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(54) **Title**: STARTING SYSTEM FOR AN ENGINE

(57) **Abstract**: A starting system includes an energy-storing hub assembly and a final member being operative to rotate about a first rotational axis. The energy-storing hub assembly includes an energy-storing hub and a resilient member, the resilient member being connected to the energy-storing hub and the final member. An electric motor is also provided to rotate the final member. Further, a locking member is configured to selectively lock the energy-storing hub such that energy is accumulated in the resilient member. Moreover, an energy-release cam is arranged to actuate the locking member such that the energy-storing hub is unlocked, thereby releasing the energy accumulated in the resilient member. Consequently, the energy-storing hub rotates and starts the internal combustion engine.

STARTING SYSTEM FOR AN ENGINE

TECHNICAL FIELD

The present invention relates to a starting system. In particular, the present invention relates to a starting system for an internal combustion engine.

BACKGROUND

Handheld products powered by internal combustion engines, such as, chainsaws, hedge trimmers, line trimmers, blowers, or the like, are well know in the art. An internal combustion engine for hand-held products is usually started manually by rotating a starter pulley via a rope. However, manual starting may require a lot of physical effort on part of the user thereby causing fatigue or injury. To avoid this, an electric starter, having an electric motor powered by a battery or mains power supply, is used for starting the internal combustion engine. However, in the case of a battery, the battery may be discharged in locations where charging means or a spare battery is not always present and, in case of main power supply, there may be a lack of access to such power.

As a solution to the above problems, starting systems that integrate a manual starter and an electric starter have been proposed in the art. For example, JP Patent Publication 2,146,260 published on June 5, 1990 and assigned to Mitsubishi Heavy Industries, LTD titled "SPIRAL-SPRING–TYPE STARTER FOR GENERAL-PURPOSE GASOLINE ENGINE", discloses a starting system, for an internal combustion engine, utilizing a spiral spring. The electric starter includes a spiral spring which is wound up by an electric starter or by a hand crank. When sufficient energy is accumulated in the spiral spring, the spiral spring is unwound to start the internal combustion engine. When using the electric starter, an electronic system is used to control the unwinding of the spiral spring. However, such an electronic system, having sensors and a solenoid, may be expensive and complex.

SUMMARY

An exemplary embodiment of a starting system includes an energy-storing hub assembly and a final member being operative to rotate about a first rotational axis. The energy-storing hub assembly includes an energy-storing hub and a resilient member, the resilient member being connected to the energy-storing hub and the final member. An electric motor is also provided to rotate the final member. Further, a

locking member is configured to selectively lock the energy-storing hub such that energy is accumulated in the resilient member. Moreover, an energy-release cam is arranged to actuate the locking member such that the energy-storing hub is unlocked, thereby releasing the energy accumulated in the resilient member. Consequently, the energy-storing hub rotates and starts the internal combustion engine. The locking member is mechanically actuated by the energy-release cam to determine the duration of accumulation of energy in the resilient member for starting the internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

Several representative embodiments will in the following be described in more detail with reference to the enclosed drawings, wherein:

FIG. **1** illustrates a schematic view of a device powered by an internal combustion engine with a starting system;

FIG. **2** illustrates an exploded view of the starting system for the internal combustion engine, according to an exemplary embodiment;

FIG. **3** illustrates a sectional view of the starting system of the embodiment of FIG. **2**;

FIG. **4** illustrates a front view of the starting system of FIGS. **2** and **3**, with a housing cover removed;

FIG. **5** illustrates a perspective view of a locking member and an energy-release cam, according to another embodiment;

FIG. **6** illustrates a detailed view of the energy-release cam of the embodiment of FIG. **5**;

FIG. **7** illustrates an exploded view of the starting system for the internal combustion engine, according to another exemplary embodiment;

FIG. **8** illustrates an exploded view of the starting system for the internal combustion engine, according to yet another exemplary embodiment; and

FIG. **9** illustrates an exploded view of the starting system for the internal combustion engine, according to yet another exemplary embodiment.

DESCRIPTION OF EMBODIMENTS

The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which example embodiments of the invention incorporating one or more aspects of the present invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. For example, one or more aspects of the present invention can be utilized in other embodiments and even other types of devices. In the drawings, like numbers refer to like elements.

FIG. **1** illustrates a device **D** powered by an internal combustion engine **E** (hereinafter referred to as "the engine **E**"), according to an embodiment of the present invention. The device **D** may be any type of powered device **D**, such as, but not limited to, hand-held tools, mowers, and outboard motors. Further, the internal combustion engine **E** may be any type, for example, a two-stroke engine, a four-stroke engine, or the like. The engine **E** may drive any working member of the device **D**, for example, a cutting member, a propeller, a blower, or the like. Moreover, a starting system **S** is provided for starting the engine **E**. In various embodiments of the present invention, the starting system **S** may be able to start the engine **E** both manually and electrically while, in other embodiments, only electrically is accommodated.

FIGS. **2-4** illustrate a starting system **S** for the engine **E**, according to an embodiment of the present invention. As illustrated in FIGS. **2** and **3**, the starting system **S** includes an energy-storing assembly **102**, a final member **104**, and a manual starter pulley **106** (hereinafter referred to as "the pulley **106**" with reference to FIGS. **2-4**) configured to rotate about a first rotational axis **R1**. The energy-storing assembly **102** includes an energy-storing hub **108** (hereinafter referred to as the "hub **108**" with reference to FIGS. **2-4**) and a resilient member **110**. The resilient member **110** is a torsion spring in the present embodiment, as illustrated in FIGS. **2-4**. However, any type of resilient member may be used in place of a torsion spring, for example, one or more rubber discs. The hub **108** includes an engaging portion **112** which includes one or more mating projections **114**. The mating projections **114** are utilized for attaching the engaging portion **112** with a corresponding part of the engine **E**, for example, but not limited to, a flywheel or a crankshaft. Thus, the starting system **S** starts the engine **E** by rotating the flywheel or the crankshaft, for example, via the hub **108**.

The starting system **S** also includes a housing **116** and a housing cover **118** to enclose at least some components of the starting system **S**. As illustrated in FIG. **3**, the engaging portion **112** of the hub **108** projects out of the housing cover **118** for attachment with a corresponding part of the engine **E**. The housing **116** and the housing cover **118** may be connected to each other via one or more mechanical fasteners (not shown). Sealing members may also be provided at an interface between the housing **116** and the housing cover **118**. Further, the housing **116** includes an integral shaft **120** on which at least the hub **108**, the final member **104** and the pulley **106** are mounted. In this embodiment, the shaft **120** has a stepped design to limit axial movement of the various mounted components. However, in other embodiments, various other shaft designs may be used.

For manual starting of the engine **E**, the pulley **106** is manually rotated via a pull member **123**, for example, a pull rope wound around a groove **121** of the pulley **106**. The pull rope may include a handle at one end so that the handle can be grasped and pulled by an operator. A second resilient member **122** is connected to the pulley **106** such that energy is stored in the second resilient member **122** when the pulley **106** is rotated by manual movement of the pull member **123**. The second resilient member **110** is a torsion spring in the present embodiment, as illustrated in FIGS. **2-4**. However, any type of resilient member may be used in place of a torsion spring, for example, one or more rubber discs. The second resilient member **122** accumulates energy when the pulley **106** is rotated and releases the energy when the pull member **123** is released. Further, a one-way clutch **124** is provided between the final member **104** and the pulley **106** to only transmit rotary motion from the pulley **106** to the final member **104** and not vice versa. The final member **104** rotates the hub **108** via the resilient member **110**. Finally, the hub **108** starts the engine **E** via the engaging portion **112**.

