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(54) **EPICYCLIC GEAR SYSTEM**

(57)

ABSTRACT

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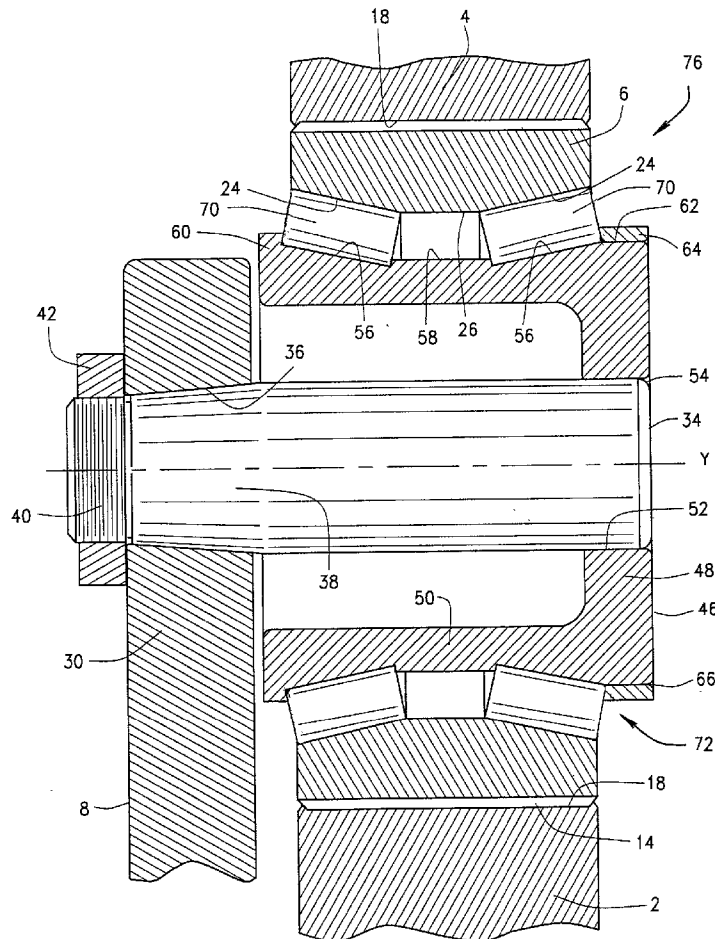
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An epicyclic gear system has a sun gear, a ring gear located around the sun gear, and planet gears located between and engaged with sun and ring gears. In addition, it has a carrier including a carrier flange offset axially from the planet gears, carrier pins projecting from the carrier flange into the planet gears, and bearings between the planet gears and the carrier pins so that the planet gears rotate on the pins. Each bearing includes an inner race having tapered raceways presented away from the carrier pin, opposing tapered raceways on the ring gear, and tapered rollers organized in two rows between the raceways. Whereas the carrier pin is cantilevered from the carrier flange, the inner race is cantilevered from the carrier pin remote from the carrier flange, and this insures that the axes about which the planet gears rotate remain parallel to the central axis of the system.



