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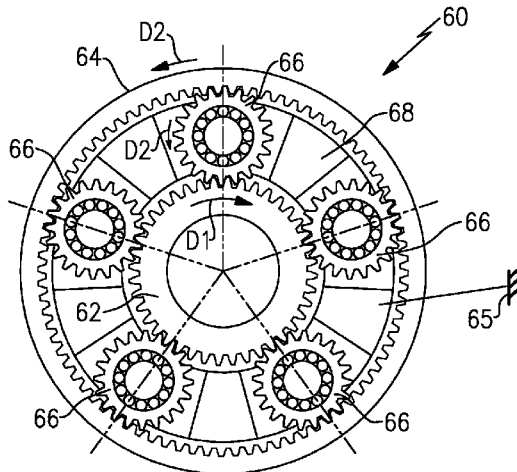


FIG. 2

(57) Abstract: An epicyclic gear assembly according to an exemplary aspect of the present disclosure includes, among other things, a carrier including a first plate axially spaced from a second plate by a radially outer connector. A first set of epicyclic gears supported adjacent the first plate include a first set of circumferentially offset intermediate gears meshing with a first sun gear and a first ring gear. A second set of epicyclic gears are axially spaced from the first set of epicyclic gears and supported adjacent the second plate, and include a second set of circumferentially offset intermediate gears meshing with a second sun gear and a second ring gear. The first epicyclic gear set and the second epicyclic gear set maintain relative intermeshing alignment during flexure induced deformation of the carrier.



FAN DRIVE GEAR SYSTEM WITH IMPROVED MISALIGNMENT CAPABILITY**BACKGROUND**

[0001] A gas turbine engine typically includes a fan section, a compressor section, a combustor section, and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-speed exhaust gas flow. The high-speed exhaust gas flow expands through the turbine section to drive the compressor and the fan section.

[0002] Some gas turbine engines include a geared architecture mechanically connecting the fan section with the turbine section. The geared architecture allows the turbine section to spin at a different rotational speed than the fan section to increase efficiency of the gas turbine engine. During operation, torsional loads are applied to the geared architecture that can deform the structure of the geared architecture. Deformation of the geared architecture structure can misalign the gears and decrease the operating life of the gears and their associated bearings.

SUMMARY

[0003] An epicyclic gear assembly according to an exemplary aspect of the present disclosure includes, among other things, a carrier including a first plate axially spaced from a second plate by a radially outer connector. A first set of epicyclic gears supported adjacent the first plate include a first set of circumferentially offset intermediate gears meshing with a first sun gear and a first ring gear. A second set of epicyclic gears are axially spaced from the first set of epicyclic gears and supported adjacent the second plate, and include a second set of circumferentially offset intermediate gears meshing with a second sun gear and a second ring gear. The first epicyclic gear set and the second epicyclic gear set maintain relative intermeshing alignment during flexure induced deformation of the carrier.

[0004] In a further non-limiting embodiment of the foregoing epicyclic gear assembly, the assembly includes at least one intermediate gear opening in the carrier. One of the first set of intermediate gears and one of the second set of intermediate gears are located within the at least one intermediate gear opening.

[0005] In a further non-limiting embodiment of either of the foregoing epicyclic gear assemblies, the first set of intermediate gears move independently of the second set of intermediate gears.

[0006] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the first ring gear includes a first set of teeth extending from a first flexible flange and the second ring gear includes a second set of teeth extending from a second flexible flange.

[0007] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the gear assembly is a planetary gear assembly with the first ring gear and the second ring gear fixed from rotation.

[0008] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the gear assembly is a star gear assembly with the carrier fixed from rotation.

[0009] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, at least one of the first set of intermediate gears and at least one of the second set of intermediate gears are attached to the carrier by at least one post.

[0010] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, at least one spherical bearing is located between the at least one post and the at least one of the first set of intermediate gears and the at least one second set of intermediate gears.

[0011] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the first set of intermediate gears and the second set of intermediate gears are spur gears.

[0012] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the first sun gear includes a first set of teeth and the second sun gear includes a second set of teeth.

[0013] In a further non-limiting embodiment of any of the foregoing epicyclic gear assemblies, the first set of teeth are clocked to align with a set of tooth roots between the second set of teeth.

[0014] A gas turbine engine according to an exemplary aspect of the present disclosure includes, among other things, a fan section rotatable about an axis and a speed

change mechanism in communication with the fan section. The speed change mechanism includes a carrier including a first plate axially spaced from a second plate by a radially outer connector. A first set of epicyclic gears supported adjacent the first plate include a first set of circumferentially offset intermediate gears meshing with a first sun gear and a first ring gear. A second set of epicyclic gears are axially spaced from the first set of epicyclic gears and supported adjacent the second plate, and include a second set of circumferentially offset intermediate gears meshing with a second sun gear and a second ring gear. The first epicyclic gear set and the set epicyclic gear set maintain relative intermeshing alignment during flexure induced deformation of the carrier.

[0015] In a further non-limiting embodiment of the foregoing gas turbine engine, the engine includes at least one intermediate gear opening in the carrier. One of the first set of intermediate gears and one of the second set of intermediate gears are located within the at least one intermediate gear opening.

[0016] In a further non-limiting embodiment of either of the foregoing gas turbine engines, the first set of intermediate gears move independently of the second set of intermediate gears.

[0017] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the first sun gear includes a first set of teeth and the second sun gear includes a second set of teeth.

[0018] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the first set of teeth are clocked to align with a set of tooth roots between the second set of teeth.

[0019] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the first set of intermediate gears and the second set of intermediate gears are spur gears.

