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(72) Inventor; and
(71) Applicant: GARNET, Jeremy [CA/CA]; 105 Whitley Ave., Pointe-Claire, Québec H9R 3A7 (CA).

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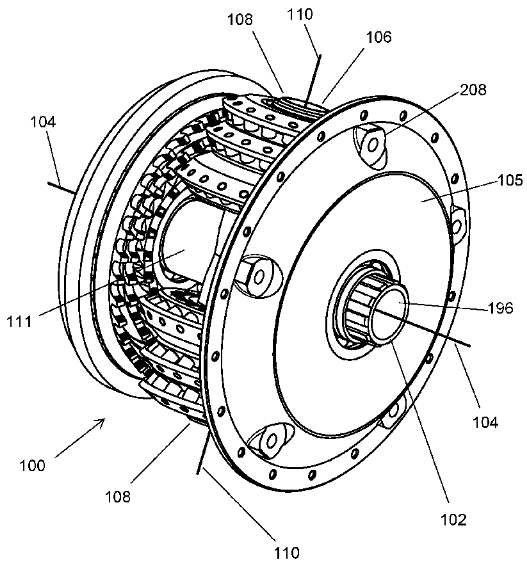

FIG. 2

(57) Abstract: A multi-speed planetary hub transmission wherein bevel planet gears arranged in clusters mesh with corresponding bevel reaction gears and bevel output gears. The large gear size resulting from the bevel architecture gives enough space for friction reducing roller teeth. Each bevel reaction gear and each bevel output gear has an associated engageable freewheel, which is engaged, or disengaged, to select the desired gear ratio. Control of the engageable freewheels may be wireless to simplify the internal gear shifting mechanisms within the hub. Examples are given of a possible 8-speed version and 11-speed version. More than 11 speeds are also possible. The hub may be used in many types of bicycles, tricycles, and human-powered vehicles, including electrically assisted. The hub may be chain-driven, as in a regular bicycle rear wheel; directly driven, as in a front wheel of a direct-drive recumbent bicycle; or directly driven as a bottom bracket gear hub.

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MULTI-SPEED BEVEL-PLANETARY HUB TRANSMISSION

Field of the Invention

The invention relates to the field of hub transmissions, specifically bicycle hub transmissions, also known as internal gear hubs. The scope includes all bicycle and tricycle types, extending to all types of human-powered vehicles. The hub may be chain-driven, as in a conventional bicycle rear wheel, or directly driven, as in a front wheel of a direct-drive recumbent bicycle. The hub may also be mounted entirely outside of a wheel to form another part of a bicycle's overall gear train system. For example, it may be directly driven as a bottom bracket gear hub with a chainring as the output element. Due to a potential for higher torque capacity, the hub transmission is also well suited for use in conjunction with electric assist, such as in pedelecs, e-bikes, electrically assisted tricycles, or other electrically assisted human-powered vehicles.

Background of the Invention

Bicycle internal gear hubs are well known and have been in production for over a century. Most of these hubs operate by means of a planetary gear train, composed of the following basic elements: a central sun gear; a planet gear carrier which positions several planet gears around the sun gear; and a ring gear externally surrounding these planet gears. Different gear ratios are available by simply preventing the rotation of one of these elements and choosing the remaining two elements as either the input or output of the transmission.

United States patent US9139254 B2 to the present inventor discloses a planetary bicycle hub transmission, having multiple speeds, and employing bevel gears and roller teeth.

The bevel gear system of US9139254 B2 permits much larger planet gears than conventional planetary systems because the bevel gear configuration allows the size of each planet gear to be independent of the gear ratio. The gear ratio is instead provided by the axial height of the planet gear cluster, or the angle of mounting of the planet gear. The planet gear size is therefore constrained only by the width of the hub. These larger planet gears permit a larger tooth pitch, resulting in a greater torque capacity for the transmission; and the larger tooth pitch provides the space for friction reducing elements such as rollers. The rollers and meshing sprockets transfer torque like a roller cam mechanism, reducing meshing friction by replacing sliding contact with rolling contact throughout all angles of tooth engagement. In contrast, the teeth of two regular spur gears have rolling contact only at the instantaneous point where the pitch circles of the two gears intersect. Furthermore, the use of bevel planet gears allows the hub transmission to achieve higher gear ratios than conventional hubs. The higher ratios are particularly well suited to direct-drive, which has no chain-drive to give an intermediate step-up ratio. Still further, the use of bevel gears increases the minimum contact ratio in the gear train, improving the smoothness of the meshing or allowing less gear teeth with the same smoothness of meshing.

However, the number of speeds (gear ratios) available in US9139254 B2 is somewhat limited. In the first embodiment of US9139254 B2, if more that four speeds are desired, the planet gear cluster becomes increasingly tall, increasing the overall outer diameter of the hub. In the second embodiment of US9139254 B2, there is little circumferential space on the planet gear carrier for more than four speeds.

Since there is strong demand in the marketplace for more than four speeds, it would be advantageous to provide a hub with the advantages of US9139254 B2, but with more speeds – preferably 8 to 16 speeds. It would also be advantageous to provide these extra speeds without multiple planetary units connected in series, and, even more preferably, to achieve these extra speeds without the need for many more planet gears or ring gears.

Summary of the Invention

Therefore, it is an object of the present invention to provide a low-friction, high-torque capacity bicycle hub transmission with 8 speeds or more, having a single planetary gear stage and a minimum number of planet gears. It is a further object to provide a simplified gear shifting configuration, particularly a simplified means of engaging and disengaging gear elements that are rotating. It is a still further object to provide a hub where the manufacturing of the bevel gear elements is simplified.

To meet these objects, the present invention improves on the transmission of US9139254 B2 by replacing the single output bevel gear with multiple output bevel gears, each selectively engageable to drive the hub by means of an associated engageable freewheel. This will increase the number of speeds from four to eight with the addition of only two more output bevel gears, or from five speeds to eleven, with the addition of only three more output bevel gears.

The engageable freewheels are preferably controlled wirelessly to eliminate the complex mechanical linkages that otherwise would be needed to reach the rotating parts.

When engaged, the selected output bevel gear drives the hub, but the hub may still overrun it if the hub is moving faster. When disengaged, the output bevel gear is free to move in either direction relative to the hub and therefore no drive is transmitted to the hub. In this way, the freewheel and gear shift elements are combined, simplifying the design.

Engageable freewheels are also provided to hold the bevel ring gears stationary.

The use of engageable freewheels prevents the transmission from jamming if the shift control system fails and several bevel ring gears are held stationary at the same time. Rather than jamming, the engaged freewheels associated with the faster moving elements will simply overrun, avoiding internal damage to the hub.

Engageable freewheels are known in the art of bicycle hub transmissions, for example in US6048287 to Rohloff. However, it is not known to apply engageable freewheels to a multi-speed bevel planetary bicycle hub transmission in such a way as to achieve the particular benefits here disclosed.

Other advantages and variations to the design will be evident from the detailed description and referenced drawings.

Brief Description of the Drawings

Figure 1 depicts an exemplary embodiment of the transmission hub according to the invention, configured for chain-drive.

Figure 2 illustrates the transmission hub of figure 1 with the cover and first gear freewheel removed.

Figure 3 is an exploded view showing the mounting of the planet clusters on the drive shaft unit.

Figure 4 is detailed view of a planet gear cluster.

Figure 5 depicts the meshing of the bevel planet gears with the bevel output gears.

Figure 6 is a plan view of the bevel output gears.

Figure 7 shows the engageable freewheel of the smallest bevel output gear.

Figure 8 illustrates the engageable freewheel configuration of figure 7 in more detail.

Figure 9 depicts the meshing of the bevel planet gears with the bevel reaction gears.

Figure 10 is a plan view of the bevel reaction gears.

Figure 11 show the first gear freewheel configuration.

Figure 12 illustrates the wireless control system for the engageable freewheels of the bevel output gears.

Figure 13 illustrates a means for controlling the engageable freewheels by linear actuators.

Figure 14 illustrates the wireless control system for the engageable freewheels of the bevel reaction gears.

Figure 15 depicts an exemplary wireless shifter unit configuration.

Figure 16 shows the ratios attainable for an 8-speed example of the transmission hub.

Figure 17 shows the ratios attainable for an 11-speed example of the transmission hub.

Figure 18 shows the transmission hub configured for direct-drive.

Figure 19 depicts the transmission hub configured for bottom bracket mounting.

Figure 20 illustrates an alternative control of the engageable freewheels using a cam ring and electric motor.

Figure 21 is a schematic of an alternate wired control system for shifting gears.

Figure 22 illustrates a means of attaining mechanical control of the rotating engageable freewheels of the bevel output gears.

Detailed Description of the Invention

Figure 1 shows an overall view of an example embodiment of the hub transmission (100) of the present invention. Figure 2 depicts the hub transmission (100) with a cover portion (101) removed. Input torque to the hub transmission (100) is transmitted by a drive shaft (102) which rotates about a drive shaft axis (104). The drive shaft (102) is directly connected to a planet gear axle (106) consisting of a stub axle (108) and an identical, but oppositely directed, stub axle (108). The stub axles (108) share a common planet gear axis (110). The planet gear axis (110) intersects the drive shaft axis (104) at 90 degrees. The drive shaft (102) combined with the stub axles (108) form a drive shaft unit (111).

Figure 3 illustrates an exploded view of the drive shaft unit (111). A planet gear cluster (112) is mounted on each stub axle (108) and rotates about the planet gear axis (110). Each one of the two planet gear clusters (112) is identical and comprises three axially-spaced bevel planet gears (114, 116, 118). The axial spacing between successive bevel planet gears (114, 116, 118) in the planet gear cluster (112) may differ – as shown. The diameter of each bevel planet gear (114, 116, 118) may also differ, as illustrated. The bevel planet gears (114, 116, 118) are integrally formed with the planet gear cluster (112) and therefore rotate together as a unit. Each one of the bevel planet gears (114, 116, 118) is equipped with roller teeth (115), which rotate on supporting pins (117) about roller tooth axes (119). Figure 4 shows a planet gear cluster (112) in more detail.

As shown in figure 5, the bevel planet gears (114, 116, 118) of each planet gear cluster (112) mesh with corresponding bevel output gears (120, 122, 124) – more clearly shown in face view in figure 6. The bevel output gears (120, 122, 124) are rotatably mounted on an inside of an output gear carrier (126), to which the cover portion (101 – figure 1) is attached, together forming a hub shell (127). As the name implies, the bevel output gears (120, 122, 124) provide output torque to a hub shell (127). The bevel output gears (120, 122, 124) have an axis of rotation that is concentric with the drive shaft axis (104). The hub shell (127) also has an axis of rotation that is concentric with the drive shaft axis (104).

As shown in figure 6, each bevel output gear (120, 122, 124) has a corresponding engageable freewheel (128, 130, 132) positioned between the corresponding bevel output gear (120, 122, 124) and the hub shell (127). The term “engageable freewheel” is defined as a freewheel that, relative to its mounting surface, allows rotation in one direction only when the freewheel is engaged and allows rotation in both directions when the freewheel is disengaged.

Figures 7 and 8 show the engageable freewheel (128) for the smallest bevel output gear (120) in more detail. A ratchet wheel (134) is integrally formed on a reverse side of the bevel output gear (120). Pawls (136) are rotatably mounted on the hub shell (127) and, in a manner well known in the art, the pawls (136) are spring-loaded to engage with a surface of the ratchet wheel (134). Therefore, when the engageable freewheel (128) is engaged, the pawls (136) transmit power to the hub shell in a clockwise direction (when viewed facing the hub right side) while allowing the hub to freewheel if it is turning faster than the bevel output gear (120). To disengage the engageable freewheel (128), the pawls (136) are lifted clear of the surface of the ratchet wheel (134) against their spring loading, and thus no power is transmitted to the hub shell (127) in either direction by the bevel output gear (120). A similar configuration of engageable pawls and corresponding ratchet wheels is employed in the engageable freewheels (130, 132) of the two larger bevel output gears (122, 124).

As illustrated in figure 9, on the left side of the hub transmission (100) the bevel planet gears (114, 116, 118) of each planet cluster (112) mesh with three corresponding bevel reaction gears (140, 142, 144) – more clearly shown in face view in figure 10. These gears are called “bevel reaction gears” because they provide the necessary reaction force for the bevel planet gears (114, 116, 118) to drive the corresponding bevel output gears (120, 122, 124) on the opposite side of the hub. The three bevel reaction gears (140, 142, 144) are rotatably mounted on a reaction gear carrier (146) and each bevel reaction gear (140, 142, 144) has an axis of rotation that is concentric with the drive shaft axis (104). The reaction gear carrier (146) is prevented from rotating by being fixed relative to the bicycle frame or fork.

As shown in figure 10, each bevel reaction gear (140, 142, 144) has a corresponding engageable freewheel (148, 150, 152) positioned between a corresponding bevel reaction gear (140, 142, 144) and the reaction gear carrier (146). The engageable freewheels (148, 150, 152) operate similarly to the engageable freewheels (128, 130, 132) of the output gears (120, 122, 124). Since the reaction gear carrier (146) is fixed relative to the mounting structure of the bicycle, when the engageable freewheels (148, 150, 152) are engaged, the corresponding bevel reaction gear (140, 142, 144) is prevented from rotating in a clockwise direction when viewed facing the right side of the hub. This provides the necessary reaction force for the corresponding bevel planet gear to drive the engaged bevel output gear and so drive the hub shell (127).

The bevel output gears (120, 122, 124) do not transmit any torque to the hub shell (127) when all their associated engageable freewheels (128, 130, 132) are disengaged. Similarly, the bevel output gears (120, 122, 124) do not transmit any torque to the hub shell (127) when all the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) are disengaged. When either, or both, of these cases are true, the hub is designed to revert to a 1:1 ratio (first gear) by means of a first gear freewheel (154). As illustrated in figure 11, the first gear freewheel (154) consists of a pawl holder (156) located at a distal end of each stub axle (108), a spring-loaded first gear pawl (158) installed in in each pawl holder (156), and first gear ratchet ring (160) fixed to the inside of the cover portion (101) of the hub shell (127) in a cover portion protrusion (103) – figure 1.

