Dec. 2, 1958 P. L. SCHNEIDER ET AL 2,862,391

ENGINE STARTING APPARATUS

Filed Jan. 11, 1956

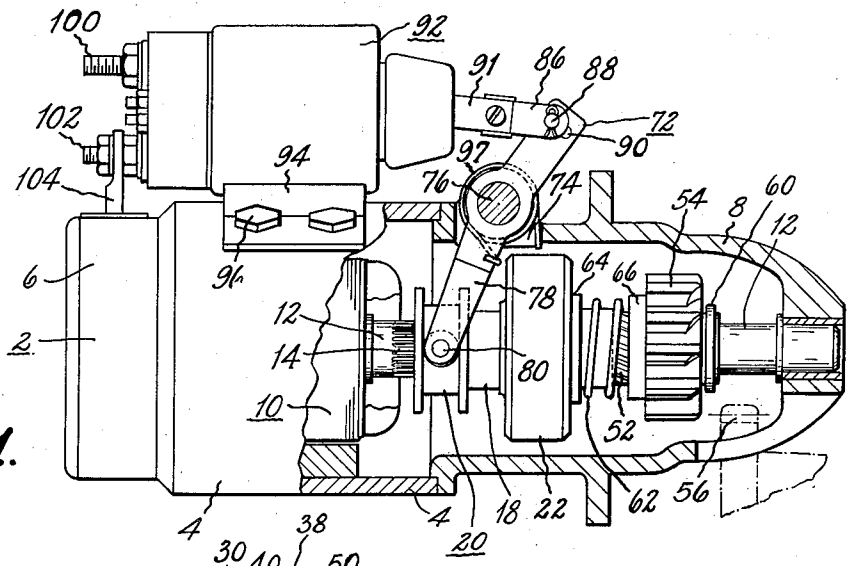


Fig. 1.

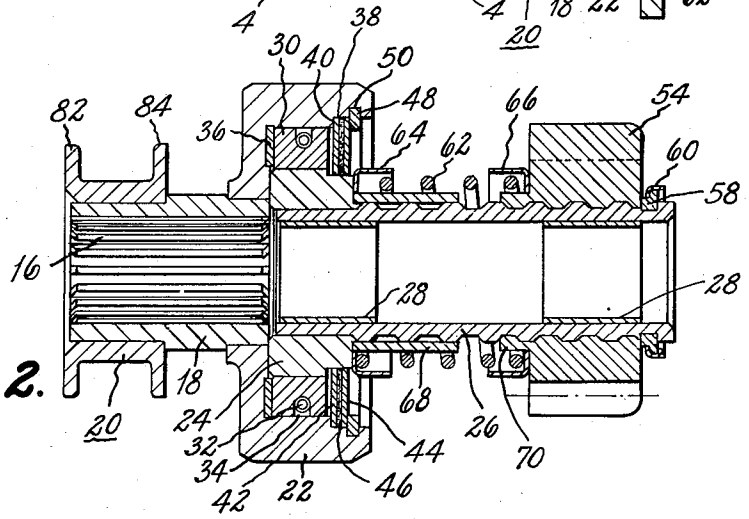


Fig. 2.

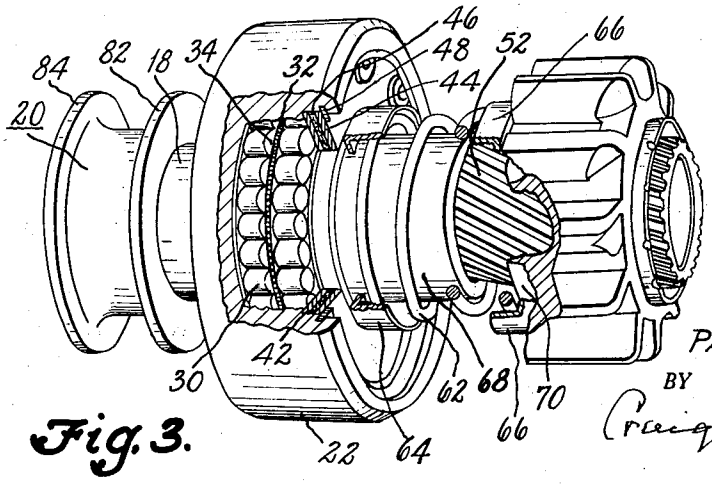


Fig. 3.