In addition to manual starting, the starting system **S** also includes an electric motor **126** (hereinafter referred to as "the motor **126**" with reference to FIGS. **2-4**) for starting of the engine **E**. The motor **126** may be any type of electric motor, for example, an AC motor or a DC motor. Further, the motor **126** may be driven by a battery or directly from a mains power source. The motor **126** is at least partly enclosed within a motor housing **127** which protrudes from the housing cover **118**. The motor **126** includes a driveshaft **128** which drives a reduction gear set **130**. The driveshaft **128** and the reduction gear set **130** rotate about a second rotational axis **R2** which is substantially parallel to and offset from the first rotational axis **R1**. In other embodiments, various other configurations can be used, such as an orthogonal arrangement of axes.

As illustrated in FIGS. **2** and **3**, the reduction gear set **130** is located inside a gear housing **132**. The gear housing **132** may include projections on an outer surface which engage with complementary features on an inner surface of the housing **116** for circumferentially fixing the gear housing **132** with respect to the housing **116**. Further, the reduction gear set **130** is a planetary gear set with a first ring gear **135** (shown in FIG. **3**) formed on an inner surface of the gear housing **132**. The reduction gear set **130** also includes a first reduction stage **136** and a second reduction stage **137**. The first reduction stage **136** includes a sun gear **138** (shown in FIG. **3**) such that the driveshaft **128** is coupled to the sun gear **138** of the first reduction stage **136**. Further, the first reduction stage **136** also includes three planet gears **140** which are disposed around the sun gear **138**. The planet gears **140** engage with the first ring gear **135** such that the planet gears **140** simultaneously rotate about their own axes as well as revolve around the sun gear **138**. A carrier member **141** is connected to each of the planet gears **140** such that the carrier member **141** rotates with revolution of the planet gears **140** around the sun gear **138**. The carrier member **141** includes attachment sections **142** (shown in FIG. **3**) which are inserted into central apertures of the corresponding planet gears **140**. Further, the carrier member **141** includes a gear section **144** (shown in FIG. **3**) which acts as a sun gear for the second reduction stage **137**. Similar to the first reduction stage **136**, three planet gears **145**, of the second reduction stage **137**, are disposed around the gear section **144** of the carrier member **141**. The planet gears **145** also engage with the first ring gear **135** such that the planet gears **145** simultaneously rotate about their own axes as well as revolve around the gear section **144** of the carrier member **141**. Moreover, an elongate member **146** is connected to each of the planet gears **145** such that the elongate member **146** rotates with revolution of the planet gears **145** around the gear section **144**. The elongate member **146** acts as the output of the reduction gear set **130**.

Further, the elongate member **146** includes three gear connecting portions **147** (shown in FIG. **3**) which are inserted into central apertures of the corresponding planet gears **145**. The elongate member **146** also includes an attachment portion **148** and a gear portion **150**. The attachment portion **148** may be attached to a drive member **149** by splines which mate with corresponding grooves present on a central aperture of the drive member **149**. As illustrated in FIGS. **2** (shown in dotted lines) and **3**, the drive member **149** is also configured to rotate about the second rotational axis **R2**. The gear housing **132** also includes an opening such that the drive member **149** can engage with the final member **104**. Further, in the embodiment illustrated in FIGS. **2-4**, the final member **104** and the drive member **149** are gears which mesh with each other.

Further, the gear portion **150** of the elongate member **146** drives the cam gear set **154** which is also configured to rotate about the second rotational axis **R2**. The cam gear set **154** is also a planetary gear set such that the gear portion **150** of the elongate member **146** acts as a sun gear. The cam gear set **154** is substantially enclosed within the gear housing **132**. The gear housing **132** also includes a second ring gear **158** formed on an inner surface. Further, the cam gear set **154** includes three planet gears **160** disposed around the gear portion **150**. Each of the planet gears **160** is also integrated with an additional gear **161** which engages with the second ring gear **158**. This enables the planet gears **160** to simultaneously rotate about their own axes as well as revolve around the gear portion **150**.

In other embodiments, the reduction gear set **130** and the cam gear set **154** may be provided in other configurations. For example, there can be any other number of planet gears in both the reduction gear set **130** and the cam gear set **154**. Further, the reduction gear set **130** may only include one reduction set. The gears (including the final member **104** and the drive member **149**) may be any type of gear, for example, spur, helical, herringbone, or the like. The reduction gear set **130** and/or the cam gear set **154** may also be any other type of gear drive other than planetary gears sets, for example, conventional gear drive, bevel drive, worm drive etc.

As illustrated in FIGS. **2** and **3**, an energy-release cam **162** (hereinafter referred to as "the cam **162**" with reference to FIGS. **2-4**) is attached to the planet gears **160** such that the cam **162** rotates with the revolution of the planet gears **160** about the second rotational axis **R2**. Further, due to the cam gear set **154**, the cam **162** may rotate at a lower rotational speed than the final member **104**. The cam **162** is a disc with a cam lobe **164** protruding from the disc. In some embodiments of the present invention, the cam lobe **164** has a length which extends to about one-third the circumference of the disc. During rotation of the cam **162**, the cam lobe **164** actuates a locking member **166** which is operative to selectively lock the hub **108**. The locking member **166** includes a ratchet **168** which is mounted on a pin **170** and normally biased by a ratchet spring **172** in a locking position. The cam **162** is partially enclosed within a cam housing **173** which has an opening so that the cam lobe **164** may actuate the locking member **166**. The cam housing **173** is located between the gear housing **132** and the motor housing **127**. Further, the pin **170** is mounted on the cam housing **173**.

As illustrated in FIG **4**, the ratchet **168** engages with any one of locking teeth **174** of the hub **108** in the locking position, thereby preventing the hub **108** from rotating. The cam lobe **164** engages with an actuating portion **176** of the ratchet **168** such that the ratchet **168** rotates against a biasing force of the ratchet spring **172** to a released position and disengages with a locking tooth **174**. Consequently, the hub **108** is permitted to rotate as long as the cam lobe **164** remains engaged with the actuating portion **176** of the ratchet **168**. Thus, in a full rotation of the cam **162**, the hub **108** is allowed to rotate along the length of the cam lobe **164** and remains locked along the rest of the circumference of the cam **162**.

For electric starting of the engine **E**, the driveshaft **128** of the motor **126** rotates the reduction gear set **130**. The elongate member **146** then drives the drive member **149** and the cam gear set **154**. The drive member **149** rotates the final member **104** while the cam gear set **154** rotates the cam **162**. The pulley **106** does not rotate with the final member **104** due to the one-way clutch **124**. The hub **108** also does not rotate as the hub **108** is locked by the ratchet **168**. Thus, the resilient member **110** winds and energy is accumulated in the resilient member **110**. Subsequently, due to the rotation of the cam **162**, the cam lobe **164** actuates the ratchet **168** to the released position such that the hub **108** is unlocked. As a result, the resilient member **110** is released and rotates the hub **108** for starting the engine **E**. In an embodiment of the present invention, the hub **108** is locked and the resilient member **110** is wound for about one to five rotations of the final member **104**, and then the hub **108** is unlocked so that the resilient member **110** can release the accumulated energy.

The starting system **S** uses the reduction gear set **130**, the cam gear set **154** and the cam **162** to determine the duration of accumulation and subsequent release of energy in the resilient member **110** for starting the engine **E**. Thus, the starting system **S** may eliminate the need for a complicated and expensive electronic system involving sensors and solenoid. The co-axial arrangement of the reduction gear set **130**, the cam gear set **154** and the cam **162** with respect to the driveshaft **128** of the motor **126** may also lead to a compact configuration of the starting system **S**. The starting system **S** may also be easily retrofitted with existing internal combustion engines, the engaging portion **112** of the hub **108** being easily attachable to an internal combustion engine (E.g., at the flywheel or the crankshaft). The integration of manual and electric starting may also improve the portability of the starting system **S**.

