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(54) Compound planetary gear apparatus for a motor vehicle starter motor.

(57) An apparatus for transferring rotation from an armature shaft (12) of the starter motor of a vehicle to an output shaft (16) is disclosed. The apparatus comprises a pinion (20) mounted on the armature shaft (12), a relatively stationary ring gear (22), a plurality of planet shafts (24,26,28,30), and a plurality of planetary gear sets (32,34,36,38). Each of the planet shafts is connected to the output shaft (16) and is orbitable about the armature shaft (12). Each planetary gear set includes two planet gears (44,46) mounted on an associated planet shaft (28). One (44) of the planet gears engages the pinion (20) so that the rotation of the pinion (20) is transferred to the first planet gear (44). The other planet gear (46) is rotatable with the first planet gear (44), and engages the ring gear (22) so that the associated planet shaft (28) orbits the armature shaft (12) and imparts rotation to the output shaft (16) sufficient to crank the engine.

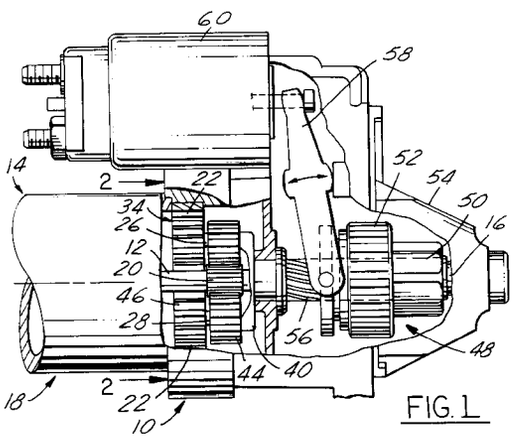

FIG. 1

EP 0 582 429 A1

This invention relates to starter motors for vehicles, and more particularly to a starter motor having a compound planetary gear reduction system.

Most starting systems for internal combustion engines include a battery-driven direct current starter motor. The starter motor is capable of armature shaft speeds much higher than the rotational speed required to start the engine, which is generally between 60 and 100 revolutions per minute for spark ignition engines, and about 80 to 200 revolutions per minute for diesel engines. Because the torque required to start the engine is greater than the starter motor armature is capable of generating, however, some provision must be made to translate the speed of the starter motor to increased torque.

Conventional automotive starter motors utilise a simple planetary gear set to reduce the speed of the armature shaft and correspondingly increase the torque available to crank the engine. The gear set typically consists of a ring gear fixed to the starter motor housing, a pinion rotatable with the armature shaft, and at least one planet gear which engages both the pinion and the ring gear. See, for example, U.S. Patent No. 4,412,457 to Colvin et al. Because of the relative diameters of the gears and the number of teeth on each gear, the described simple planetary gear set increases the torque, and reduces the speed, of the output shaft with respect to the starter motor armature shaft. Thus, a starter motor equipped with a simple planetary gear set can generate an output power equivalent to a direct drive, i.e. non-gear reduced, starter motor, while at the same time having motor components of lesser size and weight.

More complex compound planetary gear systems have been proposed for use in a wide variety of applications. These designs typically include two or more planet gears mounted on a common shaft. U.S. Patent No. 3,081,648 to Duer, for instance, teaches a compound epicyclic gear mechanism for use in a servo control mechanism of the type used in computers, navigational control instruments, guidance control systems, and the like. Also, U.S. Patent No. 3,640,150 to Leiner et al. discloses the use of compound planetary gears for actuation of hinged aircraft components such as wing flaps or wheel well doors.

Compound planetary gear systems have also been proposed for use in automotive starter motors. For example, U.S. Patent No. 4,573,364 to Givan discloses a gear reduction starter drive in which a sun gear integral with a central shaft drives several planet gears. A second set of planet gears coaxial with the first planet gears mesh with gear teeth on a driven shaft to thereby drive the driven shaft.

The present invention is an improved compound planetary gear apparatus for transferring rotation from an armature shaft of the starter motor of a vehicle to an output shaft to crank the engine. The apparatus comprises a pinion mounted on the armature shaft, a relatively stationary ring gear, a plurality of planet shafts, and a plurality of planetary gear sets. Each of the planet shafts is connected to the output shaft and is orbitable about the armature shaft. Each planetary gear set includes two planet gears mounted on an associated planet shaft. One of the planet gears engages the pinion so that the rotation of the pinion is transferred to the first planet gear. The other planet gear is rotatable with the first planet gear, and engages the ring gear so that the associated planet shaft orbits the armature shaft and imparts rotation to the output shaft sufficient to crank the engine.