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2,862,391

Patented Dec. 2, 1958

2,862,391

ENGINE STARTING APPARATUS

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Application January 11, 1956, Serial No. 558,468

11 Claims. (Cl. 74—7)

This invention relates to engine starting apparatus and more particularly to that type of starting apparatus having an electric starting motor which is connected to the engine flywheel gear for rotating the engine crank shaft to start the engine through the medium of a one-way clutch, the driving element of which is connected to said electric motor while the driven element thereof is connected to a pinion which is advanced into engagement with the flywheel gear before the gear is rotated thereby and is retracted from the gear after the engine has become self-operative and the clutch is released.

In starting apparatus of this type now in use, it is the general practice to move the clutch and pinion assembly axially along the starting motor shaft to effect engagement of the pinion with the flywheel gear by means of a solenoid which, when energized, moves the pinion toward the gear and when the solenoid is de-energized subsequent to the starting of the engine, the pinion and clutch assembly is moved back to its initial position by a spring, the force of which is overcome when the magnet is energized. In such devices the magnet or solenoid actuates a pinion shifting lever which moves the pinion and clutch assembly through the medium of a spring. If the teeth of the pinion do not abut those of the flywheel gear as the pinion is advanced, the pinion simply moves into proper meshing position and when it reaches such position, the solenoid closes the starter switch, which causes the motor to become operative and rotate the engine crank shaft for starting purposes. If the teeth of the pinion abut those of the flywheel gear, the pinion shifting spring is compressed by the solenoid until the armature of the solenoid moves far enough to close the motor switch. Substantially immediately on starting of the motor the pinion is rotated far enough to mesh properly with the engine gear, whereupon the pinion shifting spring snaps the pinion into proper engagement with the engine gear and the continued rotation of the motor effects rotation of the crank shaft and starting of the engine as previously described.

Until recently starting devices of the character described were entirely satisfactory and were in very widespread use throughout the entire automotive industry. However, with the advent of high voltage starter systems employing 12 volt current and in heavy duty installations using 24 volt current, unexpected difficulties were encountered. Apparently in the higher voltage systems, if the teeth of the pinion abut those of the flywheel gear the pinion starts to rotate so fast when the starting motor is energized that not enough time is available for the pinion shifting spring to snap the pinion into proper engagement with the engine and rotation of the crankshaft begins with insufficient engagement which causes overloading of the ends of the pinion and ring gear teeth and tooth breakage results.

It is, therefore, the primary purpose of the present invention to provide a starting apparatus of the type having an over-running clutch and driving pinion movable axially of the motor shaft to effect engagement of the driving

pinion with the engine gear to be turned thereby in which, in the event of tooth abutment between the pinion and the engine gear, meshing of the pinion with the gear is effected without closing of the starting motor circuit to effect rotary movement of the starting motor shaft and in which full driving engagement of the pinion with the engine gear is effected by axial movement of the clutch and pinion assembly on the motor shaft, even in the event of tooth abutment between the pinion and the engine gear.

According to the present invention, this is accomplished by mounting the pinion on a sleeve to which it is splined with helical splines, but on which it can slide in the event of tooth abutment. The sleeve slides on the shaft with the pinion and clutch assembly and is moved toward the engine flywheel gear to effect engagement of the pinion with such gear when the aforementioned magnet is energized. During this advance movement until the pinion reaches the flywheel gear, there is no relative movement between the pinion and sleeve, the pinion, sleeve and clutch assembly all moving as a unit. If the teeth of the pinion abut those of the engine gear, the advance movement of the pinion is stopped, but the sleeve and clutch assembly continue to advance and the helical splines of the sleeve will effect some rotary movement of the pinion, while a spring which surrounds the sleeve between the clutch assembly and pinion will be compressed.