Note that the cam **162** may be configured differently in other embodiments. For example, the cam **162** may include multiple lobes and may be located at any other location within the starting system **S**. Further, the locking member **166** may include another mechanism, for example, a friction band (not illustrated in the figures) which is operative to selectively lock the hub **108**. In such a case, the friction band may be selectively actuated by the cam **162**.

FIGS. **5** and **6** illustrate a locking member **202** and a cam **204**, according to another embodiment of the present invention. Various components of the starting system **S**, including the resilient member **110**, are not shown for clarity. As illustrated in FIGS. **5** and **6**, an energy-storing hub **205** (hereinafter referred to as “the hub **205**” with reference to FIGS. **5** and **6**) includes locking teeth **206** on the circumference. The locking member **202** includes a ratchet **208** with multiple projections **210** such that the projections **210** can selectively engage the locking teeth **206** in the locked position and prevent the hub **205** from rotating. The ratchet **208** may move in a substantially vertical direction between the locking position and the released position.

Further, the ratchet **208** may be normally biased in the locking position by the ratchet spring (not illustrated in FIGS. **5** and **6**).

As illustrated in FIGS. **5** and **6**, the cam **204** is rotatable relative to the final member **104**. The cam **204** may be rotatably mounted on the housing **116**. The cam **204** includes a cam lobe **212** which selectively engages with an actuating portion **214** of the ratchet **208**. The cam **204** also includes multiple actuating lobes **216** which are angularly displaced by a trigger member **218** formed on the final member **104**. In an embodiment of the present invention, the cam **204** includes five actuating lobes **216** which are equally spaced about 360 degrees.

During rotation of the final member **104**, the actuating lobes **216** are angularly displaced by the trigger member **218** such that the ratchet **208** is in the locking position for a predetermined fraction of a whole rotation of the cam **204**. In an embodiment of the present invention, the ratchet **208** is in the locking position for about three-fifth of a whole rotation of the cam **204** which is roughly equivalent to an angular spacing of three actuating lobes **216**. During the rest of the rotation of the cam **204**, the cam lobe **212** engages the actuating portion **214** of the ratchet **208**, thereby lifting the ratchet **208** to the released position, as illustrated in FIGS. **5** and **6**.

It should be noted that the cam **204** does not require a cam gear set **154** for actuation. Thus, in the embodiment illustrated in FIGS. **5** and **6**, the cam gear set **154** is not present. Absence of the cam gear set **154** may lead to a further reduction in size and cost of the starting system **S**. However, the drive member **149** may be rotated by the motor **126** via the reduction gear set **130**, as described in conjunction with FIGS. **2** and **3**.

Alternative mechanisms may be utilized to simulate the motion of a cam and a locking member. For example, a spiral follower mechanism (not illustrated in the figures) may be used. In such a case, the spiral may act as the cam while the follower acts as the locking member. The follower is constrained to move along a spiral groove provided on the spiral. The follower locks the hub when the follower is located in a first region of the spiral region. When the follower is located in a second region of the spiral region, the follower releases the hub. The follower and the spiral may be reset to an initial position after a starting procedure due to the presence of one or more biasing members, such as, springs.

FIG. **7** illustrates an exploded view of the starting system **S**, according to another embodiment of the present invention. The starting system **S** includes an energy-storing assembly **302**, a final member **304**, and a manual starter pulley **306** (hereinafter referred to as "the pulley **306**" with reference to FIG. **7**) configured to rotate about a first rotational axis **R3**. The final member **304** is a gear in the present embodiment. Further, the energy-storing assembly **302** includes an energy-storing hub **308** (hereinafter referred to as the "hub **308**" with reference to FIGS. **7**) and a resilient member **310**. The resilient member **310** is a torsion spring in the present embodiment, as illustrated in FIG. **7**. The hub **308** includes an engaging portion **312** which includes one or more mating projections **314**. The mating projections **314** are utilized for attaching the engaging portion **312** with a corresponding part of the engine **E**, for example, but not limited to, a flywheel or a crankshaft. Thus, the starting system **S** starts the engine **E** by rotating the flywheel or the crankshaft, for example, via the hub **308**.

The starting system **S** also includes a housing **316** and a housing cover (not illustrated in FIG. **7**) to enclose at least some components of the starting system **S**. Further, the housing **316** includes an integral shaft **318** on which at least the hub **308**, the final member **304** and the pulley **306** are mounted.

For manual starting of the engine **E**, the pulley **306** is manually rotated via a pull member (not illustrated in FIG. **7**), for example, a pull rope wound around a groove **320** of the pulley **306**. The pull rope may include a handle at one end so that the handle can be grasped and pulled by an operator. A second resilient member **322** is connected to the pulley **306** such that energy is stored in the second resilient member **322** when the pulley **306** is rotated by manual movement of the pull member. The second resilient member **322** is a torsion spring in the present embodiment, as illustrated in FIG. **7**. The second resilient member **322** accumulates energy when the pulley **306** is rotated and releases the energy when the pull member is released. Further, a one-way clutch **324** is provided between the final member **304** and the pulley **306** to only transmit rotary motion from the pulley **306** to the final member **304** and not vice versa. The final member **304** rotates the hub **308** via the resilient member **310**. Finally, the hub **308** starts the engine **E** via the engaging portion **312**.

In addition to manual starting, the starting system **S** also includes an electric motor **325** (hereinafter referred to as "the motor **325**" with reference to FIG. **7**) for starting of the engine **E**. The motor **325** is at least partly enclosed within a motor housing **326** and a motor housing cover **327**. The motor **325** includes a driveshaft **328** which drives a transmission assembly **330**. The driveshaft **328** and different components of the transmission assembly **330** rotate about a second rotational axis **R4** which is substantially parallel to and offset from the first rotational axis **R3**.

As illustrated in FIG. **7**, the transmission assembly **330** includes a reduction gear set **332**, a cam gear set **334**, a first carrier **336**, a second carrier **338** and an elongate member **340**. Further, the transmission assembly **330** is located inside a transmission housing **342**. Moreover, the reduction gear set **332** and the cam gear set **334** are planetary gear sets. The reduction gear set **332** is provided with the first carrier **336**, while the cam gear set **334** is provided with the second carrier **338**. A ring gear **344** is formed on an inner surface of the transmission housing **342** such that the ring gear **344** acts as a stationary ring gear for both the reduction gear set **332** and the cam gear set **334**. Moreover, the elongate member **340** acts as the output of the reduction gear set **332**. The elongate member **340** includes a gear portion (not shown in FIG. **7**) and an attachment portion **345**. The gear portion acts as an input for the cam gear set **334** while the attachment portion **345** is configured to engage with a corresponding engaging part **346**. The engaging part **346** is integrated to a drive member **348**. As illustrated in FIG. **7**, the drive member **348** is a gear which drives an intermediate gear **350**. Further, the intermediate gear **350** drives the final member **304**.

Further, the second carrier **338** includes an energy-release cam **352** (hereinafter referred to as "the cam **352**" with reference to FIG. **7**) which rotates with the second carrier **338** about the second rotational axis **R4**. The cam **352** may rotate at a lower rotational speed than the final member **304** due to the cam gear set **334**. The cam **352** actuates a locking member **354** which is operative to selectively lock the hub **308**. The locking member **354** includes a ratchet **356** which normally biased by a ratchet spring **358** in a locking position. In the locking position, the ratchet **356** engages with locking teeth **360** provided on the hub **308**, thereby locking the hub **308**. Further, the transmission housing **342** has an opening so that the ratchet **356** may protrude out while an actuating portion **362** is located inside the transmission housing **342** and is actuated by the cam **352**.