Figure 12 illustrates the transmission hub (100) with a side cover (105 – figure 1) removed showing the control elements for the engageable freewheels (128, 130, 132) of the bevel output gears (120, 122, 124). Each engageable freewheel (128, 130, 132) of each bevel output gear (120, 122, 124) is controlled by an actuation system comprising a pair of linear actuators (162, 164, 166) respectively. Each pair of linear actuators (162, 164, 166) disengages each of the respective engageable freewheels (128, 130, 132) by lifting the associated pawls clear of ratchet wheel surface, and engages the freewheel by retracting, allowing the pawls to return to the ratchet wheel surface under spring load. A typical arrangement is shown in figure 13 for the smallest bevel output gear (120) – the linear actuators (162) lift the pawls (136) from the surface of the ratchet wheel (134) to disengage engageable freewheel (128). The pairs of linear actuators (162, 164, 166) of the engageable freewheels (128, 130, 132) of the bevel output gears (120, 122, 124) are wirelessly controlled by an output gear controller (168), output gear receiver (170), and output gear power source (four rechargeable batteries 172 – figure 12). The output gear receiver (170) receives an incoming wireless signal that is subsequently processed by the output gear controller (168) to operate the linear actuators (162, 164, 166) according to the selected gear. In this way, complex mechanical linkages between the rotating hub shell (127) and the bicycle frame or fork are avoided, as well as shifter cables.

Referring to figure 14, a similar control system is applied to the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) on the left side of the hub. In a manner similar to figure 13, pairs of linear actuators (184, 186, 188) disengage the associated engageable freewheel (148, 150, 152) by moving the respective freewheel pawls clear of the ratchet wheel surface, and engage the associated engageable freewheel by retracting, allowing the pawls to return to the ratchet wheel surface under spring load. The pairs of linear actuators (184, 186, 188) of the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) are also wirelessly controlled. A reaction gear controller (190), a reaction gear receiver (192), and reaction gear power sources (four rechargeable batteries 172) are mounted on the reaction gear carrier (146) on the left side of the hub. Although a mechanical linkage is simpler on the left side of the hub than on the right side because the left side is stationary, the exemplary wireless control is preferable for compatibility with the right-side control system, and to avoid shifter cables.

As shown schematically in figure 15, the output gear receiver (170) and the reaction gear receiver (192) receive wireless signals (193) from a transmitter (174) forming part of a shifter unit (176) mounted on the handlebars (177) of the bicycle. The shifter unit (176) comprises a gear selector (178), a shifter unit controller (180), the transmitter (174), and a shifter unit power source (182).

All the linear actuators (162, 164, 166, 184, 186, 188) are preferably latching solenoids. Latching solenoids hold their retracted and extended position without any power input, requiring electrical power only when moving. They are therefore much more efficient than conventional solenoids. The linear actuators may alternatively be lead screw actuators, which encompass a small electric motor and lead screw to give the linear motion.

Operation

The hub transmission operates as follows. For the lowest gear (having a ratio of 1:1), all the engageable freewheels (128, 130, 132, 148, 150, 152) are disengaged, allowing the bevel reaction gears (140, 142, 144) and bevel output gears (120, 122, 124) to rotate freely with the no torque transmitted through them to the hub shell (127). As a result, the torque is instead transmitted to the hub shell (127) through the first gear freewheel (154), giving the 1:1 ratio.

Higher gears are obtained by engaging one engageable freewheel (148, 150, 152) corresponding to one of the bevel reaction gears (140, 142, 144) and one engageable freewheel (128, 130, 132) corresponding to one of the bevel output gears (120, 122, 124). Since this will always result in a ratio greater than 1:1, the first gear freewheel (154) will overrun, and the ratio will be determined by the engaged freewheels alone. Since there are three bevel output gears (120, 122, 124) and three bevel reaction gears (140, 142, 144), theoretically a total of nine extra gear ratio combinations should be available. However, three of these ratios will be the same (1:2) giving two redundant ratios and thus seven extra ratios available. This means that the example hub transmission (100) has a total of eight speeds (including the 1:1 first gear). Expressed generally, where n is the number bevel planet gears per planet gear cluster, the total number of ratios (N) available will be:

$$N = n^2 - n + 2$$

The ratios are determined by the following equation:

$$R = 1 + \left(\frac{D_{PO}}{D_{PR}}\right)\left(\frac{D_R}{D_O}\right)$$

Where,

R is the ratio

D_{PO} is the pitch diameter of the bevel planet gear than meshes with the engaged bevel output gear

D_{PR} is the pitch diameter of the bevel planet gear than meshes with the engaged bevel reaction gear

D_R is the pitch diameter of the engaged bevel reaction gear

D_O is the pitch diameter of the engaged bevel output gear

Example hub dimensions and ratios for the illustrated embodiment (8-speed)

Table 1 presents the dimensions for the example hub transmission (100) described above and shown in figures 1-15. The gear module is 2.7.

Table 2 presents the gear ratios and control combinations for each ratio, where an engaged freewheel is represented by “x” and a disengaged freewheel is represented by “0”.

Table 1: 8-speed example bevel gear dimensions

Gear element	Number of teeth	Pitch diameter [mm]
Bevel planet gear (114)	24	64.8
Bevel planet gear (116)	20	54.0
Bevel planet gear (118)	18	48.6
Bevel output gear (120)	18	48.6
Bevel output gear (122)	30	81.0
Bevel output gear (124)	38	102.6
Bevel reaction gear (140)	18	48.6
Bevel reaction gear (142)	30	81.0
Bevel reaction gear (144)	38	102.6

Table 2: 8-speed engageable freewheel control combinations and resulting ratio

Gear	Ratio	Engageable freewheels					
		Bevel reaction gear freewheels			Bevel output gear freewheels		
		1st (148)	2nd (150)	3rd (152)	1st (128)	2nd (130)	3rd (132)
1	1.00	0	0	0	0	0	0
2	1.36	x	0	0	0	0	x
3	1.50	x	0	0	0	x	0
4	1.71	0	x	0	0	0	x
5	2.00	0	x	0	0	x	0
6	2.41	0	0	x	0	x	0
7	3.00	0	x	0	x	0	0
8	3.81	0	0	x	x	0	0

A graph of the resulting ratios is presented in figure 16 including a comparison to the theoretical best ratios (ratios having a constant percentage increment). The available ratios vary within 12% of the theoretical best ratios.

Increasing the number of planet gears per cluster to four (11-speed example)

Table 3 presents example dimensions for an embodiment of the transmission hub having four bevel planet gears per planet gear cluster. The gear module is 2.7.

Table 4 presents the gear ratios and control combinations for each ratio, where an engaged freewheel is represented by an “x” and a disengaged freewheel is represented by a “0”. Although fourteen gears are available, several of these gears are very close in ratio resulting in eleven useful ratios, as shown in the table.

Table 3: 11-speed example bevel gear dimensions

Gear element	Number of teeth	Pitch diameter [mm]
1st bevel planet gear	21	56.7
2nd bevel planet gear	20	54.0
3rd bevel planet gear	19	51.3
4th bevel planet gear	18	48.6
1st bevel output gear	18	48.6
2nd bevel output gear	28	75.6
3rd bevel output gear	44	118.8
4th bevel output gear	54	145.8
1st bevel reaction gear	18	48.6
2nd bevel reaction gear	28	75.6
3rd bevel reaction gear	44	118.8
4th bevel reaction gear	54	145.8

Table 4: 11-speed engageable freewheel control combinations and resulting ratio

		Engageable freewheels							
		Bevel reaction gear freewheels				Bevel output gear freewheels			
Gear	Ratio	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1	1.00	0	0	0	0	0	0	0	0
2	1.29	x	0	0	0	0	0	0	x
3	1.47	0	x	0	0	0	0	0	x
4	1.61	x	0	0	0	0	x	0	0
5	1.77	0	0	x	0	0	0	x	0
6	2.00	0	0	x	0	0	0	x	0
7	2.30	0	0	0	x	0	0	x	0
8	2.63	0	x	0	0	x	0	0	0
9	3.14	0	0	0	x	0	x	0	0
10	3.70	0	0	x	0	x	0	0	0
11	4.50	0	0	0	x	x	0	0	0

A graph of the resulting ratios is presented in figure 17 including a comparison to the theoretical best ratios (ratios having a constant percentage increment). The ratios are within 11% of the theoretical best ratios.

Mounting and drive options

The hub transmission (100) is designed to be mounted for chain-drive, as in a regular bicycle, but it can also be mounted for direct-drive, where the hub is driven directly by the pedal cranks. This allows the hub to be used in a direct-drive recumbent bicycle which is front-wheel drive and has no chain. Other direct-drive wheel mountings are also possible. The direct-drive configuration also allows the hub to be mounted in the bicycle frame as a bottom bracket gear.

For standard chain-drive, as shown in figure 1, an axle (194) is rotatably mounted in a drive shaft bore (196 – figure 2) in the drive shaft (102), allowing the drive shaft (102) to rotate freely relative to the axle (194) around the drive shaft axis (104). The axle is fixed to the bicycle frame in a manner well-known in the art. A sprocket (198) is fixed to the outer diameter of the drive shaft (102) on the right side. A chain drives the sprocket (198) to provide driving torque to the drive shaft (102). Toothed belt drive, or shaft drive, may be used rather than chain drive.

For direct-drive, as shown in figure 18, the axle (194) is removed and replaced with splined crank axle ends (200). The sprocket (198) is removed and replaced with a mounting bearing (202). A similar mounting bearing (202) is mounted on the left outer surface of the drive shaft (102). The hub is then mounted to the bicycle on the mounting bearings (202) and cranks are attached to crank axle ends (200) to provide driving torque to the drive shaft (102).

For bottom bracket mounting, as illustrated in figure 19, the hub is configured for direct-drive as described above, but the hub is not built into a wheel. Instead, it is mounted by the mounting bearings (202) in a specially configured bottom bracket. A chainring (206) is bolted to chainring mounting bosses (208 – figure 18) to provide drive to the chain. When not used for bottom bracket mounting, the chain ring bosses (208) may be employed as a disk brake mounting, although this would mean a non-standard right-side disk brake position. Separate disk brake mounting bosses (not shown) may also be integrated into the left side of the hub shell (127) in a conventional manner. Similarly, a belt drive sprocket may be attached to the chainring mounting bosses (208) to provide drive to a toothed belt, rather than a chain.

Instead of being adaptable between chain-drive, direct-drive, and bottom bracket mounting (as described above), the hub transmission may be customized for chain-drive alone, direct-drive alone, or bottom bracket mounting alone. For chain-drive alone, the mounting surfaces for the mounting bearings (202) may be excluded, as well as the chainring mounting bosses (208). For direct-drive alone, the crank axle ends (200) can be integral with the drive shaft (102) and the chainring mounting bosses (208) excluded. For a customized bottom bracket application, the crank axle ends (200) can be integral with the drive shaft (102) and the spoke flanges excluded.

E-bike or pedelec options

The potential for higher torque capacity of the hub transmission (100) is well suited for use in conjunction with electric assist, such as in pedelecs or e-bikes. For example, the hub transmission may be mounted in a rear wheel for chain-drive as described above, and the crank axle electrically assisted as is known in the art.

Alternatively, the hub transmission may be configured for bottom bracket mounting as described above, and the drive shaft unit (111) electrically assisted, or the front wheel electrically assisted as is known in the art.

The hub transmission may also be mounted in a rear wheel for chain-drive as described above, and the front wheel electrically assisted as is known in the art.

Alternatively, the hub transmission may be mounted in a front wheel of a direct-drive recumbent bicycle as described above, and the drive shaft unit (111) electrically assisted. Or the rear wheel may be electrically assisted, avoiding the traction issues with front wheel electric assistance.

The control of the gear shifting may include communication with the e-bike or pedelec torque sensor to provide automatic shifting.

Planet gear variations

The planet gear clusters may have more, or less, than the three or four bevel planet gears presented. Furthermore, there may be more than two stub axles mounted to the drive shaft, so that more than two planet gear clusters are employed, or there may be only one stub axle and a single planet gear cluster.

The bevel planet gears may be equally axially spaced within each planet cluster, or they may be differently spaced apart axially, as in the example embodiment. Similarly, the pitch diameter of each bevel planet gear within each planet cluster may be the same, or different, as in the example embodiment.

The bevel planet gears in each planet gear cluster may be separable rather than integrally formed, but each planet gear must be interlocked, to transmit torque therebetween.

Roller tooth options

The roller teeth may be placed on the bevel reaction gears and bevel output gears, rather than on the bevel planet gears.

The roller teeth may be frustoconical in shape, whereby an imaginary apex of the engaging surface of each roller intersects the planet gear axis and the drive shaft axis. This is theoretically the best geometry. However, employing cylindrical roller teeth, as in the example embodiment, simplifies the manufacturing of the rollers, and allows the teeth of the meshing gears to be machined using simpler tooling. The deviation from the frustoconical shape is very small due to the relatively small face width of bevel reaction gear teeth and bevel output gear teeth. These teeth can have a narrower face width due to the lower loads that result from the larger gear size.

The rollers may rotate directly on the supporting pins as in the example embodiment, or the rollers may be fitted with bushings. Alternatively, the roller may be mounted on ball bearings, roller bearings, or needle bearings to further decrease friction. In some cases, the exterior race of the ball, roller, or needle bearing may form the roller body, with no separate roller.

Other gear shifting arrangements

As an alternative to linear actuators, the engageable freewheels (128, 130, 132, 148, 150, 152) may be engaged and disengaged by a cam ring arrangement, as shown for the right side of the hub in figure 20. A shifter motor (210) drives a cam ring (212) through a worm gear (214). The cam ring has indents (216) and raised portions (218) that interact with push rods (220) to engage or disengage the freewheel pawls to select the required gear. The control system is configured to position the cam ring (212) in the correct position for each selected gear. A similar configuration may be employed for the left side of the hub.

The control of the engageable freewheels may be wired, rather than wireless. As illustrated in figure 21, a wired shifter unit (222) mounted to the handlebars (177) provides control and power directly by wires (225, 227) to the transmission hub (100). Since the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) are mounted on the reaction gear carrier (146) which is stationary, the wires (225) can enter the hub directly. The engageable freewheels (128, 130, 132) of the bevel output gears (120, 122, 124), however, rotate relative to the bicycle frame with the output gear carrier (126). Therefore slip rings (224) are required to make the electrical connection between the wires (227) and the rotating output gear carrier (126). Alternatively, the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) may be wired, and the engageable freewheels (128, 130, 132) of the bevel output gears (120, 122, 124) may be wirelessly controlled to avoid the need for the slip rings (224).

To reduce freewheeling friction from the first gear freewheel (154), when the transmission is in a gear higher than first gear, the first gear freewheel (154) may be wirelessly controlled to disengage. The first gear freewheel may be located differently than shown, for example the first gear freewheel may be located between the drive shaft (102) of the drive shaft unit (111) and the output gear carrier (126) section of the hub shell (127), rather than between the stub axle (108) of the drive shaft unit (111) and the cover portion (101) of the hub shell (127).