If the pinion is rotated sufficiently by the advance movement of the sleeve to bring the teeth into proper meshing relation with those of the engine gear, the above mentioned spring will expand and move the pinion into full meshing engagement with such gear. If, however, the pinion teeth are not rotated to proper meshing position, the advance movement of the sleeve and clutch assembly is stopped by the engagement of a stop member on said assembly with a cooperating stop on the pinion before the starting motor circuit can be closed by actuation of operating solenoid. When this takes place, the control circuit of the solenoid is opened and the parts, including the clutch, sleeve and pinion, are permitted to return to normal position, the control circuit for the solenoid is then reclosed and the operation is repeated, the clutch assembly, sleeve and pinion being advanced toward the engine gear a second time. Due to the fact that the pinion was rotated to some extent with reference to the engine gear during the first operation of the solenoid, the parts will not be in quite the same position as they were initially when the second operation of the solenoid is effected. If the teeth of the pinion again abut those of the flywheel gear, the advance movement of the sleeve will again rotate the pinion and will bring the teeth into proper meshing relation with those of the flywheel gear, so that expansion of the spring will force the pinion into proper meshing position. The armature of the solenoid will then continue to move until the main starting motor switch is closed, the starting motor will become operative and the engine crank shaft will be rotated by such motor until the engine is started.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred embodiment of the present invention is clearly shown.

In the drawings:

Fig. 1 is a side elevation, partly in section, of a starting motor in which the present invention is incorporated.

Fig. 2 is an enlarged section through the clutch assembly and driving pinion of the present invention.

Fig. 3 is a perspective view of the mechanism shown in section in Fig. 2.

Referring to Fig. 1 of the drawings, the starting motor,

which is indicated generally by the reference numeral 2, includes a field frame 4 in which the field windings, not shown, of the motor are housed, while an end plate 6 and a housing or cover member 8 which surrounds the clutch and pinion assembly are secured in any desirable way to the field frame. The rotating motor armature is indicated at 10 and this is secured to a motor shaft 12, the ends of which are suitably mounted for rotation in the end plate 6 and housing 8. The specific construction of the motor is of no material importance, so far as the present invention is concerned, so the structural details of the motor are not illustrated and the motor will not be further described.

Adjacent the armature 10 the motor shaft has straight splines 14 which engage cooperating splines 16 formed on the inner surface of a short sleeve 18 which surrounds the shaft. Suitably secured to the left end of this sleeve in any conventional manner is a collar 20 which is adapted to be engaged by a shifting lever, more fully described later, which is effective to move the collar and associated mechanism axially with reference to the shaft 12. At the right end of the sleeve it is connected by brazing or other suitable method, to the driving member of an over-running clutch having an inner or driven member 24 which is secured by brazing or otherwise to a sleeve 26 which is both rotatable and slidable on the shaft 12 and which is surrounded by suitable bushings 28 which are positioned between the sleeve and the shaft.

As shown in the drawings, the clutch is a sprag clutch of the construction which is fully shown and described in the copending application of Schneider et al., S. N. 407,998, filed February 3, 1954. It will be understood, however, that use of a sprag clutch is not at all necessary so far as the present invention is concerned and a roller clutch of conventional form such as shown in the patent to Critchfield 2,211,053, of August 13, 1940, could be used just as well.

In the device illustrated in the drawings, there are a series of tiltable sprags 30 positioned in the annular space between the driving and driven members of the clutch 22 and 24 respectively. These sprags are positioned substantially adjacent each other and are surrounded by a garter spring 32 which engages slots 34, one of which is formed in the outer edge of each sprag. This spring normally holds the sprags against the surface of the driven clutch member and also tends to tilt the sprags so that they will be gripped between the driving and driven clutch members when the driving member is rotated by the starting motor. As in the case of a roller clutch, when the engine starts to run under its own power, the driven member is rotated more rapidly than the driving member and when this takes place, the sprags tilt to a non-gripping position and the clutch is released. Also the effect of the spring 32 is substantially nullified when the engine becomes self-operative, due to the effect of centrifugal force and this aids in effecting release of the clutch.