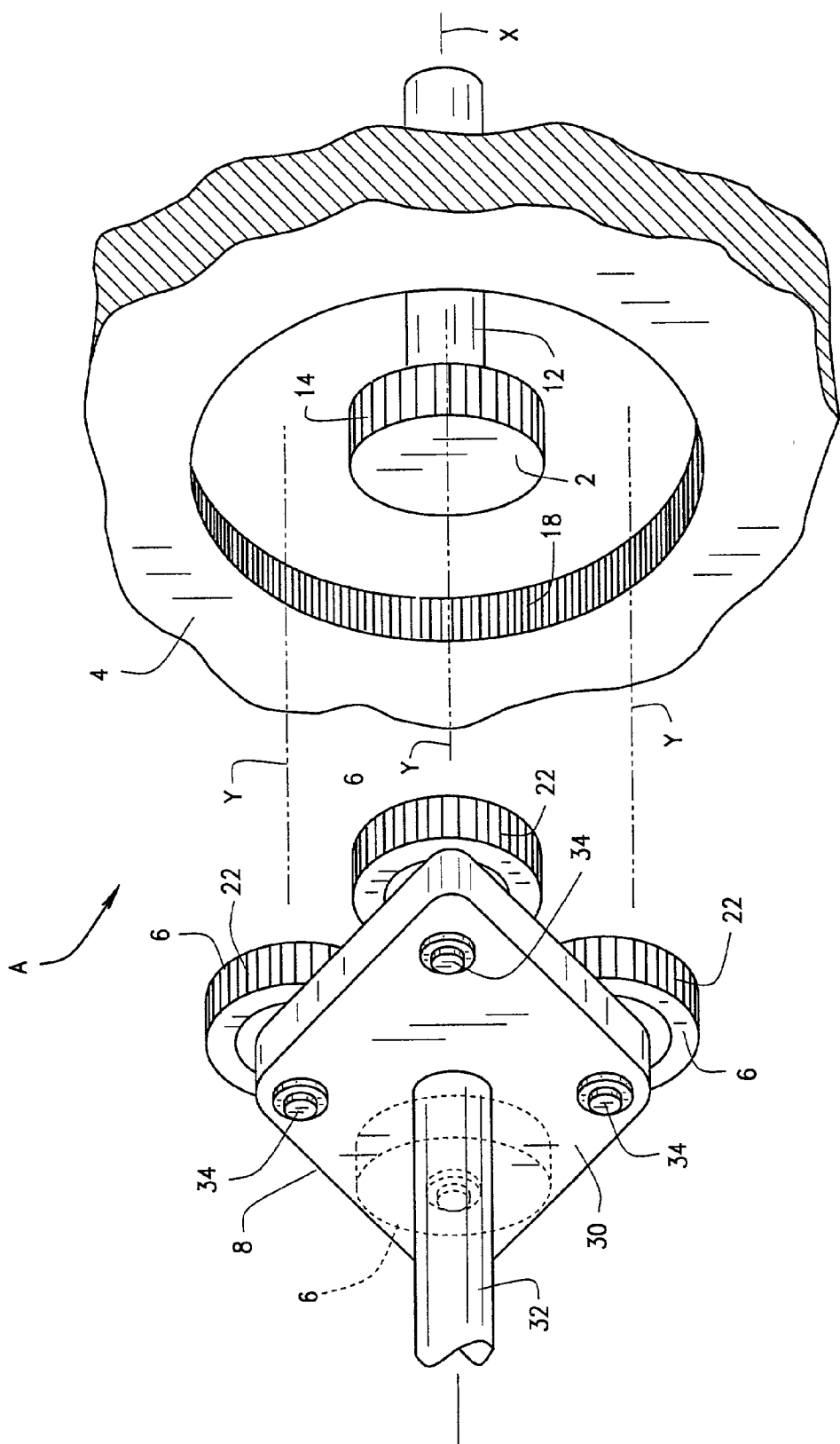


FIG. 1

FIG. 2

FIG. 3

EPICYCLIC GEAR SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] None

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] None

BACKGROUND OF THE INVENTION

[0003] This invention relates in general to gear systems and, more particularly, to an epicyclic gear system.

[0004] The typical epicyclic or planetary gear system basically has a sun gear provided with external teeth, a ring gear provided with internal teeth, and several planet gears located between the sun and ring gears and having external teeth which mesh with the teeth on the sun and ring gears. In addition to its gears, the typical system has a carrier to which the planet gears are coupled. Either the sun gear, the ring gear, or the carrier is held fast, while power is delivered to and taken from the remaining two components, and thus power is transferred through the planetary system with a change in angular velocity and an inverse change torque.

