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Non-Pneumatic Wheel

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Abstract

A non-pneumatic wheel which includes: first and second hub components; a first set of spaced curved resilient members connected between said first hub component and a wheel tyre; a second set of spaced curved resilient members connected between said second hub component and the wheel tyre; wherein said first set of resilient members curves in a direction opposite to the direction of curvature of said second set of resilient members; said wheel further including adjustment means engaged with said first and second hub components and adapted to rotate said hub components relative to each other so as to adjust the force exerted by said first and second sets of resilient members on said wheel tyre.

Fig. 1

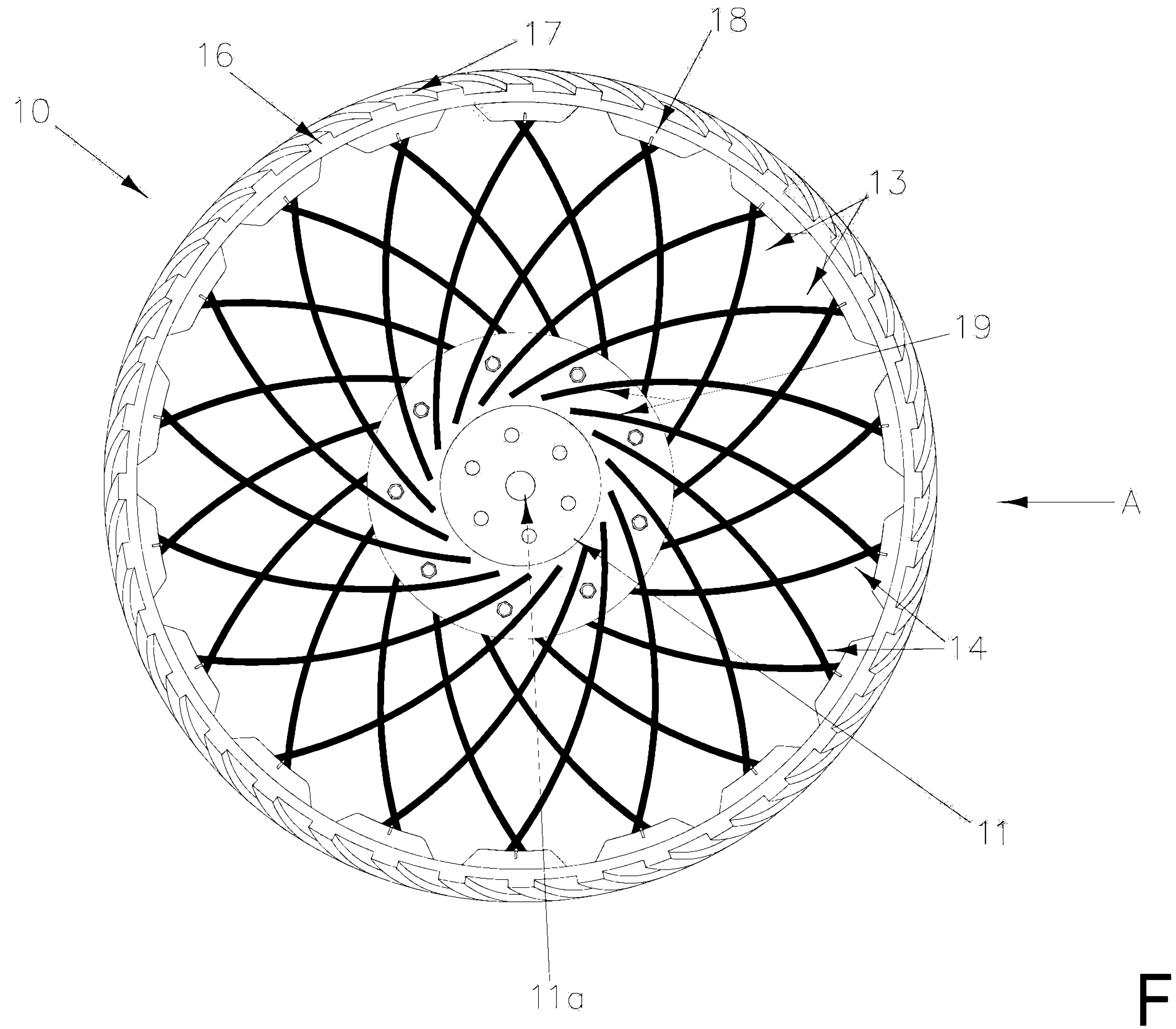

Fig.1

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Non-Pneumatic Wheel

Technical Field

The present invention relates to a non-pneumatic wheel designed so that it is possible to adjust the pressure applied by the wheel quickly and easily.

Background Art

Pneumatic wheels are very widely used in a huge range of applications. Pneumatic wheels can be adapted so that the tyre pressure can be changed, by decreasing or increasing the amount of air within the tyre. However, pneumatic wheels suffer from the well-known disadvantage that, if the outer casing is pierced, the wheel loses pressure and needs to be repaired or replaced. For lightweight vehicle tyres, there are available solutions such as “runflat” tyres, but these are not appropriate for large tyres such as agricultural equipment tyres. Obviously, large tyres of this type are the most likely to be used in potentially damaging environments.