The present invention provides an apparatus which effects a more efficient means of obtaining larger gear reduction between the motor armature shaft and the output shaft than is available from simple planetary gear sets.

The present invention provides an apparatus which has a large gear reduction ratio.

Further the present invention provides an apparatus which allows smaller and lighter motor armatures and motor field components, and which maintains an output power equivalent to direct drive or simple planetary gear reduced starter motors.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a partial cross-sectional view of a vehicle starter motor having a compound planetary gear apparatus according to the present invention; and

Figure 2 is a cross-sectional view of the starter motor taken along line 2-2 of Figure 1.

With reference to the drawings, the preferred embodiments of the present invention will be described. Figures 1 and 2 show a compound planetary gear apparatus 10 according to the present invention for transferring rotation from an armature shaft 12 of a starter motor 14 of a motor vehicle to an output shaft 16. Rotation of the output shaft 16 can thereafter be transferred to a crankshaft of the vehicle engine (not shown) to start the engine, as described below.

A motor housing 18 of the starter motor 14 supports therein a series of field flux generating devices such as conventional field coils or permanent magnets, as is well known. The flux generating devices act to rotate the armature shaft 12 at a relatively high rate of speed when the ignition switch of the motor vehicle is turned to the start position, as is also well known in the art.

The compound planetary gear apparatus 10 comprises a pinion 20, a ring gear 22, a plurality of planet shafts 24, 26, 28 and 30, and a plurality of planetary gear sets 32, 34, 36 and 38. The pinion 20 is fixedly mounted on the armature shaft 12, and therefore rotates at a relatively high speed with the armature shaft 12 when the ignition switch is turned to the start position. The ring gear 22 is fixedly mounted to the

motor housing 18, and is therefore maintained stationary with respect to the rotation of the armature shaft 12. Typically, the motor housing 18 is about three inches in diameter, and holds the ring gear 22 disposed concentrically around the armature shaft 12.

Each of the planet shafts 24, 26, 28 and 30 is affixed to a plate member 40 which is integral with one end of the output shaft 16. The plate member 40 is thus rotatable in the motor housing 18, and supports the planet shafts 24, 26, 28 and 30 such that each one extends to a point between the armature shaft 12 and the ring gear 22. Each planet shaft 24, 26, 28 and 30 is orbitable about the armature shaft 12 as the plate member 40 and the output shaft 16 rotate. Although the embodiment shown in Figures 1 and 2 includes four planet shafts arranged equilangularly around the armature shaft 12, it should be understood that only a single planet shaft is necessary to effect the function of the present invention.

The planetary gear sets 32, 34, 36 and 38 are mounted on and supported by the planet shafts 24, 26, 28 and 30. Each of the planetary gear sets 32, 34, 36 and 38 includes a set of two planet gears. For purposes of illustration, reference is made to the planetary gear set 36, which comprises a first planet gear 44 and a second planet gear 46 on the planet shaft 28.

The first planet gear 44 is rotatably mounted on the planet shaft 28 by bearings pressed into the first planet gear 44. The first planet gear 44 engages the pinion 20 so that the rotation of the armature shaft 12 is transferred to the first planet gear 44. The second planet gear 46 is similarly rotatably mounted on the planet shaft 28, and is attached to the first planet gear 44 so as to be rotatable therewith about the axis of rotation defined by the planet shaft 28. The second planet gear 46 has a diameter less than the diameter of the first planet gear 44, and as the second planet gear 46 rotatably engages the ring gear 22, the planet shaft 28, drives carrier plate 40 and integral output shaft 16.

Alternatively, one skilled in the art will appreciate that the first and second planet gears 44 and 46 can be attached directly to the planet shaft 28 so as to be relatively non-rotatable with the planet shaft 28. The planet shaft 28 and the other planet shafts 24, 26 and 30 would be rotatably supported on the plate member 40 of the output shaft 16.

In operation, rotation and torque of the armature shaft 12 is transmitted from the pinion 20 to the first planet gear 44 and the other first planet gears of the gear sets 32, 34 and 38, generating a change in speed from the armature shaft 12 to the planetary gear sets proportionate to the relative diameters of the gears and the number of teeth on each gear. The second planet gear 46, which rotates at the same speed as the first planet gear 44, contacts the stationary ring gear 22 and travels circumferentially therealong. The compound planetary gear sets 32, 34, 36 and 38 thus rotate around the axes of the planet shafts to which they are mounted, and the planetary gear shafts 24, 26, 28 and 30 in turn revolve around the axis of the pinion 20 and the output shaft 16. Motion and torque are thus transmitted to the output shaft 16.