[0005] The sun and ring gears for all intents and purposes share the same axis, a central axis, while the planet gears revolve about radially offset axes that are parallel to the central axis—or at least they should. Often the offset axes and the central axis are not parallel, and as a consequence the planet gears skew slightly between sun and ring gears. This causes excessive wear along the teeth of the planet, sun and ring gears, generates friction and heat, and renders the entire system overly noisy.

[0006] The problem certainly exists in straddle carriers. With this type of carrier the pins on which the planet gears rotate extend between two carrier flanges in which the pins are anchored at their ends. The carrier experiences torsional wind up which causes one carrier flange to rotate slightly ahead of the other flange. Not only does this skew the pin for each of the planet gears such that one end lies circumferentially ahead of the other, but it also causes the leading end of the pin to dip toward the central axis and the other end to draw away from the central axis. The end result is a poor mesh between the planet gears and the sun and ring gears, and of course the friction, wear and noise associated with poorly meshed gears. To counteract this tendency, some planetary systems rely on gears that are wider than necessary and thus offer greater tolerance to skewing along the gear contact. But these systems can occupy excessive space and can be quite heavy.

[0007] Other transmissions rely on a double cantilever arrangement at the pins for their planetary gears to maintain the planet gears and the sun and ring gears properly meshed. In this arrangement the carrier has a single carrier flange located beyond the ends of the planet gears, and the carrier pins project from that flange into, and indeed through, the gears. Each carrier pin has one end anchored in the carrier flange and its other end anchored in a sleeve which turns back over the pin to support the planet gear. U.S. Pat. No. 3,303,713 to R. J. Hicks shows a double cantilevered arrangement. Often an antifriction bearing is fitted between

the sleeve and the planet gear. But antifriction bearings consume space, making the planet gears excessively large in diameter, which in turn makes the entire gear system too large and heavy.

SUMMARY OF THE INVENTION

[0008] The present invention resides in an epicyclic gear system that has a sun gear, a ring gear around the sun gear and at least one planet gear located between and engaged with the sun and ring gears. A carrier flange is offset axially from the planet gear and a carrier pin projects from it into the planet gear. An inner race is attached to the carrier pin remote from the carrier flange, and it has a raceway which is presented toward a raceway carried by the planet gear. Rolling elements are organized in a row between the opposed raceways to enable the planet gear to revolve about the carrier pin. The invention also resides in a carrier and bearing for such a gear system.

DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is an exploded perspective view of an epicyclic gear system constructed in accordance with and embodying the present invention;

[0010] FIG. 2 is a sectional view of the gear system at one of its planet gears and showing the coupling between the planet gear and the carrier; and

[0011] FIG. 3 is a sectional view of the gear system similar to the system of FIG. 2, but showing a modified coupling.

DETAILED DESCRIPTION OF INVENTION

[0012] Referring now to the drawings, a planetary transmission A (FIG. 1), which is actually an epicyclic gear system, has the capacity to transmit power of considerable magnitude, given its size and weight. In short, it has a high power density. In contrast to some planetary transmissions, the transmission A relies on meshing gears that are quite narrow, yet the teeth of those gears remain properly meshed, even when transmitting substantial power and torque. The transmission A has a central axis X of rotation about which torque is transferred to the transmission A and delivered from it. The transmission A basically includes a sun gear 2 having its axis coincident with the central axis X, a ring gear 4 which surrounds the sun gear 2 and shares the axis X with it, and planet gears 6 which mesh with and rotate between the sun and ring gears 2 and 4 about axes Y that are offset radially from, yet parallel to, the central axis X. In addition, the transmission A has a carrier 8 to which the planet gears 6 are coupled, and the carrier 8 likewise shares the axis X.

[0013] Referring more specifically to the sun gear 2, it is attached to a shaft 12 or some other supporting structure with which it normally rotates, but it may be fixed against rotation in some installations. The sun gear 2 has external teeth 14 which are presented outwardly away from the axis X.