Non-pneumatic wheels, (i.e. wheels in which the pressure on the outer tread of the wheel is applied by some means other than enclosed air or other gas) have been known for many years, but suffer from a number of limitations and drawbacks.

The simplest form of a non-pneumatic wheel is a solid-tyred wheel, e.g. a solid wooden, metal or rubber tyre, but even if the solid wheel is made of resilient material such as rubber, a wheel of this type provides little in the way of shock absorption and thus is very limited in its range of application.

A number of wheel designs have been proposed over the years in which a tyre tread is supported from a hub by adjustable rigid spokes, or by spokes in the form of resilient members. See for example US Patent 818,857 (1906), US Patent 2,321,954 (1943), UK Patent 1,078,817 (1965), US Patent 8,091,596 (2012). However, none of these design proposals has so far gone into regular use; indeed, it appears that many of the proposals may never have gone beyond the “theoretical proposal” stage. It is therefore impossible to guess what shortcomings these designs may have had in practice.

Disclosure of Invention

An object of the present invention is the provision of a non-pneumatic wheel in which the pressure exerted on an underlying surface by the wheel can be varied easily, and in which the wheel is robust and suitable for use in demanding applications, such as use on agricultural equipment.

The wheel of the present invention has been developed particularly for vehicles and machinery, and therefore will be described with especial reference to that application. However, it will be appreciated that the wheel of the present invention also could be used for a wide range of applications which require a wheel type element.

The present invention provides a non-pneumatic wheel which includes:

- first and second hub components;
- a first set of spaced curved resilient members connected between said first hub component and a wheel tyre;
- a second set of spaced curved resilient members connected between said second hub component and the wheel tyre;
- wherein said first set of resilient members curve in a direction opposite to the direction of curvature of said second set of resilient members;
- said wheel further including adjustment means engaged with said first and second hub components and adapted to rotate said hub components relative to each other so as to adjust the force exerted by said first and second sets of resilient members on said wheel tyre.

Preferably, said resilient members are connected to the corresponding hub component by engaging one end of each resilient member with a slot in said hub component.

Preferably, each resilient member comprises a leaf spring. Each leaf spring may be made of any of a range of tough, flexible materials capable of withstanding the necessary loadings.

Preferably, the adjustment means includes a worm and worm wheel drive mounted within a housing and positioned between said first and second hub components, with the worm wheel connected to one of said hub components and the housing connected to the other of said hub components, such that rotation of said worm drive rotates one

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hub component in a first direction and the other hub component in an opposite direction, at the same rate of rotation.

However, it would be possible to use other means for rotating the hub components in opposite directions. For example, the hub components could be rotated using a drive from the vehicle's hydraulic system.

Brief Description of the Drawings

By way of example only, a preferred embodiment of the present invention is described in detail with reference to the accompanying drawings in which:–

Figure 1 is a side view of a wheel in accordance with the present invention;

Figure 2 is a view in the direction of arrow A of Figure 1, with the tyre of the wheel removed;

Figure 3 is a partial side view, similar to Figure 1 but on a larger scale, and showing only part of the tyre;

Figure 4 is an isometric view of part of the hinged bracket used to attach each resilient member to the wheel tyre;

Figure 5 is a diagram showing the adjustment mechanism for the hub components, with the separation between the hub components exaggerated for clarity;

Figure 6 is a diagrammatic exploded view of the wheel of Figure 1, but with the wheel tyre removed; and

Figure 7 is a side view of one of the hub components on a larger scale.

In the drawings, the slots formed in the hub components are shown as solid lines rather than broken lines, for clarity.

Best Mode for Carrying out the Invention

Referring to the drawings, a wheel 10 in accordance with the present invention includes first and second hub components 11, 12, to each of which is secured an array of spaced, curved, resilient members 13, 14. Each of the hub components 11, 12 is secured to an adjustment means 15, as hereinafter described. The ground engaging surface of the wheel is formed by an annular wheel tyre 16, which is formed with an external tread 17 in known manner. The wheel tyre 16 is essentially a flat strip of material formed into an annulus, and does not provide sidewalls like a pneumatic wheel tyre. However, each side of the wheel may be protected by side-plates (not shown) to prevent mud and debris from fouling the working components of the wheel.

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The inner, (i.e. non-ground engaging) side of the tyre 16 has a row of brackets 20 rigidly secured around it, e.g. by bolting. The brackets are spaced apart with the sides of each bracket adjacent the edges 18 of the tyre 16.

The brackets 20 are equidistantly spaced around the inner side of the tyre. As shown in Figure 4, each bracket 20 includes a backplate 21 which has a width W slightly less than the width of the tyre. The backplate 21 is formed with spaced holes 22 through which bolts or other securing means may be inserted to secure each bracket to the tyre.