The engageable freewheels may also be mechanically controlled. For the stationary left side of the hub this is relatively simple. For example, the engageable freewheels (148, 150, 152) of the bevel reaction gears (140, 142, 144) may be controlled mechanically by a cable that rotates a cam ring, similar to the cam ring (212) shown in figure 20.

Transferring mechanical control to the rotating right side of the hub is much more complex, however. Figure 22 shows a possible means to achieve this mechanical control. A cable ring (226) is threaded to a stationary mounting (228) so that the cable ring (226) moves axially in the direction of the drive shaft axis (104) as the cable ring (226) is rotated around the drive shaft axis (104) by a control cable (231) in cable groove (230). By means of a shifter bearing (232), the cable ring (226) translates this axial motion, against the pressure of return springs (234), to a mechanical actuator (236) that rotates with the hub shell (127). The mechanical actuator (236) has axially extended arms (238) having cam surfaces (240) at the outward facing surfaces of each axially extending arm (238). The cam surfaces (240) interact with mechanical push rods (242) that are similar to push rods (220) in figure 20. The mechanical push rods (242) engage or disengage the freewheel pawls of the engageable freewheels (128, 130, 132) of the bevel output gears (120, 122, 124) to select the required gear.

The above detailed description describes a possible embodiment with design variations. The following claims define the full scope of the invention claimed.

Claims

1. A hub transmission comprising:

a drive shaft unit rotatable about a drive shaft axis, whereby an input torque is applied to the drive shaft unit in a drive direction;

one or more planet gear clusters rotatably mounted on the drive shaft unit; each planet gear cluster having an axis of rotation that intersects the drive shaft axis, and each planet gear cluster comprising a plurality of bevel planet gears axially spaced along the axis of rotation and fixed together to transmit torque therebetween;

a plurality of bevel reaction gears rotatable about a reaction gear axis coaxial with the drive shaft axis;

a plurality of bevel output gears rotatable about an output gear axis coaxial with the drive shaft axis;

wherein each bevel planet gear is equipped with roller teeth, or each bevel reaction gear and each bevel output gear is equipped with roller teeth;

wherein each bevel planet gear meshes with a bevel reaction gear of and a bevel output gear; and

a hub shell rotatable about a hub shell axis coaxial with the drive shaft axis;

each bevel reaction gear having a first engageable freewheel that, when engaged, prevents rotation of the bevel reaction gear in the drive direction and permits rotation in a direction opposite to the drive direction, and, when disengaged, permits rotation of the bevel reaction gear in both the drive direction and the direction opposite to the drive direction;

each bevel output gear having a second engageable freewheel that, when engaged, transmits a drive torque in the drive direction to the hub shell but permits the hub shell to overrun the bevel output gear when the hub shell is rotating faster in the drive direction than the bevel output gear, and, when disengaged, does not transmit the drive torque to the hub shell and permits the hub shell to overrun the bevel output gear when the hub shell is rotating faster in the drive direction than the bevel output gear;

a first gear freewheel that drives the hub shell in the drive direction by means of the drive shaft unit, and overruns when the hub shell is rotating faster than the drive shaft unit in the drive direction;

wherein a first gear ratio is selected by disengaging all of the first engageable freewheels and disengaging all of the second engageable freewheels, whereby the hub shell is driven in the drive direction through the first gear freewheel; and

wherein gear ratios higher than first gear are obtained by engaging a selected first engageable freewheel and a selected second engageable freewheel.

2. The hub transmission of claim 1 wherein the first engageable freewheels and the second engageable freewheels are operated by an electrical control system.

3. The hub transmission of claim 1 wherein the first engageable freewheels and the second engageable freewheels are operated by a mechanical control system.

4. The hub transmission of claim 1 wherein the first engageable freewheels are operated by a mechanical control system, and the second engageable freewheels are operated by an electrical control system.

5. The hub transmission of claim 2 or claim 4 wherein the electrical control system is a wireless control system.

6. The hub transmission of claim 2 or claim 4 wherein the electrical control system is a wired control system.

7. The hub transmission of claim 2 wherein the electrical control system is a wireless control system and wherein the wireless control system comprises: a shifter unit powered by a shifter unit power source; the shifter unit mounted remotely from the hub transmission in a location convenient to a user; the shifter unit comprising: a gear selector, a shifter unit controller, and a transmitter that transmits a wireless signal indicative of a selected gear change; wherein the hub transmission controls the first engageable freewheels through a first receiver that receives the wireless signal, whereby a first controller processes the wireless signal to control a first actuation system that engages or disengages the first engageable freewheels; and wherein the hub transmission controls the second engageable freewheels through a second receiver that receives the wireless signal, whereby a second controller processes the wireless signal to control a second actuation system that engages or disengages the second engageable freewheels.

8. The hub transmission of claim 2 wherein the electrical control system is a wired control system and the wired control system comprises: a shifter unit powered by a shifter unit power source; the shifter unit mounted remotely from the hub transmission in a location convenient to a user; the shifter unit comprising a gear selector, a shifter unit controller, and first control wires that transmit a first control signal and second control wires that transmit a second signal, the first and second control signals indicative of a selected gear change; wherein the hub transmission controls the first engageable freewheels through a first controller that receives the first signal through the first control wires, whereby the first controller processes the first control signal to control a first actuation system that engages or disengages the first engageable freewheels; and wherein the hub transmission controls the second engageable freewheels through a second controller that receives the second control signal through the second control wires and associated slip rings, whereby the second controller processes the second signal to control a second actuation system that engages or disengages the second engageable freewheels.

9. The hub transmission of claim 7 or claim 8 wherein the first and second actuation systems comprise latching solenoids to engage or disengage the first and second engageable freewheels to select the required gear.

10. The hub transmission of claim 7 or claim 8 wherein the first and second actuation systems comprise lead screw actuators to engage or disengage the first and second engageable freewheels to select the required gear.

11. The hub transmission of claim 7 or claim 8 wherein the first and second actuation systems each comprise a cam ring driven by a motor; wherein the cam ring comprises indents and raised portions that interact with push rods to engage or disengage the first and second engageable freewheels to select the required gear.

12. The hub transmission of any one of claims 1-11 wherein the first and second engageable freewheels comprise ratchet gears and pawls.

13. The hub transmission of any one of claims 1-11 wherein the first and second engageable freewheels comprise axial freewheels.

14. The hub transmission of any one of claims 1-13 wherein each planet gear cluster comprises three bevel planet gears.

15. The hub transmission of any one of claims 1-13 wherein each planet gear cluster comprises four bevel planet gears.

16. The hub transmission of any one of claims 1-13 wherein each planet gear cluster comprises more than four bevel planet gears.

17. The hub transmission of any one of claims 1-16 comprising two planet gear clusters 180 degrees opposed.

18. The hub transmission of any one of claims 1-16 comprising three planet gear clusters.

19. The hub transmission of any one of claims 1-18 wherein an intersecting angle between the axis of rotation of each planet gear cluster and the drive shaft axis is 90 degrees.

20. The hub transmission of any one of claims 1-19 wherein the bevel planet gears in each planet gear cluster are separable.

21. The hub transmission of any one of claims 1-19 wherein the bevel planet gears in each planet gear cluster are integrally formed.

22. The hub transmission of any one of claims 1-21 wherein a meshing surface of the roller teeth is cylindrical in shape, wherein an axis of rotation of each roller tooth intersects the axis of rotation of each planet gear cluster and the drive shaft axis.

23. The hub transmission any one of claims 1-21 wherein the roller teeth are frustoconical in shape, wherein both an imaginary apex of a meshing surface of each roller tooth and an axis of rotation of each roller tooth intersect the axis of rotation of each planet gear cluster and the drive shaft axis.

24. The hub transmission of any one of claims 1-23 wherein the roller teeth are mounted on bushings.

25. The hub transmission of any one of claims 1-23 wherein the roller teeth are mounted on ball bearings.

26. The hub transmission of any one of claims 1-23 wherein the roller teeth are mounted on roller bearings.

27. The hub transmission of any one of claims 1-23 wherein the roller teeth are mounted on needle bearings.

28. The hub transmission of claim 22 wherein the meshing surface of the roller teeth is formed by an outer surface of an outer race of a ball bearing, roller bearing, or needle bearing.

29. The hub transmission of any one of claims 1-28 wherein the first gear freewheel is wirelessly controlled to disengage when the hub shell speed in the drive direction exceeds the drive shaft speed in the drive direction.

30. The hub transmission of claim 3 or 4 wherein the mechanical control system of the first engageable freewheels comprises: a shifter cable rotating a cam ring; the cam ring having indents and raised portions that interact with mechanical push rods to engage or disengage the first engageable freewheels to select the required gear.

31. The hub transmission of claim 3 wherein the mechanical control system of the first engageable freewheels comprises: a shifter cable rotating a cam ring; the cam ring having indents and raised portions that interact with mechanical push rods to engage or disengage the first engageable freewheels to select the required gear; and wherein the mechanical control system of the second engageable freewheels comprises: a cable ring rotatably driven by a second shifter cable; the cable ring threaded to a stationary mounting so that the cable ring moves axially in the direction of the drive shaft axis as the cable ring is rotatably driven by the second shifter cable; a shifter bearing that translates the axial motion of the cable ring to a mechanical actuator rotating with the hub shell, the axial motion acting against a pressure of return springs; wherein the mechanical actuator has axially extended arms having cam surfaces that interact with second mechanical push rods that engage or disengage the second engageable freewheels to select the required gear.

32. The hub transmission of any one of claims 1-31 configured for chain-drive; wherein an axle is rotatably mounted in a drive shaft bore in the drive shaft unit, such the drive shaft unit may rotate relative to the axle around the drive shaft axis when the axle is fixed to a frame of a bicycle; a sprocket fixed to the drive shaft unit, the sprocket driven by a chain to provide the input torque to the drive shaft unit in the drive direction.

33. The hub transmission of any one of claims 1-31 configured for belt-drive; wherein an axle is rotatably mounted in a drive shaft bore in the drive shaft unit, such the drive shaft unit may rotate relative to the axle around the drive shaft axis when the axle is fixed to a frame

of a bicycle; a sprocket fixed to the drive shaft unit, the sprocket driven by a belt to provide the input torque to the drive shaft unit in the drive direction.

34. The hub transmission of any one of claims 1-31 configured for direct-drive; wherein the drive shaft unit is mounted on bearings so as to rotate about the drive shaft axis relative to a frame or fork of a bicycle; and wherein crank axle ends are fixed to the drive shaft unit and cranks are attached to crank axle ends to provide the input torque to the drive shaft unit in the drive direction.

35. The hub transmission of any one of claims 1-31 configured for bottom bracket mounting; wherein the drive shaft unit is mounted on bearings so as to rotate about the drive shaft axis relative to a frame of a bicycle; and wherein crank axle ends are fixed to the drive shaft unit and cranks are attached to crank axle ends to provide the input torque to the drive shaft unit in the drive direction; and a chainring is attached to the hub shell to provide output drive torque to a chain.

36. The hub transmission of any one of claims 1-31 configured for bottom bracket mounting; wherein the drive shaft unit is mounted on bearings so as to rotate about the drive shaft axis relative to a frame of a bicycle; and wherein crank axle ends are fixed to the drive shaft unit and cranks are attached to crank axle ends to provide the input torque to the drive shaft unit in the drive direction; and a belt-drive sprocket is attached to the hub shell to provide output drive torque to a toothed belt.

37. The hub transmission of claim 32 or 33 mounted in the rear wheel of a bicycle.

38. The hub transmission of claim 34 mounted in the front wheel of a direct-drive recumbent bicycle.

39. The hub transmission of claim 37 wherein the bicycle is equipped with an electrically assisted crank axle.

40. The hub transmission of any one of claims 34-36 and 38 wherein the drive shaft unit is electrically assisted.

41. The hub transmission of any one of claims 32, 33, and 35-37 wherein the bicycle is equipped with an electrically assisted front wheel.

42. The hub transmission of claim 38 wherein the direct-drive recumbent bicycle is equipped with an electrically assisted rear wheel.

43. The hub transmission of any one of claims 39-42 wherein gear shifting control communicates with a torque sensor of the electrical assistance to provide automatic shifting.

44. The hub transmission of any one of claims 1-31 configured for chain-drive, belt-drive, direct-drive, or bottom bracket mounting in a tricycle or other human-powered vehicle.

