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(54) **PLANETARY GEAR TRAIN FOR USE WITH EXTENDED LENGTH SUN IN HIGH TORQUE APPLICATIONS**

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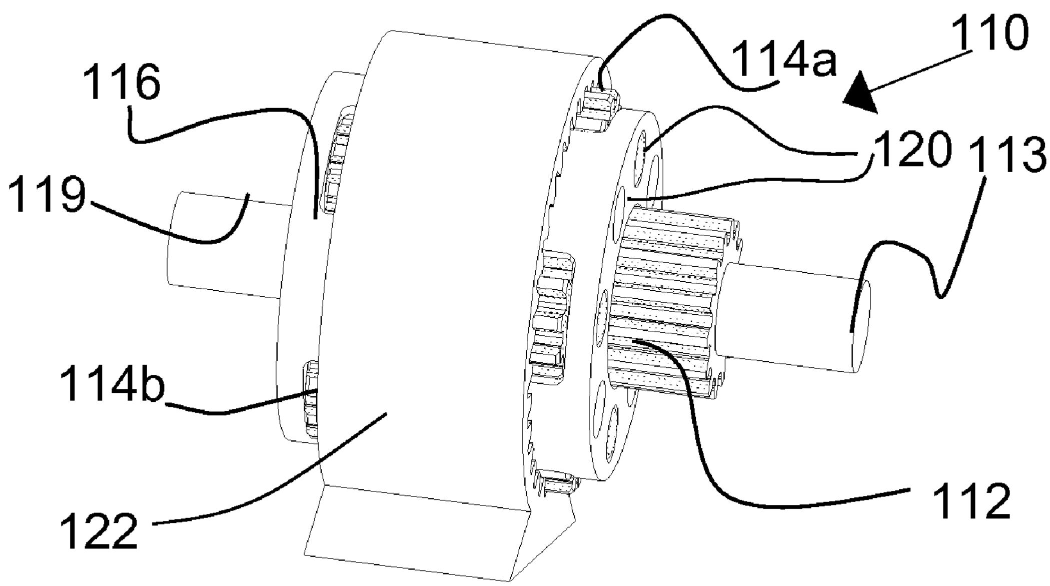
(57) **ABSTRACT**

A planetary gearbox, also known as an epicyclical gearbox is disclosed herein. The gearbox includes multiple rows of planets and a ring gear. The sun gear is a single unitary structure which simultaneously engages the multiple rows of planets. The system lowers the stress level on torque generating devices incorporating such a gearbox.