For electric starting of the engine **E**, the driveshaft **328** of the motor **325** rotates the reduction gear set **332**. The elongate member **340** then drives the drive member **348** and the cam gear set **334**. The drive member **348** rotates the final member **304** via the intermediate gear **350**. Moreover, the cam gear set **334** rotates the cam **352** via the second carrier **338**. The pulley **306** does not rotate with the final member **304** due to the one-way clutch **324**. The hub **308** also does not rotate as the hub **308** is locked by the ratchet **356**. Thus, the resilient member **310** gets wound up and energy is accumulated in the resilient member **310**. Subsequently, due to the rotation of the cam **352**, the cam **352** actuates the ratchet **356** to a released position such that the hub **308** is unlocked. As a result, the resilient member **310** is released and rotates the hub **308** for starting the engine **E**.

FIG. **8** illustrates an exploded view of the starting system **S**, according to another embodiment of the present invention. The embodiment illustrated in FIG. **8** is substantially similar to the embodiment illustrated in FIG. **7**. However, in the present embodiment, a final member **402** and a drive member **404** are belt sprockets. Further, the drive member **404** drives the final member **402** via a belt **406**. The belt **406** may be a toothed belt to prevent slipping.

FIG. **9** illustrates an exploded view of the starting system **S**, according to another embodiment of the present invention. The starting system **S** includes a final member **502**, a manual starter pulley **504** (hereinafter referred to as "the pulley **504**" with reference to FIG. **9**) and an energy-storing hub assembly **506** configured to rotate about a first rotational axis **R5**. The energy-storing hub assembly **506** includes an energy-storing hub **508** (hereinafter referred to as "the hub **508**" with reference to FIG. **9**), a common hub **510** and a resilient member **511**. The resilient member **511** is connected to the final member **502** and the hub **508**. The resilient member **511** is a torsion spring in the present embodiment, as illustrated in FIG. **9**. Further, the common hub **510** includes an engaging portion **512** with one or more mating projections **514** which engage with a corresponding part of the engine **E**, for example a flywheel **516**. Further, as illustrated in FIG. **9**, the various parts of the starting system **S** are at least partly enclosed by a housing **518** and a housing cover **520**. The engaging portion **512** of the common hub **510** projects out of the housing cover **520** so that the engaging portion **512** may engage with the flywheel **516**.

For manual starting of the engine **E**, the pulley **504** is manually rotated via a pull member **521**. A second resilient member **523** is connected to the pulley **504** such that energy is stored in the second resilient member when the pulley **504** is rotated. The second resilient member **523** is a torsion spring in the embodiment illustrated in FIG. **9**. Thus, the second resilient member **523** accumulates energy when the pulley **504** is rotated and releases energy when the pulley **504** is released. Further, a set of manual starter dogs (not shown in FIG. **9**) are provided on the pulley **504** to only transmit rotary motion from the pulley **504** to the common hub **510**. The manual starter dogs engage with locking projections **522** of the common hub **510**, thereby rotating the common hub **510**. Hence, the common hub **510** rotates the flywheel **516** and starts the engine **E**.

The starting system **S**, as illustrated in Fig. **9**, also includes an electric motor **524** (hereinafter referred to as "the motor **524**" with reference to FIG. **9**) for electrically starting the engine **E**. The motor **524** is at least partly enclosed within a motor housing **526** which may protrude from the housing cover **520**. A driveshaft **528** of the motor **524** drives a reduction gear set **530**. A fixing member **532** secures the reduction gear set **530** to a gear housing **533**. In some embodiments of the present invention, the reduction gear set **530** may be a planetary gear set. Further, the motor housing **526** may be integral with the gear housing **533**. The reduction gear set **530** rotates a drive member **534** which in turn rotates the final member **502**. The driveshaft **528**, the reduction gear set **530** and the drive member **534** rotate about a second rotational axis **R6** which is parallel to and offset from the first rotational axis **R5**.

The final member **502** includes a sun gear portion (not shown in FIG. **9**) which rotates a cam gear set **536**. The cam gear set **536** is a planetary gear set with three planet gears **538** disposed around the sun gear portion of the final member **502**. The planet gears **538** also engage with a ring gear **539** provided on an inner surface of the housing **518** such that the planet gears **538** simultaneously rotate about their own axes as well as revolve around the sun gear portion of the final member **502**. Further, an energy-release cam **540** (hereinafter referred to as "the cam **540**" with reference to FIG. **9**) is attached to the planet gears **538** such that the cam **540** rotates with the revolution of the planet gears **538** around the sun gear portion of the final member **502**. Thus, the cam gear set **536** and the cam **540** rotate about the first rotational axis **R5**.

As illustrated in FIG. **9**, the cam **540** includes a cam lobe **542** which actuates a locking member **544** during rotation of the cam **540**. The locking member **544** includes a ratchet **546** which is normally biased in a locking position by a spring member (not shown in FIG. **9**). As illustrated in FIG. **9**, the ratchet **546** engages locking teeth **548** of the hub **508** to lock the hub **508**.

For electric starting of the engine **E**, the driveshaft **528** of the motor **524** drives the reduction gear set **530** which in turn rotates the drive member **534**. The drive member **534** then rotates the final member **502**. Hence, the sun gear portion of the final member **502** rotates the cam **540** via the cam gear set **536**. However, the hub **508** is locked by the ratchet **546**. Thus, the resilient member **511** winds and energy is accumulated in the resilient member **511**. Subsequently, due to the rotation of the cam **540**, the cam lobe **542** actuates the ratchet **546** to a released position and the hub **508** is unlocked. As a result, the resilient member **511** is released and rotates the hub **508**. Further, the hub **508** includes a set of hub starter dogs **550** which selectively engages with locking projections **522** of the common hub **510** to only transmit rotary motion from the hub **508** to the common hub **510**. Finally, the common hub **510** rotates the flywheel **516** to start the engine **E**.

In the drawings and specification, there have been disclosed several exemplary embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation, the scope of the invention being set forth in the following claims.

CLAIMS

1. A starting system for use with an internal combustion engine, the starting system comprising:

an energy-storing hub assembly and a final member operative to rotate about a first rotational axis;

the energy-storing hub assembly comprising an energy-storing hub and a resilient member, wherein the resilient member is connected to the energy-storing hub and the final member;

an electric motor operative to rotate the final member;

a locking member operative to selectively lock the energy-storing hub such that energy is accumulated in the resilient member; and

an energy-release cam operative to actuate the locking member such that the energy-storing hub is unlocked and the energy accumulated in the resilient member is released to rotate the energy-storing hub for starting the internal combustion engine.

2. The system of claim 1, wherein the electric motor drives a reduction gear set, the reduction gear set being operative to drive a drive member, and the drive member being operative to drive the final member.

3. The system of claim 2, wherein the final member and the drive member are gears.

4. The system of claim 3, wherein the drive member directly drives the final member.

5. The system of claim 3, wherein the drive member drives the final member via an intermediate gear.

6. The system of claim 2, wherein:

the drive member drives the final member via a belt; and

the drive member and the final member are belt sprockets.

7. The system of claim 2, wherein the reduction gear set drives a cam gear set, the cam gear set being operative to drive the energy-releasing cam.

8. The system of claim 7, wherein the reduction gear set and the cam gear set are planetary gear sets.

9. The system of claim 7, wherein a driveshaft of the electric motor, the energy-release cam, the reduction gear set, the drive member and the cam gear set are operative to rotate about a second rotational axis which is offset from the first rotational axis.

10. The system of claim 1, wherein:

the locking member comprises a ratchet, the ratchet being normally biased in a locking position; and

the energy-storing hub comprises at least one locking tooth, the ratchet being operative to engage with the locking tooth on the energy-storing hub in the locking position.

11. The system of claim 10, wherein:

the energy-release cam comprises at least one cam lobe; and

the cam lobe is operative to selectively actuate the ratchet to a released position such that the ratchet disengages with the locking tooth of the energy-storing hub.

12. The system of claim 10, wherein:

the energy-release cam further comprises a plurality of actuating lobes, the energy-release cam being rotatable relative to the final member; and

the final member comprises a trigger member, the trigger member is operative to displace one of the plurality of actuation lobes such that the cam lobe selectively actuates the ratchet to the released position.

