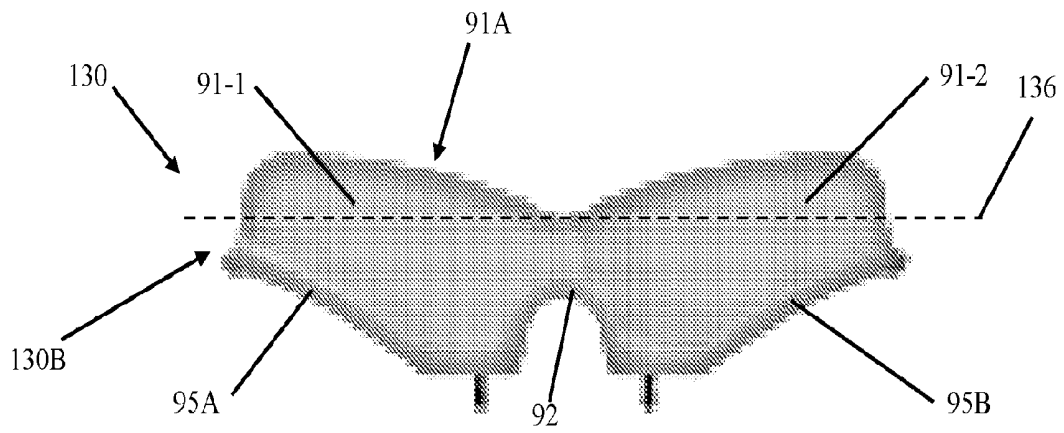


FIG. 16A

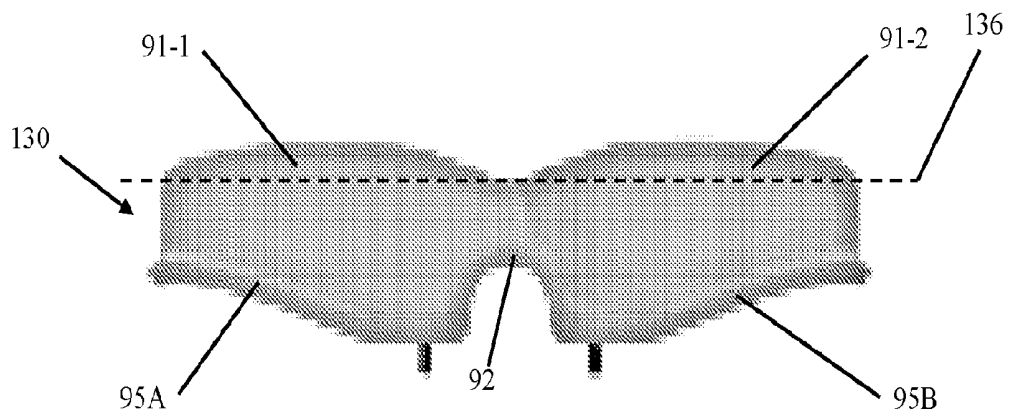


FIG. 16B