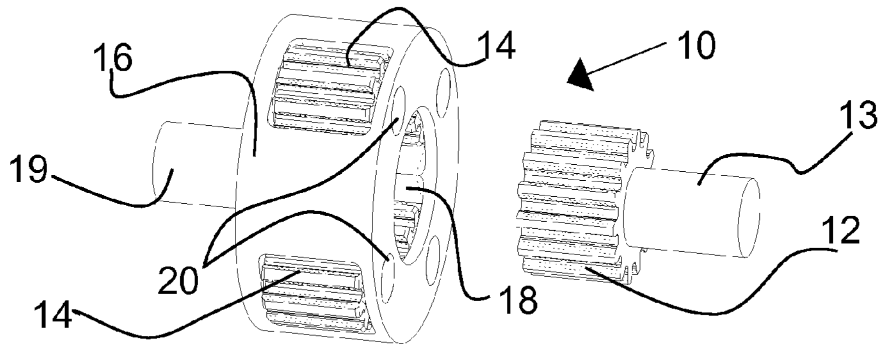


Figure 1 - Prior Art

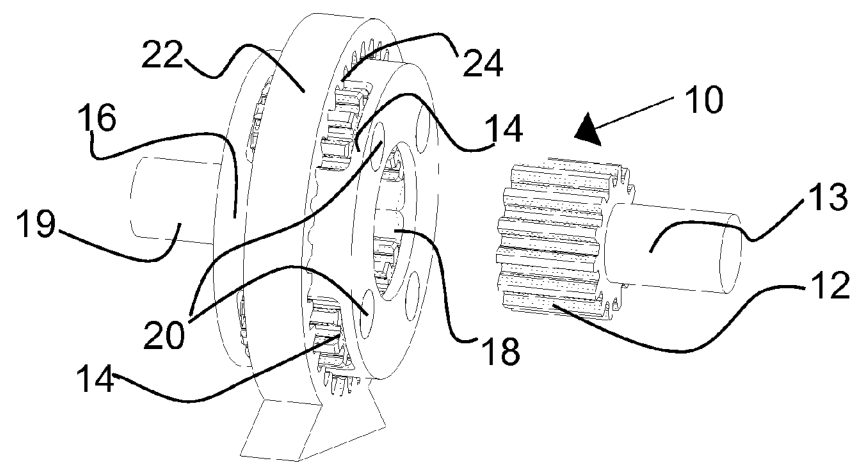


Figure 2 - Prior Art

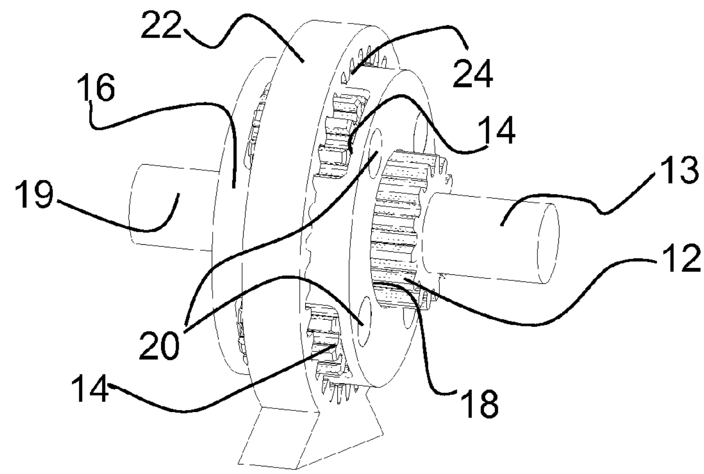


Figure 3 - Prior Art

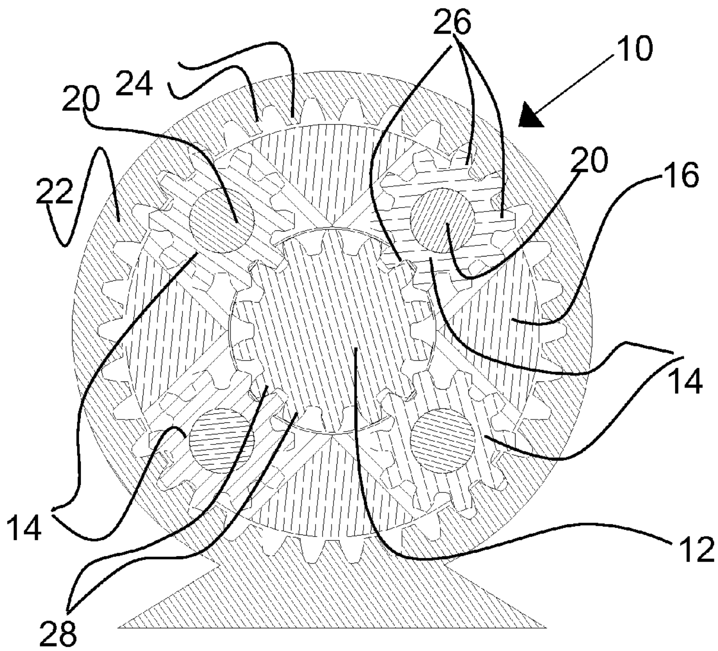


Figure 4 - Prior Art

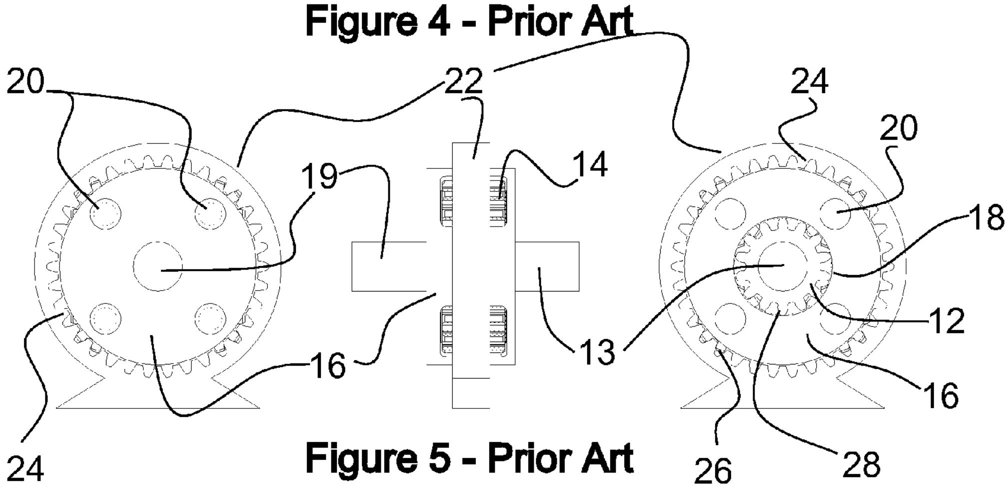


Figure 5 - Prior Art

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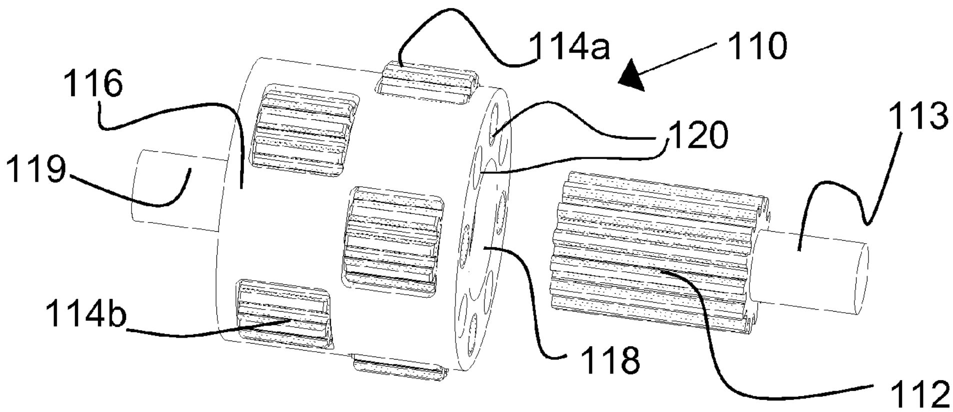