[0020] A method of operating a gear assembly according to another exemplary aspect of the present disclosure includes, among other things, rotating a first plate on a carrier relative to a second plate on the carrier. A first load is transferred through a first set of epicyclic gears adjacent the first plate, including a first ring gear, a first set of circumferentially offset intermediate gears, and a first sun gear. A second load is transferred through a second set of epicyclic gears adjacent the second plate, including a second ring

gear, a second set of circumferentially offset intermediate gears, and a second sun gear independently of the first load. The first set of epicyclic gears are axially spaced from the second set of epicyclic gears.

[0021] In a further non-limiting embodiment of the foregoing method, rotating a first plate on a carrier relative to a second plate on the carrier further includes counteracting the rotation of the first plate and the second plate with a radially outer connector.

[0022] In a further non-limiting embodiments of either of the foregoing methods, at least one of the first set of intermediate gears and the second set of intermediate gears is mounted on a spherical bearing.

[0023] The various features and advantages of this disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 illustrates a schematic, cross-sectional view of an example gas turbine engine.

[0025] Figure 2 illustrates an example geared architecture that can be incorporated into the gas turbine engine.

[0026] Figure 3 illustrates the geared architecture of Figure 2 incorporated into the gas turbine engine.

[0027] Figure 4 illustrates another example geared architecture that can be incorporated into the gas turbine engine.

[0028] Figure 5 illustrates the geared architecture of Figure 4 incorporated into the gas turbine engine.

[0029] Figure 6 is a perspective view of an example sun gear.

[0030] Figure 7 is a perspective view of an example carrier.

[0031] Figure 8 is a perspective cross-sectional view of a spherical gear.

[0032] Figure 9 illustrates the carrier under a torsional load.

DETAILED DESCRIPTION

[0033] Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbofan that generally incorporates a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section 22 drives air along a bypass flow path B in a bypass duct defined within a fan case or fan duct 15, while the compressor section 24 drives air along a core flow path C for compression and communication into the combustor section 26 then expansion through the turbine section 28. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

[0034] The exemplary engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided, and the location of bearing systems 38 may be varied as appropriate to the application.

[0035] The low speed spool 30 generally includes an inner shaft 40 that interconnects a fan 42, a low pressure compressor 44 and a low pressure turbine 46. The inner shaft 40 is connected to the fan 42 through a speed change mechanism, which in exemplary gas turbine engine 20 is illustrated as a geared architecture 48 to drive the fan 42 at a lower speed than the low speed spool 30. The high speed spool 32 includes an outer shaft 50 that interconnects a high pressure compressor 52 and high pressure turbine 54. A combustor 56 is arranged in exemplary gas turbine engine 20 between the high pressure compressor 52 and the high pressure turbine 54. A mid-turbine frame 57 of the engine static structure 36 is arranged generally between the high pressure turbine 54 and the low pressure turbine 46. The mid-turbine frame 57 further supports bearing systems 38 in the turbine section 28. The inner shaft 40 and the outer shaft 50 are concentric and rotate via bearing systems 38 about the engine central longitudinal axis A which is collinear with their longitudinal axes.

[0036] The core airflow is compressed by the low pressure compressor 44 then the high pressure compressor 52, mixed and burned with fuel in the combustor 56, then expanded over the high pressure turbine 54 and low pressure turbine 46. The mid-turbine frame 57 includes airfoils 59 which are in the core airflow path C. The turbines 46, 54 rotationally drive the respective low speed spool 30 and high speed spool 32 in response to the expansion. It will be appreciated that each of the positions of the fan section 22, the compressor section 24, the combustor section 26, the turbine section 28, and the geared architecture 48 may be varied. For example, geared architecture 48 may be located aft of the combustor section 26 or even aft of turbine section 28, and fan section 22 may be positioned forward or aft of the location of the geared architecture 48.

[0037] The engine 20 in one example is a high-bypass geared aircraft engine. In a further example, the engine 20 bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture 48 is an epicyclic gear train, such as a planetary gear system, star gear system, or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine 46 has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine 20 bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor 44, and the low pressure turbine 46 has a pressure ratio that is greater than about five 5:1. Low pressure turbine 46 pressure ratio is pressure measured prior to inlet of low pressure turbine 46 as related to the pressure at the outlet of the low pressure turbine 46 prior to an exhaust nozzle. The geared architecture 48 may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

[0038] A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section 22 of the engine 20 is designed for a particular flight condition - typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft, with the engine at its best fuel consumption - also known as "bucket cruise Thrust Specific Fuel Consumption (TSFC)" - is the industry standard parameter of lbf of thrust the engine produces at that minimum point.

"Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(T_{\text{fan}} / (518.7 \text{ } ^\circ\text{R}))]^{0.5}$. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft / second.

[0039] Figure 2 illustrates the geared architecture 48 including an example star gear assembly 60. In this example, the star gear assembly 60 includes a sun gear 62, a ring gear 64 disposed about the sun gear 62, and circumferentially offset intermediate gears 66, or star gears, positioned between the sun gear 62 and the ring gear 64. A carrier 68 carries the intermediate gears 66. In this embodiment, the carrier 68 is connected to a static structure 65 to prevent rotation.

[0040] The sun gear 62 receives an input from the low pressure turbine 46 (see Figure 1) and rotates in a first direction D1 thereby turning the plurality of intermediate gears 66 in a second direction D2 that is opposite of the first direction D1. Movement of the plurality of intermediate gears 66 is transmitted to the ring gear 64, which can then rotate in the second direction D2 opposite from the first direction D1 of the sun gear 62. The ring gear 64 is connected to the fan 42 for rotation (see Figure 1).

[0041] Figure 3 illustrates the star gear assembly 60 incorporated into a gas turbine engine 20. In this embodiment, the star gear assembly 60 is an epicyclic gear system with the carrier 68 attached to the static structure 65 with a spline 70 that fixes the carrier 68 from rotation.