As shown in Figure 1 and as is conventional in the art, a starter drive 48 includes a pinion 50 and an overrunning clutch 52. The pinion 50 is driven by the overrunning clutch 52 which is shiftably disposed on and driven by the output shaft 16. The pinion 50 is meshable with a flywheel (not shown) on the engine to be cranked. For this purpose, an end 54 of the motor housing 18 has an opening (not shown) to accommodate meshing of the pinion 50 with the flywheel of the engine, as is well known in the art. A helical spline 56 is also provided on the output shaft 16, and is adapted to cooperate with matching helical grooves in the overrunning clutch 52 to cause the starter drive 48 to rotate slightly whenever the starter drive 48 is shifted axially relative to the output shaft 16 by an engagement lever 58 of a solenoid 60. The axial shifting of the starter drive 48 brings the pinion 50 into engagement with the flywheel of the engine.

The compound planetary gear apparatus of the present invention provides a reduction ratio between the speeds of the armature shaft 12 and the output shaft 16 of about 9.5 to 1, as compared with typical reduction ratios available from simple planetary gear sets of about 4.36 to 1. It should be understood that the reduction ratio of the present invention can be varied by varying the number of teeth on each of the gears, and/or the diameters of the gears.

The compound planetary gear apparatus of the present invention generates an output torque of about 10 to 12 ft-lbs and a peak power of about 1 to 2 kW, which is comparable to the output torque and power available from direct drive or conventional simple planetary gear reduced starter motors. Furthermore, the components of the present invention are lighter and smaller than those of either direct drive or conventional simple planetary gear mechanisms.

Claims

1. A compound planetary gear apparatus for a starter motor of a vehicle, the apparatus comprising:
   a rotatable armature shaft (12);
   an output shaft (16);
   a pinion (20) fixedly mounted on the armature shaft (12);
   a ring gear (22) disposed around the armature shaft;
   a plurality of planet shafts (24,26,28,30) connected to the output shaft (16), each planet shaft being orbitable about the armature shaft

(12) to impart rotation to the output shaft (16); and

a plurality of planetary gear sets (32,34,36,38), each planetary gear set including:

a first planet gear (44) mounted on a corresponding planet shaft (28), the first planet gear (44) engaging the pinion (20) so that the rotation of the armature shaft (12) is transferred to the first planet gear (44), and

a second planet gear (46) mounted on the corresponding planet shaft (28), the second planet gear (46)engaging the ring gear (22) so that the corresponding planet shaft (28)orbits the armature shaft (12)and imparts rotation to the output shaft (16).

2. An apparatus as claimed in claim 1, wherein the ring gear is fixedly mounted to a housing.

3. An apparatus as claimed in claim 1, wherein the first planet gear is fixed against rotation relative to the second planet gear.

4. An apparatus as claimed in claim 3, wherein the first planet gear is attached to the second planet gear.

5. An apparatus as claimed in claim 1, wherein the first planet gear is rotatably mounted on the corresponding planet shaft.

6. An apparatus as claimed in claim 1, wherein the second planet gear is rotatably mounted in the corresponding planet shaft.

7. An apparatus as claimed in claim 1, wherein the ring gear is concentrically disposed around the armature shaft.

8. An apparatus as claimed in claim 1, wherein the first planet gear has a first diameter, the second planet gear has a second diameter, and the first diameter is greater than the second diameter.