Figure 6

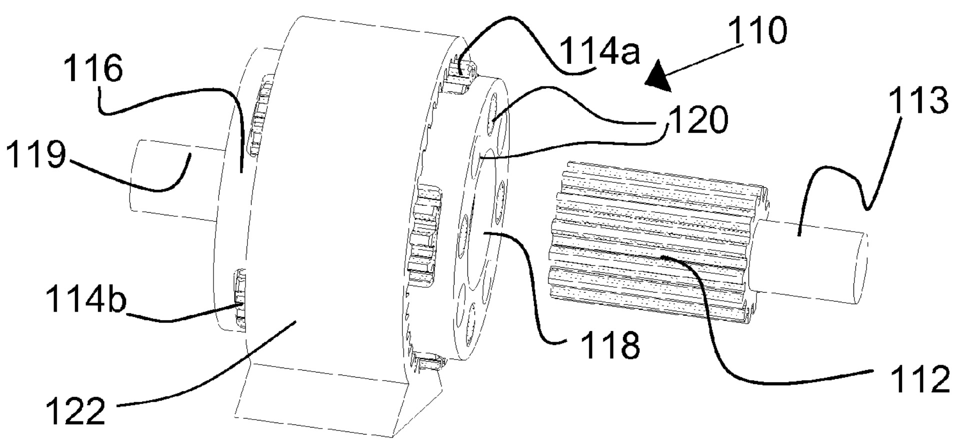

Figure 7

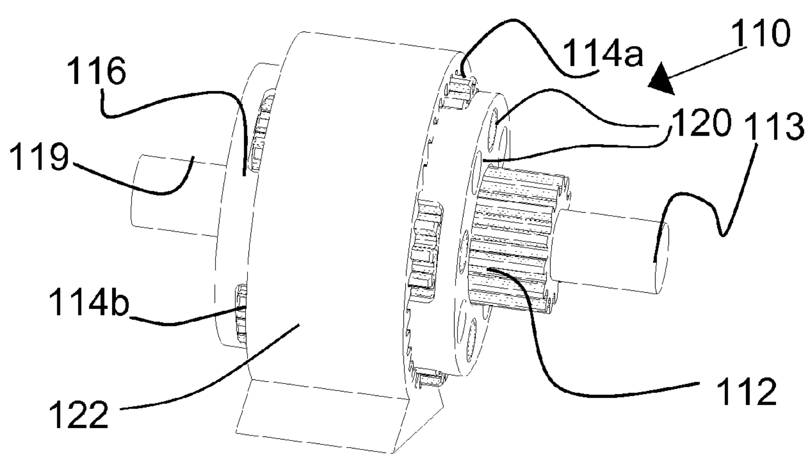

Figure 8

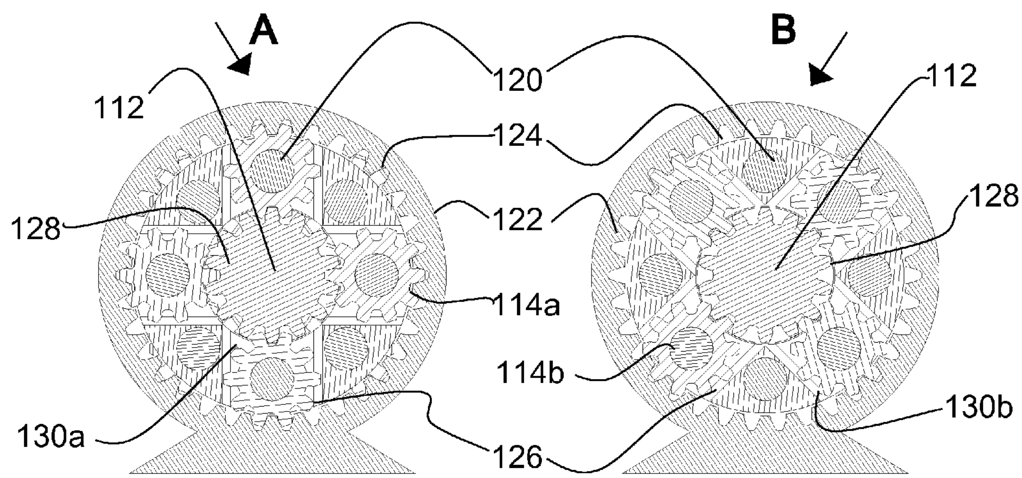

Figure 9

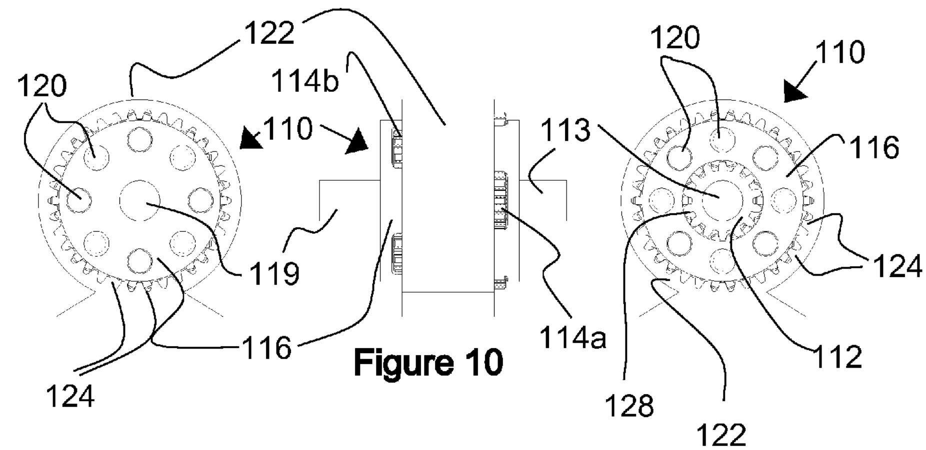

Figure 10

PLANETARY GEAR TRAIN FOR USE WITH EXTENDED LENGTH SUN IN HIGH TORQUE APPLICATIONS

BACKGROUND OF THE DISCLOSED TECHNOLOGY

[0001] Planetary gears, also known as sun gears and as epicyclic gears, comprise one or more outer gears, or planet gears, revolving about a central, or sun gear. Typically, the planet gears are mounted on a movable carrier or cage or arm which itself may rotate relative to the sun gear. Planetary gears also include the use of an outer ring gear, which meshes with the planet gears.

[0002] Planet gears are used in different types of torque generating devices, such as wrenches and gearboxes However, planetary gears existing in the prior art suffer a major disadvantage, in that torque generated by the torque generating device transfers much stress to the gearing system, causing great wear to the gears.

[0003] There is a long felt need in the art for a gearing system which reduces stress in the torque generating device and on the gear system included therein.

[0004] U.S. Patent Application Publication 2013/0072344 to Volkov et al discloses an epicycle gear with housing and an externally toothed central shaft, such as a sun gear. The planet gears are disposed in rows in corresponding apertures. However, each row of planet gears are not axially offset from each adjacent row of planets.

[0005] U.S. Pat. No. 4,964,844 to Bagnall discloses a gearbox arrangement which uses a planetary gear to drive a multi-bladed rotor. Two different gears are used for each rotor. As such, at times the blades, or planets, will be axially offset from each other. However, these planet gears are not within the same ring gear and are not held in an axially offset position by a housing.

[0006] China Utility Model Publication 202914647 discloses two rows of planets, arranged around two sun gears and two rings as an input, and additional portions of the gear as an output.

SUMMARY OF THE DISCLOSED TECHNOLOGY