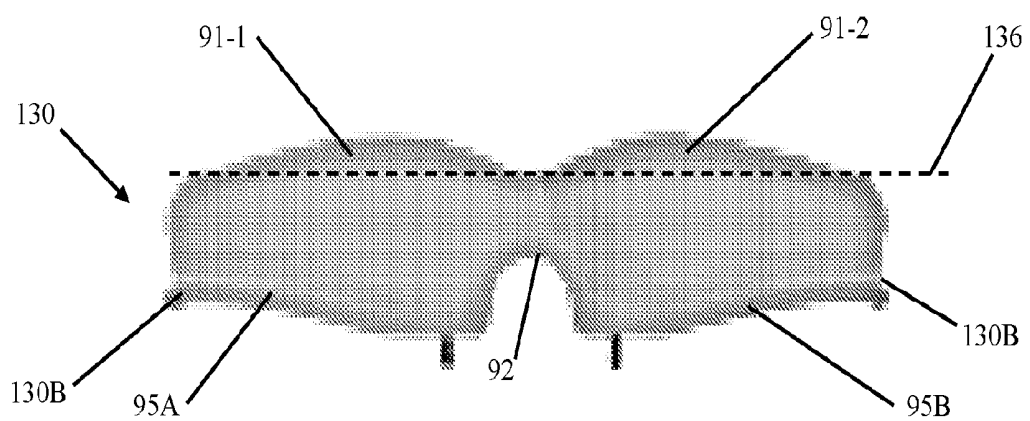


FIG. 16C

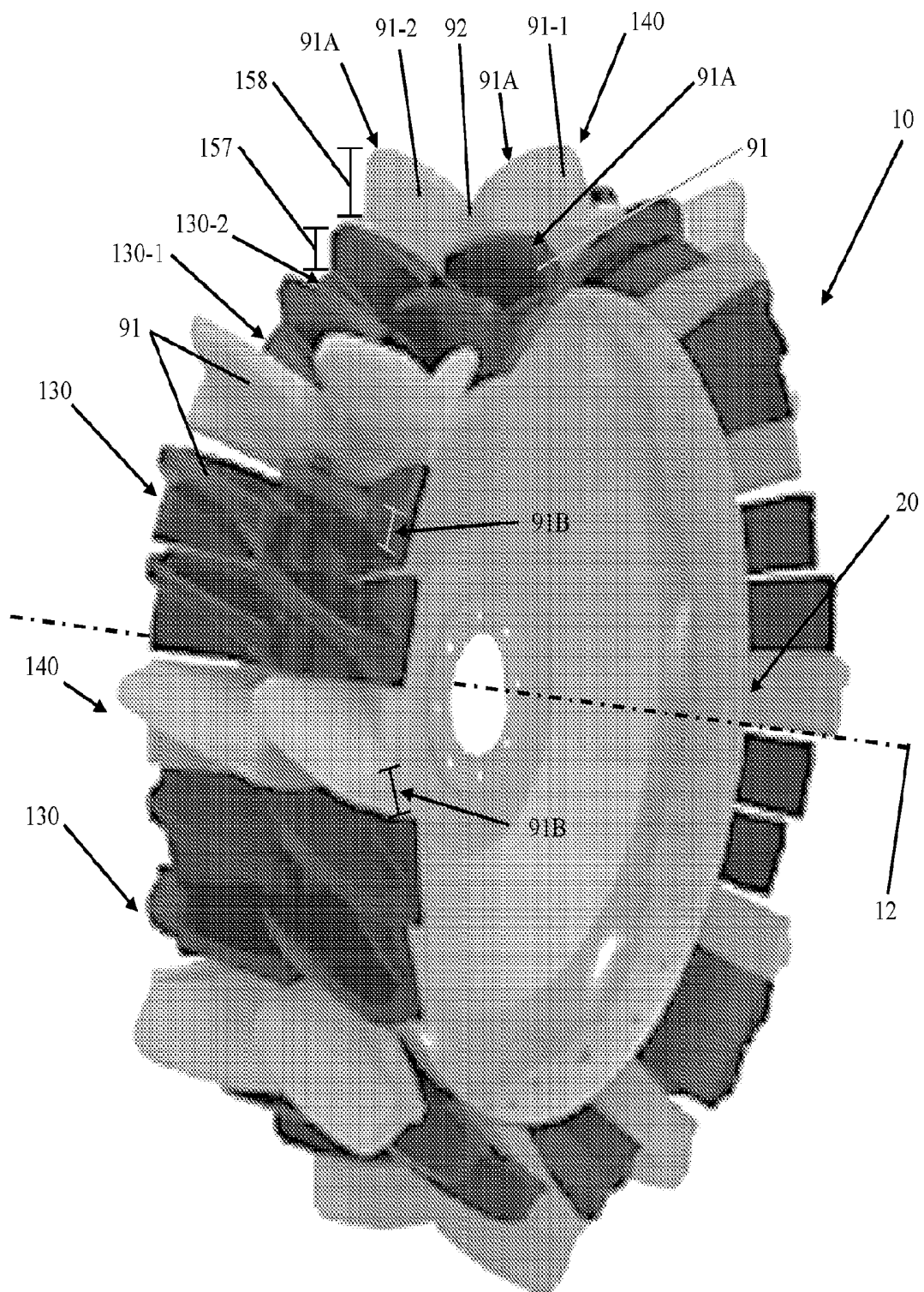


FIG. 17A