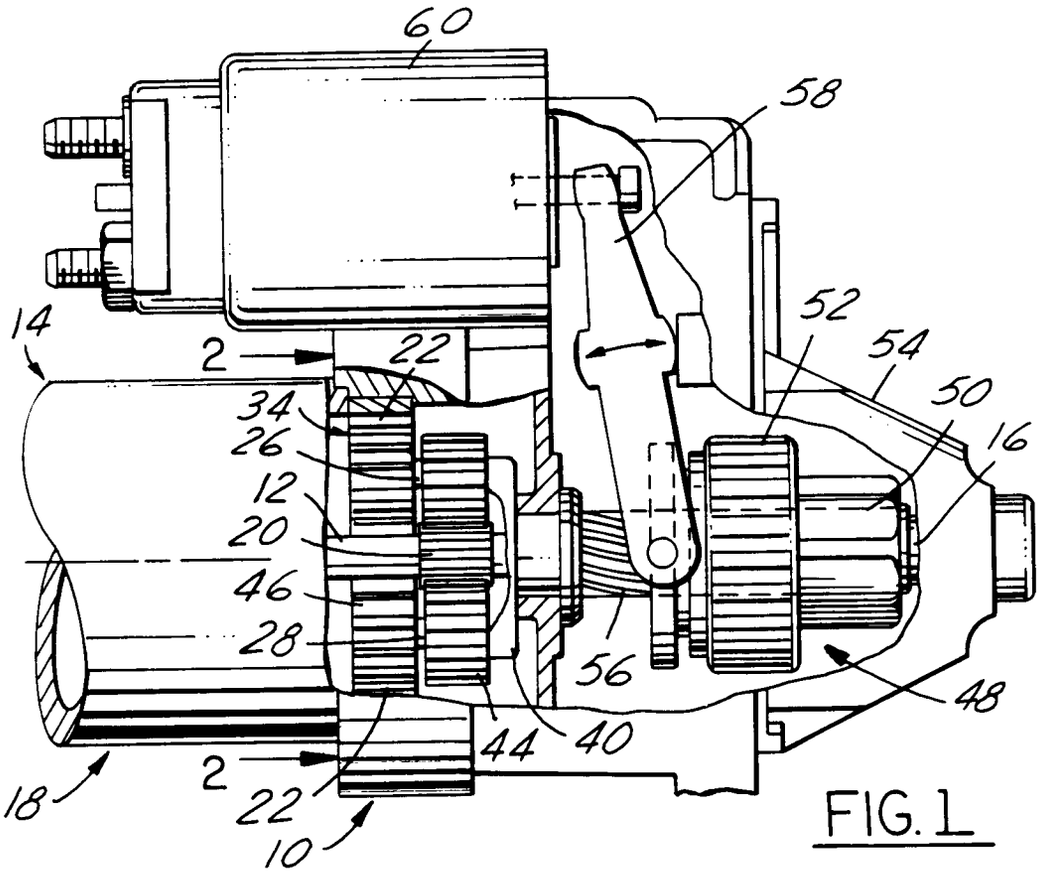
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FIG. 1

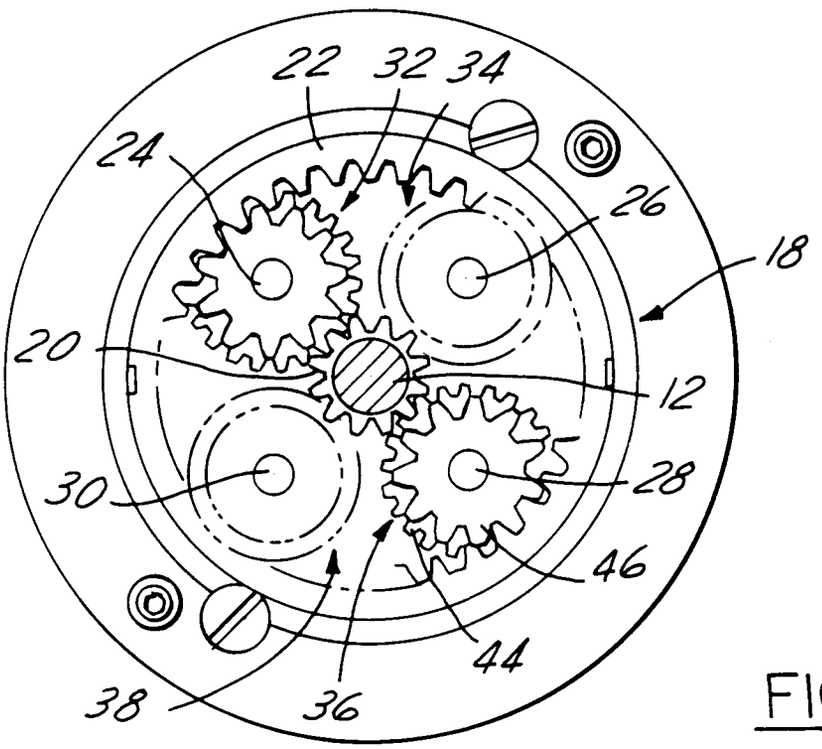
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FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 5940

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-145 527 (ROBERT BOSCH) * page 3, line 38 - line 54; figures 1-3 *	1-7	F02N15/04
D,A	US-A-4 573 364 (GIVAN) * column 2, line 38 - line 59; figure 1 *	1,7	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F02N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 OCTOBER 1993	BIJN E.A.

CATEGORY OF CITED DOCUMENTS

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