45. The hub transmission of claim 44 wherein the tricycle or other human-powered vehicle is electrically assisted.

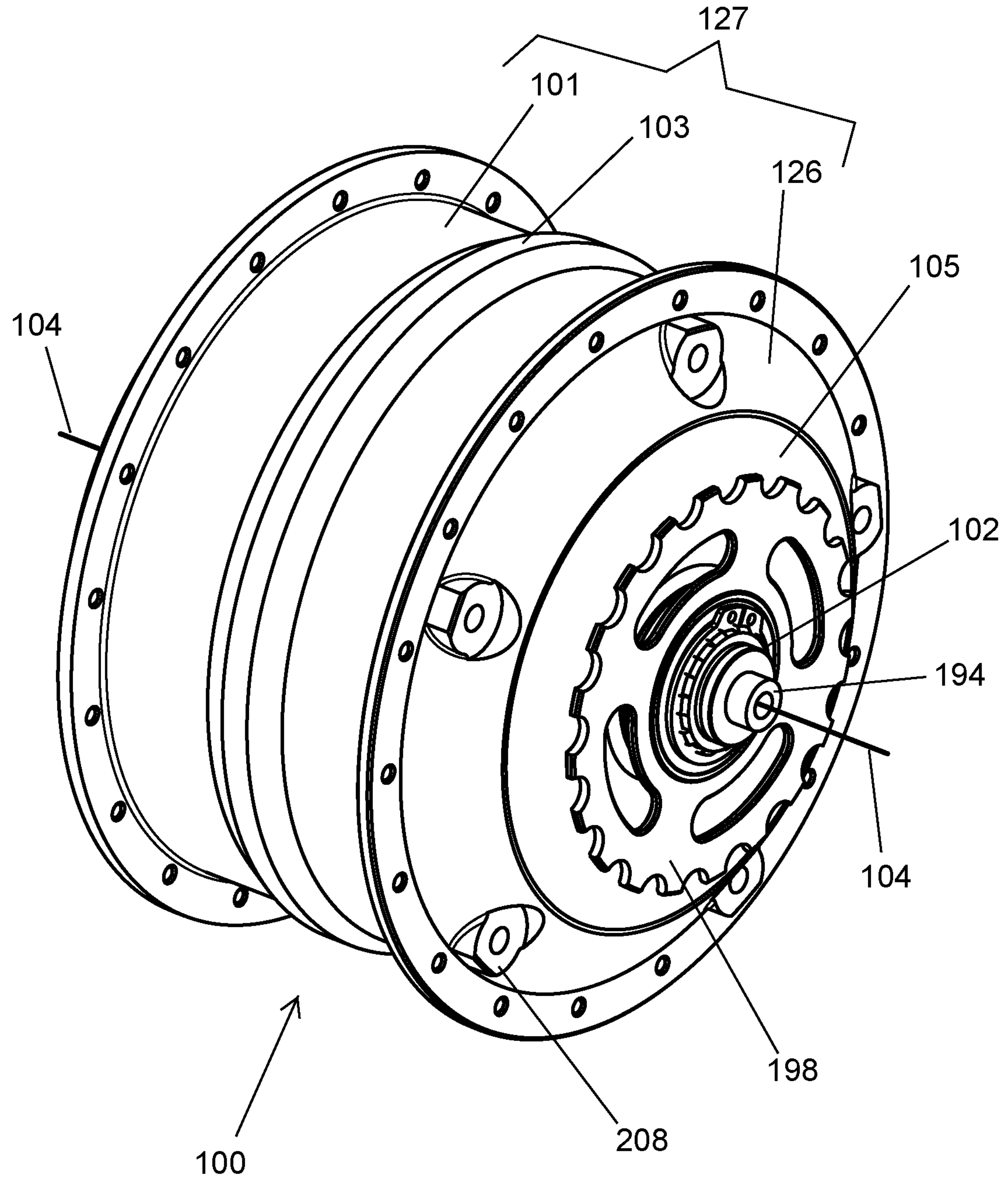

FIG. 1

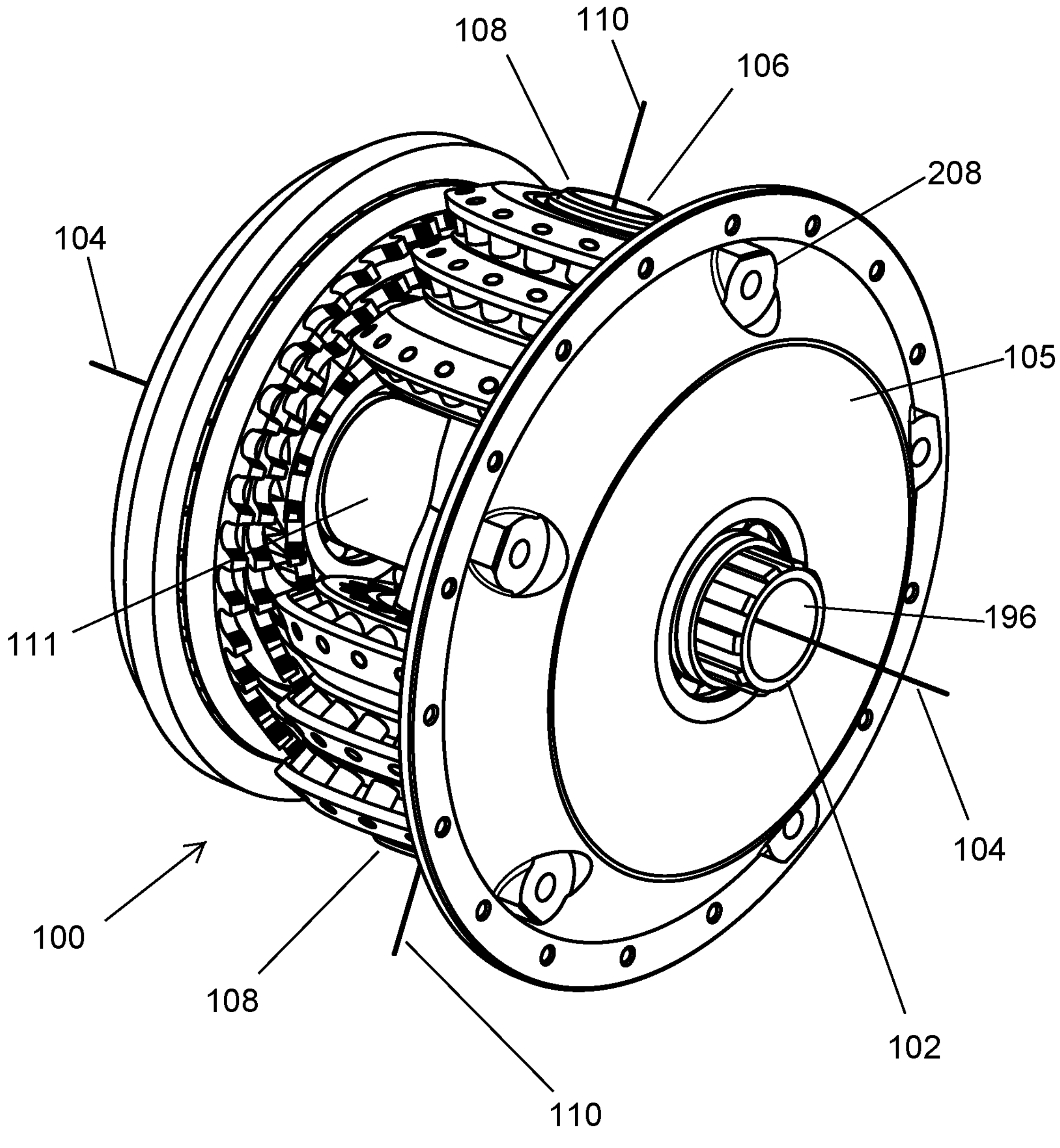

FIG. 2

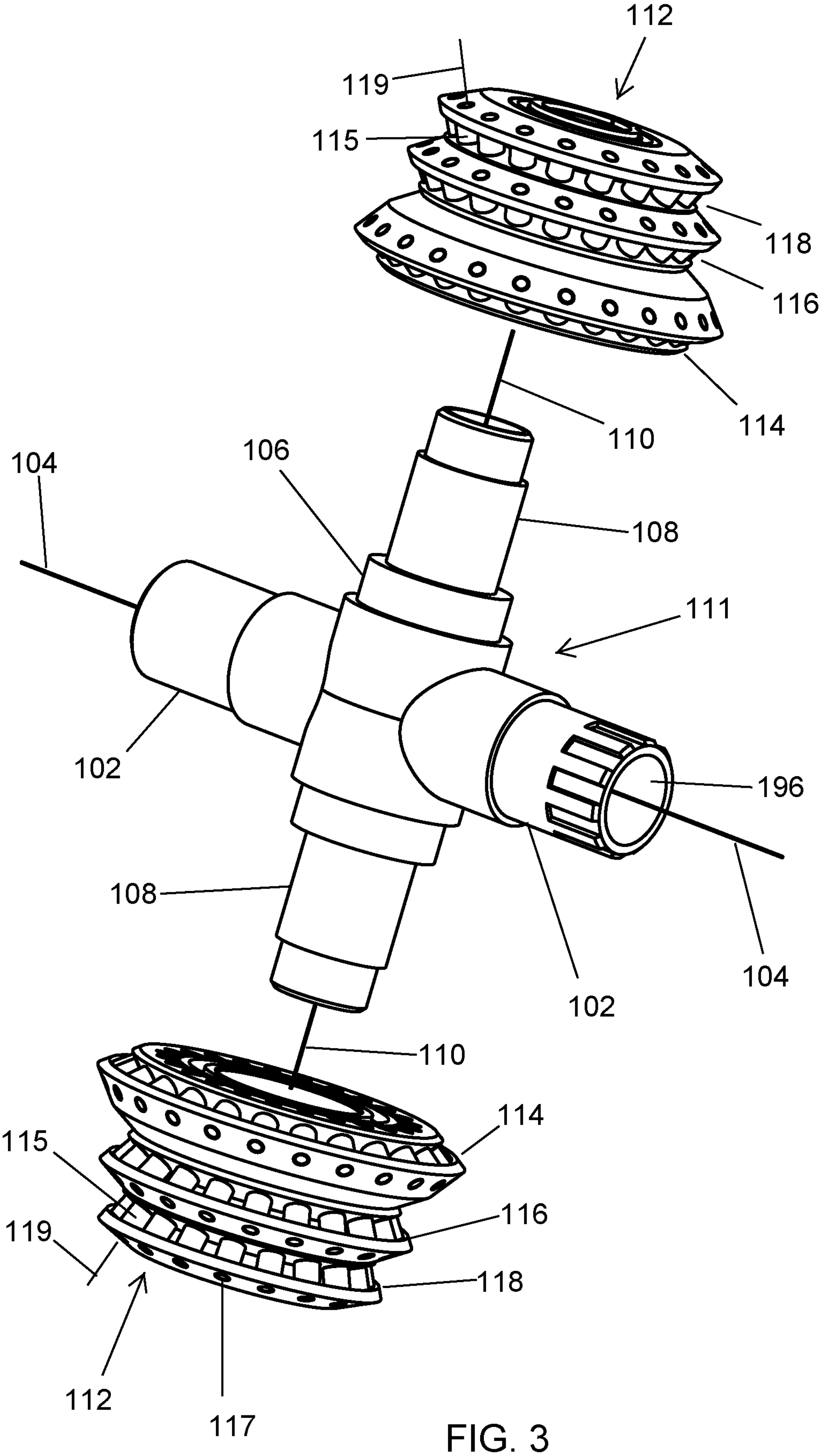
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FIG. 3