As seen in Fig. 2, a flat annular steel washer 36 is positioned in the driving member 22 at the left of the sprags 30 while at the right of the sprags the member is slightly enlarged at 38 forming a shoulder 40 adjacent which are positioned 3 washers, 2 of which, 42 and 44, are metal. A grease retaining felt washer 46 is positioned between the two metal washers, and all of these are held in position by a split retaining washer 48 which is received in a groove 50 formed in the driving member 22.

The outer surface of the sleeve 26 has helical splines 52 formed thereon from a point immediately adjacent the driven clutch member 24 to the right end of the sleeve and a driving pinion 54 which is adapted to be moved axially into engagement with the flywheel gear 56 is mounted on the splined portion of the sleeve 26. This pinion has cooperating splines formed on the inner surface thereof which engage the splines 52 and obviously if the pinion is held against axial movement, as the sleeve moves axially toward gear 56, further axial movement of the sleeve 26 will effect rotation of the pinion because of the engagement of the helical splines 52 with the cooperating splines on the pinion. The pinion is normally held in the position shown in Figs. 2 and 3 at the right end of the sleeve 26 against a retaining washer 58 which engages a groove in the outer surface of sleeve 26 and is surrounded by a cap shaped member 60 which is crimped around the washer 58 as shown in Fig. 2.

In order to normally hold the pinion in the position referred to, a compression spring 62 is provided. This spring surrounds the sleeve 26 between the clutch assembly and the pinion and the ends of the spring engage cup-shaped members 64 and 66 which are positioned adjacent the clutch assembly and the pinion respectively. The members 64 and 66 are loosely mounted, respectively, on two annular stop members 68 and 70 which extend through the members 64 and 66 and lie between the turns of spring 62 and the outer surface of the sleeve 26. The stop member 68 is not splined, but is secured to the sleeve 26 and moves with said sleeve both axially and rotatively, the member 68 being shrunk on the outer surface of sleeve 26 so that it has a tight fit thereon and can not move relatively to the sleeve. The stop member 70 is integral with the pinion and surrounds the sleeve 26 immediately to the left of the pinion, as shown in Figs. 2 and 3. The function of these stop members will be described more fully later.

Axial movement of the clutch assembly and pinion on the motor shaft 12, toward and away from the flywheel gear 56, is effected by a lever 72 which extends through an opening 74 in the housing 8 and which is pivoted on a stud 76 which extends across the opening 74. The lower end of the lever 72 is bifurcated to form arms 78 which straddle the motor shaft and each of which carries a stud or pin 80 which is received between flanges 82 and 84 of the collar 20. As shown, the upper end of the lever has a pin and slot connection with an operating link 86 so that there is lost motion between the link and the lever. A pin 88, which is secured to the link 86, extends through a slot 90 formed in the upper end of the lever 72. The link 86 is adjustably connected by any suitable means to another link 91 which is connected to the armature of a solenoid designated generally by the reference numeral 92 and which is suitably secured to a mounting bracket 94, held in position on the field frame 4 of the starting motor by machine screws 96 or in any other suitable way.

The lever 72 and associated parts are normally held in the position shown in Fig. 1 and returned to such position when the solenoid is de-energized by a coil return spring 97 which surrounds the stud 76. One end of the spring engages the housing 8 while the other is hooked around the lever 72 as shown in Fig. 1, so that the spring exerts a force tending to rotate the lever 72 clockwise at all times.

The construction of the solenoid and the operating connections between such solenoid and the lever 72 constitute no part of the present invention and will not be more specifically described herein. The construction of the magnet and its operating connections may be, for example, of the form shown in the patent to Dyer 2,387,791 of June 30, 1942, or of any other suitable construction. Likewise the means for controlling the operation of the solenoid is no part of the present invention and its action may be controlled by the means shown in the Dyer patent, or by a mere manual switch, or by any other suitable means.