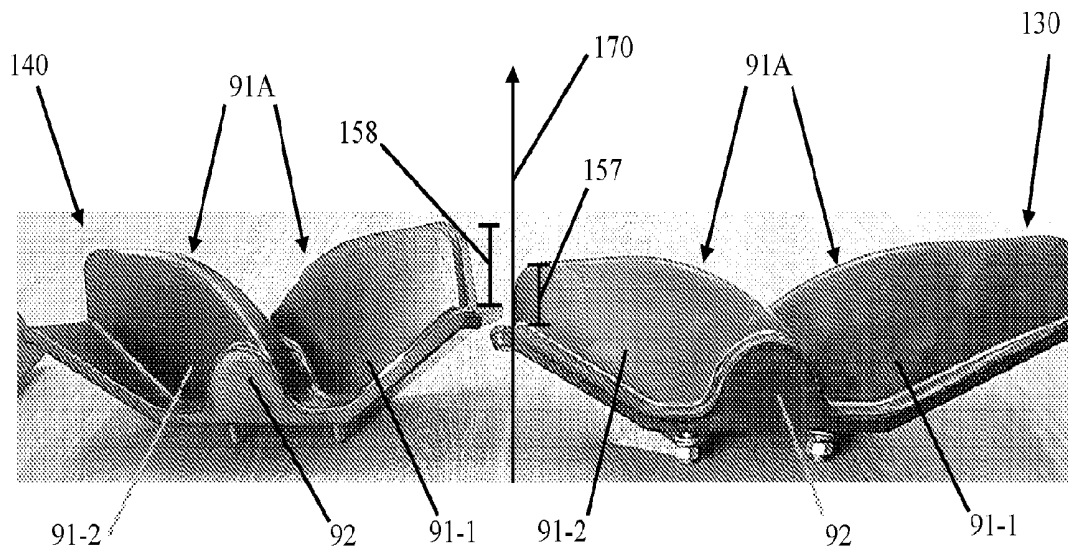


FIG. 17B

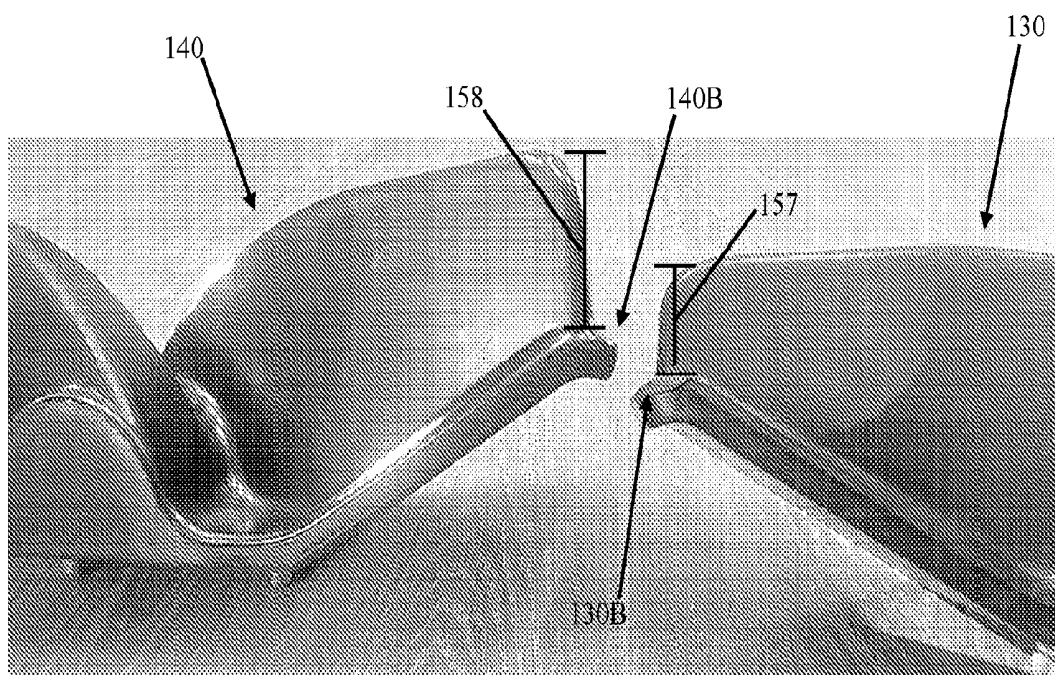