[0042] A fan drive shaft 72 is attached to a first ring gear 64a and a second ring gear 64b. The fan drive shaft 72 is supported by bearing systems 38-1 and 38-2, such as ball bearings or roller bearings, located between the static structure 65 and the drive shaft 72. In this example, the bearing system 38-1 is generally located between the star gear assembly 60 and a fan hub 74 and the bearing system 38-2 is generally located aft and radially outward from the star gear assembly 60. The bearing system 38-2 could be located at various locations adjacent to the star gear assembly 60, such as radially inward of the carrier 68.

[0043] A first set of intermediate gears 66a having spherical bearings 76a is located adjacent a first plate 68a of the carrier 68. In this example, the first set of intermediate

gears 66a are spur gears. Spherical bearings 76a permit angular rotation of the first set of intermediate gears 66a in multiple orthogonal directions. A post 78a extends through post openings 100 (Figure 7) in the first plate 68a to connect the first set of intermediate gears 66a and spherical bearings 76a to the carrier 68.

[0044] A second set of intermediate gears 66b having spherical bearings 76b is located adjacent a second plate 68b of the carrier 68. In this example, the second set of intermediate gears 66b are spur gears. Spherical bearings 76b permit angular rotation of the second set of intermediate gears 66b in multiple orthogonal directions. A post 78b extends through post openings 100 (Figure 7) in the second plate 68b to connect the second set of intermediate gears 66b and spherical bearings 76b to the carrier 68.

[0045] The first set of intermediate gears 66a are axially spaced from the second set of intermediate gears 66b and rotate independently of each other. An axis of rotation of at least one of the first set of intermediate gears 66a is substantially aligned with an axis of rotation of at least one of the second set of intermediate gears 66b.

[0046] The first set of intermediate gears 66a engage a first set of teeth 69a extending from a first flexible flange 67a on the first ring gear 64a and a first row of teeth 92 on a first sun gear 62a. The second set of intermediate gears 66b engage a second set of teeth 69b extending from a second flexible flange 67b on the second ring gear 64b and a second row of teeth 94 on a second sun gear 62b. The first and second flexible flanges 67a and 67b have a stiffness that is less than a stiffness of the static structure 65.

[0047] The first and second set of intermediate gears 66a and 66b engage the first and second ring gears 64a and 64b on a first side and the first and second sun gears 62a and 62b, respectively, on a second opposite side that is radially inward relative to the engine axis of rotation A.

[0048] The first and second sun gears 62a and 62b are attached with a common splined connection 80 to the inner shaft 40 to receive an input from the low pressure turbine 46. Although the example embodiment illustrates sun gears 62a and 62b attached to the low pressure turbine shaft 40 through splines 80, it can be appreciated that one skilled in the art could conceivably make this attachment with a variety of mechanical connections such as pins, bolts, flanges or tangs. It could also be conceived that either one of the sun gears 62a or 62b could be permanently attached to low pressure turbine shaft 40 while the other sun gear

62a or 62b is flexibly mounted to spline 80 or some other alternate mechanical connection to low turbine shaft 40.

[0049] The star gear assembly 60 is capable of carrying separate loads between the first set of intermediate gears 66a, the first ring gear 64a, and the first sun gear 62a, and the second set of intermediate gears 66b, the second ring gear 64b, and the second sun gear 62b, because of the axial separation between the respective elements. For example, when the first plate 68a on the carrier 68 is rotated relative to the second plate 68b on the carrier 68, a first load is transferred through the first ring gear 64a, the first set of intermediate gears 66a, and the first sun gear 62a, and a second load is transferred independently of the first load through the second ring gear 64b, the second set of intermediate gears 66b, and the second sun gear 62b.

[0050] Figure 4 illustrates the geared architecture 48 including an example planetary gear assembly 90. The planetary gear assembly 90 is similar to the star gear assembly 60 except where noted below. In this example, the planetary gear assembly 90 includes a sun gear 62, a ring gear 64' disposed about the sun gear 62, and the circumferentially offset intermediate gears 66, or planet gears, positioned between the sun gear 62 and the fixed ring gear 64'. A carrier 68' carries and is attached to each of the intermediate gears 66. In this embodiment, the ring gear 64' does not rotate and is connected to the static structure 65 of the gas turbine engine 20.

[0051] The sun gear 62 receives an input from the low pressure turbine 46 (see Figure 1) and rotates in a first direction D1 thereby turning the intermediate gears 66 in a second direction D2 that is opposite of the first direction D1. Movement of the intermediate gears 66 is transmitted to the carrier 68', which rotates in the first direction D1. The carrier 68' is connected to the fan 42 for rotating the fan 42 (see Figure 1) in the first direction D1.

[0052] Figure 5 illustrates an example planetary gear assembly 90 incorporated into a gas turbine engine 20. In this embodiment, the planetary gear assembly 90 is an epicyclic gear system with a first ring gear 64a' and a second ring gear 64b' attached to the static structure 65 with a spline 70' and fixed from rotation.

[0053] Fan drive shaft 72' is attached to the carrier 68' and supported by bearing system 38-1', such as a ball bearing or roller bearing, located between the static structure 65 and the drive shaft 72'. The bearing system 38-1' is generally located between the planetary

gear assembly 90 and the fan hub 74. In this example, a bearing system 38-2', such as a ball bearing or roller bearing, is located on the carrier 68' generally aft and radially outward from the planetary gear assembly 90. However, the bearing system 38-2' could be located at various locations adjacent the planetary gear assembly 90.

[0054] The first set of intermediate gears 66a are axially spaced from the second set of intermediate gears 66b and rotate independently of each other. The first set of intermediate gears 66a engage a first set of teeth 69a' extending from a first flexible flange 67a' on the first ring gear 64a' and a first row of teeth 92 on the first sun gear 62a. The second set of intermediate gears 66b engage a second set of teeth 69b' extending from a second flexible flange 67b' on the second ring gear 64b' and the second row of teeth 94 on the second sun gear 62b. The first and second set of intermediate gears 66a and 66b engage the first and second ring gears 64a' and 64b' on a first side and the first and second sun gears 62a and 62b, respectively, on a second opposite side that is radially inward relative to the engine axis of rotation A.