So far as the present invention is concerned, it is sufficient to point out that when the solenoid is energized the armature moves to the left and moves the upper end of the lever 72 to the left so that the lever is rotated in a counterclockwise direction, and the lower end of such lever, with the clutch assembly and the pinion 54, is moved to the right. If the pinion is in such position

that it will be moved properly into mesh with the gear **56** when this movement of the solenoid armature and lever **72** takes place, the armature will move far enough to the left to move a movable contact which is not shown, but may be of the construction shown in the Dyer patent, into two fixed contacts which are also not shown, but are electrically connected with the two binding posts **100** and **102**, the first of which is adapted to be connected with a suitable source of current, such as a storage battery, not shown, while the post **102** is connected by a bar **104** with the starting motor, so that when the movable contact is in engagement with the two fixed contacts, current will flow from the battery to the starting motor, the latter will be energized, the shaft **12** will be rotated and through the medium of the clutch assembly and pinion **54** will rotate the gear **56**, so that the engine will be cranked, and started.

As soon as the engine is operating under its own power, the pinion, the sleeve **26** and the driven member **24** of the clutch will be rotated by the engine more rapidly than the driving member of the clutch is rotated by the starting motor. In other words, the driven member of the clutch will overrun the driving member, the sprags will no longer constitute a gripping means between the driving and driven clutch members and the clutch will release. Also when the engine becomes self-operative, the solenoid magnet **92** will be automatically de-energized if a control system therefor, such as shown in the Dyer patent, is employed or it may be manually de-energized by opening a manually operable control switch. Upon de-energization of the magnet the return spring **97** will restore the lever **72**, the clutch assembly and pinion to normal position, disengaging the pinion **54** from the gear **56**. At the same time a spring will disengage the movable contact of the solenoid from the two fixed contacts, as in the Dyer patent, thus rendering the starting motor inoperative, so that after the engine is started, the parts will come to rest in the position shown in Fig. 1.

If, upon energization of the magnet, the pinion teeth are in such position that upon axial movement of the pinion to the right, its teeth abut those of the gear **56**, further movement of the pinion to the right is prevented. When the axial movement of the pinion to the right is stopped, movement of the sleeve **26** continues until the stop member **68** engages the member **70**. During this movement of the sleeve, the pinion will, ordinarily, be rotated to some extent due to the engagement of the helical splines **52** with corresponding splines on the pinion, and this rotation of the pinion is generally enough to bring the teeth of the pinion into proper alignment with those on the gear **56**. If this takes place, the pinion will be moved on into proper meshing engagement with the gear **56** by expansion of the spring **62** and the clutch assembly and lever **72** will continue to move until the starting motor switch is closed as previously described, at which time the starting motor will become operative and the engine will be started.

Upon rather rare occasions, in the event of tooth abutment between teeth of the pinion and those of the flywheel gear, rotation of the pinion is prevented, either entirely or partially, upon further advance of the sleeve **26** due to the engagement of burrs or rough spots on the pinion and engine gear, and the pinion will not be brought into proper gear engaging position by the time stop member **70** is engaged by stop member **68** and axial movement of the sleeve **26** is stopped. If rotation of the pinion is stopped either wholly or partially, axial movement of the sleeve, after rotation of the pinion is stopped, will effect a reverse rotary movement of the clutch assembly, the sleeve **26** and motor armature will be effected. Since the pinion does not rotate, due to the aforementioned roughness or for any other reason, the sleeve must rotate reversely because of the helical splines. This reverse rotation of the sleeve and parts connected thereto changes the rotative position of the sleeve relative to the gear **56** from that which it occupied when the axial movement of the sleeve was initiated. In other words, axial movement of the sleeve, if rotation of the pinion is prevented, will cause the sleeve rather than the pinion to be rotated relative to the gear **56**.