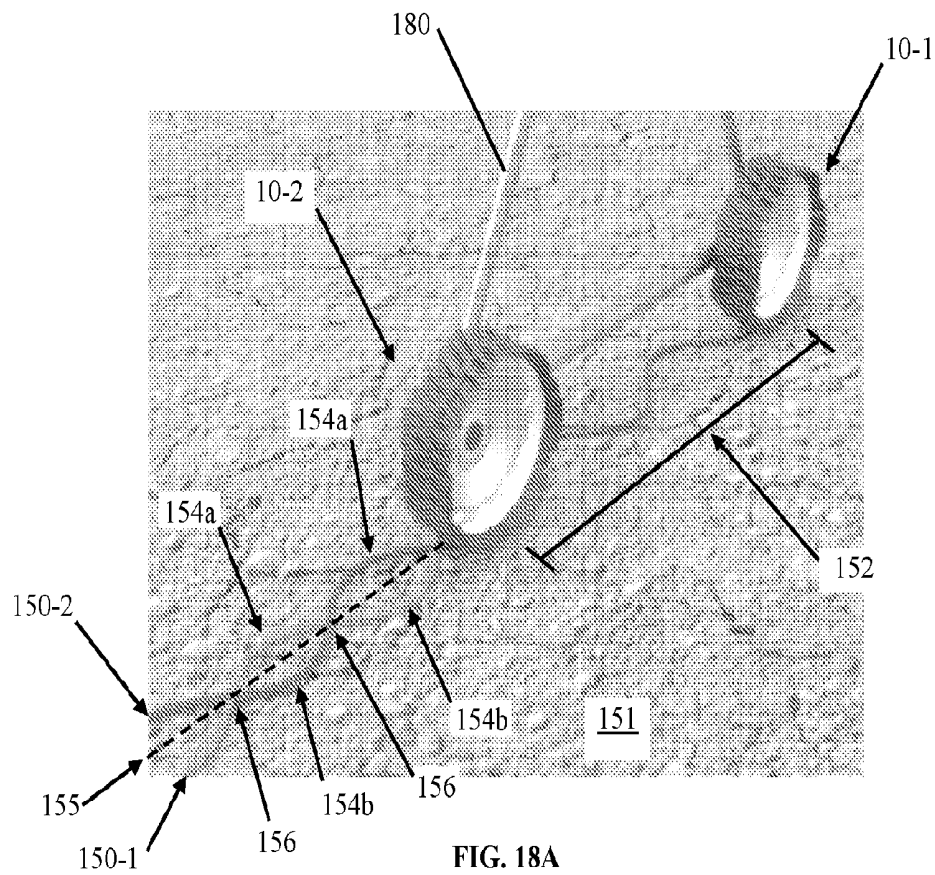
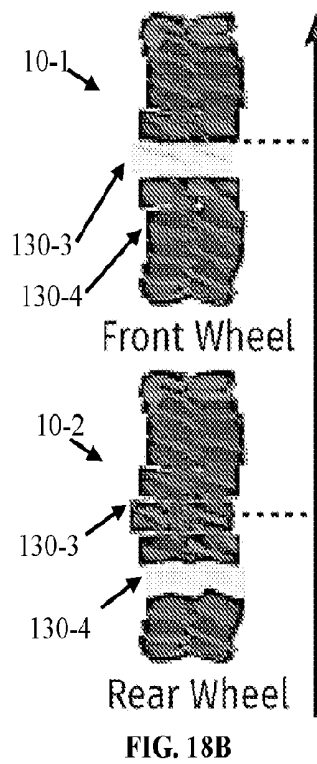
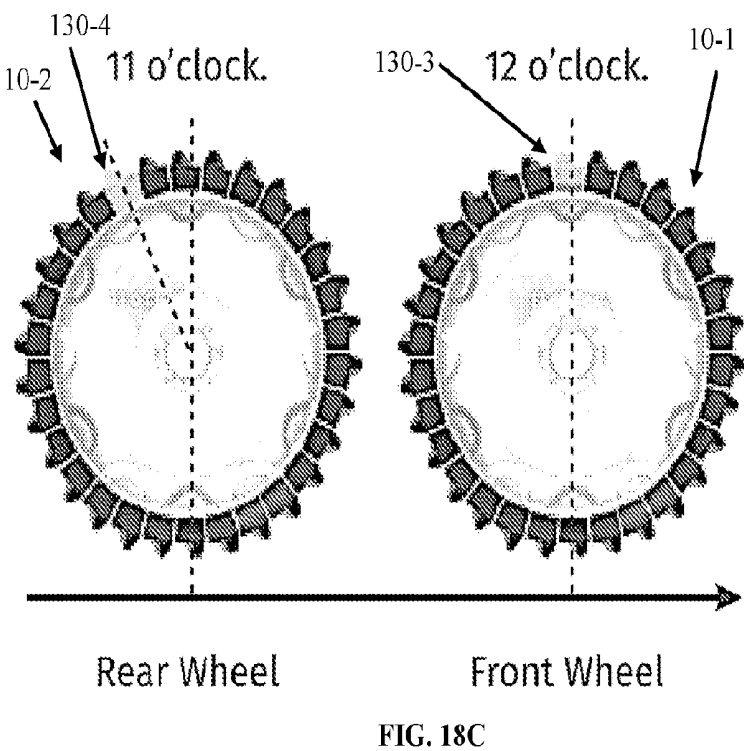