13. The system of claim 1, wherein:

the energy-storing hub comprises an engaging portion; and

the engaging portion comprises a plurality of mating projections operative to engage with a part of the internal combustion engine.

14. The system of claim 7, wherein the energy storing hub assembly further comprises a common hub, the common hub being selectively engageable with the energy-storing hub.

15. The system of claim 14, wherein:

the energy-storing hub further comprises a set of hub starter dogs; and the common hub comprises a plurality of locking projections, the set of hub starter dogs being operative to selectively engage with the locking projections to transmit motion from the energy-storing hub to the common hub.

16. The system of claim 14, wherein:

the cam gear set and the energy-releasing cam are operative to rotate about the first rotational axis; and

a driveshaft of the electric motor, the reduction gear set and the drive member are operative to rotate about a second rotational axis which is offset from the first rotational axis.

17. The system of claim 14, wherein:

the common hub comprises an engaging portion; and

the engaging portion comprises a plurality of mating projections operative to engage with a part of the internal combustion engine.

18. The system of claim 1, wherein the system further comprises a manual starter pulley and a pull member, the manual starter pulley being operative to selectively rotate the energy-storing hub assembly responsive to manual movement of the pull member for starting the internal combustion engine.

19. The system of claim 1, wherein the resilient member is a torsion spring.

20. A device comprising:

an internal combustion engine; and

a starting system according to any of claims 1 – 20, wherein the starting system is operative to start the internal combustion engine..

21. The device of claim 20, wherein the device is a handheld power tool.

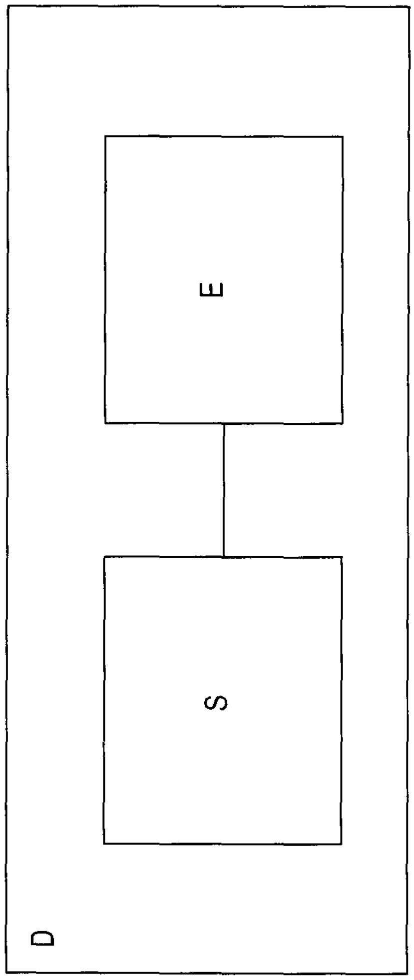
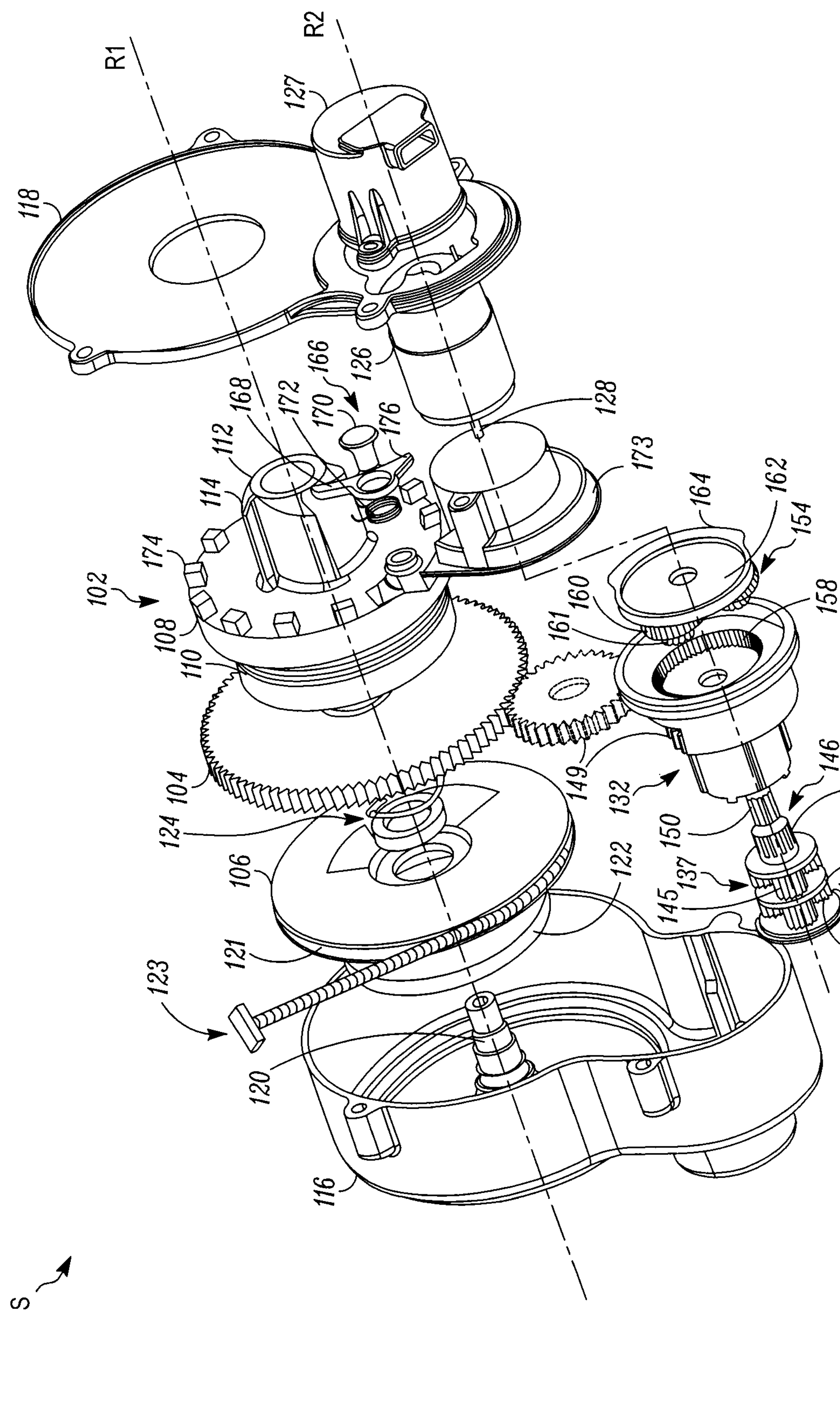