Each bracket 20 also provides a surface 23, the plane of which is substantially perpendicular to the plane of the backplate 21. One plate 24 of a standard barrel hinge 25 is secured to the surface 23 by screws 26; the other plate 27 of the hinge 25 is secured to one end of an associated resilient member 13, 14, using any suitable securing means such as bolts or screws. Figure 3 shows hinges 25 secured to the ends of some of the resilient members. A separate hinge 25 is used for each resilient member 13, 14:- each backplate 21 accommodates two hinges 25, side-by-side; only one hinge is shown in Figure 4.

The hinge 25 is of known type, i.e. a pair of plates, 24, 27 secured together along their adjacent edges by a pin 28 passing through a knuckle 29 formed by interlocking cylindrical portions formed on the adjacent ends of the plates 24, 27.

The combination of the bracket 20 plus the hinge 25 secures one end of each of the resilient members 13, 14 securely to the inner surface of the tyre, but allows each resilient member to pivot relative to the tyre, in the plane of the wheel.

Referring in particular to Figures 1, 3 and 7, the first set of resilient members 13 is mounted on the first hub component 11, and the second set of resilient members 14 is mounted on the second hub component 12.

Each hub component 11, 12 consists of a short cylinder formed with an axial aperture, 11a, 12a, and also formed with a series of equidistantly spaced blind ended slots 19. In the drawings, the slots 19 are shown as solid lines, for clarity. Each slot 19 extends from the outer wall 11b, 12b, of the cylinder into the body of the cylinder. The slots are not radial:– the angle of each slot is selected such that the resilient members provide

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optimal deflection, and to reduce the stresses on the radial member at the open end of each slot, thereby reducing the fatigue on the radial member.

One configuration of the slots which has been found to work well is to angle each slot at approximately 45˚ to a radial line drawn between the centre of the hub component and the outer end of the slot. However, it is envisaged that a range of other angles may also be suitable. Friction between the outer end of each slot and the corresponding resilient member possibly may inhibit smooth movement of the resilient member relative to the slot. It is advantageous to provide a roller at the end of each slot, for the resilient member to bear against, to address this problem.

Alternatively or additionally, a further improvement is to curve each slot along its length, to reduce the stress concentration along the corresponding resilient member.

Each of the resilient members is mounted on the corresponding hub component by sliding one end of the resilient member into one of the slots; each resilient member is retained within the slot by the sides of the slot, and when under load, as described below, the end of each resilient member will slide to the blind end of the corresponding slot.

When all of the resilient members are mounted on the corresponding hub components, each hub component has an array of resilient members extending outwards from the hub component, around the entire circumference of the hub component.

The first and second hub components 11, 12 are mounted on a central axle (not shown) which passes through the axial aperture 11a, 12a. The hub components are separated and connected by an adjustment means 15 (Figure 5), which is mounted on the central axle between the two hub components. The spacing between the first and second hub components and the adjustment means is greatly exaggerated in Figure 5, for visibility.

As shown diagrammatically in Figure 5, the adjustment means 15 includes a worm drive 31 which is engaged with a worm wheel 32 enclosed in a housing 33. The first hub component 11 is rigidly secured to the housing 33 by a first connector 34, such that the first hub component 11 rotates with the housing 33. The second hub component 12 is rigidly secured to the worm wheel 32 by a second connector 35, such

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that the second hub component 12 rotates with the worm wheel 32. For visibility, the lengths of the connectors 34, 35 are exaggerated in Figure 5.

Rotation of the worm drive 31 in the direction of arrow A rotates the worm wheel 32 in the direction of arrow B, rotating the second hub component 12 in the same direction. At the same time, the housing 33 rotates in the direction of arrow C, rotating the first hub component 11 in the same direction. Thus, driving the worm drive 31 in a first direction rotates the first and second hub components in opposite directions; reversing the direction of drive of the worm drive 31 still rotates the first and second hub components in opposite directions, but these directions are of course reversed.

As described above, the outer end of each of the resilient members 13, 14 is secured to the inner wall of the wheel tyres 16. The first set of resilient members 13 has each member of that set curved in a clockwise direction between the first hub component 11 and the corresponding brackets securing the outer end of each member to the inner wall of the wheel tyre. The second set of resilient members 14 has each member of that set curved in an anticlockwise direction between the second hub component 12 and the corresponding brackets securing the outer end of each member to the inner wall of the wheel tyre. Curving the resilient members in opposite directions in this manner balances the wheel in use.

Both sets of resilient members 13, 14 have the same curvature, so that an even pressure is applied to the inner surface of the wheel tyre right around the wheel. The greater the curvature of the resilient members, the greater is the pressure applied to the wheel tyre. Thus, increasing the curvature of the resilient members in both sets makes the wheel stiffer and less deformable and so decreases the tyre footprint on the underlying ground. Similarly, decreasing the curvature of the resilient members in both sets makes the wheel less stiff and more deformable, and thus increases the tyre footprint on the underlying ground.