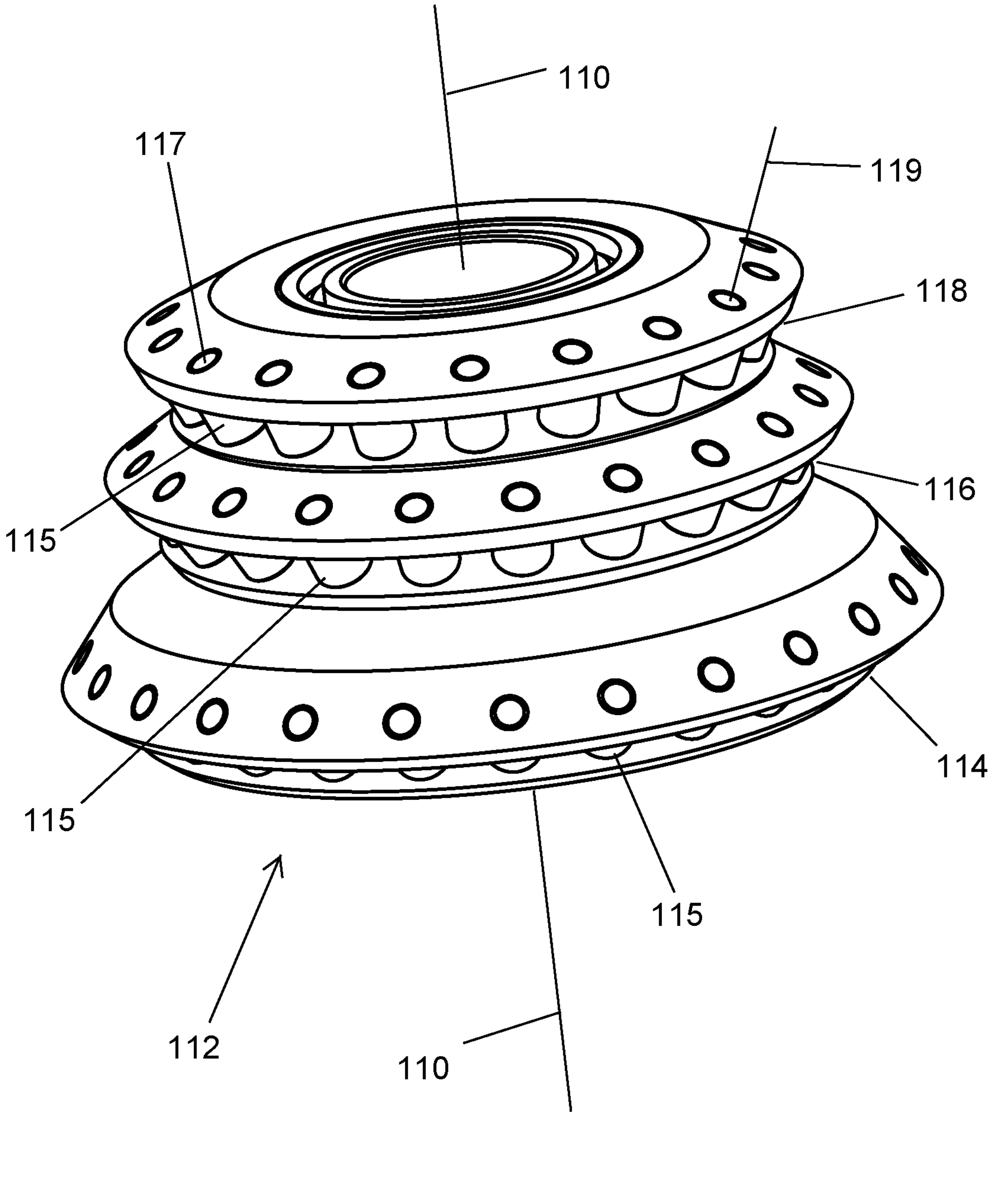

FIG. 4

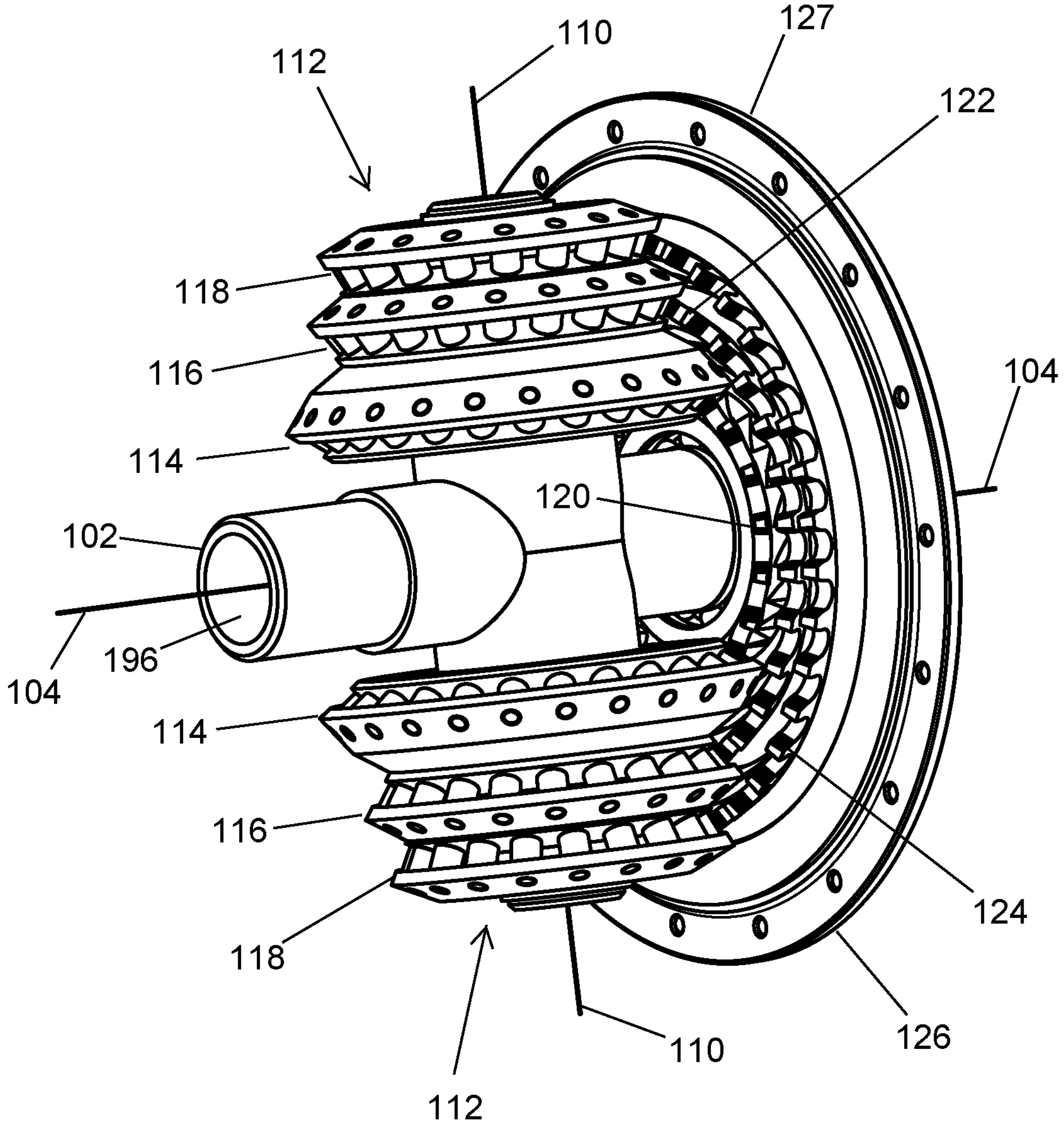
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FIG. 5

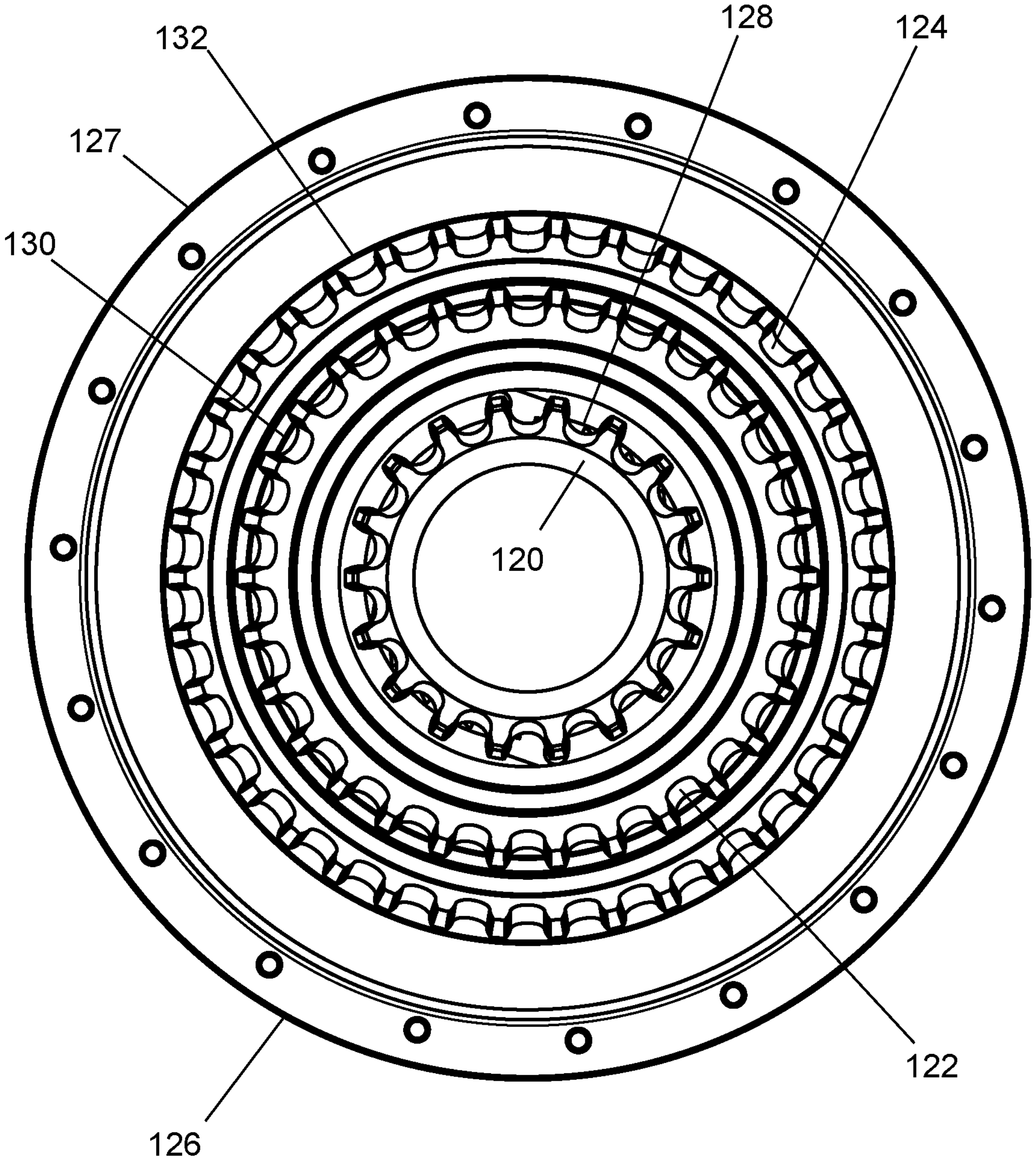

FIG. 6

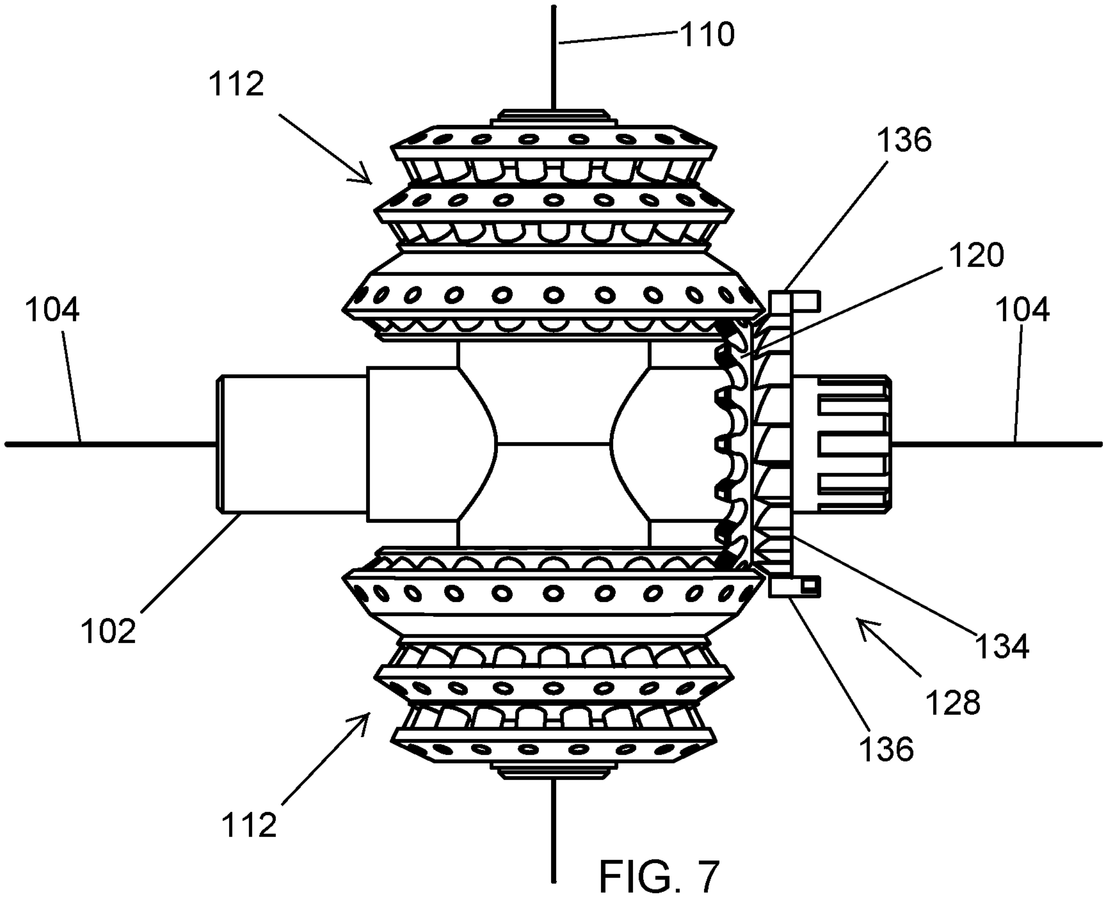
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FIG. 7

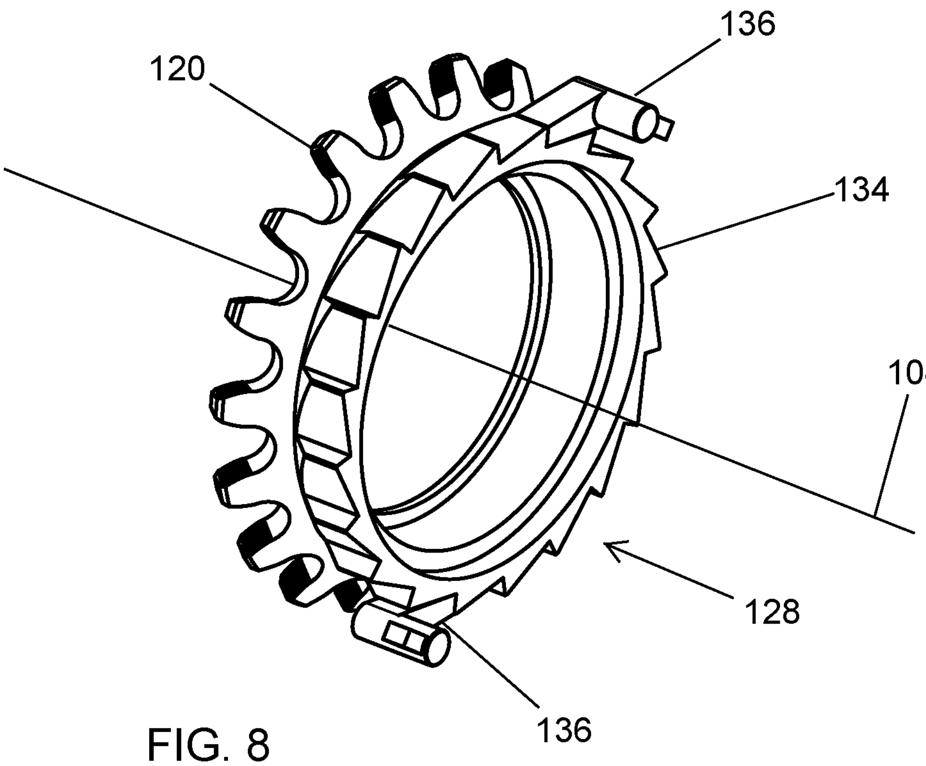
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FIG. 8