[0014] The ring gear 4 is typically fixed, and thus does not rotate, although it may rotate in some installations. In any event, the ring gear 4 has internal teeth 18 which are presented inwardly toward the axis X and toward the external teeth 14 on the sun gear 2 and lie concentric with them. The ring gear 4 may be part of or integrated into a housing for the transmission A.

[0015] An annular space exists between the sun and ring gears 2 and 4, and the planet gears 6 occupy that space. Each has external teeth 22 which mesh with the external teeth 14 or the sun gear 2 and the internal teeth 18 on the ring gear 4. Thus, when the sun gear 2 rotates relative to the ring gear 4 about the axis X or vice versa, the planet gears 6 will revolve, each about its offset axis Y that lies parallel to the central axis X. The planetary gears 6 are hollow, with each having two raceways 24 (FIG. 2) which taper downwardly to an intervening surface 26 located midway between the ends of the gear 6. The large ends of the raceways 24 for each planet gear 6 open out of the ends of the gear 6.

[0016] The carrier 8 includes (FIG. 1) a carrier flange 30 to which all of the planet gears 6 are coupled, it being offset axially beyond corresponding ends on each of the gears 6. Normally, the carrier 8 rotates about the axis X, although it may remain fixed in some installations. When the carrier 6 rotates, it is usually coupled to a shaft 32 that lies along the axis X. In addition to the carrier flange 30, the carrier 6 has carrier pins 34 which project from the flange 30 into the planet gears 6, their axes generally corresponding to the axes Y of rotation for the planet gears 6.

[0017] More specifically, the carrier flange 30 opposite each planet gear 6 has a tapered hole 36 (FIG. 2). The carrier pins 34, on the other hand, have tapered surfaces 38 which lead out to threaded ends 40. The tapered surfaces 38 conform in configuration to the tapered holes 36 in the flange 30 and indeed fit snugly into the tapered holes 36 so that the pins 34 project from the face of the carrier flange 30 that is presented toward the planet gears 6. The threaded ends 40 project beyond the other face of the carrier flange 30 where they are engaged by nuts 42 which are turned down snugly against that face. This lodges the carrier pins 34 at their tapered surfaces 38 firmly in the carrier flange 30. Thus, each pin 34 is, in effect, cantilevered from the carrier flange 30.

[0018] Each carrier pin 34 projects through its planet gear 6, and at the opposite end of the gear 6, that is the end remote from the carrier flange 30, is fitted to an inner race 46 which the planet gear 6 also encircles. The inner race 46 has an end wall 48 and a sleeve 50 formed integral with the end wall 48. Indeed, the sleeve 50 turns backwardly from the end wall 48 into the interior of the gear 6 and thus encircles the carrier pin 34. The end wall contains a bore 52 into which the end of the carrier pin 34 fits with an interference fit. At its very end the carrier pin 34 is joined to the end wall 48 along a weld 54. Thus, the interference fit together with the weld 54 secure the inner race 46 firmly to the carrier pin 34. The interior surface of the sleeve 50 is somewhat larger than the carrier pin 34, and as a consequence the inner race 46 at its end wall 48 is cantilevered from the remote end of the carrier pin 34.

[0019] The sleeve 50 of the inner race 46 lies within the interior of the planet gear 6 and has two tapered raceways 56 which taper downwardly to a separating rib 58. The raceways 56, which have their centers along the axis Y, are presented outwardly away from the axis Y and toward the raceways 24 on the gear 6, each raceway 56 on the inner race 46 being opposite one of the raceways 24 on the gear 6. On the other hand, the separating rib 58 lies opposite the intervening surface 26 of the gear 6. Each raceway 56 on the inner race 46 tapers in the same direction as the raceway 24

toward which it is presented on the planet gear 6. The raceway 56 closest to the carrier flange 30 leads out to a thrust rib 60 that is formed integral with the sleeve 50 of the inner race 26. The other raceway 56 leads out to a cylindrical mounting surface 62 that surrounds the end wall 48. The mounting surface 62 has a rib ring 64 fitted to it with an interference fit and further secured with a weld 66 at its end. The rib ring 64 extends axially from the weld 66 to the large end of the tapered raceway 56, so the rib ring 64 forms another thrust rib, similar function to the rib 60 at the end of the inner race 46 that is remote from the carrier flange 30.