[0055] Figure 6 illustrates the first sun gear 62a including the first row of teeth 92 and the second sun gear 62b including the second row of teeth 94 spaced from the first row of teeth 92. In this example, the first and second sun gears 62a and 62b are aligned circumferentially on a common spline 80 as shown in Figures 3 and 5. The first row of teeth 92 are clocked from the second row of teeth 94 such that a tooth root 92a on the first row of teeth 92 is aligned with a tooth on the second row of teeth 94. Conversely, a tooth root 94a on the second row of teeth 94 is aligned with a tooth on the first row of teeth 92. By clocking the first row of teeth 92 relative to the second row of teeth 94, vibration of the geared architecture 48 is reduced by decreasing the number of teeth 92 and 94 in meshing engagement at a single time.

[0056] Figure 7 illustrates the carrier 68. A radially outer connector 96 extends between the first plate 68a and the second plate 68b. In this example, the connector 96 are solid continuous pieces of material that are free of fluid passageways. However, in another example, the connect 96 could include passages for delivering a fluid. The connector 96 may be made of a separate piece of material and attached to the first plate 68a and the second plate 68b by bonding, welding, or mechanical connection. Alternatively, the connector 96, the first plate 68a, and the second plate 68b could be made of a single unitary piece of material.

[0057] Intermediate gear openings 98 are circumferentially spaced around a perimeter of the carrier 68 and are defined by the connectors 96, the first plate 68a, and the second plate 68b. The intermediate gear openings 98 are sized to each accept one of the first set of intermediate gears 66a adjacent the first plate 68a and one of the second set of intermediate gears 66b adjacent the second plate 68b. The posts 78 extend through post openings 100 in the first plate 68a and the second plate 68b to secure the intermediates gears 66 to the carrier 68.

[0058] Figure 8 illustrates an example spherical bearing 76 including an inner race 104 for engaging the post 78, an outer race 106 for engaging the intermediate gear 66, and roller bearings 108 located between the inner race 104 and the outer race 106. Spherical bearings 76 allow the inner race 104 to rotate in a direction orthogonal to the outer race 106.

[0059] Figure 9 illustrates deformation of the carrier 68 during application of a torsional force. When torsional force T is applied in the direction as shown in Figure 9, the carrier 68 flexes in response to the force. The flexing of the carrier 68 can lead the intermediate gears 66 to move out of alignment with the ring gear 64 or the sun gear 62. Because the spherical bearings 76 allow for rotation in multiple orthogonal directions, the spherical bearings 76 are able to maintain the first and second set of intermediate gears 66a and 66b in alignment with the first and second ring gears 64a and 64b and the first and second sun gears 62a and 62b even when the carrier 68 is being deformed by the torsional force. Additionally, the first flexible flange 67a and 67a' and the second flexible flange 67b and 67b' provide flexibility to the first ring gear 64a/a' and the second ring gear 64b/b', respectively, to further maintain alignment with the intermediate gears 66 during flexure of the carrier 68.

[0060] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

What is claimed is:

1. An epicyclic gear assembly comprising:
a carrier including a first plate axially spaced from a second plate by a radially outer connector;
a first set of epicyclic gears supported adjacent the first plate, including a first set of circumferentially offset intermediate gears meshing with a first sun gear and a first ring gear;
and
a second set of epicyclic gears axially spaced from the first set of epicyclic gears and supported adjacent the second plate, and including a second set of circumferentially offset intermediate gears meshing with a second sun gear and a second ring gear, whereby the first epicyclic gear set and the second epicyclic gear set maintain relative intermeshing alignment during flexure induced deformation of the carrier.
2. The assembly of claim 1, including at least one intermediate gear opening in the carrier, wherein one of the first set of intermediate gears and one of the second set of intermediate gears are located within the at least one intermediate gear opening.
3. The assembly of claim 1, wherein the first set of intermediate gears move independently of the second set of intermediate gears.
4. The assembly of claim 1, wherein the first ring gear includes a first set of teeth extending from a first flexible flange and the second ring gear includes a second set of teeth extending from a second flexible flange.
5. The assembly of claim 1, wherein the gear assembly is a planetary gear assembly with the first ring gear and the second ring gear fixed from rotation.
6. The assembly of claim 1, wherein the gear assembly is a star gear assembly with the carrier fixed from rotation.

7. The assembly of claim 1, wherein at least one of the first set of intermediate gears and at least one of the second set of intermediate gears are attached to the carrier by at least one post.

8. The assembly of claim 7, including at least one spherical bearing located between the at least one post and the at least one of the first set of intermediate gears and the at least one second set of intermediate gears.

9. The assembly of claim 1, wherein the first set of intermediate gears and the second set of intermediate gears are spur gears.

10. The assembly of claim 1, wherein the first sun gear includes a first set of teeth and the second sun gear includes a second set of teeth.

11. The assembly of claim 10, wherein the first set of teeth are clocked to align with a set of tooth roots between the second set of teeth.