[0007] The disclosed technology described herein addresses a need, unfulfilled in the prior art, for providing a planetary gear system, including a single sun gear including external sun-gear teeth, a plurality of planet gears, each including external planet gear teeth, the plurality of planet gears being arranged in at least two rows of planet gears, a circular housing portion having the plurality of planet gears rotatably attached thereto such that the planet gears extend into a hollow interior of the housing, and a ring gear disposed exterior to the circular housing and including internal gear teeth, the external planet gear teeth of each planet gear simultaneously engaging the external sun gear teeth of the sun gear and the internal teeth of the ring gear. Each planet gear simultaneously engages the single sun gear, and further, the ring gear simultaneously engages each planet gear, in embodiments of the disclosed technology$_{y}$. a generally circular plane of the housing, and a ring gear disposed exterior to the circular housing and including internal gear teeth, the external planet gear teeth of each planet gear simultaneously engaging the external sun gear teeth of the sun gear and the internal teeth of the ring gear. Each planet gear simultaneously engages the single sun gear, and further, the ring gear simultaneously engages each planet gear, in embodiments of the disclosed technology.

[0008] In some embodiments, the planet gears in each row generally form a circle of planet gears in the row. In some embodiments, the planet gears form a general circle of planet gears about the sun gear.

[0009] In some embodiments, the planet gears in a first row are arranged in a first cross-shape, and the planet gears in a second row are arranged in a second cross-shape, the first cross-shape and the second cross-shape being rotationally offset from one another.

[0010] In some embodiments, the planet gears in different rows are not axially aligned with one another in the carrier.

[0011] In some embodiments, the gear system further includes a plurality of bores extending through the carrier, each of the plurality of bores extending through a center of a single one of the planet gears. In some such embodiments, the plurality of bores may have screws or receptacles there-for to attached to a torque generating device.