It follows that if a vehicle equipped with these tyres is required to move as rapidly as possible over firm ground, then decreasing the tyre footprint by increasing the curvature of the resilient members gives optimum performance. Conversely, if a vehicle equipped with these tyres is required to travel over slippery or swampy ground where it is desirable to spread the weight of the vehicle as much as possible by increasing the tyre footprint, then the curvature of the resilient members should be decreased to give an increased tyre footprint on the ground.

As described above, the hub components 11, 12 can be rotated in either direction (but always in opposite directions) by selecting the appropriate direction of rotation of the worm 31. The worm 31 could if necessary be manually rotated, but it is envisaged that the worm 31 normally would be driven by a small electric motor mounted within the wheel and battery-operated and remotely controlled, so that the pressure exerted by each wheel on the underlying ground could be remotely and individually controlled by the person operating the vehicle. Alternatively, the controls could be such that all wheels of the vehicle were automatically controlled together to set all wheels to the same pressure.

In use, a wheel of the above described type is mounted on a vehicle axle with the axle extending through the apertures 11a, 12a in the hub components; the axle is drivably engaged with the second hub component 12, but the hub component 11 is not directly engaged with the axle, but is driven from the hub component 12 via the adjustment means 15.

Claims

1. A non-pneumatic wheel which includes:

- first and second hub components;
- a first set of spaced curved resilient members connected between said first hub component and a wheel tyre;
- a second set of spaced curved resilient members connected between said second hub component and the wheel tyre;
- wherein said first set of resilient members curves in a direction opposite to the direction of curvature of said second set of resilient members;
- said wheel further including adjustment means engaged with said first and second hub components and adapted to rotate said hub components relative to each other so as to adjust the force exerted by said first and second sets of resilient members on said wheel tyre.

2. The wheel as claimed in claim 1 wherein each resilient member comprises a leaf spring.

3. The wheel as claimed in claim 1 or claim 2 wherein each resilient member is connected to the corresponding hub component by engaging one end of each resilient member with a slot in the corresponding hub component.

4. The wheel as claimed in claim 3, wherein each slot extends at approximately 45 degrees to a radial line drawn between the centre of the hub component and the outer end of the slot.

5. The wheel as claimed in claim 3 or claim 4, wherein each slot is curved along its length.

6. The wheel as claimed in any one of claims 3-5, wherein a roller is provided at the outer end of each slot, arranged such that the corresponding resilient member bears against the roller when moving relative to the slot.

7. The wheel as claimed in any one of the preceding claims wherein the adjustment means includes a worm and worm wheel drive positioned between said first and second hub components, with the worm wheel enclosed in a

housing which is rigidly secured to one of said hub components, and the worm wheel rigidly secured to the second of said hub components, such that rotation of the worm drive rotates the worm wheel and said second hub component in a first direction, and simultaneously rotates the housing and said first hub component in the opposite direction.

8. The wheel as claimed in claim 7 wherein the worm drive is rotatable manually.

9. The wheel as claimed in claim 7 wherein the wheel drive is driven by an electric motor mounted within the wheel.

10. The wheel as claimed in claim 9 wherein said electric motor is remotely controlled.

11. The wheel as claimed in any one of claims 1– 6 wherein the adjustment means includes a hydraulic drive from a vehicle's hydraulic system.

12. The wheel as claimed in any one of the preceding claims wherein both sets of resilient members have the same curvature.

13. The wheel as claimed in any one of the preceding claims wherein the wheel tyre comprises a strip of material formed into an annulus.

14. The wheel as claimed in any one of the preceding claims, further including side plates arranged to cover each side of the wheel so as to prevent fouling of the working components of the wheel.

15. The wheel as claimed in any one of the preceding claims wherein the non-ground engaging side of the wheel tyre is provided with a spaced row of brackets rigidly secured thereto, each said bracket providing means for pivotally securing one end of one of said first set of resilient members and one end of one of said second set of resilient members to said wheel tyre so as to allow each resilient member to pivot relative to the wheel tyre in the plane of the wheel.

16. The wheel as claimed in claim 15 wherein each said pivotally securing means consists of a pair of barrel hinges secured side-by-side to said bracket, with one plate of each said hinge rigidly secured to said bracket and the other plate of each said hinge secured to one end of a resilient member.

17. The combination of a vehicle having at least two wheels as claimed in any one of claims 1–16, wherein the adjustment means of each wheel is arranged to be individually adjustable.

18. The combination of a vehicle having at least two wheels as claimed in any one of claims 1 – 16, wherein the adjustment means of both or all wheels are arranged to be adjusted simultaneously.

19. The combination as claimed in claim 17 or claim 18, wherein each wheel is mounted on a vehicle axle with the axle extending through a central aperture in each of the hub components, and wherein the axle is drivably engaged with only one of said hub components.