12. A gas turbine engine comprising:
 - a fan section rotatable about an axis; and
 - a speed change mechanism in communication with the fan section, the speed change mechanism including:
 - a carrier including a first plate axially spaced from a second plate by a radially outer connector;
 - a first set of epicyclic gears supported adjacent the first plate, including a first set of circumferentially offset intermediate gears meshing with a first sun gear and a first ring gear; and
 - a second set of epicyclic gears axially spaced from the first set of epicyclic gears and supported adjacent the second plate, and including a second set of circumferentially offset intermediate gears meshing with a second sun gear and a second ring gear, whereby the first epicyclic gear set and the set epicyclic gear set maintain relative intermeshing alignment during flexure induced deformation of the carrier.
13. The engine of claim 12, including at least one intermediate gear opening in the carrier, wherein one of the first set of intermediate gears and one of the second set of intermediate gears are located within the at last one intermediate gear opening.
14. The engine of claim 12, wherein the first set of intermediate gears move independently of the second set of intermediate gears.
15. The engine of claim 21, wherein the first sun gear includes a first set of teeth and the second sun gear includes a second set of teeth.
16. The engine of claim 15, wherein the first set of teeth are clocked to align with a set of tooth roots between the second set of teeth.
17. The engine of claim 12, wherein the first set of intermediate gears and the second set of intermediate gears are spur gears.

18. A method of operating a gear assembly, comprising the steps of:
- a) rotating a first plate on a carrier relative to a second plate on the carrier;
 - b) transferring a first load through a first set of epicyclic gears adjacent the first plate, including a first ring gear, a first set of circumferentially offset intermediate gears, and a first sun gear; and
 - c) transferring a second load through a second set of epicyclic gears adjacent the second plate, including a second ring gear, a second set of circumferentially offset intermediate gears, and a second sun gear independently of the first load, wherein the first set of epicyclic gears are axially spaced from the second set of epicyclic gears.
19. The method of claim 18, wherein step a) further includes counteracting the rotation of the first plate and the second plate with a radially outer connector.
20. The method of claim 18, wherein at least one of the first set of intermediate gears and the second set of intermediate gears is mounted on a spherical bearing.