[0020] The annular region between each planet gear 6 and inner race 46 that the gear 6 surrounds is occupied by rolling elements in the form of tapered rollers 70 organized into two rows. One row lies along the integral thrust rib 60 that is adjacent to the carrier flange 30 and contacts the opposed raceways 24 and 56 at that end, while the other row lies along the rib ring 64 that surrounds the end wall 48 of the inner race 46 and contacts the raceways 24 and 56 at that end. Indeed, the tapered rollers 70 contact the raceways 24 and 56 along their tapered side faces, there being generally line contact here. They also bear against the thrust rib 60 and rib ring 64 at their large end faces. The thrust rib 60 and rib ring 64 prevent the rollers 70 from moving up the raceways 24 and 56 and being expelled from the annular region between the planet gear 6 and the inner race 46. The rollers 70 of each row are on apex, meaning that the conical envelopes in which the side faces of the rollers 70 of a row lie will have their apices located at a common point along the axis Y. This produces pure rolling contact between the side faces of the rollers 70 and the raceways 24 and 56. While the rollers 70 of each row may be separated with a cage, preferably they are not so confined. This enables each row to contain the maximum number of rollers 70.

[0021] The rollers 70 together with the inner race 46 and the raceways 24 on the planet gear 6 form a double row tapered roller bearing 72 that couples the planet gear 6 to the carrier pin 34 about which the gear 6 rotates. Indeed, the bearing 72 has the capacity to facilitate rotation of the planet gear 6 about the axis Y with minimal friction, while confining the gear 6 radially and axially on the carrier pin 34. In other words, the bearing 72 takes thrust loading in both axial directions. Moreover, the bearing 72 is set to a condition of light preload, and as a consequence no axial or radial clearances exist within it. This enables the gear 6 to rotate on the carrier pin 34 without axial or radial free motion and without wobbling.

[0022] The carrier pins 34 possess a measure of flexibility and indeed will flex well within their elastic limits when torque is transferred through the planet gears 6. The double cantilever arrangement enables the axes Y to remain parallel to the axis X, and hence the planet gears 6 remain properly meshed with the sun and ring gears 2 and 4. Thus, the planet gears 6, and likewise the sun and ring gears 2 and 4, need not be excessively wide to account for off-center gear contact.

[0023] To assemble the carrier 8, each carrier pin 34 at its cylindrical end is forced into the bore 52 in the carrier flange 48 of the inner race 46 for that pin 34. Then the carrier pin 34 at its end is welded to the end wall 48, producing the weld 54. Thereupon, the rollers 70 for the row remote from the end wall 48 are placed along the raceway 56 that leads up to the thrust rib 60, with the large end faces of those rollers

being 70 against the rib 60. Next the planet gear 6 is installed over the inner race 46 and the row of rollers 70 on that race 46. The leading raceway 24 in the gear 6 seats against the side faces of those tapered rollers 70. This leaves an annular void between the raceways 24 and 56 at the opposite end planet gear 6. More rollers 70 are inserted into this void with their small ends leading, thus creating a second row of rollers 70 having their large ends located along the end of the mounting surface 62 for inner race 46. With the gear 6 and the two rows of rollers 70 in place around the inner race 46, the rib ring 64 is forced over the mounting surface 62 on the inner race 46, and advanced toward the large ends of the rollers 70 that are at the mounting surface 62. As the rib ring 64 approaches the large end faces of the rollers 70, the gear 6 is rotated to insure that the rollers 70 of the two rows seat against the raceways 24 and 56 and along the thrust rib 60 and rib ring 64. After the rib ring 64 comes against the large end faces of the rollers 70 in the row that is along it, the bearing 72 will enter preload. The advance continues a short distance until the bearing 72 acquires the proper preload. Then the rib ring 64 is welded to the inner race 46, producing the weld 66. The gear 6, rollers 70, inner race 46 and carrier pin 3434 constitute a subassembly 76, and enough subassemblies 76 are produced in the foregoing manner to complete the carrier 8.