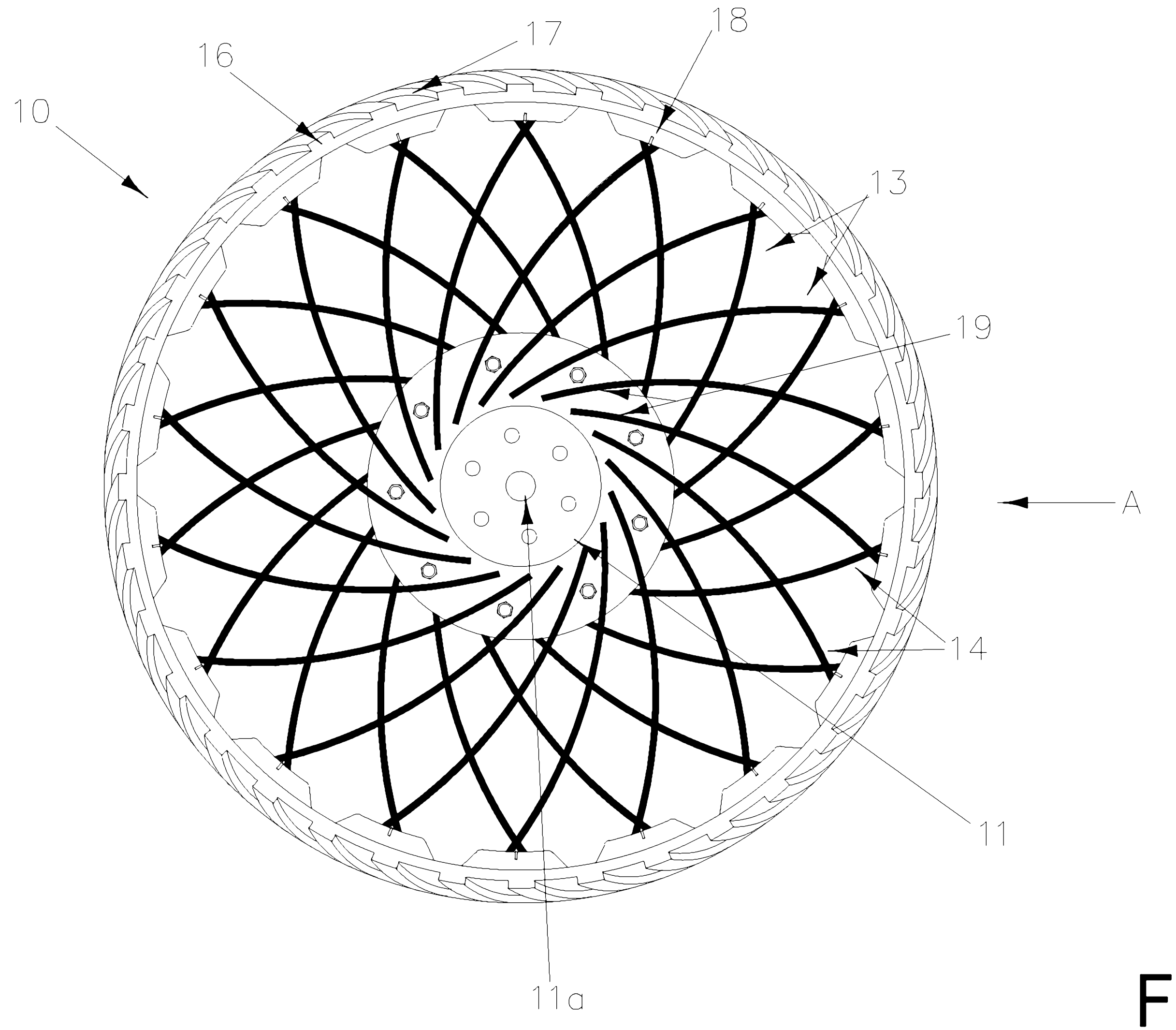

Fig.1

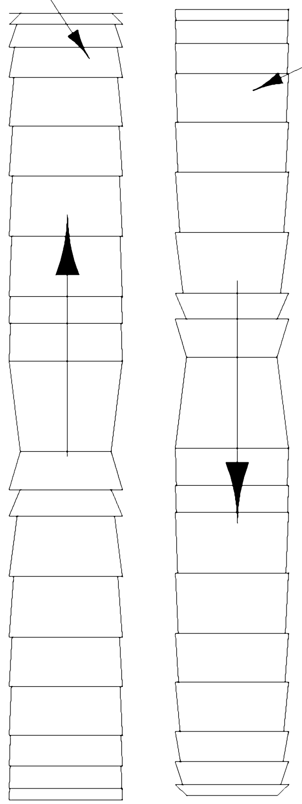