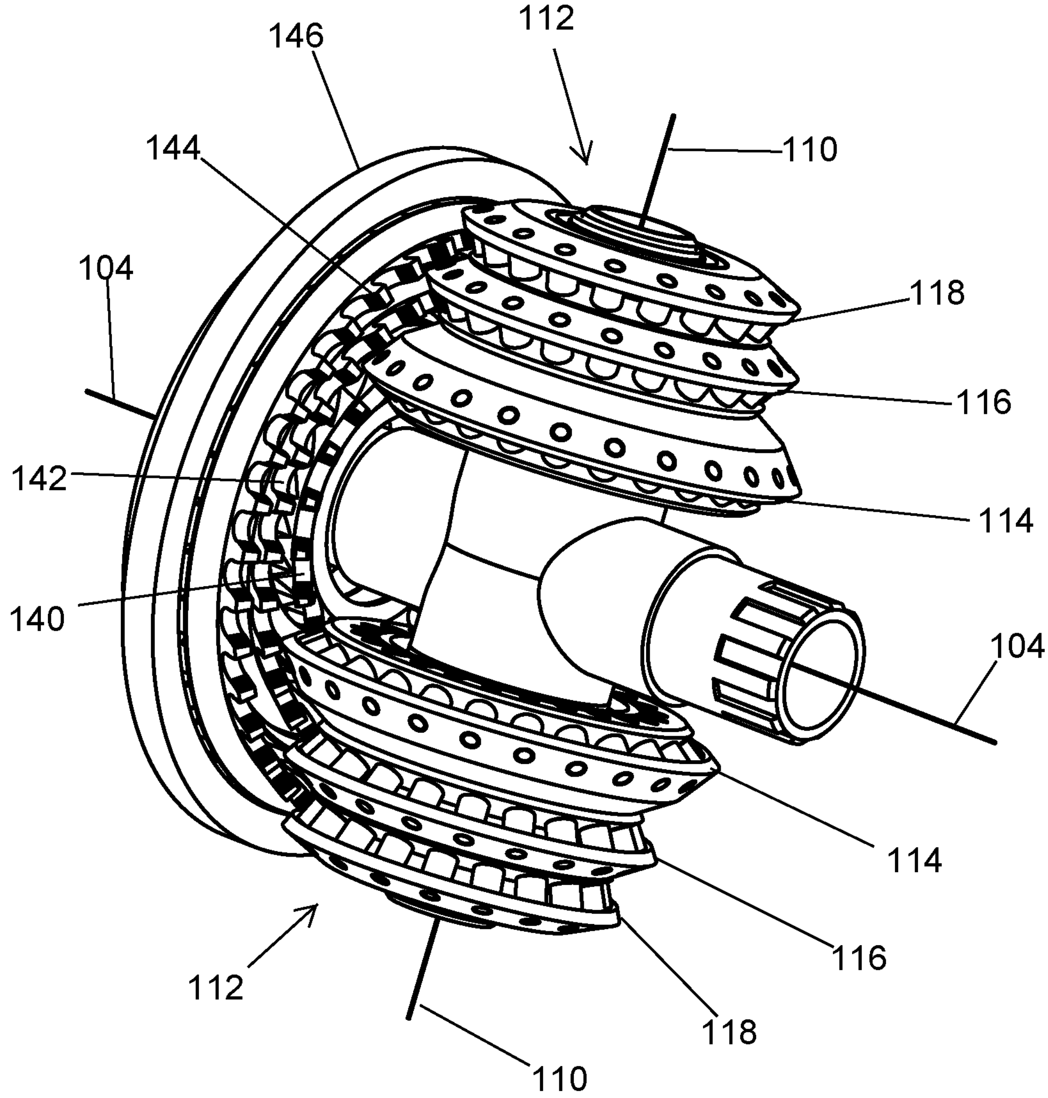

FIG. 9

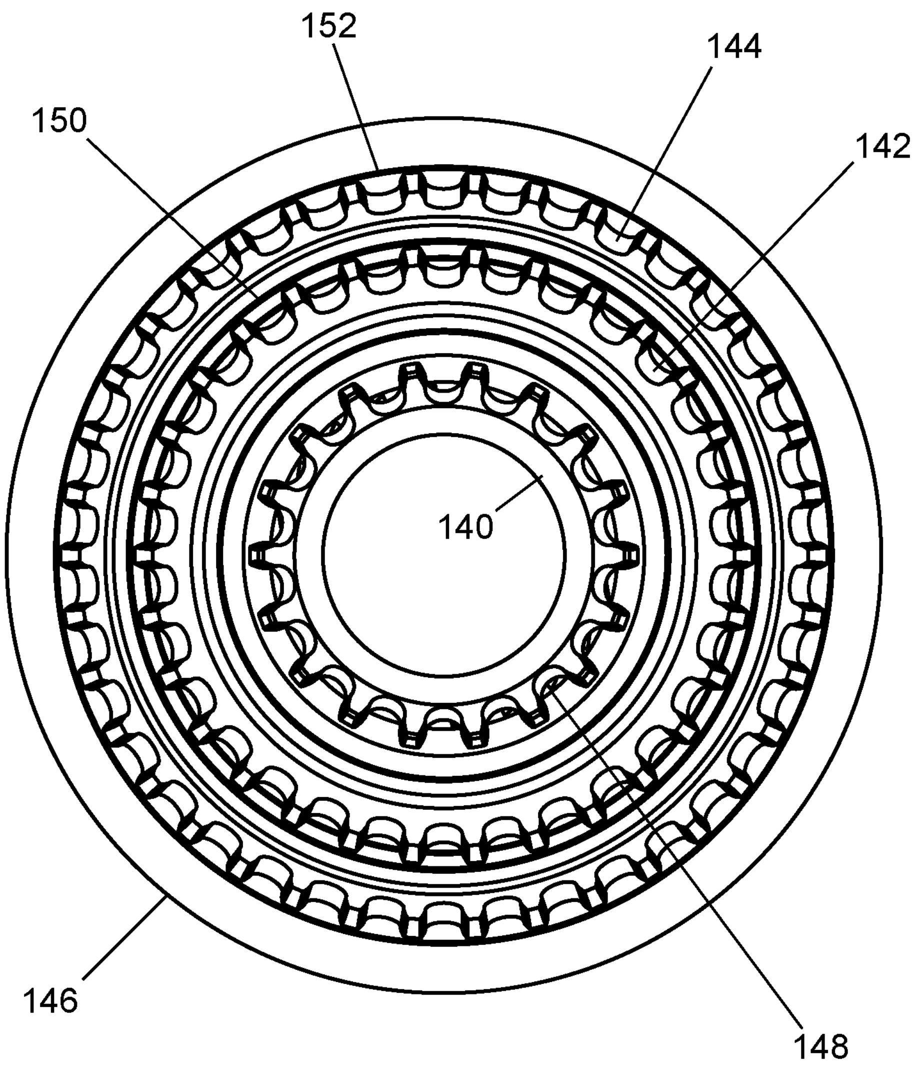

FIG. 10

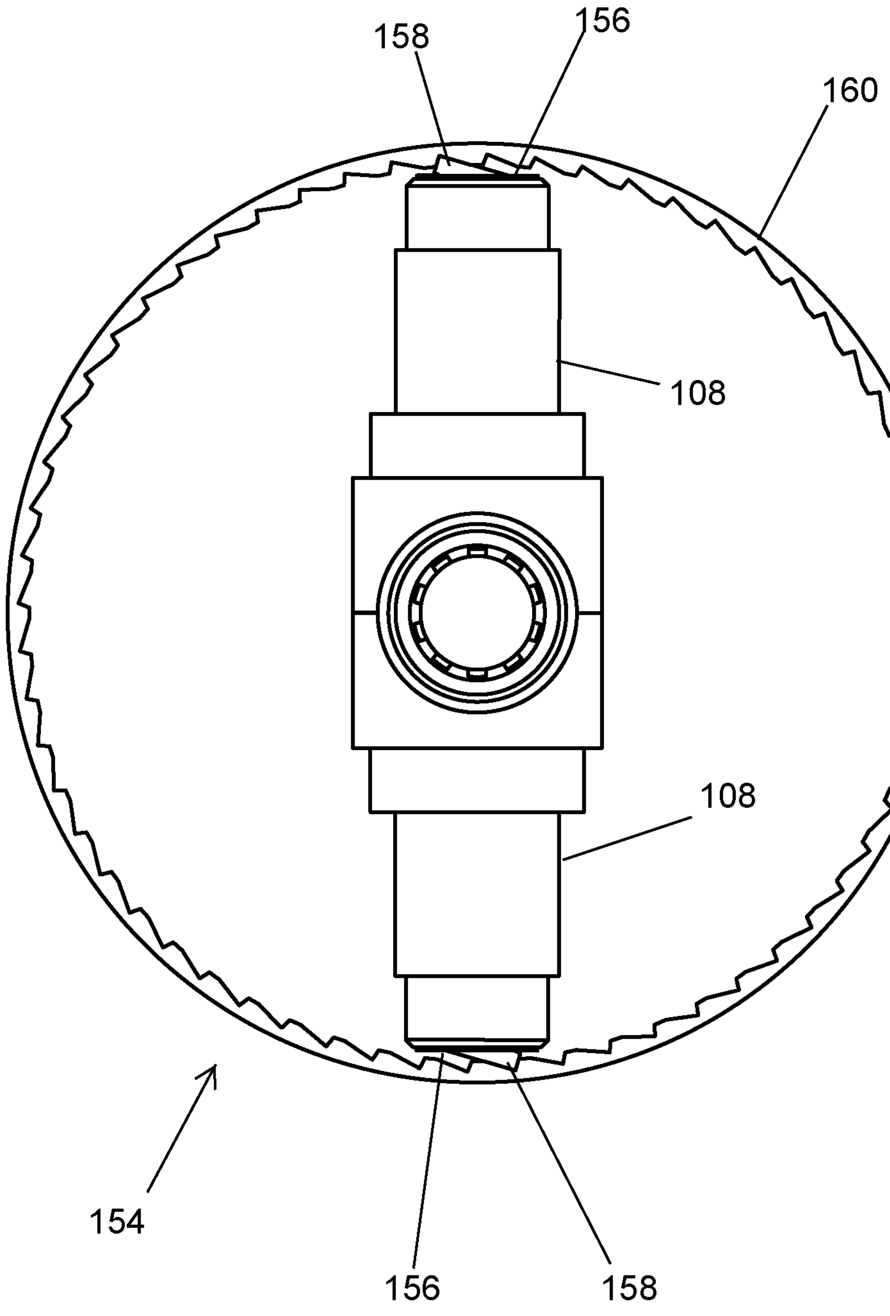

FIG. 11

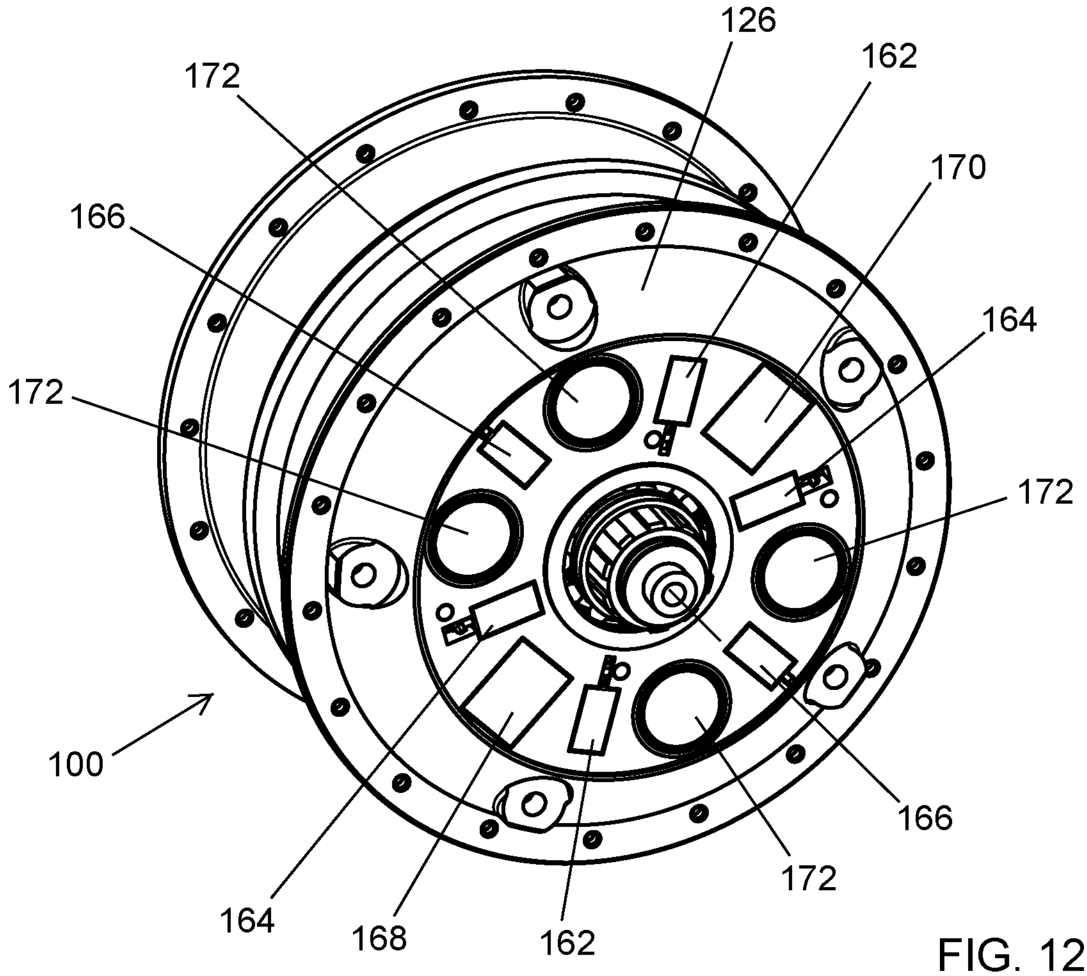
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FIG. 12

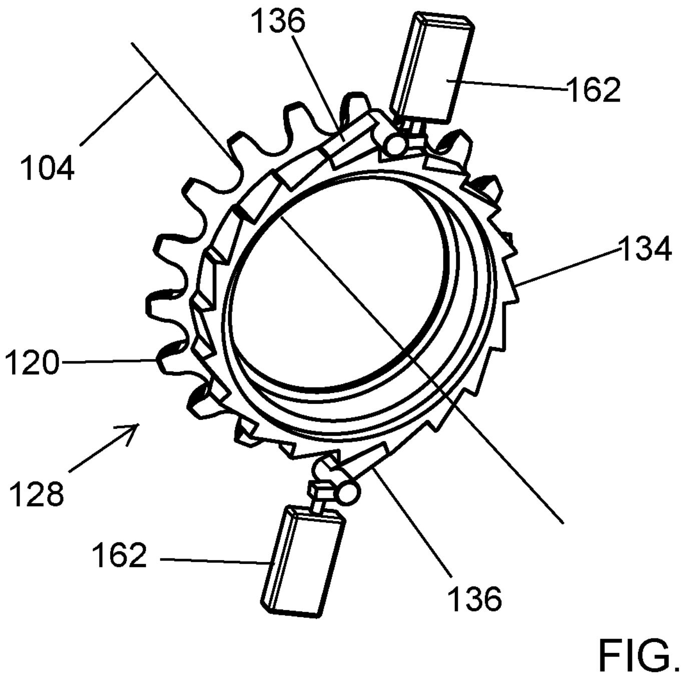
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FIG. 13