[0012] In accordance with another aspect of the disclosed technology, there is also provided a planetary gear system, including a single sun gear including external sun-gear teeth, a circular carrier portion including a first cross shaped manifold and a second cross shaped manifold, the second cross shaped manifold being rotationally offset from the first cross shaped manifold, a plurality of planet gears, each including external planet gear teeth, some of the plurality of planet gears rotatably attached to the first cross shaped manifold thereby to form a first row of planet gears, and some of the plurality of planet gears rotatably attached to the second cross shaped manifold thereby to form a second row of planet gears, and a ring gear disposed exterior to the circular carrier and including internal gear teeth, the external planet gear teeth of each the planet gear simultaneously engaging the external sun gear teeth of the sun gear and the internal teeth of the ring gear.

[0013] In some embodiments, the planet gears in each row are arranged on the cross shaped manifold so as to form a general circle of planet gears in the row.

[0014] In some embodiments, the planet gears in the first and second rows form a general circle of planet gears about the sun gear.

[0015] In some embodiments, the planet gears in different the rows are not axially aligned with one another.

[0016] In some embodiments, the planetary gear system further includes a plurality of bores extending through the carrier, each of the plurality of bores extending through a center of a single one of the planet gears. gcarrier, each of the plurality of bores extending through a center of a single one of the planet gears.

[0017] In accordance with another aspect of the disclosed technology, there is also provided a planetary gear system, including a generally circular ring gear having ring-gear teeth formed on an internal surface thereof; single sun gear including external sun-gear teeth, a circular carrier portion disposed within the ring gear, a plurality of planet gears, each including external planet gear teeth, the plurality of planet gears being rotatably attached to the carrier portion and being arranged in at least two rows of planet gear, and a sun gear removably disposed in a center of the carrier portion and including external sun gear teeth, the external planet gear teeth of each the planet gear simultaneously engaging the external sun gear teeth of the sun gear and the internal ring gear teeth of the ring gear.

[0018] In some embodiments, the planet gears in each row generally form a circle of planet gears in the row. In some embodiments, the planet gears form a general circle of planet gears about the sun gear.

[0019] In some embodiments, the planet gears in a first row are arranged in a first cross-shape, and the planet gears in a second row are arranged in a second cross-shape, the first cross-shape and the second cross-shape being rotationally offset from one another.

[0020] In some embodiments, the planet gears in different the rows are not axially aligned with one another in the carrier.

[0021] In some embodiments, the gear system further includes a plurality of bores extending through the carrier, each of the plurality of bores extending through a center of a single one of the planet gears.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. **1** shows a perspective view of a planetary gearbox according to the prior art, including a carrier with a single row of planets with a sun gear. carrier with a single row of planets with a sun gear.

[0023] FIG. **2** shows a perspective view of a planetary gearbox according to the prior art, including a single row of planets and a ring gear.

[0024] FIG. **3** shows a perspective view of an assembled planetary gearbox according to the prior art, including a row of planets, a ring gear, and a sun gear.

[0025] FIG. **4** shows a cross section of a planetary gearbox including a single row of planets according to the prior art.

[0026] FIG. **5** shows front, side and back views of a planetary gearbox including a single row of planets according to the prior art.

[0027] FIG. **6** shows a perspective view of a planetary gearbox, including multiple rows of planets and a sun gear, in an embodiment of the disclosed technology.

[0028] FIG. **7** shows a perspective view of a planetary gearbox, including multiple rows of planets, a sun gear, and a ring gear, in an embodiment of the disclosed technology.

[0029] FIG. **8** shows a perspective view of an assembled planetary gearbox, including a ring gear, multiple rows of planets, and a sun gear in operational position, in an embodiment of the disclosed technology.

[0030] FIG. **9** shows two cross section views of a planetary gearbox including different rows of planets in an embodiment of the disclosed technology

[0031] FIG. **10** shows front, side, and back views of a planetary gearbox of the disclosed technology.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE DISCLOSED TECHNOLOGY

[0032] The presently disclosed technology is directed towards a planetary gearbox, also known as an epicyclical gearbox, The gearbox includes multiple rows of planets and a ring gear. The sun gear is a single unitary structure which simultaneously engages the multiple rows of planets. The system is designed to lower the stress level on torque generating devices incorporating such a gearbox by shortening the length of each planet. In an epicyclical gear stage the planets react against the ring gear and they are engaged with the rotating sun causing the centers of the planets to orbit around the sun; the centers of the planets are connected axially to the bores of the carrier, causing the carrier to rotate. For a planetary gear train to be efficient, each planet must be rigid enough not to deform while under load. The present invention accomplishes that by splitting the length of the planets into multiple rows for applications where the planet/sun length is required to be large with comparison to their respective diameters.

[0033] FIG. **1** shows a perspective view of a planetary gearbox **10** according to the prior art, including a carrier with a single row of planets with a sun gear. The planetary gearbox **10** comprises a sun gear **12** connected to a shaft **13**, one set of two or more planets **14**, and a carrier **16**, sometimes also called a cage, in which the planets **14** are mounted. The external teeth of planets **14** are configured to engage with internal teeth of another gear or carrier portion, for example a ring gear, as shown in FIG. **2**. During construction, the sun gear **12** is inserted into carrier **16** at a bore **18** located on a first side of carrier **16**, and on a second side thereof the carrier **16** includes a cylindrical arm or shaft **19**. At least two circular bores **20** are included in side walls of carrier **16**, typically adjacent to, or overlying, planets **14**. The sun gear **12** is shown separate from the carrier **16**. In other embodiments, three, four, five, six, or eight circular bores may be used.