Fig.2

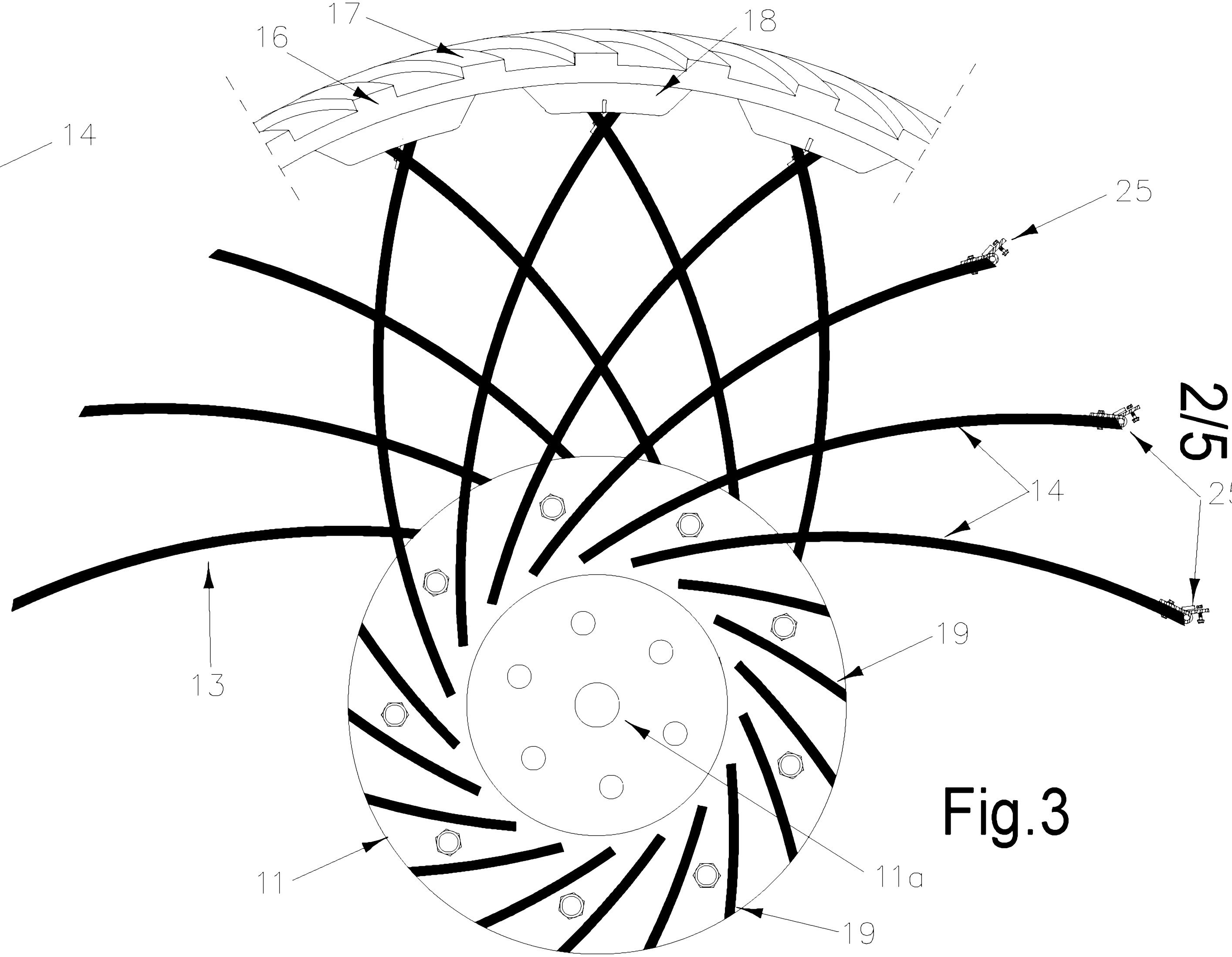

Fig.3

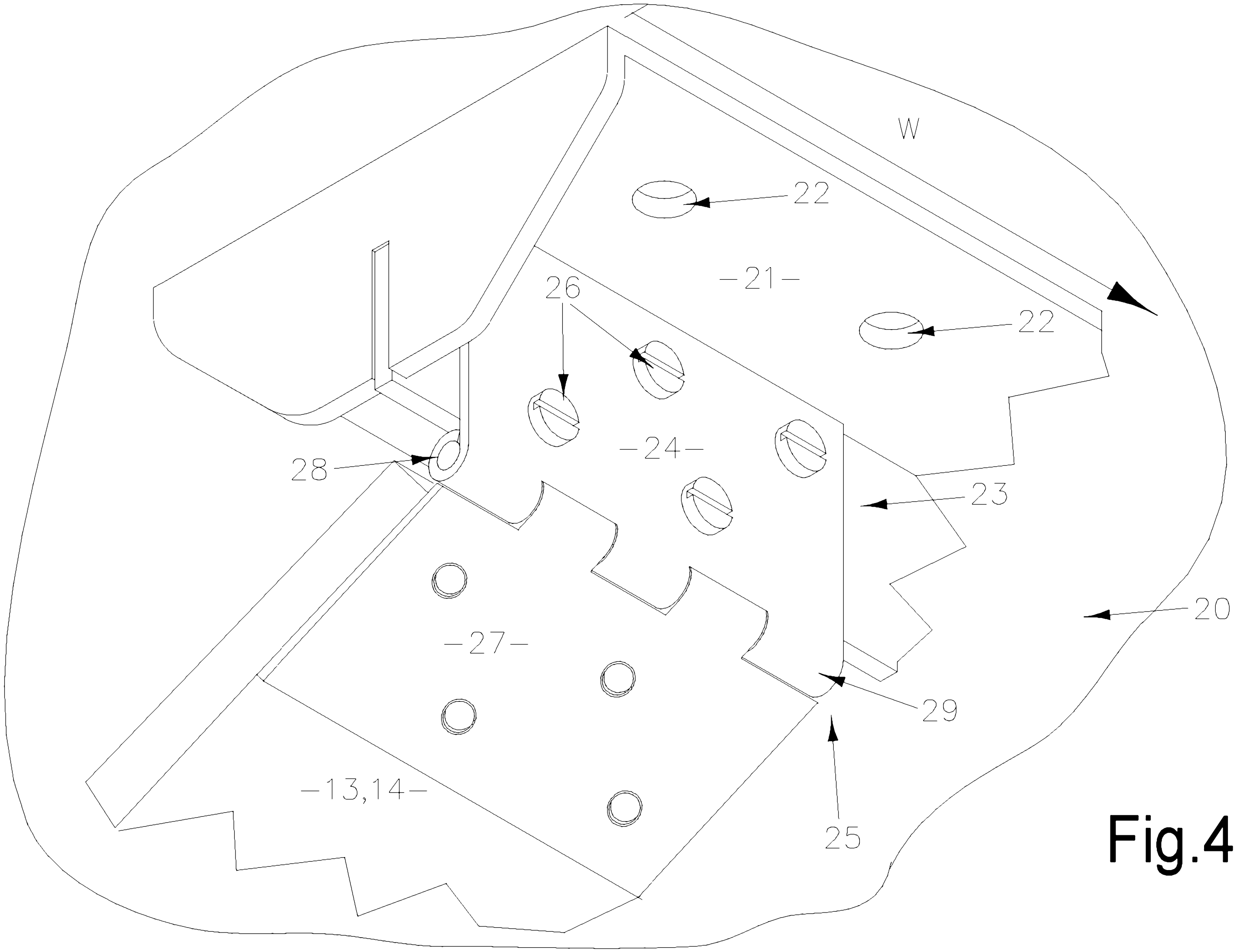