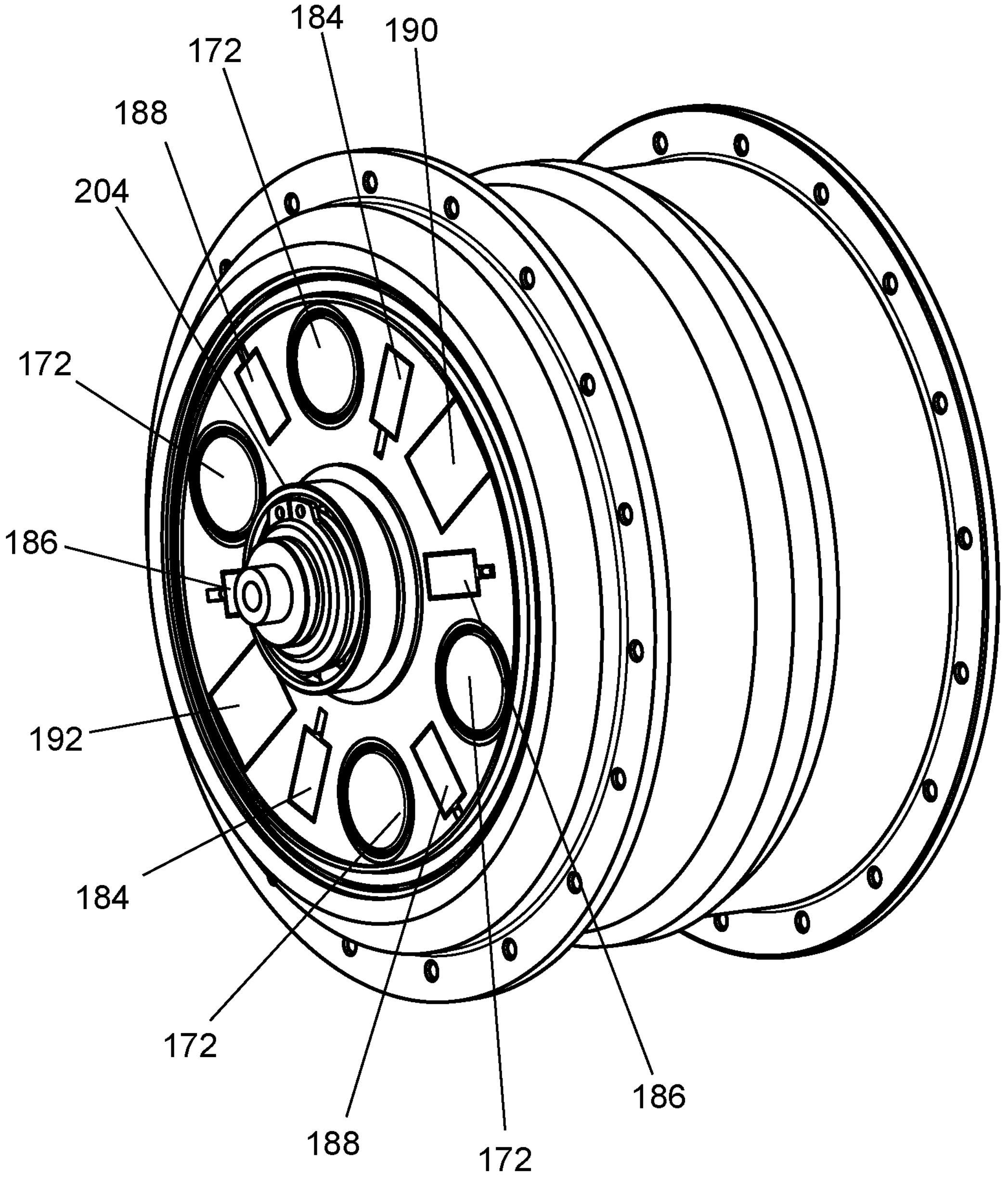
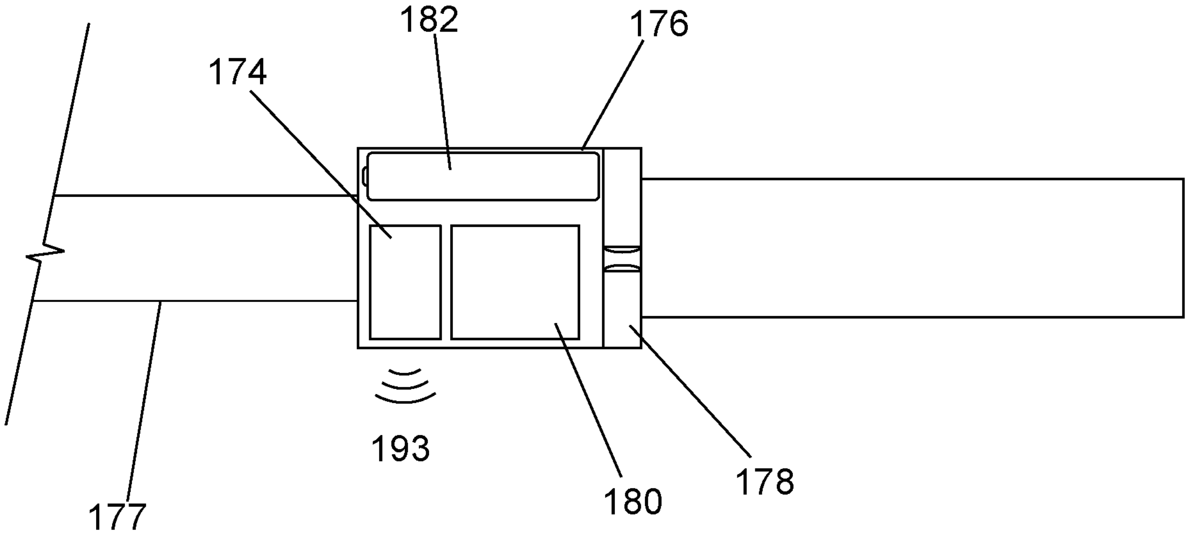


FIG. 14



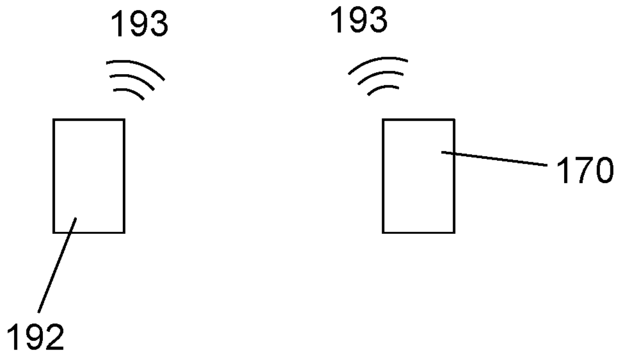
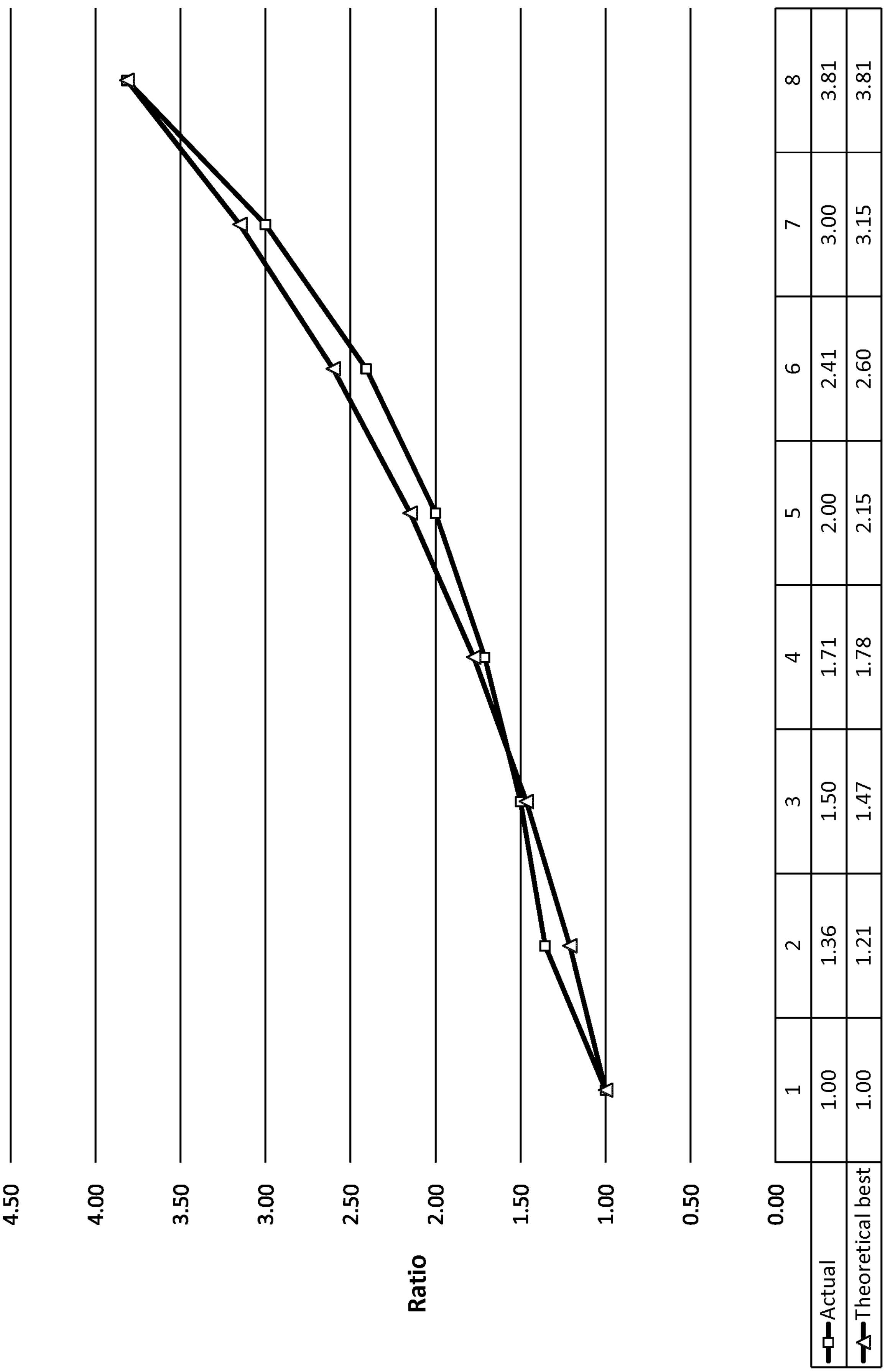


FIG. 15



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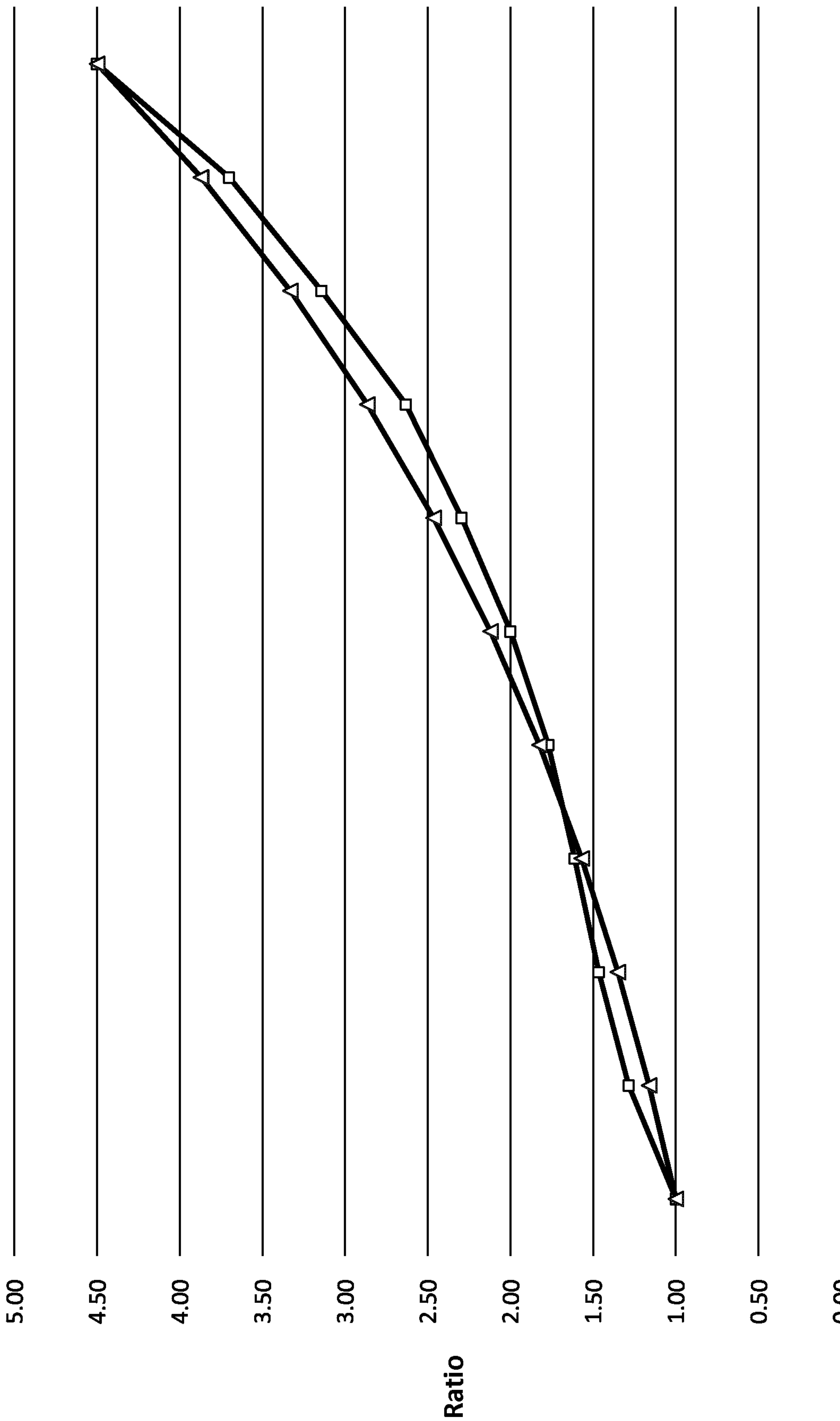
Actual	1.00	1.36	1.50	1.71	2.00	2.41	3.00	3.81
Theoretical best	1.00	1.21	1.47	1.78	2.15	2.60	3.15	3.81

FIG. 16



	1	2	3	4	5	6	7	8	9	10	11
Actual	1.00	1.29	1.47	1.61	1.77	2.00	2.30	2.63	3.14	3.70	4.50
Theoretical best	1.00	1.16	1.35	1.57	1.83	2.12	2.47	2.87	3.33	3.87	4.50