[0024] Within each subassembly 76 the tapered surface 38 of the carrier pin 34 extends beyond the open end of the sleeve 50 for the inner race 46 and beyond the corresponding end of the planet gear 6 as well. The tapered surface 38 of the carrier pin 34 is inserted into one of the tapered holes 36 of the carrier flange 30, whereupon one of the nuts 42 is engaged with the threaded end 40 that projects out of the flange 30. The nut 42 is turned down firmly against the carrier flange 30 to draw the tapered surface 38 of the carrier pin 34 snugly into the tapered hole 36. This secures the carrier pin 34 and inner race 46 firmly to the carrier flange 30. The remaining subassemblies 76 are installed on the carrier flange 30 in a like manner.

[0025] With the carrier 8 so assembled, it is installed over the sun gear 2 and into the ring gear 4 such that the external teeth 22 on the planet gears 6 engage the external teeth 14 in the sun gear 2 and the internal teeth 18 on the ring gear 4.

[0026] When torque is applied to the shaft 12 to rotate the sun gear 2, the planet gears 6 revolve and move along the ring gear 4, thus imparting rotation to the carrier 8 and the shaft 32 extended from it. The angular velocities of the two shafts 12 and 32 differ and with that difference a change in the torque ensues. Of course, the torque may be applied to the shaft 32 and taken from the shaft 12. Actually, any one of the sun gear 2, ring gear 4 and carrier 8 may be held fast and torque delivered to and taken from the remaining two components.

[0027] In a modified subassembly 78 (FIG. 3) the carrier pin 34 is formed integral with the inner race 46.

[0028] The cantilever of the carrier pins 34 from the carrier flange 30 and the cantilever of the inner races 46 from the carrier pins 34, that is the so-called "double cantilever", insures that the axes Y of rotation for the ring gears 6 remain parallel to the center axis X. As a consequence, the ring gears 6 do not require excessive width to resist skewing. The inner races 46, being mounted directly on the carrier pins 34,

instead of on intervening components, together with the integration of the outer raceways 24 into the planet gears 6, enables the bearings 72 to be of a diameter that is smaller than the diameters of bearings in more conventional epicyclic gear systems. This, in turn, can permit use of smaller sun and ring gears 2 and 4, and otherwise render the entire transmission highly compact and light in weight.

[0029] In lieu of a double row tapered roller bearing 70, each planet gear 6 may be coupled to its carrier pin 34 on the carrier 8 with a double row angular contact ball bearing or even with a cylindrical or spherical roller bearing. Also, more or less than four planet gears 6 may be used between the sun gear 2 and ring gear 4.

EPICYCLIC GEAR SYSTEM		
A	transmission	
X	axis	
Y	axes	
2	sun gear	
4	ring gear	
6	planet gears	
8	carrier	
12	shaft	
14	external teeth	
18	internal teeth	
22	external teeth	
24	raceways	
26	intervening surface	
30	carrier flange	
32	shaft	
34	carrier pins	
36	tapered hole	
38	tapered surface	
40	threaded ends	
42	nut	
46	inner race	
48	end wall	
50	sleeve	
52	bore	
54	weld	
56	tapered raceway	
58	separating member	
60	thrust rib	
62	mounting surface	
64	rib ring	
66	weld	
70	tapered rollers	
72	bearing	
76	subassembly	
78	subassembly	

What is claimed is:

1. An epicyclic gear system comprising: a sun gear located along a central axis; a ring gear located around the sun gear and sharing the central axis with the sun gear; at least one planet gear located between and engaged with the sun and ring gears for rotation about an offset axis, the planet gear having a raceway that is presented toward the offset axis; and a carrier coupled to the planet gear and including a carrier flange, a carrier pin projecting from the flange into the planet gear, an inner race attached to the carrier pin remote from the carrier flange and also located within the ring gear where it has a raceway presented outwardly away from the offset axis and toward the raceway carried by the ring gear, and rolling elements located in a row between and contacting the raceways on the ring gear and inner race.

2. A gear system according to claim 1 wherein the carrier pin is cantilevered from the carrier flange, and the inner race is cantilevered from the carrier pin at a location remote from the carrier flange.

3. A gear system according to claim 2 wherein the inner race includes a sleeve which surrounds, but is spaced from the carrier pin, and an end wall connected to the sleeve at one end of the sleeve; wherein the raceway for the inner race is on the sleeve; and wherein the carrier pin is connected to the inner race at the end wall of the inner race.

4. A gear system according to claim 3 wherein the end wall and the sleeve are formed integral.

5. A gear system according to claim 4 wherein the carrier pin and the end wall of the inner race are formed integral.

6. A gear system according to claim 3 wherein the raceway on the planet gear is one of two outer raceways which are located oblique to the offset axis and are inclined in opposite directions; wherein the raceway on the inner race is one of two inner raceways that are oriented oblique to the offset axis and inclined in opposite directions, one of the inner raceways being located within and inclined in the same direction as one of the outer raceways and the other inner raceway being located within and inclined in the same direction as the other outer raceway; and wherein the rolling elements are arranged in two rows between the outer and inner raceways.

7. A gear system according to claim 6 wherein the raceways are tapered; wherein the rolling elements are tapered rollers; wherein the sleeve of the inner race has thrust ribs at the large ends of the tapered inner raceways; and wherein one of the thrust ribs fits over the inner race as an initially separate component.

8. In an epicyclic gear system including a sun gear located along a central axis, a ring gear located around the sun gear and sharing the central axis; planet gears located between and engaged with the sun and ring gears for rotation about offset axes that are located around the central axis; a carrier coupled with the planet gears and including a carrier flange offset axially from the planet gears, carrier pins cantilevered from the carrier flange and projected into the planet gears along the offset axes, there being a separate carrier pin for each planet gear, an inner race cantilevered from each carrier pin remote from the carrier flange and located within the planet gear into which the pin projects, a first inner raceway carried by each inner race and presented outwardly away from the offset axes for that inner race, a first outer raceway carried by the planet gear that is located around the carrier pin and presented inwardly toward the offset axes and toward the first inner raceway on the inner race; and rolling elements located between and contacting the first raceways.

9. The combination according to claim 8 and further comprising a second inner raceway carried by the inner race around each carrier pin and presented outwardly away from the offset axes for that carrier pin, a second outer raceway carried by the planet gear that is around the carrier pin and presented inwardly toward the offset axes and the second inner raceway; and wherein the rolling elements are arranged in two rows, with one row being between the first inner and outer raceways and the other row being between the second inner and outer raceways.

10. The combination according to claim 9 wherein the raceways are oblique to the offset axes; and wherein the first inner and outer raceways are inclined in the same direction and the second inner and outer raceways are inclined in the

same direction, which direction is opposite to the direction of inclination of the first raceways, whereby the rolling elements in the row between the first raceways will transfer thrust loads in one axial direction and the rolling elements in the row between the second raceways will transfer thrust loads in the opposite axial direction.

11. The combination according to claim 10 wherein the raceways are tapered and the rolling elements are tapered rollers.

12. The combination according to claim 11 wherein the first and second raceways taper inwardly toward each other so that the large ends of the rollers in the row between the first raceways are presented away from the large ends of the rollers in the row between the second raceways.