Fig.4

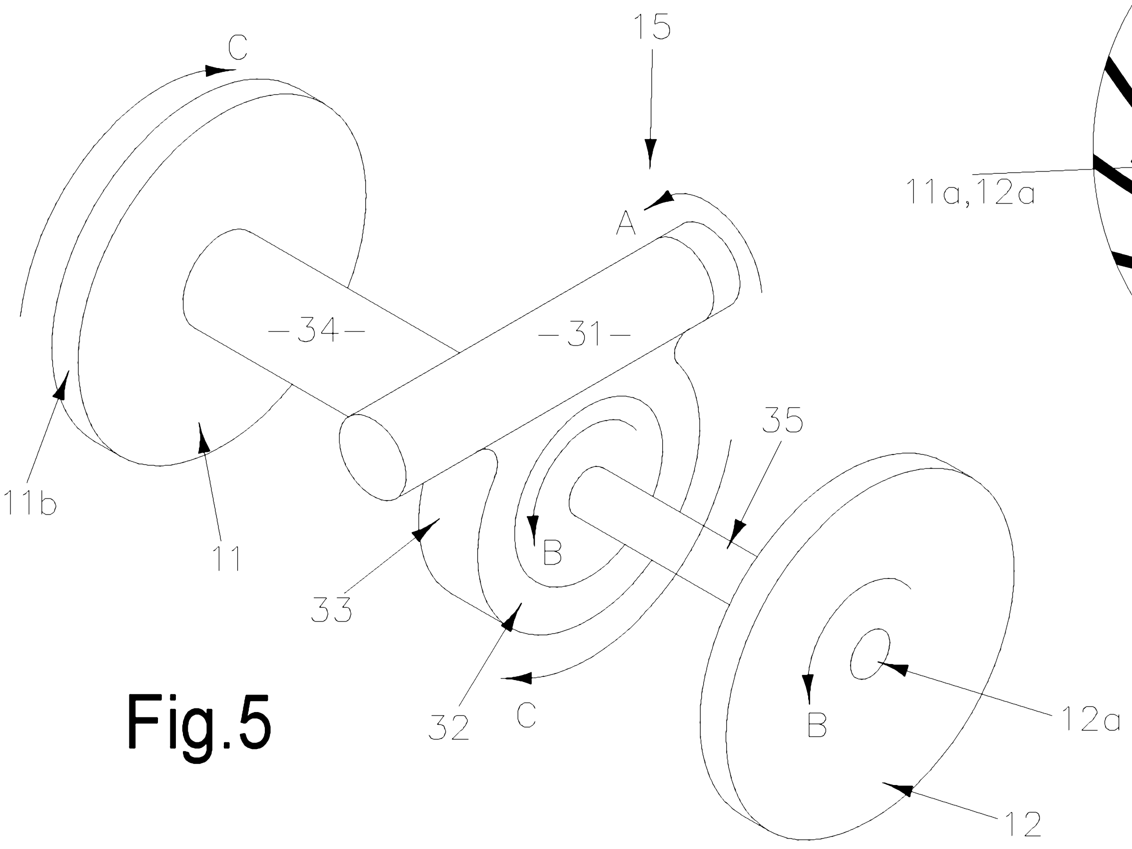

Fig.5