FIG. 17

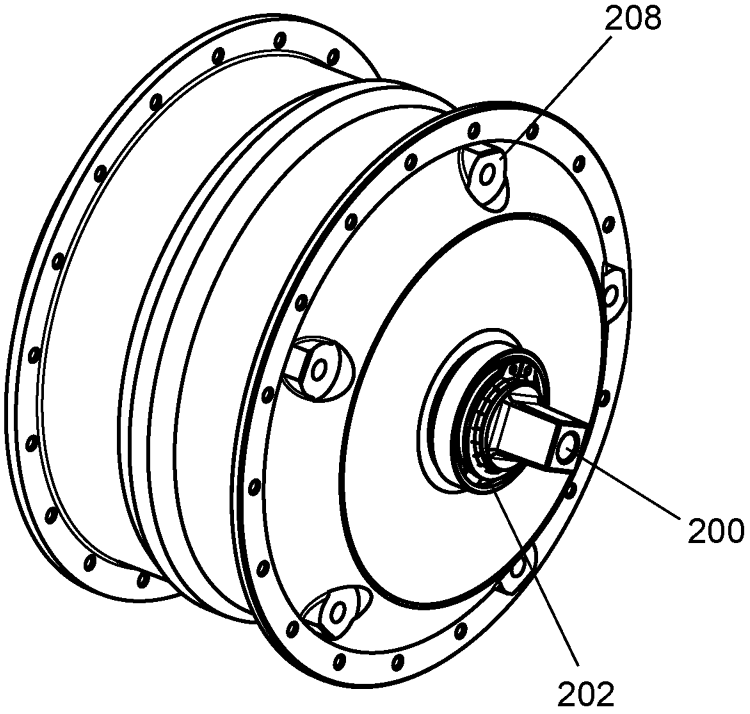


FIG. 18

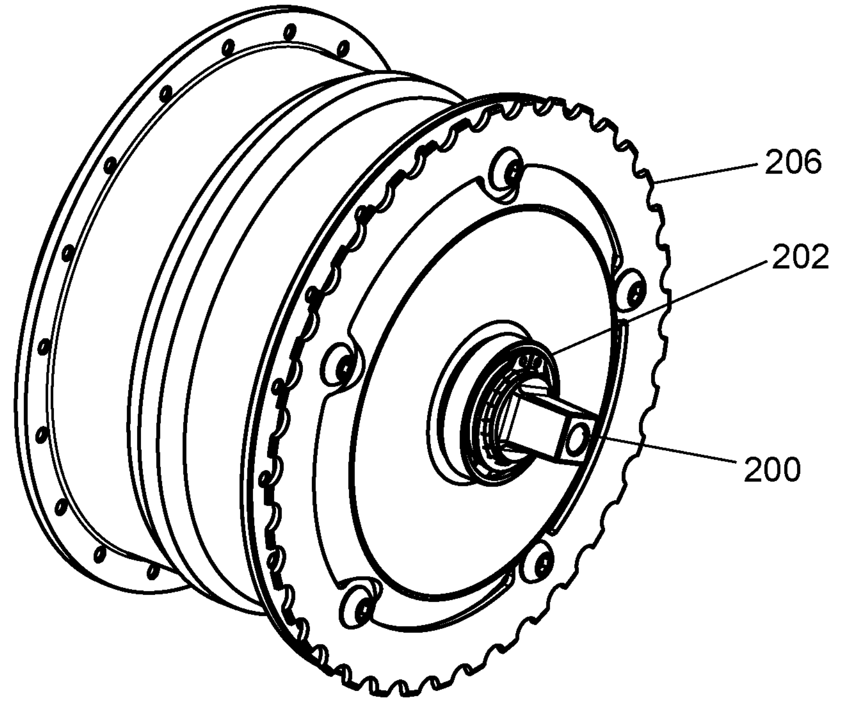


FIG. 19

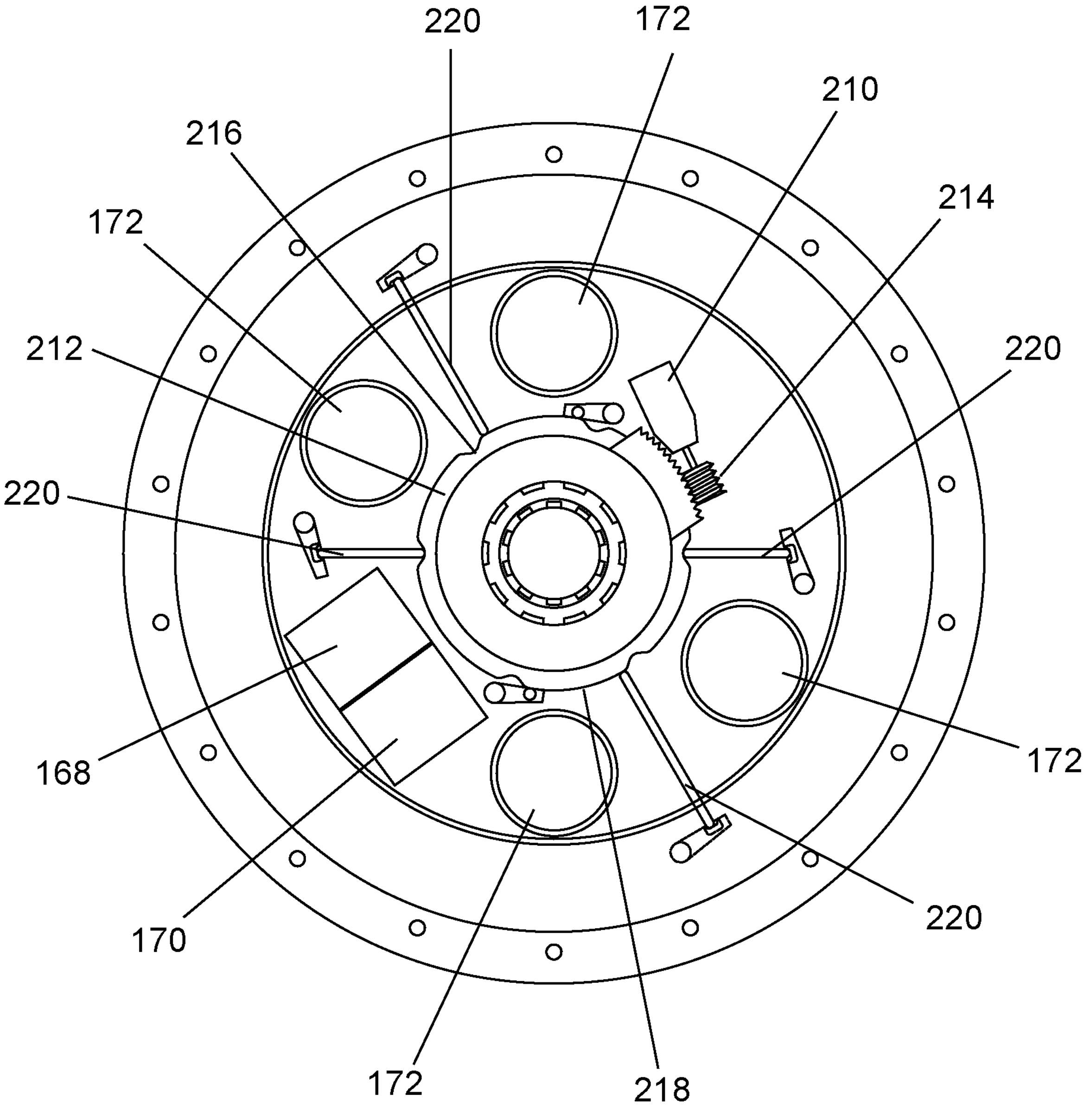


FIG. 20

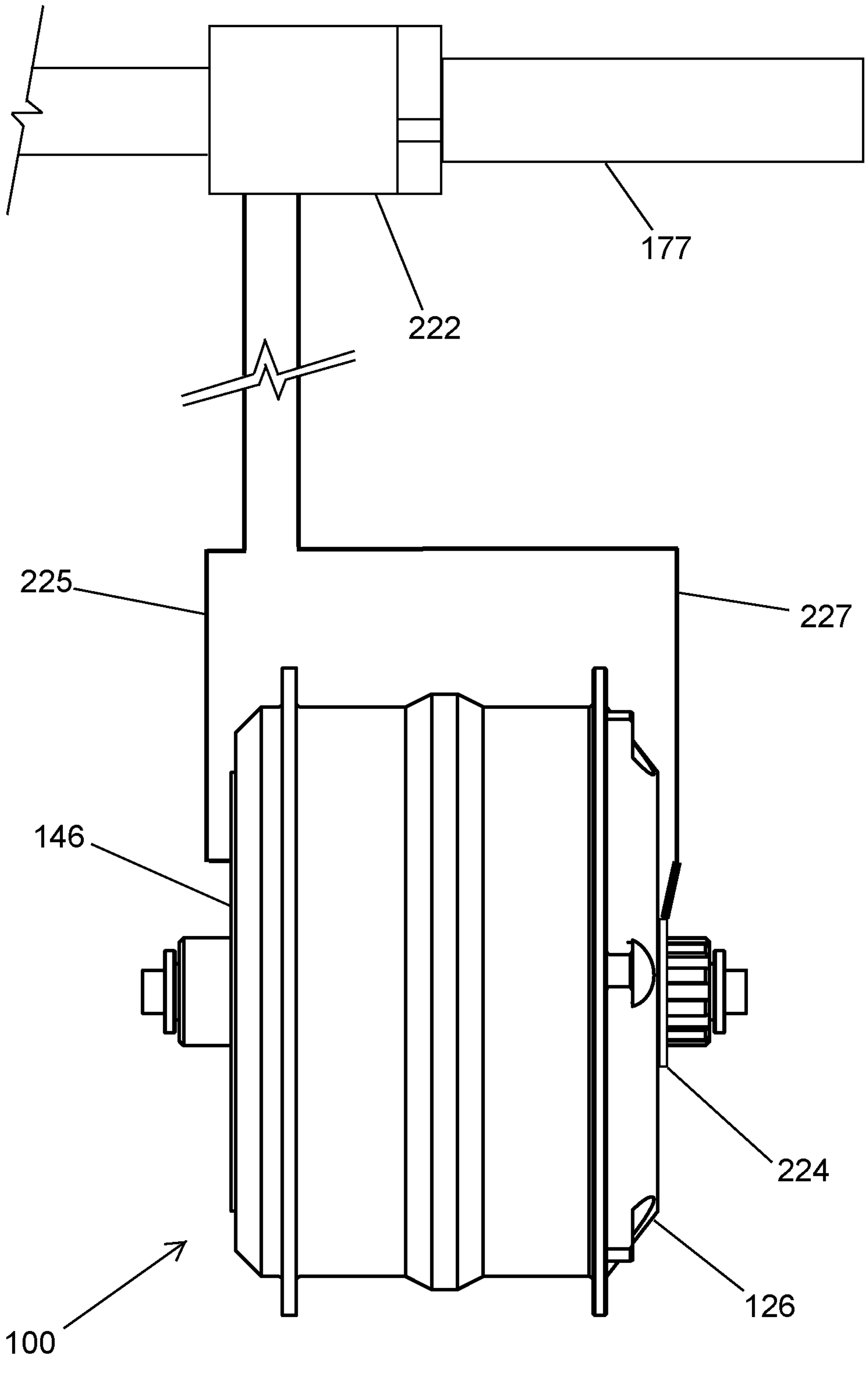


FIG. 21

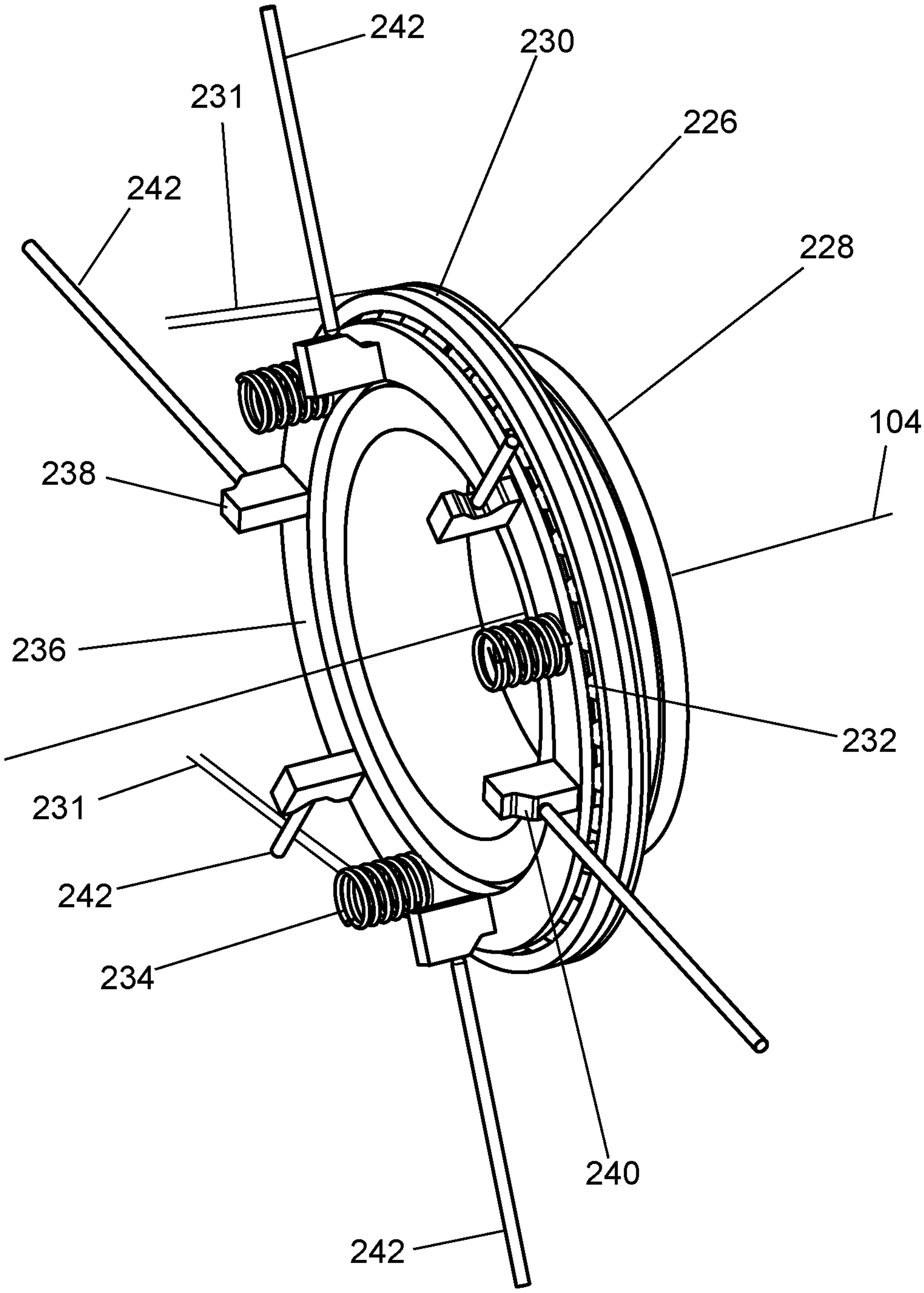


FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2019/050886

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F16H 3/44*** (2006.01) , ***B62M 11/10*** (2006.01) , ***B62M 11/14*** (2006.01) , ***F16H 3/64*** (2006.01) , ***F16H 48/05*** (2012.01) , ***F16H 48/08*** (2006.01) (more IPCs on the last page)

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)
F16H (2006.01) and ***B62M*** (2006.1).

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
None.

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Intellect (Canadian Patent Database), Questel-Orbit (FamPat Database).
Keywords: plant, hub, roller, transmission, gear, bevel and direction.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US9139254 (Garnet) 22 September 2015 (22-09-2015); *whole document*	1-45
A	JP2005/324603 (Fujiwara) 24 November 2005 (24-11-2005); *whole document*	1-45
A	US2011/0275475 (Esenbeil) 10 November 2011 (10-11-2011). *whole document*	1-45

☐ 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	Date of mailing of the international search report
25 February 2020 (25-02-2020)	28 February 2020 (28-02-2020)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer
Sorin Muntean (819) 639-7875

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US9139254B2	22 September 2015 (22-09-2015)	US2014302963A1	09 October 2014 (09-10-2014)
		US9139254B2	22 September 2015 (22-09-2015)
		CA2812588A1	04 October 2014 (04-10-2014)
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