Since the sleeve can not move axially far enough to close the starting motor switch, if the pinion is not moved into proper meshing alignment with the engine gear, being stopped by engagement of members **68** and **70**, when the rotation of the pinion is blocked as described, the magnet is de-energized to permit the parts to return to the Fig. 1 position and the magnet is again energized and this second action of the magnet will move the pinion into proper meshing relation with the gear. Since the position of the sleeve relative to the gear is changed by the first energization of the magnet when the magnet is de-energized and the pinion is restored to its normal position on the sleeve, its position rotatively relative to the gear is also changed and it does not occupy the same position relative to the gear that it did when the magnet was first energized. Therefore, when the pinion is advanced into engagement with the gear a second time, it is in a different position when it engages the gear and the pinion teeth may, on the second advance of the pinion, be in proper alignment with those of the engine gear so that the pinion will advance immediately into proper gear engaging position. If there is abutment, the abutting surfaces will not be the same as upon the first advance of the pinion, so that whatever prevented rotation of the pinion, upon abutment thereof with the flywheel gear during its first advance will probably no longer be effective and the pinion will normally rotate to a position where the teeth of pinion and gear will be in proper meshing alignment. If such rotation is effected, the pinion will be moved promptly to gear engaging position by spring **62** after which the switch will be closed and the engine will be started.

It will be understood that a second advance of the pinion in order to effect meshing of the pinion with the flywheel gear is very seldom necessary. Usually, in the event of tooth abutment, the pinion is immediately rotated by action of the helical splines sufficiently for the teeth to be brought into proper meshing alignment, meshing is effected and the motor is then rendered operative. This action takes place more than 95 percent of the time and in less than 5 percent of attempted starts is it necessary to effect a second advance movement of the pinion.

It should also be understood that rotation of the pinion might possibly be prevented upon the second advance movement of the pinion toward the flywheel gear so that proper meshing engagement of the pinion and gear would not be effected. In such event, the control switch for the solenoid would be opened, so that the parts could return to normal position as previously described, and would be reclosed to energize the solenoid, thus effecting a third advance movement of the pinion. However, this is a situation which occurs so infrequently as to be negligible and if the pinion fails to mesh properly with the flywheel gear upon the first energization of the solenoid, the pinion will be properly meshed with the flywheel gear in substantially all instances when the solenoid is energized a second time.

It will also be understood that while the present invention is illustrated in a starting apparatus having a solenoid for shifting the driving pinion into engagement with the flywheel gear, the invention could be incorporated in a starting apparatus in which the lever **72** is operated manually as in the Critchfield patent previously referred to. Also, while the invention is of more importance when embodied in a starting apparatus employing current at 12 or 24 volts, it can be used in a system employing the former conventional 6 volt current. The difficulties which the invention eliminates would not be present to as great degree but the invention could be used just as well in such a system.

While the embodiment of the present invention as herein disclosed, constitutes a preferred form, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. Starting apparatus for internal combustion engines having, in combination, an electric starting motor having a rotatable driving shaft, a driving pinion movable axially with respect to said driving shaft into mesh with a gear of the engine to be started and rotatable by said motor after said pinion is meshed with the engine gear to effect starting of the engine, a member movable axially of the shaft to effect movement of the pinion toward the engine gear, resilient motion transmitting means between said member and the pinion, actuating means for moving said member and controlling operation of the starting motor, means for rotating the pinion relatively to said engine gear upon continued movement of said member, in the event of tooth abutment between the pinion and engine gear, means preventing sufficient movement of the actuating means to cause the starting motor to become operative until the pinion is moved into proper meshing engagement with gear, said last named means comprising cooperating stop members on said member and the pinion.

2. Starting apparatus for internal combustion engines having, in combination, an electric starting motor having a rotatable driving shaft, a driving pinion movable axially with respect to said driving shaft into mesh with a gear of the engine to be started and rotatable by said motor after said pinion is meshed with the engine gear to effect starting of the engine, a driven shaft supporting said pinion, an overrunning clutch connecting the motor shaft and said driven shaft, means for advancing said driven shaft toward the engine gear to move the pinion into engagement therewith and for controlling operation of the starting motor, said pinion being rotatable with said driven shaft when in proper meshing engagement with said engine gear and slidable on the shaft if the teeth of the pinion abut those of the gear as the pinion is moved toward the gear, means on said driven shaft to effect rotation of the pinion relative to the gear in the event of tooth abutment, and means for preventing movement of the advancing means for said driven shaft sufficiently to cause operation of the starting motor until the pinion is moved into proper meshing engagement with said gear.