13. The combination according to claim 12 wherein the inner race has thrust ribs at the large ends of the inner raceways; and wherein one of the thrust ribs is a rib ring formed as a separate component that is installed on the inner race after the rollers are placed between the planet gear and the inner race.

14. The combination according to claim 10 wherein inner race includes a sleeve on which the inner raceways are located and an end wall at one end of the sleeve; the end wall being attached firmly to the carrier pin remote from the carrier flange with the sleeve surrounding, but being spaced from the carrier pin.

15. In an epicyclic gear system having a central axis and a planet gear that rotates about an offset axis that is offset radially from the central axis, the improvement comprising: a carrier flange located beyond one end of the planet gear, a carrier pin projecting from the carrier flange into the planet gear such that it is cantilevered from the carrier flange; and a bearing located between the carrier pin and the planet gear for coupling the planet gear to the carrier flange and enabling the planet gear to rotate about the offset axis, the bearing including an inner race which is attached to the carrier pin remote from the carrier flange and includes a sleeve which surrounds the carrier pin, yet is spaced from the pin, the sleeve having a first raceway that is presented outwardly away from the offset axis for the planet gear, the bearing also including a first outer raceway that is carried by the planet gear and is presented inwardly toward the offset axis and the first inner raceway, the bearing further including rolling elements arranged in a row between the first inner and outer raceways.

16. The combination according to claim 15 wherein the inner race also includes an end wall extended between the sleeve and the carrier pin and attached firmly to the pin remote from the carrier, whereby the inner race is cantilevered from the carrier pin.

17. The combination according to claim 15 wherein the first inner and outer raceways are inclined in the same direction with respect to the offset axis; wherein the inner race has a second inner raceway that is presented outwardly away from the offset axis and is inclined with respect to the offset axis in a direction opposite the inclination of the first raceways, and the bearing also includes a second outer raceway carried by the planet gear and presented inwardly toward the second inner raceway and inclined with respect to the offset axis in the same direction as the second inner raceway; and wherein the rolling elements are organized in first and second rows, the rolling elements of the first row being between the first raceways and the rolling elements of the second row being between the second raceways.

18. The combination according to claim 17 wherein the raceways are tapered and the rolling elements are tapered rollers; wherein the inner race has a thrust rib at the large end of the first inner raceway with the rib projecting beyond the first inner raceway, the large ends of the rollers in the first row being against the thrust rib, and the inner race also has a mounting surface at the large end of the second inner raceway with the mounting surface having a diameter no greater than the diameter of the large end of the second inner raceway, and wherein an initially separate rib ring is located around the mounting surface on the inner race and projects outwardly beyond the large end of the second inner raceway, the large ends of the tapered rollers in the second row being against the rib ring.

19. The combination according to claim 18 wherein the inner race also includes an end wall extended between the sleeve and the carrier pin and attached firmly to the carrier pin remote from the carrier flange, whereby the inner race is cantilevered from the carrier pin.

20. The combination according to claim 19 wherein the end wall and sleeve of the inner race are integral.

21. In an epicyclic gear system having a central axis and a planet gear offset radially from the central axis where it is located between and engaged with other gears, the improvement comprising: a carrier flange located beyond one end of the planet gear; a carrier pin projecting from the carrier flange into the planet gear, the carrier pin being offset from the central axis and cantilevered from the carrier flange; an inner race attached to the pin remote from the carrier flange such that the inner race is cantilevered from the pin, the inner race having an inner raceway that is presented outwardly away from the carrier pin; an outer raceway carried by the planet gear and presented toward the inner raceway on the inner race; and rolling elements located in a row between and contacting the inner and outer raceways.

22. The combination according to claim 21 wherein the inner race includes a sleeve which surrounds the carrier pin and carries the inner raceway, yet is spaced from the pin, and an end wall at one end of the sleeve, with the inner race being attached to the carrier pin at the end wall.

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