[0034] In use, the planets **14** rotate around the sun gear **12**. The sun gear **12** typically provides the input power of the gearbox, which is transformed into output power and is outputted through the shaft **19**.

[0035] FIG. **2** shows a perspective view of a planetary gearbox according to the prior art, such as planetary gearbox **10** of FIG. **1**, including a single row of planets and a ring gear. As seen in FIG. **2**, in some embodiments the planetary gearbox of FIG. **1** additionally includes a ring gear **22** disposed around the carrier **16**. Ring gear **22** is typically stationary, and includes internal gear teeth **24** which engage the gear teeth of planet gears **14** mounted on carrier **16**, such that the planets **14** revolve around ring gear **22**. Similarly to FIG. **1**, though sun gear **12** is illustrated externally to carrier **16**, it is configured to be placed in bore **18** of the carrier **16**. As in FIG. **1**, four circular bores **20** are located in a wall of carrier **16**, their locations generally corresponding to locations of planets **14**.

[0036] FIG. **3** shows a perspective view of an assembled planetary gearbox according to the prior art, including a row of planets, a ring gear, and a sun gear, such as assembled gearbox **10** of FIGS. **1** and **2**. As seen in FIG. **3**, when gearbox **10** is assembled, sun gear **12** is inserted in bore **18**, such that shaft **13** of sun gear **12** is generally aligned with, and is on the opposite side of carrier **16** to shaft **19**.

[0037] FIG. **4** shows a cross section of a planetary gearbox including a single row of planets engaging a ring gear according to the prior art, similar to planetary gearbox **10** of FIGS. **1** to **3**. As seen in FIG. **4**, the teeth **24** of ring gear **22** engage the teeth **26** of the planets **14**. Teeth **26** of planets **14** further engage teeth **28** of sun gear **12**, disposed in bore **18** in the center of carrier **16**. Further, each one of the four circular bores **20** extends through the entire thickness of the wall of carrier **16** and through the center of a single planet **14**.

[0038] FIG. **5** shows front, side and back views of an assembled planetary gearbox including a single row of planets, a sun gear, and a ring gear, according to the prior art, such as planetary gearbox **10** of FIGS. **1** to **4**. The side view shows the ring gear **22** holding carrier **16** with planet gears **14** as well as the sun gear, such that shaft **19** extends out of one side of carrier **16**, and sun gear shaft **13** extends out of the other side of carrier **16**.

[0039] The front view shows the teeth **24** of the ring gear **22**, the four circular bores **20** that extend through the walls of the carrier **16**, and the shaft **19** located in the center of carrier **16**.

[0040] The back view shows the ring gear **22** and its teeth **24**, and the four circular bores **20** extending through the walls of carrier **16**. The circular center bore **18** located in the center of the carrier **16** and used to accommodate sun gear **12** is shown in the back view, as well as the planet teeth **26** engaging teeth **28** of the sun gear **12** in order to transform the input force coming from the sun gear **12** into rotary motion.

[0041] FIG. **6** shows a perspective view of a planetary gearbox **110**, including multiple rows of planets and a sun gear, in an embodiment of the disclosed technology. The planetary gearbox **110** comprises a sun gear **112** connected to a shaft **113**. A first set of planets **114***a*, arranged in a first row, or layer, and a second set of planets **114***b*, arranged in a second row, or layer, are disposed within a carrier **116**. In the illustrated embodiment, there are four planets **114***a* in the first set, and four planets **114***b* in the second set, totaling eight planets. However, any suitable number of planets may be used. In the illustrated embodiment, the planets **114** generally form a circle, and planets **114***a* are arranged such that they are not aligned with, or concentric to, planets **114***b*, though in other embodiments planets on different rows may be aligned with one another. External teeth **126** of planets **114** are designed to engage internal teeth of a housing portion or another gear, as described hereinbelow.

[0042] During construction, the sun gear **112** is inserted into carrier **116** at a bore **118** located on a first side of carrier **116**, and on a second side thereof the carrier **116** includes a cylindrical arm or shaft **119**. A plurality of circular bores **120** are included in side walls of carrier **116**, typically aligned with and overlying planets **114**, such that a single bore **120** corresponds to a single planet **114**. As such, the illustrated embodiment shows eight bores, though any other suitable number of bores may be used, provided that the number of bores corresponds to the number of planets. In the illustrated embodiment, the sun gear **112** is shown separate from the carrier **116**.

[0043] Similarly to the prior art, in use, the planets **114** rotate around the sun gear **112**. The sun gear **112** typically provides the input power of the gearbox **110**, which is transformed into output power and is outputted through the shaft **119**.

[0044] The length of components that may be used in a planetary gearbox is mechanically limited. For higher torque capacities, the length of the components must be increased to provide increased engagement of the gear teeth. However, there is a limit to the ratio of planet diameter to planet length, primarily due to the lack of planet support when the planets become too long. As a result, the torque capacity of planetary gearboxes including a single row, or layer, of planets, such as prior art system **10** described in FIGS. **1** to **5** hereinabove, is limited by the relatively short length of the components. By contrast, due to the multiple rows of planets, embodiments of the disclosed technology allow for greater torque capacity of the planetary gearbox than prior art systems, without increasing the length of the planets.