3. Starting apparatus for internal combustion engines having, in combination, an electric starting motor having a rotatable driving shaft, a driving pinion movable axially with respect to said driving shaft into mesh with a gear of the engine to be started and rotatable by said motor after said pinion is meshed with the engine gear to effect starting of the engine, a driven shaft supporting said pinion, an overrunning clutch connecting the motor shaft and said driven shaft, means for advancing said driven shaft toward the engine gear to move the pinion into engagement therewith and for controlling operation of the starting motor, said pinion being rotatable with said driven shaft when in proper meshing engagement with said engine gear and slidable on the shaft if the teeth of the pinion abut those of the gear as the pinion is moved toward the gear, cooperating helical splines on the pinion and driven shaft operable to effect rotation of the pinion relative to engine gear in the event of tooth abutment, and means for preventing movement of the advancing means for said driven shaft sufficiently to cause operation of the starting motor until the pinion is moved into proper meshing engagement with said gear.

4. Starting apparatus for internal combustion engines having, in combination, an electric starting motor having a rotatable driving shaft, a driving pinion movable axially with respect to said driving shaft into mesh with a gear of the engine to be started and rotatable by said motor after said pinion is meshed with the engine gear to effect starting of the engine, a driven shaft supporting said pinion, an overrunning clutch connecting the motor shaft and said driven shaft, means for advancing said driven shaft toward the engine gear to move the pinion into engagement therewith and for controlling operation of the starting motor, said pinion being rotatable with said driven shaft when in proper meshing engagement with said engine gear and slidable on the shaft if the teeth of the pinion abut those of the gear as the pinion is moved toward the gear, resilient means normally preventing axial movement of the pinion on its supporting shaft and yieldable to permit such movement in the event of tooth abutment between the pinion and gear, means on the driven shaft to rotate the pinion relative to said gear if tooth abutment occurs, and means for preventing movement of the shaft advancing means sufficiently to cause operation of the starting motor until the pinion is moved into proper meshing engagement with the engine gear.

5. Starting apparatus for internal combustion engines having, in combination, an electric starting motor having a rotatable driving shaft, a driving pinion movable axially with respect to said driving shaft into mesh with a gear of the engine to be started and rotatable by said motor after said pinion is meshed with the engine gear to effect starting of the engine, a sleeve slidably supported on the motor shaft operatively connectable with said shaft for rotation therewith and supporting said pinion, the latter being rotatable with the sleeve and slidable thereon, means for sliding said sleeve on the motor shaft toward the engine gear to engage the pinion therewith and for controlling the operation of the starting motor, a spring surrounding said sleeve and normally holding the pinion against axial movement relative thereto as the sleeve is moved toward the engine gear but permitting the pinion to slide on the sleeve if the teeth of the pinion abut those of the engine gear as the pinion is advanced, means on the sleeve for rotating the pinion relative to the engine gear as the pinion slides on the sleeve in the event of tooth abutment and means including cooperating stops on the pinion and sleeve advancing means for preventing movement of the sleeve advancing means sufficiently to cause operation of the starting motor until the pinion is moved into proper meshing engagement with the engine gear.

6. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven shaft having a driving pinion slidable thereon and rotatable therewith, a one-way clutch connecting the driving and driven shafts, actuating means for moving said driven shaft, clutch and pinion as a unit toward the engine gear to effect meshing engagement of the pinion with said gear, means normally holding the pinion against sliding movement on the driven shaft as the pinion is advanced toward the engine gear but permitting the pinion to slide on such shaft if the pinion teeth abut those of the gear as the pinion is advanced toward said gear, means operable by said actuating means for controlling the starting motor, means for effecting rotation of the pinion relative to said gear in the event of tooth abutment and means preventing sufficient movement of said actuating means to cause the starting motor to become operative until the pinion is moved into proper meshing engagement with the engine gear.

7. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven shaft having a driving pinion slidable thereon and rotatable therewith, a one-way clutch connecting the driving and driven shafts, actuating means for moving said driven shaft, clutch and pinion as a unit toward the engine gear to effect meshing engagement of the pinion with said gear, a spring surrounding the driven shaft between the clutch and pinion and normally holding the pinion against sliding movement on the driven shaft as the pinion is advanced toward the

engine gear but permitting the pinion to slide on such shaft if the pinion teeth abut those of the gear as the pinion is advanced toward said gear, means operable by said actuating means for controlling the starting motor, means for effecting rotation of the pinion relative to said gear in the event of tooth abutment and means preventing sufficient movement of said actuating means to cause the starting motor to become operative until the pinion is moved into proper meshing engagement with the engine gear.

8. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven shaft having a driving pinion slidable thereon and rotatable therewith, a one-way clutch connecting the driving and driven shafts, actuating means for moving said driven shaft, clutch and pinion as a unit toward the engine gear to effect meshing engagement of the pinion with said gear, means normally holding the pinion against sliding movement on the driven shaft as the pinion is advanced toward the engine gear but permitting the pinion to slide on such shaft if the pinion teeth abut those of the gear as the pinion is advanced toward said gear, means operable by said actuating means for controlling the starting motor, means for effecting rotation of the pinion relative to said gear in the event of tooth abutment and cooperating stop members on the driven shaft and pinion for preventing sufficient movement of said actuating means to cause the starting motor to become operative until the pinion is moved into proper meshing engagement with the engine gear.

9. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven sleeve slidable on said shaft, a driving pinion slidable on the sleeve and rotatable therewith, a one-way clutch for connecting the sleeve to said shaft for rotation therewith and slidable with the sleeve on said shaft, actuating means for moving the sleeve, clutch and pinion toward the engine gear to effect meshing engagement of the pinion with said gear, means normally holding the pinion against sliding movement on the sleeve as the sleeve and pinion are moved toward the engine gear but permitting the pinion to slide thereon if the pinion teeth abut those of the gear during such movement, means operable by said actuating means for controlling operation of the starting motor, means for rotating said pinion relative to the gear in the event of tooth abutment and means preventing sufficient movement of the actuating means to cause the starting motor to become operative until the pinion is moved into proper meshing engagement with the engine gear.

10. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven sleeve slidable on said shaft, a driving pinion slidable on the sleeve and rotatable therewith, a one-way clutch for connecting the sleeve to said shaft for rotation therewith and slidable with the sleeve on said shaft, actuating means for moving the sleeve, clutch and pinion toward the engine gear to effect meshing engagement of the pinion with said gear, a spring surrounding the sleeve between the clutch and pinion normally holding the pinion against sliding movement on the sleeve as the sleeve and pinion are moved toward the engine gear but permitting the pinion to slide thereon if the pinion teeth abut those of the gear during such movement, means operable by said actuating means for controlling operation of the starting motor, means for rotating said pinion relative to the gear in the event of tooth abutment and means preventing sufficient movement of the actuating means to cause the starting motor to become operative, until the pinion is moved into proper meshing engagement with the engine gear.

11. Starting apparatus for internal combustion engines having, in combination, an electric motor having a driving shaft, a driven sleeve slidable on said shaft, a driving pinion slidable on the sleeve and rotatable therewith, a one-way clutch for connecting the sleeve to said shaft for rotation therewith and slidable with the sleeve on said shaft, actuating means for moving the sleeve, clutch and pinion toward the engine gear to effect meshing engagement of the pinion with said gear, means normally holding the pinion against sliding movement on the sleeve as the sleeve and pinion are moved toward the engine gear but permitting the pinion to slide thereon if the pinion teeth abut those of the gear during such movement, means operable by said actuating means for controlling operation of the starting motor, cooperating helical splines on said sleeve and pinion if the pinion slides on said sleeve in the event of tooth abutment and means preventing sufficient movement of the actuating means to cause operation of the starting motor until the pinion is moved into proper meshing engagement with the engine gear.

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