FIG. 1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S

FIG. 2

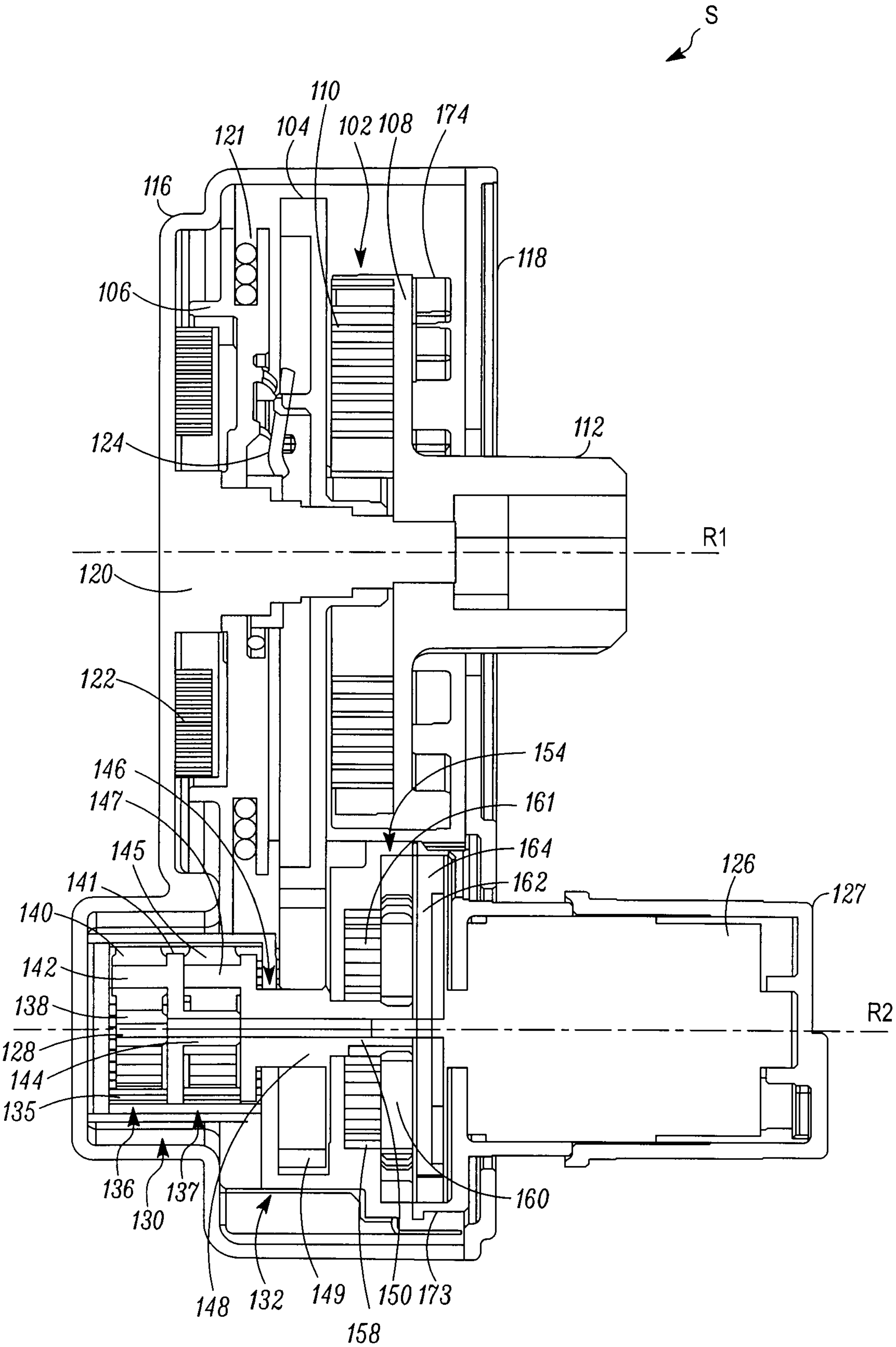
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FIG. 3