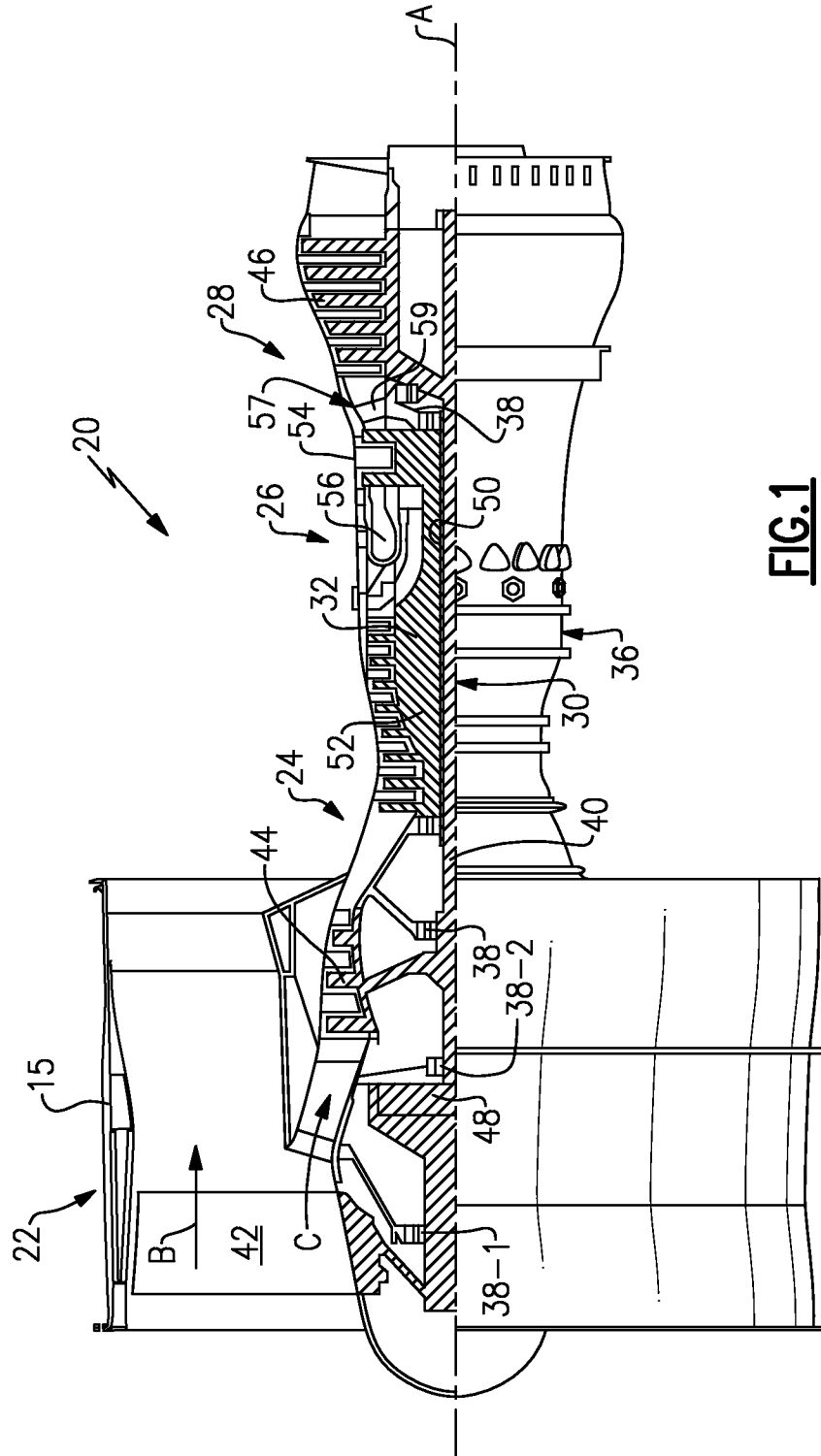


FIG. 1

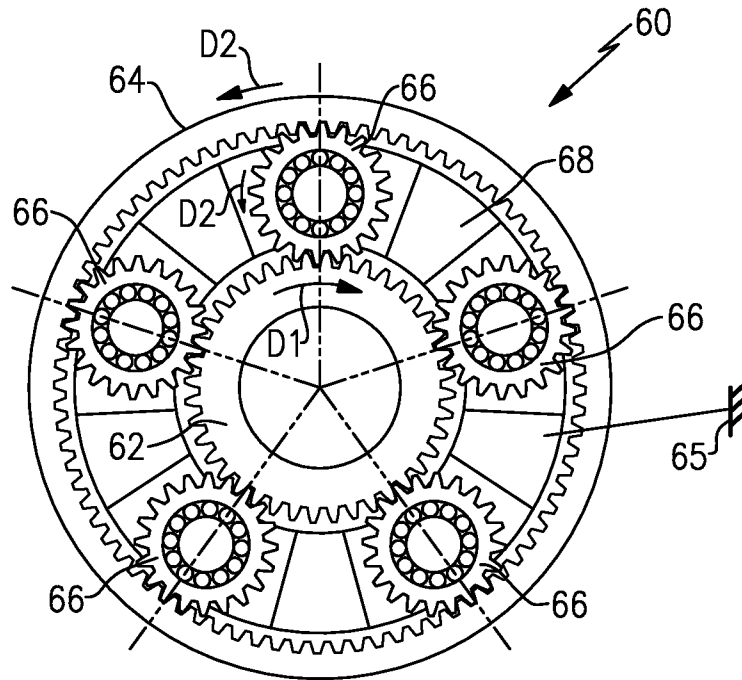


FIG. 2

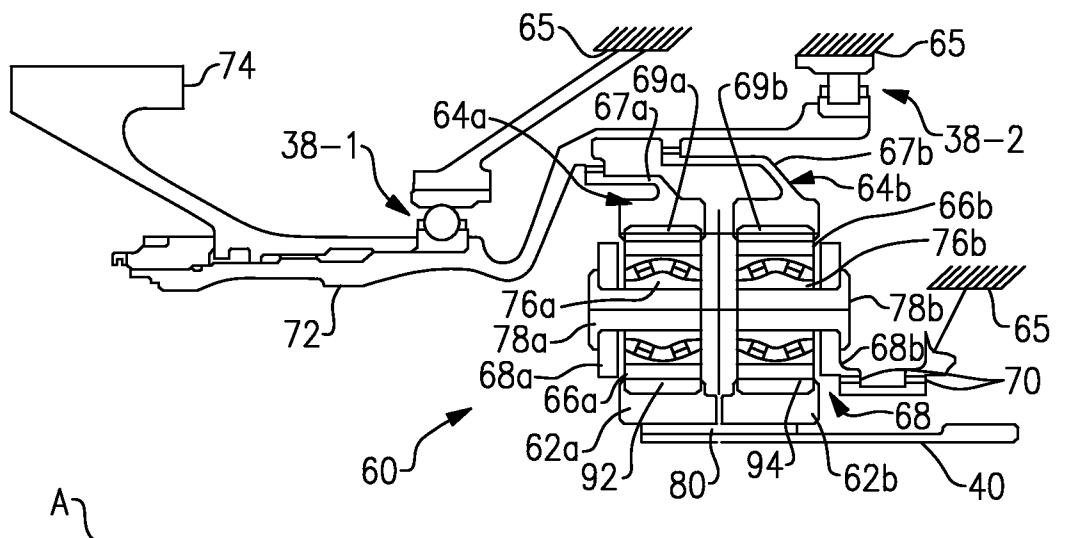


FIG. 3

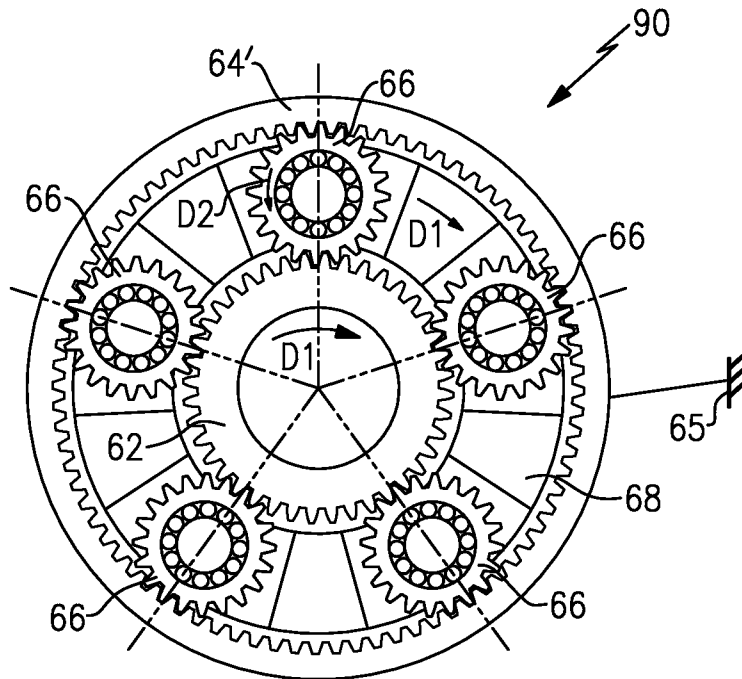