FIG. 17C



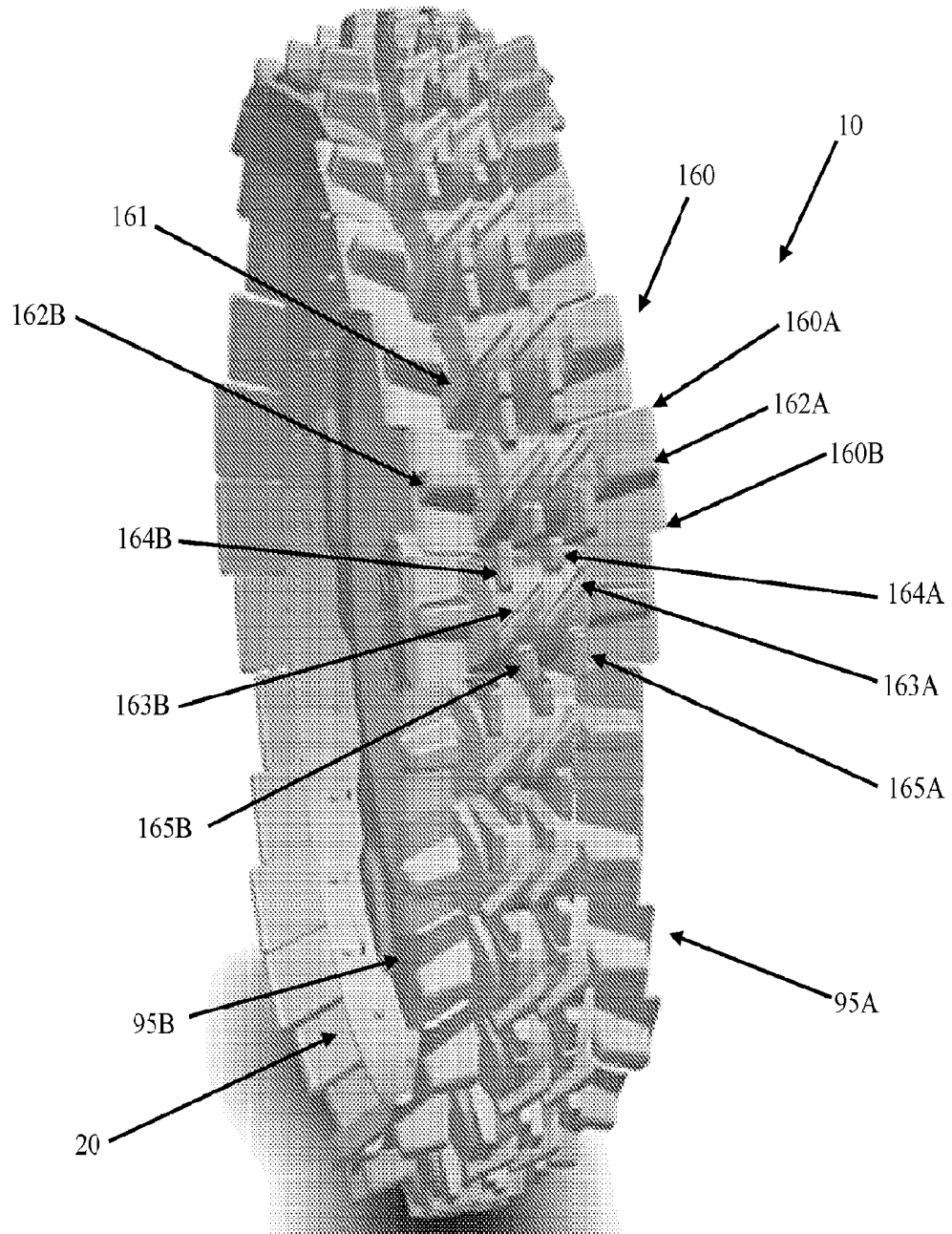


FIG. 19A

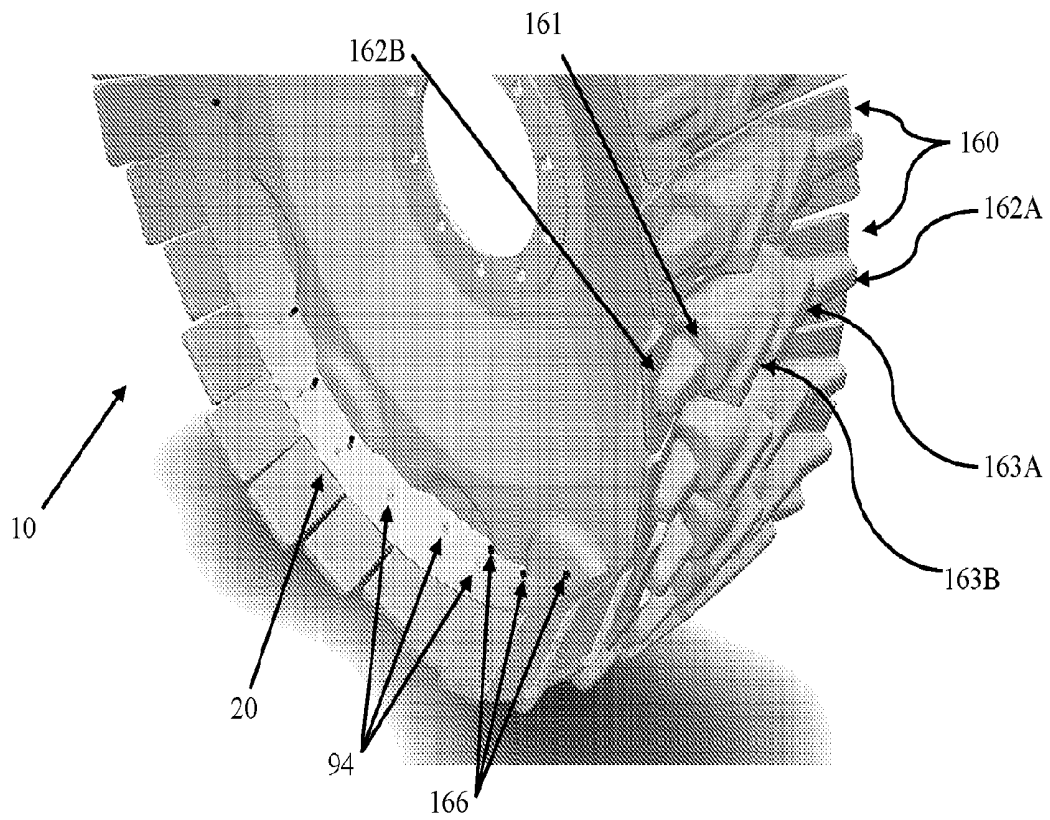


FIG. 19B

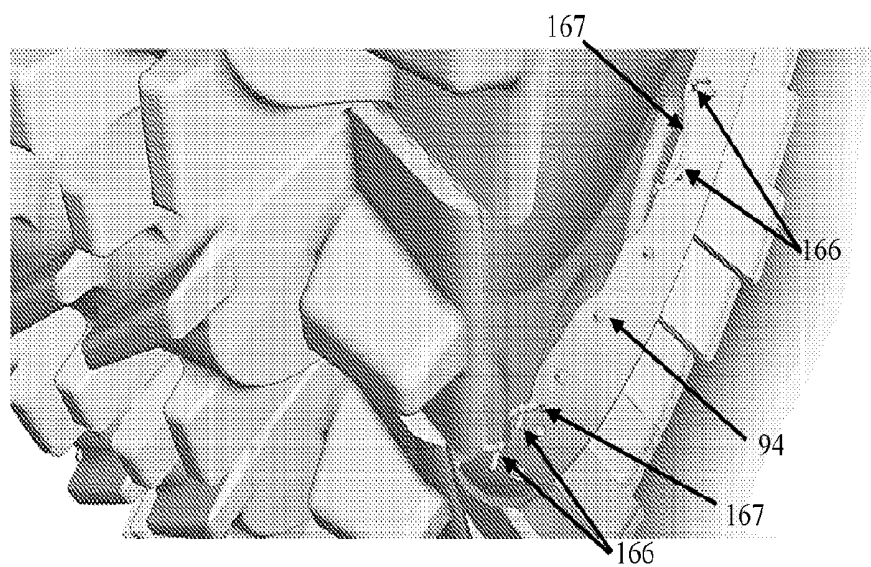


FIG. 19C

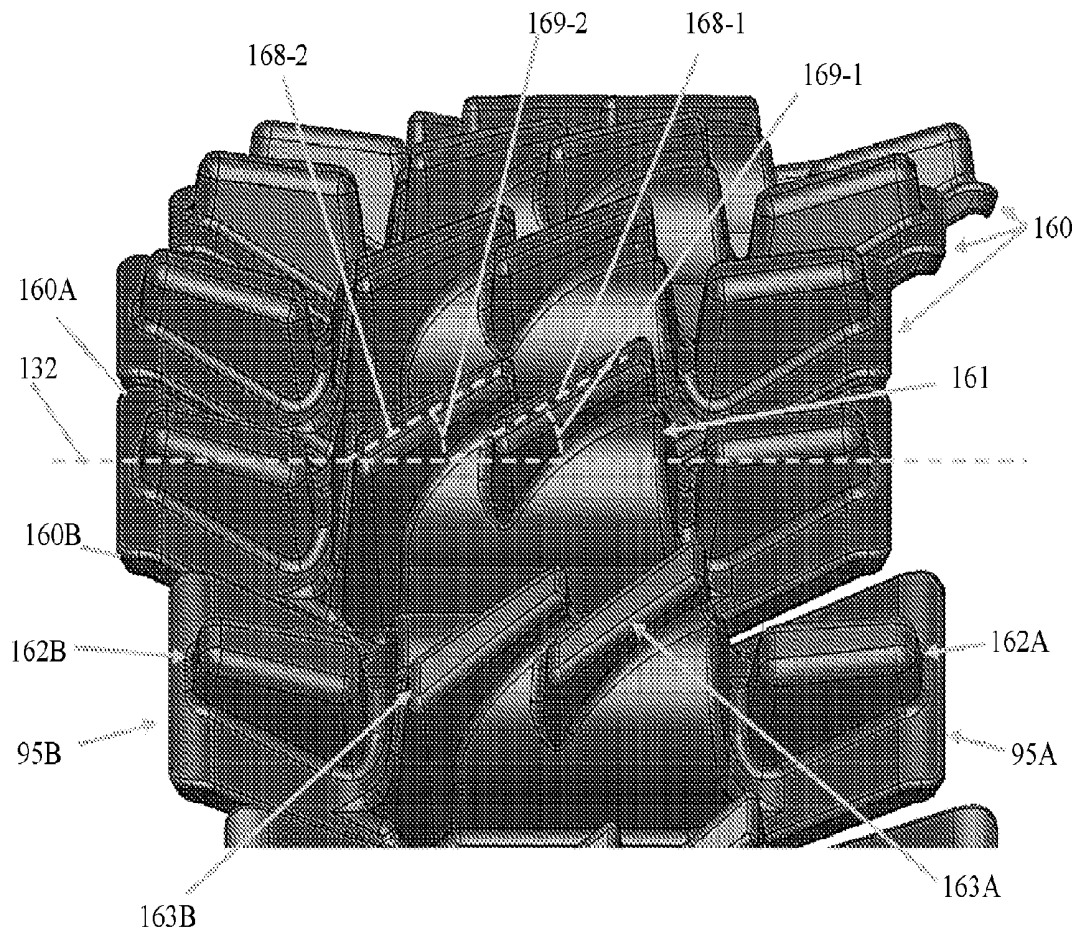


FIG. 20A

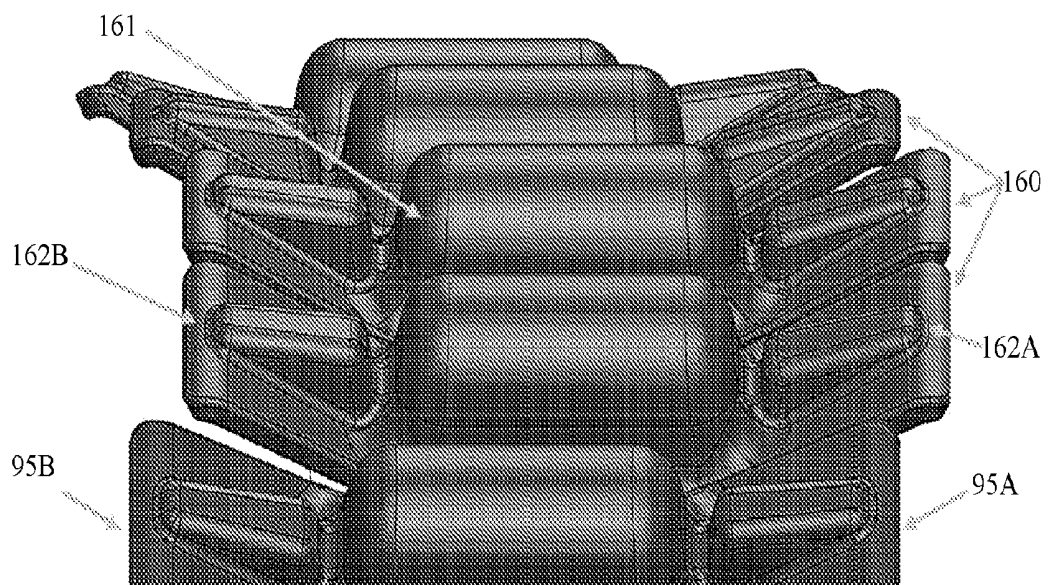


FIG. 20B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US23/77145

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. B60B 15/18; A01B 29/06; B60B 15/02; B60B 23/00 (2023.01)
 ADD. A01G 25/09; B60B 15/20; B60B 15/22; B60B 19/06 (2023.01)
 CPC - INV. B60B 15/18; A01B 29/06; B60B 15/02; B60B 23/00
 ADD. A01G 25/09; B60B 15/20; B60B 15/22; B60B 19/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 See Search History document

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
 See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 2022/0266625 A1 (SHARK WHEEL INC) 25 August 2022; Figs. 6, 7A-7C; paras. [0055], [0057]	1-4, 6, 8-10 --- 7, 11, 12 --- 5