[0045] FIG. **7** shows a perspective view of a planetary gearbox, similar to planetary gearbox **110** of FIG. **6**, including multiple rows of planets, a sun gear, and a ring gear, in an embodiment of the disclosed technology. As seen in FIG. **7**, in some embodiments of the disclosed technology, the planetary gearbox of FIG. **6** additionally includes a ring gear **122** disposed around the carrier **116**. Ring gear **122** is typically stationary, and includes internal gear teeth **124** which engage the gear teeth **126** of planet gears **114***a* and **114***b* mounted in carrier **116**, such that the planets **114** revolve around ring gear **122**. Thus, ring gear **122** is sufficiently wide to engage both rows of planets **114***a* and **114***b*, or any number of rows of planets used in a specific embodiment. As such, ring gear **122** is relatively wider than the ring gear used in prior art planetary gears, such as ring gear **22** of FIGS. **2** to **5** described hereinabove. As in the description of FIG. **6** hereinabove, planets **114** generally form a circle about sun gear **112**, and planets **114***a* are arranged such that they are not aligned with, or parallel to, planets **114***b*, though in other embodiments planets on different rows may be aligned with one another.

[0046] Similarly to that illustrated in FIG. **6**, though sun gear **112** is illustrated externally to carrier **116**, it is configured to be placed in bore **118** of the carrier **116**. As in FIG. **6**, eight circular bores **120** are located in a wall of carrier **116**, their locations corresponding to locations of planets **114***a* and **114***b*, such that a single bore **120** corresponds to a single planet **114**.

[0047] FIG. **8** shows a perspective view of an assembled planetary gearbox, such as an assembled gearbox **110** of FIGS. **6** and **7**, including a ring gear, multiple rows of planets, and a sun gear in operational position, in an embodiment of the disclosed technology. As seen in FIG. **8**, when gearbox **110** is assembled, sun gear **112** is inserted in bore **118**, such that shaft **113** of sun gear **112** is generally aligned with, and is on the opposite side of carrier **116** to shaft **119**. Similar to the disclosure of FIGS. **6** and **7**, gearbox **110** includes a first row of planets **114***a* and a second row of planets **114***b*, surrounding sun gear **112**. The multiple rows of planets **114** allow the gearbox **110** to provide more torque, additional stability, operate in limited spaces, and enable shorter planet lengths with shorter unsupported lengths of planet shafts.

[0048] FIG. **9** shows two cross section views of a planetary gearbox including multiple rows of planets engaging a ring gear in an embodiment of the disclosed technology, similar to planetary gearbox **110** of FIGS. **6** to **8**. As seen, a first cross section view labeled 'A', is taken along a plane of carrier **116** housing planet gears **114***a*, whereas a second cross section view labeled 'B' is taken along a plane of carrier **116** housing planet gears **114***b*.

[0049] As seen in FIG. **9**, the teeth **124** of ring gear **122** engage the teeth **126** of the planets **114***a* and **114***b*. Teeth **126** of planets **114** further engage teeth **128** of sun gear **112**, disposed in bore **118** in the center of carrier **116**. Further, each one of the eight circular bores **120** extends through the entire thickness of the wall of carrier **116** and through the center of a single one of planets **114**. As such, bores **120** may be used to connect the planetary gearbox **110** to another tool unit, thereby reducing stress on gearbox **110** and on the other tool unit.

[0050] The planets **114***a* are arranged on a first cross shaped manifold **130***a*, and the planets **114***b* are arranged on a second cross shaped manifold **130***b*, the second cross shaped manifold **130***b* being rotationally offset relative to the first cross shaped manifold **130***a*, such that planet gears **114** generally form a circle about sun gear **112** and bore **118** and such that planets **114***a* do not lie concentric to planets **114***b*.

[0051] FIG. **10** shows front, side, and back views of a planetary gearbox in an embodiment of the disclosed technology, such as planetary gearbox **110** of FIGS. **6** to **9**. The side view shows the ring gear **122** holding carrier **116** with planet gears **114** as well as the sun gear such that shaft **119** extends out of one side of carrier **116**, and sun gear shaft **113** extends out of the other side of carrier **116**.

[0052] The front view shows the teeth **124** of the ring gear **122**, the eight circular bores **120** arranged in a circle around carrier **116** and extending through the walls of the carrier **116**, and the shaft **119** located in the center of carrier **116**.

[0053] The back view shows the ring gear **122** and its teeth **124**, and the eight circular bores **120** extending through the walls of carrier **116**. The circular center bore **118** located in the center of the carrier **116** and used to accommodate sun gear **112** is shown in the back view, as well as the teeth **126** of the planets **114** engaging teeth **128** of the sun gear **112** in order to transform the input force coming from the sun gear **112** into rotary motion.