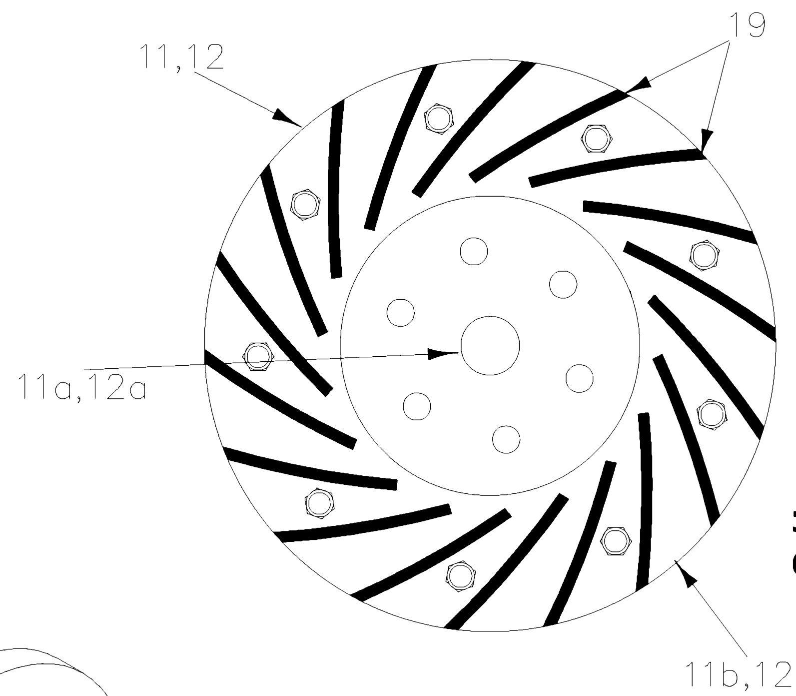

Fig.7

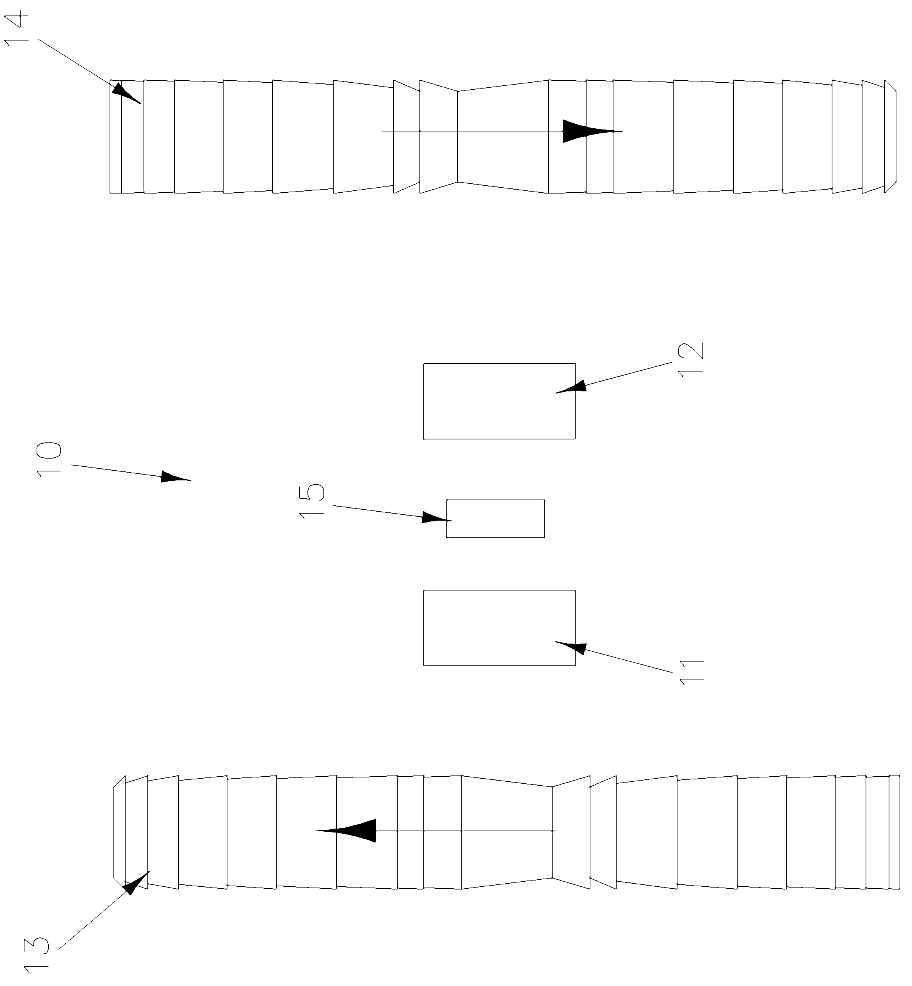

Fig.6