FIG. 4

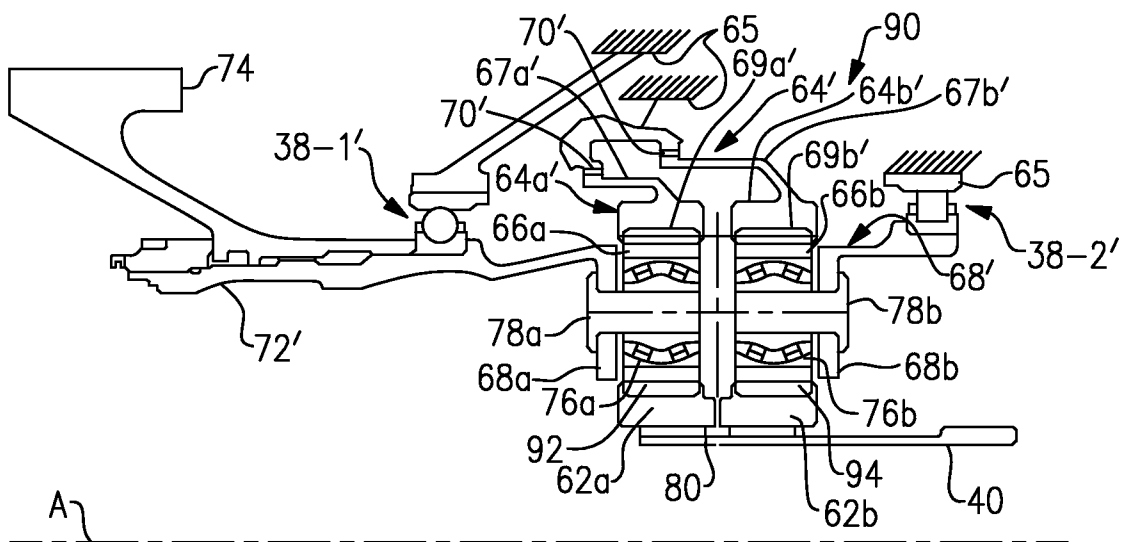


FIG. 5

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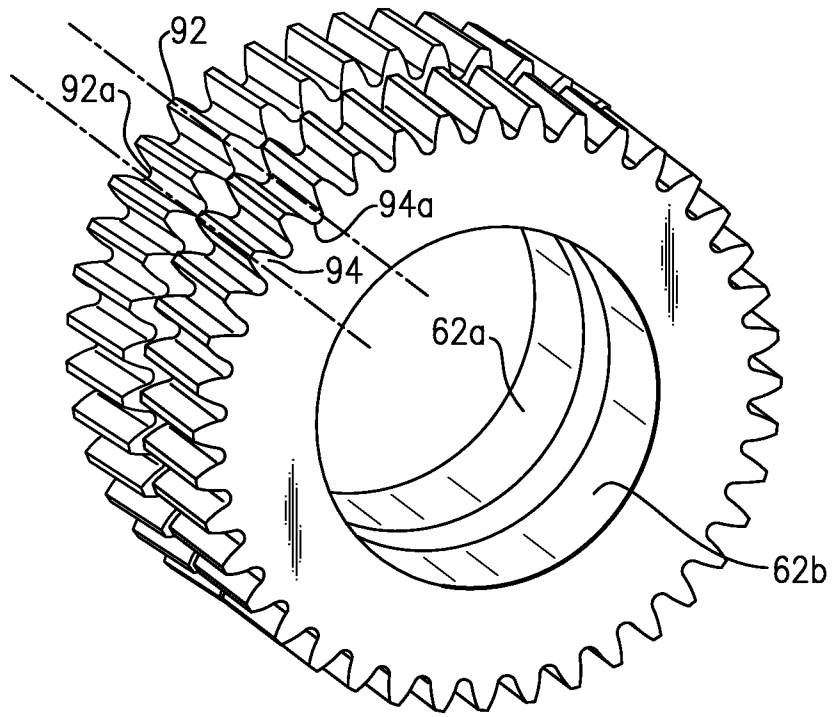