[0054] It should further be understood, that the sun gear can be formed from a unitary structure having a continuous elongated length. The planets held in a carrier can each simultaneously engage the sun gear. In turn, each planet, simultaneously engages a ring gear. As such, the multiple planets simultaneously engage both a single sun gear and single ring gear, thereby maximizing torque and efficiency. While the technology has been described with input torque applied to the shaft of the sun gear with reference to a stationary ring gear, thereby causing, based on rotation of the shaft, the sun gear and ring gear to rotate, one having ordinary skill in the art should understand that the input torque can be applied to the ring gear or any other gear described herein This, in turn, causes the rest of the engaged gears to turn.

[0055] While the disclosed technology has been taught with specific reference to the above embodiments, a person having ordinary skill in the art will recognize that changes can be made in form and detail without departing from the spirit and the scope of the disclosed technology. The described embodiments are to be considered in all respects only as illustrative and not restrictive. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope. Combinations of any of the methods, systems, and devices described herein above are also contemplated and within the scope of the invention.

I claim:

1. A planetary gear system, comprising:

a single sun gear including external sun-gear teeth;

a plurality of planet gears, each including external planet gear teeth, said plurality of planet gears being arranged in at least two rows of planet gears, wherein each planet gear simultaneously engages said single sun gear;

a circular carrier portion having said plurality of planet gears rotatably attached thereto such that said planet gears extend into a hollow interior of said carrier as well as outside a generally circular plane of said carrier; and

a ring gear disposed exterior to said circular carrier and including internal gear teeth,

said external planet gear teeth of each said planet gear simultaneously engaging said external sun gear teeth of said sun gear and said internal teeth of said ring gear.

2. The planetary gear system of claim **1**, wherein said planet gears in each said row generally form a circle of planet gears in said row.

3. The planetary gear system of claim **1**, wherein said planet gears form a general circle of planet gears about said sun gear.

4. The planetary gear system of claim **1**, wherein said planet gears in a first said row are arranged in a first cross-shape, and said planet gears in a second said row are arranged in a second cross-shape, said first cross-shape and said second cross-shape being rotationally offset from one another.

5. The planetary gear system of claim **1**, wherein said planet gears in different said rows are not axially aligned with one another in said carrier.

6. The planetary gear system of claim **1**, further comprising a plurality of bores extending through said carrier, each of said plurality of bores extending through a center of a single one of said planet gears.

7. The planetary gear system of claim **6**, wherein said plurality of bores are removably fastened into a torque generating device thereby reducing stress of said torque generating device.

8. A planetary gear system, comprising:

a single sun gear including external sun-gear teeth;

a circular carrier portion comprising a first cross shaped manifold and a second cross shaped manifold, said second cross shaped manifold being rotationally offset from said first cross shaped manifold;

a plurality of planet gears, each including external planet gear teeth, some of said plurality of planet gears rotatably attached to said first cross shaped manifold thereby to form a first row of planet gears, and some of said plurality of planet gears rotatably attached to said second cross shaped manifold thereby to form a second row of planet gears;

a ring gear disposed exterior to said circular carrier and including internal gear teeth,

said external planet gear teeth of each said planet gear simultaneously engaging said external sun gear teeth of said sun gear and said internal teeth of said ring gear.

9. The planetary gear system of claim **8**, wherein said planet gears in each said row are arranged on said cross shaped manifold so as to form a general circle of planet gears in said row.

10. The planetary gear system of claim **8**, wherein said planet gears in said first and second rows form a general circle of planet gears about said sun gear.

11. The planetary gear system of claim **8**, wherein said planet gears in different said rows are not axially aligned with one another.

12. The planetary gear system of claim **8**, further comprising a plurality of bores extending through said carrier, each of said plurality of bores extending through a center of a single one of said planet gears.

13. The planetary gear system of claim **12**, wherein said plurality of bores are adapted to be attached into a torque generating device.

14. A planetary gear system, comprising:

a generally circular ring gear having ring-gear teeth formed on an internal surface thereof; single sun gear including external sun-gear teeth;

a circular carrier portion disposed within said ring gear;

a plurality of planet gears, each including external planet gear teeth, said plurality of planet gears being rotatably attached to said carrier portion and being arranged in at least two rows of planet gears; and

a sun gear removably disposed in a center of said carrier portion and including external sun gear teeth, said external planet gear teeth of each said planet gear simultaneously engaging said external sun gear teeth of said sun gear and said internal ring gear teeth of said ring gear.

15. The planetary gear system of claim **14**, wherein said planet gears in each said row generally form a circle of planet gears in said row.

16. The planetary gear system of claim **14**, wherein said planet gears form a general circle of planet gears about said sun gear.

17. The planetary gear system of claim **14**, wherein said planet gears in a first said row are arranged in a first cross-shape, and said planet gears in a second said row are arranged in a second cross-shape, said first cross-shape and said second cross-shape being rotationally offset from one another.

18. The planetary gear system of claim **14**, wherein said planet gears in different said rows are not axially aligned with one another in said carrier.

19. The planetary gear system of claim **14**, further comprising a plurality of bores extending through said carrier, each of said plurality of bores extending through a center of a single one of said planet gears.

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