Y --- A	US 2008/0211301 A1 (JEE WOO ET AL.) 04 September 2008; Fig. 2A, para. [0025]	7, 11, 12 --- 5
A	US 2016/0037703 A1 (COOK IVAN) 11 February 2016; entire disclosure	1-12

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 January 2024 (24.01.2024)

Date of mailing of the international search report

FEB 28 2024

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
 P.O. Box 1450, Alexandria, Virginia 22313-1450
 Facsimile No. 571-273-8300

Authorized officer

Shane Thomas

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US23/77145

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-Please See Supplemental Page-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-12

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US23/77145

Continued From Box No. III: Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-12 are directed towards a wheel comprising a plurality lugs with first and second lug plates.

Group II: Claims 13-20 are directed towards a wheel comprising a plurality lugs with leg paddles.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include at least a first lug plate adapted to connect the first leg to the center rib; and a second lug plate adapted to connect the second leg to the center rib; wherein a distal edge of the first lug plate and a distal edge of the second lug plate are configured to radially extend beyond the center rib, which are not present in Group II.

The special technical features of Group II include at least a first leg paddle associated with the first leg; and a second leg paddle associated with the second leg, which are not present in Group I.

The common technical features shared by Groups I-II are a wheel comprising a plurality of lugs, each lug having: a center rib; a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other.

However, these common features are previously disclosed by US 555,330 A to Price. Price discloses a wheel (invention relates to the road-wheels of traction-engines, pg. 1, ll. 12-13) comprising a plurality of lugs (cleats are arranged on the outer circumference of the wheel, Fig. 1, pg. 1, ll. 27-35), each lug having: a center rib (each cleat has a central projection/rib b, Fig. 1-2, pg. 1, ll. 27-35); a first leg and a second leg, each leg extending from the center rib laterally and opposite of each other (each cleat has opposing legs c extending laterally from projection b, Fig. 1-2, pg. 1, ll. 27-35).

Since the common technical features are previously disclosed by the Price reference, these common features are not special and so Groups I-II lack unity.