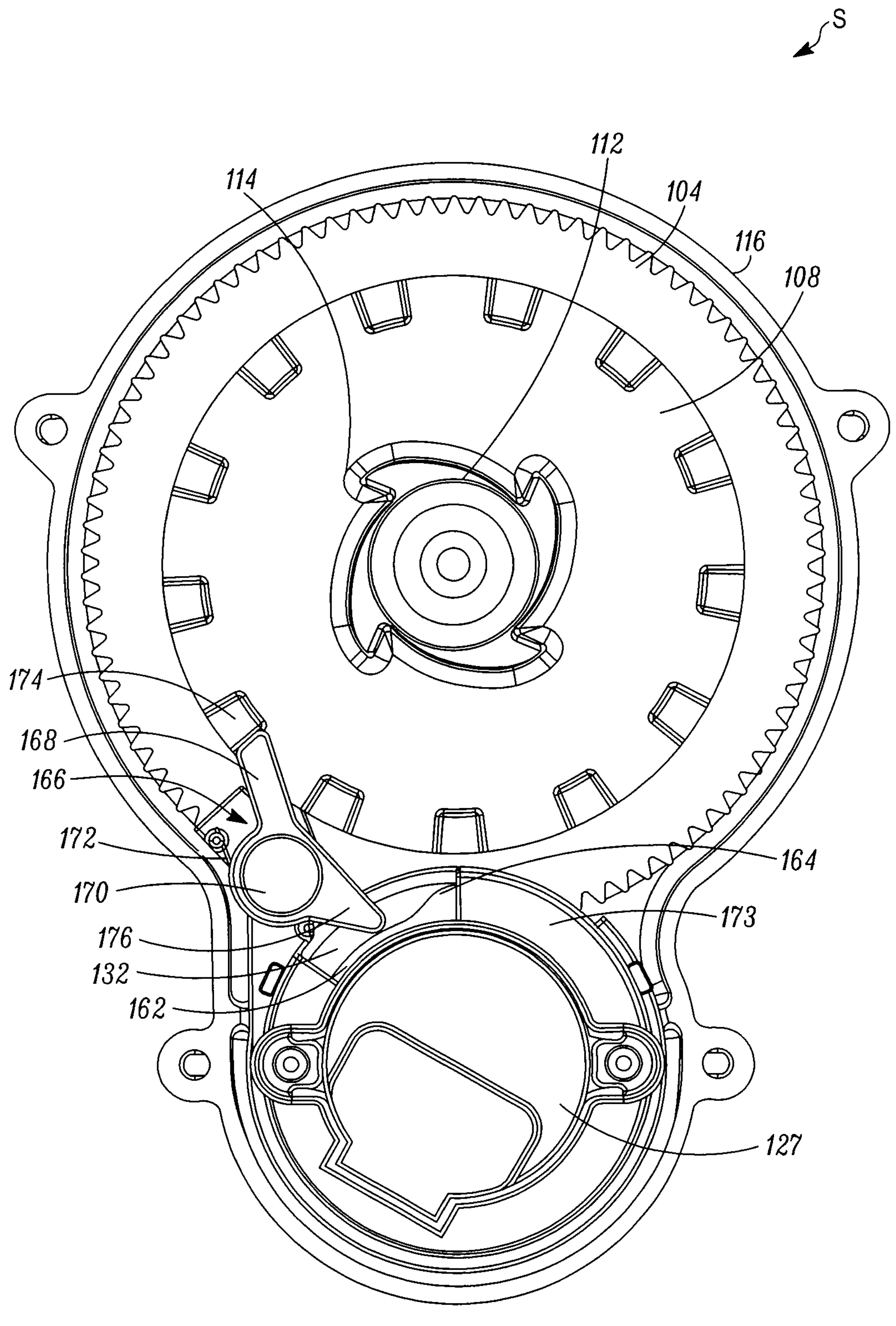

FIG. 4

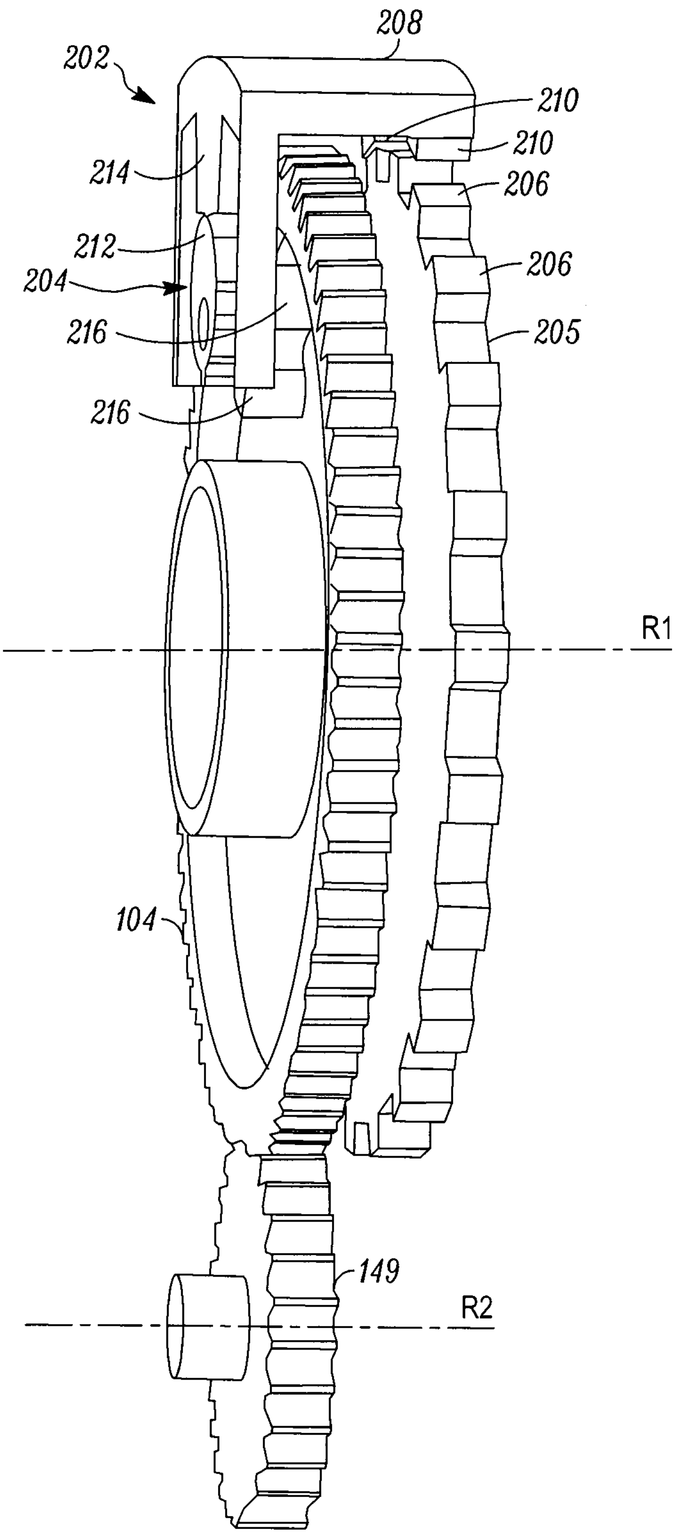

FIG. 5

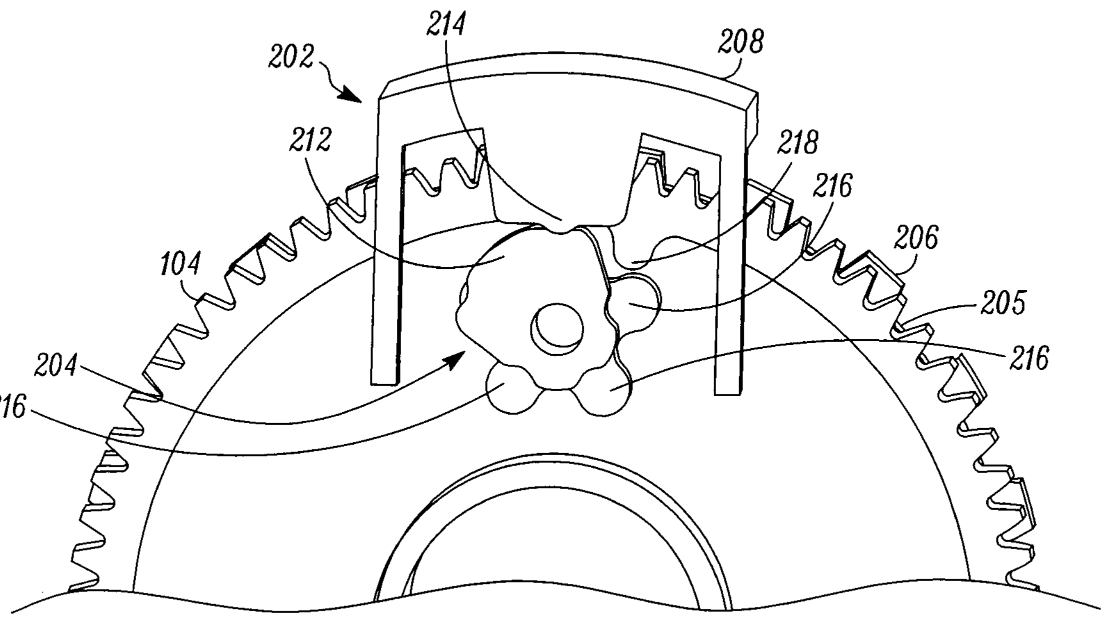

FIG. 6

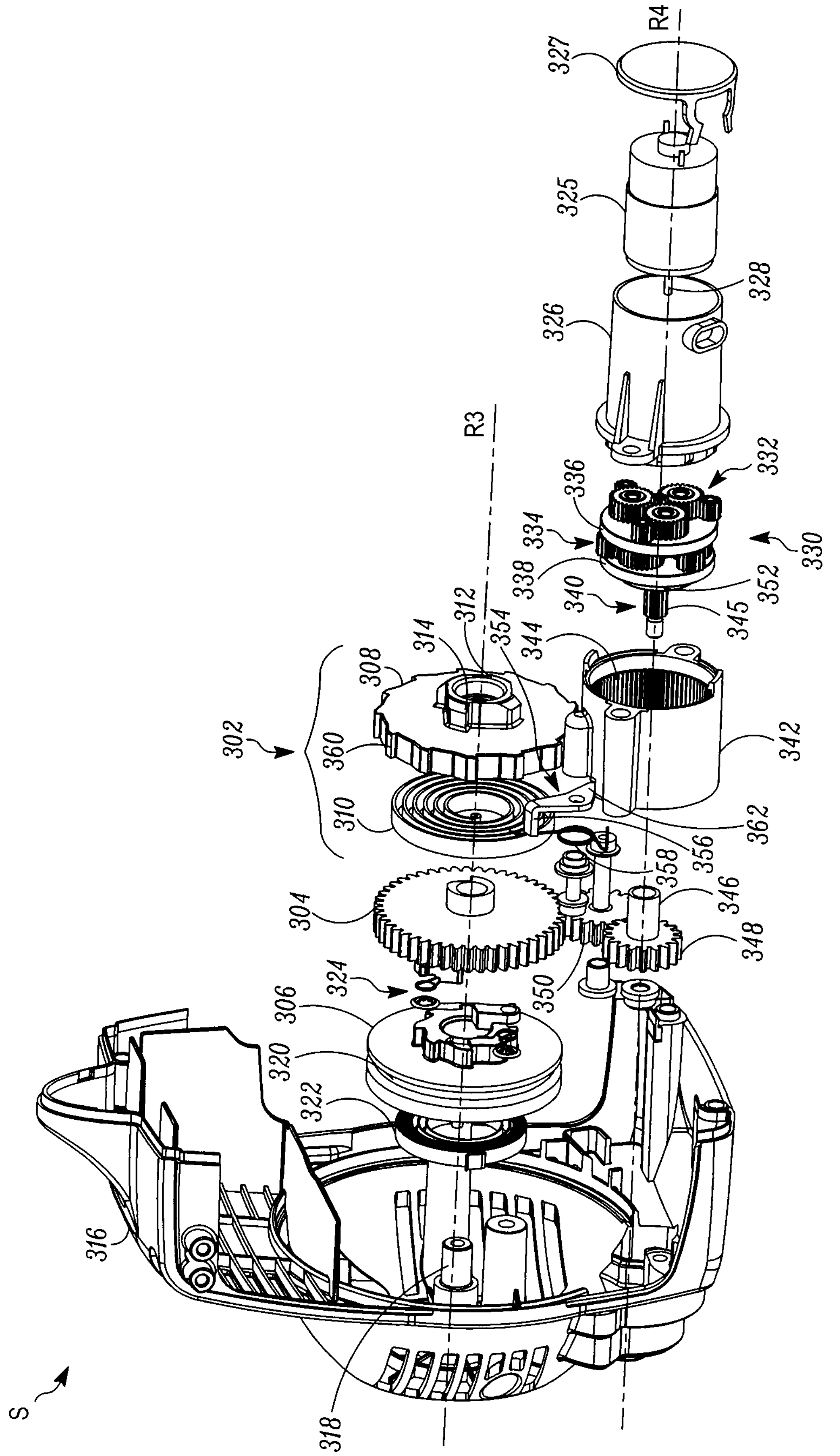
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FIG. 7