FIG. 6

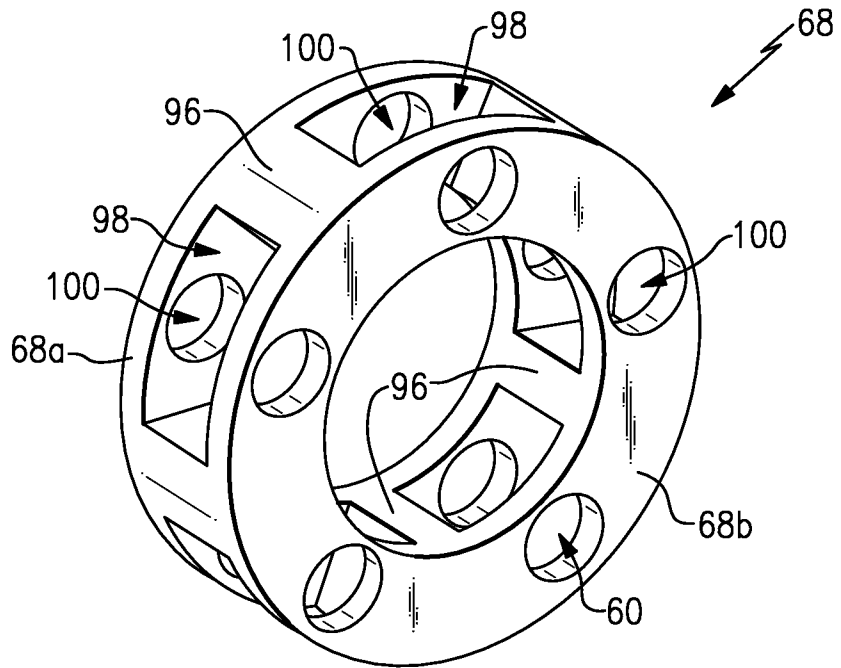
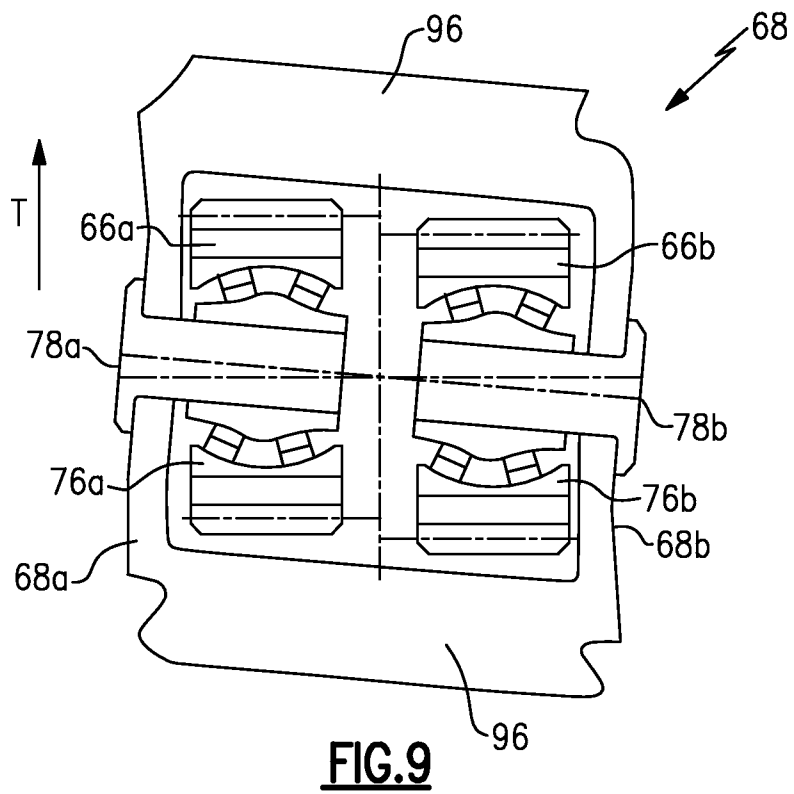
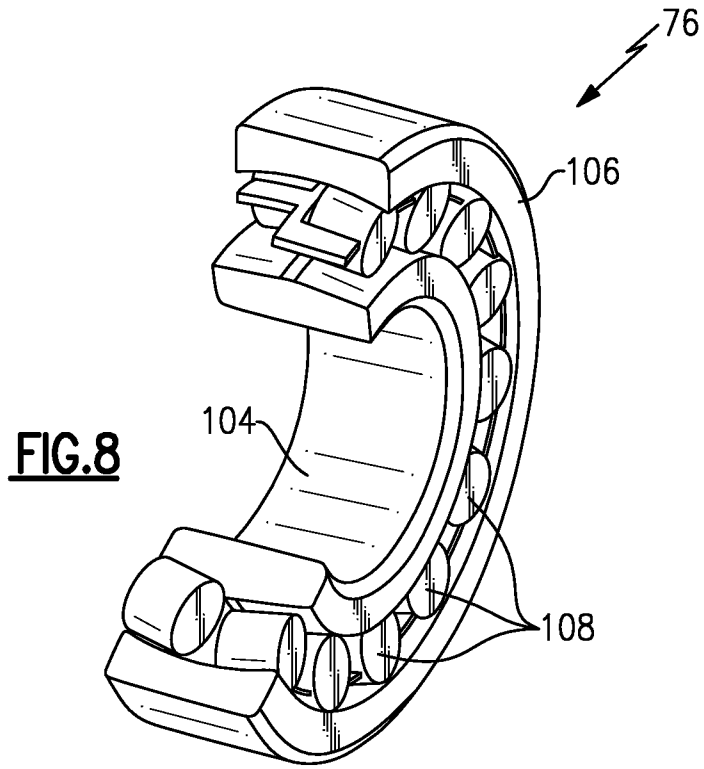


FIG. 7



PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 26745WO-2506	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/US2014/035412	International filing date (<i>day/month/year</i>) 25 April 2014 (25.04.2014)	(Earliest) Priority Date (<i>day/month/year</i>) 08 May 2013 (08.05.2013)
Applicant UNITED TECHNOLOGIES CORPORATION		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of :

the international application in the language in which it was filed

a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. **Certain claims were found unsearchable** (See Box No. II)

3. **Unity of invention is lacking** (See Box No. III)

4. With regard to the **title**,

the text is approved as submitted by the applicant.

the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

the text is approved as submitted by the applicant.

the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

a. the figure of the **drawings** to be published with the abstract is Figure No. 2

as suggested by the applicant.

as selected by this Authority, because the applicant failed to suggest a figure.

as selected by this Authority, because this figure better characterizes the invention.

b. none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/035412**A. CLASSIFICATION OF SUBJECT MATTER****F16H 1/28(2006.01)i, F16H 1/48(2006.01)i, F02C 7/00(2006.01)i, F01D 25/00(2006.01)i, F16C 19/38(2006.01)i**

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 1/28; F16H 57/08; F03D 11/02; F16H 1/48; F02C 7/00; F01D 25/00; F16C 19/38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: epicyclic gear, sun, planet, ring gear, deform and flexible**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	w0 2012-070199 AI (KAWASAKI JUKOGYO K.K.) 31 May 2012 See abst ract ; paragraphs 16-19 , 27 and figures 1, 2.	1,4-8 ,10-12 ,15,16
Y		2,3,9,13,14,17-20
Y	US 2011-0053730 AI (FOX et al.) 03 March 2011 See abst ract ; paragraphs 20-26 and figures 1-4 , 6.	2,3,9,13,14,17-20
A	US 2008-0194378 AI (FOX, GERALD P.) 14 August 2008 See abst ract ; paragraphs 12-17 and figures 1, 2.	1-20
A	US 8172717 B2 (LOPEZ et al.) 08 May 2012 See abst ract ; column 3, line 51 - column 4, line 56 and figures 1, 2.	1-20
A	US 2012-0045336 AI (CASTELL MARTINEZ, DANIEL) 23 February 2012 See abst ract ; paragraphs 27, 29-32 and figures 1, 2.	1-20

 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

"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

14 August 2014 (14.08.2014)

Date of mailing of the international search report

14 August 2014 (14.08.2014)

Name and mailing address of the ISA/KR



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/035412

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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