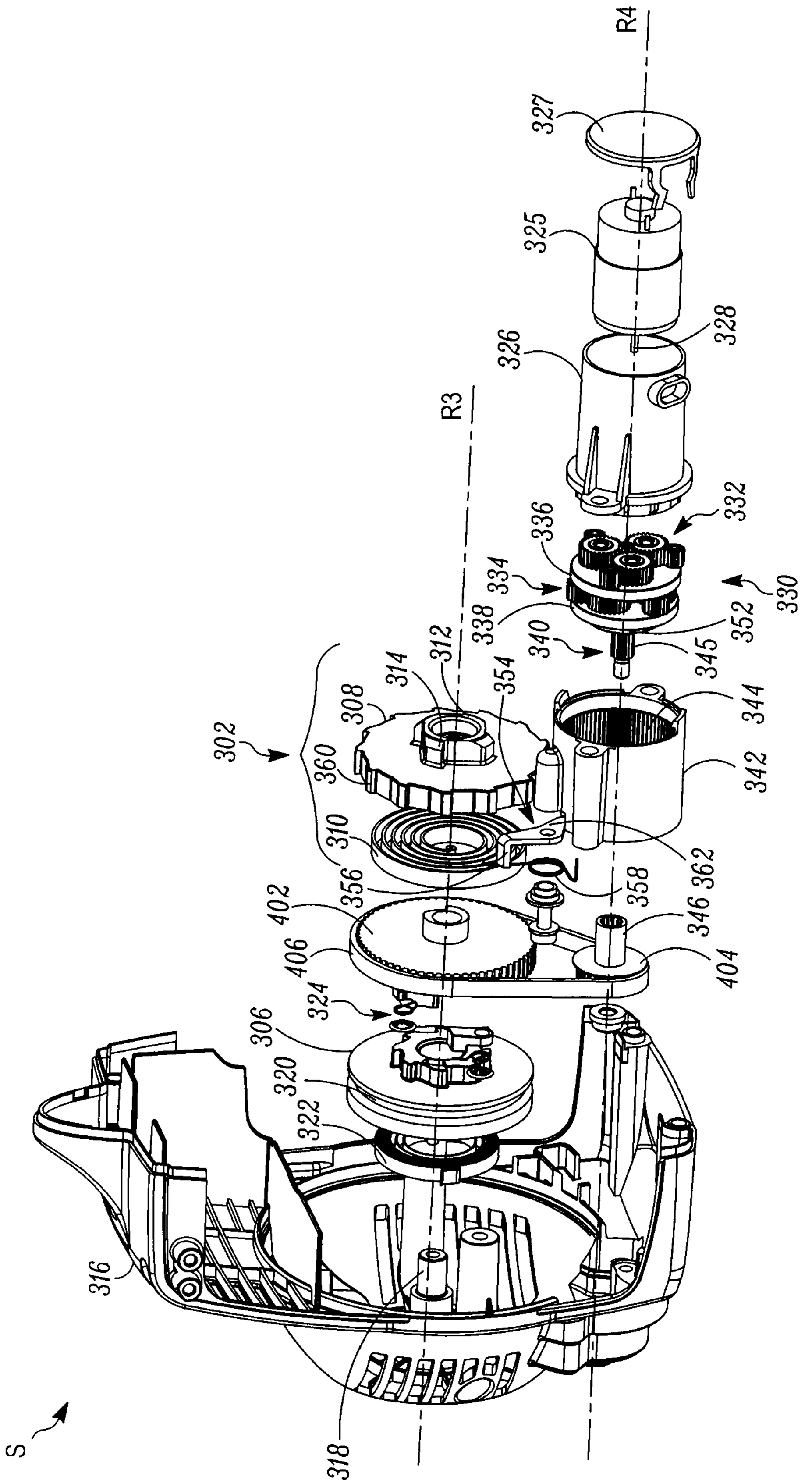
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FIG. 8

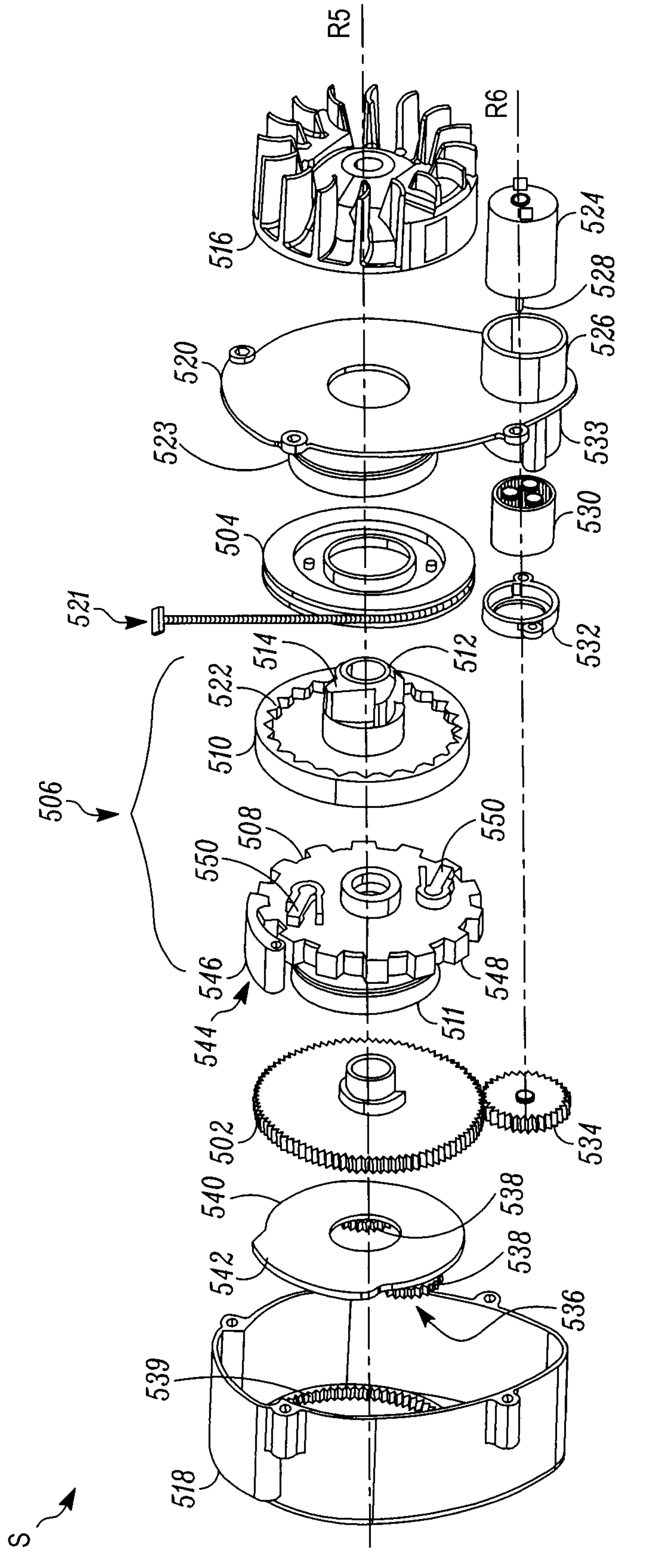
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FIG. 9